Project GeoStorm: Bridging the 'killer gap' by integrating developer and educator perspectives in the development of a tablet-based app for tertiary education

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Contents

List of tables

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Judit Klein

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Abstract

Teaching and learning practices in tertiary institutions are increasingly mediated by new educational technologies. However, literature and practice have also identified the limitations of these technologies to transform learning in the open and mass-participatory ways that have been promised (Selwyn, 2011).

This thesis focuses on the adoption of tablet computers in tertiary settings in light of Selwyn's (2011) discussion of why there has been no 'killer app' for education. It identifies a disconnect – or gap - between what educators need and what app developers are providing. The research builds on Puentedura's (2008) Substitution Augmentation Modification Redefinition (SAMR) model to propose an approach that integrates these discrete perspectives.

The outcome of the research - an app supported by documentation of the process undertaken to create it – facilitates real time collaboration on the iOS platform between users working on a common topic or idea, to support and contextualise topics being studied, or to facilitate brainstorming in collaborative projects. The researcher draws on personal theoretical and practical experience as a student, teaching and research assistant, mobile educational technology trainer and software developer.

The research asks what can be revealed from the process of developing a tablet-based app and thus provides a practical example of how a greater understanding of the development process enhances the utilisation and affordances of tablet computers in tertiary education.

Chapter 1: Establishing the Field of Knowledge

1.1 Introduction

Selwyn (2011) has suggested that most people working in the area of educational technology are driven by an underlying belief that digital technologies are, in some way, capable of improving education. In this sense, educational technology can be seen as an essentially positive project and the *de facto* role of the educational technologist is understood to be one of finding ways to make these technology-based improvements happen (Selwyn, 2011:713). New tools are rolled out with the assumption that they will make education 'better', that they will reinvent pedagogy, enable us to be more productive, more collaborative, more engaged, flip the classroom, or better yet, never even have to step into one at all and conduct everything virtually.

However, Selwyn also notes that this optimistic view of the potential of technology to solve problems in education runs counter to many of the recent experiences of educational technology in practice.

> "As anyone familiar with education provision or practice will attest, fundamental elements of contemporary learning and teaching have remained largely untouched by the waves of digital technologies that have been introduced inside and outside of the classroom over the last three decades." (ibid: 713)

The argument about the validity of educational technology is not a new one (see e.g. Kling & Lacono,1988). With each new technological advancement or new device, the debates over their effectiveness is reignited. Not long after the release of the Apple iPad in 2010, this consumer device was already being hailed as the 'game changer' for education (Brown-Martin, 2010).[1] Four years later, however, there is still no evidence that education has changed significantly since its introduction.

Mobile devices are among the most recent technologies to be widely adopted. The researcher has observed and experienced the uptake from different perspectives: as a student, commencing a new degree at a time just before the appearance of the iPad; as a teaching and research assistant, playing an active role working with teachers, lecturers and professors to help them learn how to use mobile devices in their own work, research and teaching, and; as a software developer, during a period of widespread so called innovation in mobile products and services.

During this period, the researcher has observed that educators are either unduly optimistic about the effect of new technology or narrowly focused on the logistical benefits; students take to the technology immediately and are dissatisfied that their teachers are not using it in their teaching, and; software developers see education as a rich industry to develop for. Researchers, meanwhile, have tended to focus on examples of where the technology can be shown to 'work' or to provide 'proof of concept' or evidence of 'best practices' (Sewlyn, 2011).

Moreover, as teaching practices are increasingly mediated by mobile technologies, learner interactions are influenced by the choice of apps. Yet, existing research has tended to focus on hardware with little attention

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[1] Within the context of this study, discussion of "education" will generally refer to traditional "instructivist" teacher-centred, lecture-based models of knowledge transfer. This is the "game" that contemporary educational technologists typically claim is being changed or transformed by new technologies. A detailed account of the myriad forms of pedagogy and educational theory lies beyond the scope of this study.

paid to software. Software is responsible for all actions and behaviours enabled by technology and teachers are being taken advantage of by developers whose intention is to make money by selling them a solution with no research to back up 'education enhancing' claims.

If we are to utilise mobile technologies in an educational setting, then expertise that comes from education needs to be integrated with the process of creating the software. To date, there has been limited expertise within the field of education to write the software and therefore, education has been unable to design and/or control the technological framework, the "architecture', of the educational environment.

This study aims to integrate all of these perspectives (which rarely intersect in the current research context) to find a practical way to address the disconnect between what educators need and what app developers are making. The research also aims to work with rather than against the formal educational settings such as classrooms or seminar spaces, recognising the ongoing relevance of space and place as "the settings where the vast majority of learning and teaching continues to take place despite of academic valorisation of the informalisation of educational activity" of educational (Selwyn, 2011:717).

The outcome of this research is an app and the documentation of the process undertaken to create it. Though evaluation of the finished product is beyond the scope of this study, it is argued that by revealing the process through which apps come into being, further research can build on it to support the creation of custom apps, by teachers, for teachers.

1.2 Research context

Despite the same promises of a 'game changer' being made about each new iteration of educational technology, the focus of much research into how new technology is used has been on the teacher-centric, content-delivery model. The expectations in countless trials of educational technology are that mobile and distance learning will replace the physical classroom, that new technologies will enable more collaborative ways of working and that the role of the teacher will change as more students have devices as they each hold in their hands the access to the same information.

The generalisability of much of this existing research remains problematic. Although extensive research has been carried out on the impact of the latest technology - mobile devices – it aims only to prove that the technology 'works' or to provide 'proof of concept' or 'best practice' models (Selwyn, 2011). While the findings of existing research or trials are consistent, most offer only 'theoretical frameworks' for learning that are rarely implemented,(Medzini et. al, 2014) since the hardware and infrastructure limitations inhibited successful outcomes, (Tohill, 2014) and there are found to be 'no significant differences' to learning outcomes (Reeves, 2005).

However, this is not entirely a failing of educational research. Our experience of education is increasingly mediated by technology and not enough is understood about the process by which this technology or, more specifically, the software which underpins it, comes into existence nor the impact this process has on the end user (Williamson, 2013).

To date, little attention has been paid to a very obvious research problem: the way in which mobile devices are used depends on the 'apps' that are used. An app is a piece of software, short for application, designed to fulfil a purpose and is more typically associated with mobile platforms (Oxford Dictionary, n.d.)**.**

There are 1.2 million apps available for Apple's iOS mobile platform (Apple Inc., 2014b) and another 1.2 million on Google's Android mobile platform (AppBrain, 2014) with some overlap of apps available cross platform. The mass adoption of the mobile platform has resulted in a shift in how we approach software and it poses an incredible challenge to filter through and find apps most suitable for a given context. Where previously, educators would have used software pre-configured by an IT department, they now have greater, direct, individual access to a wide range of cheap software.

The huge availability of apps is a result of the knowledge and tools required to create apps being democratised: everyone has access to the same tools for building apps for free. With the playing field levelled, independent developers as well as big companies can build and sell apps, resulting in a fast growing app development industry with over 9 million people registered on Apple's developer programme alone. (Apple Inc., 2014b). App development has grown into a lucrative industry. Apple announced in 2013 that they have paid out over US$10B to developers, half of that in the previous year alone (Apple Inc., 2013). The growth of the mobile industry and associated development platforms has led to computer science being perceived as a portal to wealth, aspiring to build the next 'killer app' (Clear, 2013).

This creates another research problem where, in amongst the millions of apps, it is difficult to know whether an app used in education has been created by someone with any understanding of or interest in education. Was the incentive for the developer to create an engaging experience of education or to make money?

There is a gap in knowledge that results from the use of these apps as 'off the shelf' solutions, taken as-is, and adopted to work within an existing education paradigm, existing ideas and lessons. It can be argued that teachers are being taken advantage of as apps are used in good faith with the expectation that the technology will deliver an enhanced experience of education. Effectively, the lack of regulation of app marketing allows developers to sell their bicycle solution as a Rolls Royce.

1.21 Research problem: the 'killer gap'

The conception has emerged that in amongst the millions of apps available, there is a 'killer app' that will deliver on the promises made by 'game changing' technologies. The notion of the 'killer app' embodies a multitude of concepts. It is generally understood as a software application that is commercially successful or popular (Dasgupta, 2002). It can refer in broad terms to a function, such as email or web browsing, of a device or a specific software application.

In the context of education, even if the term is not directly used, this represents the perception that in the sea of millions of apps, one which is highly successful and used by many other people, particularly other educators, is likely to be suitable for one's own needs. However, this research supports Selwyn (2011): apps are not fulfilling the expectations of users, there has been no 'killer app'.

The experience of using the device is limited by the inherent behaviours already coded into the app. This study will refer to the research problem as the 'killer gap': that is, the gap between the app developer and the end user. The app is the end product of the software development process and by the time it is used in an education context, decisions have been made by the developer that impact on the end user. However, it can be assumed that these decisions were made without knowledge of the needs of the end user. This study argues that developers do not know enough about education and educators do not know enough about the software to take control of the technology for their needs. Though the researcher is not an educator or an expert in either field, the aim of the research is to incorporate the researcher's experience and understanding in both fields.

1.22 Key terms, concepts and scope of the research

This research sets out to go beyond just another 'theoretical framework' and investigate through practical implementation what lies inside the 'killer gap'. The literature and field review suggests that existing apps have not been fulfilling the expectations of mobile device use in education.

The study will use the notion of the 'killer app' as a way to describe and encapsulate that expectation. The term 'users' describes the standard university lecturer delivering information in a lecture hall and their students. Literature reviewed focuses specifically on tertiary education and on the Apple iPad as a specific example of a mobile device because it has over 95% of the market share of tablet computers in the U.S. education market (Apple Inc., 2014a). A similar and reliable local statistic was not available, but a press

release by market research company Frost and Sullivan (2013) suggests that the market in New Zealand is very different with the iPad holding 59% of the overall tablet market share.

This approach aims to reverse-engineer the 'killer gap' by starting with the end point: the existing 'off the shelf' solutions. By first understanding the educational context, the findings can inform the starting point of a practical outcome, an app. By then undertaking the mobile app development process, it is hoped to reveal what lies between the two points of the gap.

To address this question, what needs to be understood is the expectations of the users, what the 'off the shelf' solutions are, what they actually deliver and what causes the disconnect between the two. To understand the expectations of users, the notion of the 'killer app' will be explored in relation to educational technologies, as well as historical documentation and modern usage and relevance of the term.

From the education perspective, papers from the iPad in Higher Education Conference 2014 proceedings will be reviewed to establish the current usage of iPads in relation to what apps are being utilised and whether expectations are being met.

From a technological perspective, it is appropriate to also examine what these 'off the shelf' solutions are and the modes through which they end up in teachers' hands. These apps will then be evaluated using the SAMR model to find the cause of the disconnect between the expectation and the reality.

The following field review will examine relevant literature and apps with the aim of informing the research design and identifying an appropriate research methodology for answering the question: what can be revealed from the process of developing a tablet-based app that can be applied to utilising mobile devices in tertiary education?

1.3 Literature and Field Review

1.31 The killer app

The concept of a 'killer app' is not a new one, and it represents an ideal that never seems to be met. Dvorak (1999) lists the emerging hardware of the time and identifies a different kind of 'killer app gap', where focus is on the hardware, rather than finding anything new and innovative to use it for.

In an even earlier article, Kask (1989) argued that the industry was not likely to see anything revolutionary and he too lists the emerging hardware of the time and their limitations. Despite the continuous improvements in hardware, the hardware itself is not enough to justify its reason for being: the software defined the use case.

For example, Mace and West (2010) suggested that web browsing is the killer app that led to the rapid success of the Apple iPhone. Even though mobile phones existed prior to the iPhone with this capability, and earlier examples of software driving computing hardware sales, the iPhone was the first instance of software driving the sale of mobile phone hardware. This trend has consistently been seen in the evolution of mobile phones: hardware sales have been driven by the integration of new software capabilities such as SMS, MMS and web browsing.

Used as early as 1989, an article titled 'Waiting for Killer Applications' (Scannell, 1989) identified that the success of OS/2, an operating system created by Microsoft and IBM, relied on it having a variety of 'killer' applications'. It is argued that previous operating systems did not have applications which fully utilised the system (Scannell, 1989).

VisiCalc is a spreadsheet program that is considered to be the first example of a 'killer app' by the definition that it was a piece of software that became so necessary to an industry that the hardware it runs on becomes necessary (Zynda, 2013). At the time, it was argued that VisiCalc was reason enough to justify purchasing a computer system (Green, 1980).

However, while VisiCalc's ability to create spreadsheets may have once been perceived as revolutionary, it is now commonplace. The most significant idea to emerge from the literature is that what starts as a unique piece of software becomes ubiquitous and generic once proven to be necessary to the system. Therefore, 'killer app' could be understood as a transient state, whereby a revolutionarily capability truly takes advantage of hardware affordances then becomes a standard across all subsequent technology.

The popularity associated with a 'killer app' is a side effect, rather than a sole qualifier or indicator. With shorter periods of time between hardware advancements, the constantly shifting goal posts could suggest why at any given point in time, there is a search for the 'killer app'.

In the context of education, Selwyn suggests that;

If there is anything to be learnt from the past 30 years of 'computer-assisted learning' and 'technology-enhanced learning', it surely is that there is little point in maintaining a Pollyannaish stance towards technology use in education. Instead, there are a host of often overlooked critical issues and themes that need to be brought to the forefront of any contemporary discussion of educational technology. Perhaps the overriding change that this entails is shifting the field away from asking 'state-of-the-art' questions about technology and towards asking questions that can be described as being concerned with the 'state-of-the-actual.'

In other words, educational technology scholarship should look beyond questions of how technology could and should be used and instead asking questions about how technology is actually being used in practice. (Selwyn, 2011:715)

The expectation of a killer app is that it will fulfil a need that has not been met by previous systems. There has been no evidence of any app for the iPad that has driven the sales of the device itself: though the hardware itself offers benefits to education, the selling points are not education centric.

1.32 Mobile Devices in Education

Many studies have attempted to examine the benefits of using mobile devices in education. The iPad in Higher Education 2014 conference proceedings were used to scope the most up to date field of knowledge of previous adoption in education across a broad range of disciplines and the results. These benefits will be described as affordances, where the mobile device exhibits the possibility for the user to perform an action.

Commonly perceived affordances include the ability to access and transfer information, as well as enabling students to analyse, reflect and discuss course content in a 1-1 model (Burden & Hopkins, 2014). A number of studies identified that the hardware itself enables a greater degree of mobility and accessibility, where in many instances, the convenience was seen as the greatest benefit that made a difference to students (Tohill, 2014; Adefila & Clouder, 2014; France et al. 2014). The study by Altena (2014) identifies student study tasks related to these affordances, including reading textbooks, searching databases, viewing videos, listening to podcasts, managing tasks and writing assignments. These expectations are based around how to continue with 'business as usual' by using mobile devices to emulate and enhance existing practice, rather than anything new or revolutionary.

In attempting to justify the need for an iPad, 'off the shelf' solutions are adopted into education contexts and often teaching practices are limited by the technology. There appears to be a lack of apps focused on specialised knowledge, especially at a higher education level. For example, the study by Adefilia and Clouder (2014) highlighted that there were no apps specific to occupational therapy. Apps for areas such as health can however be problematic as extra certification and approval is needed for any software selling medical information as fact.

In a study of iPads in a biology context (Procter & Taylor, 2014), despite the afforded mobility of the hardware that enabled students to take the devices out into the field, none of the apps that were trialled were able to deliver the level of specialised knowledge that was required.

The App Store is the sole source for downloading apps onto the iPad, therefore it can be assumed that recommendations and claims made on the App Store play an important role in app selection. Apps can be classified in multiple categories and it is not uncommon to see general tools recommended for education alongside specialised education tools. For example, Notability (2014), a general note taking app, appears

featured on the front page of the App Store under 'Best New Education Apps'. However, there is a lack of information in the literature addressing app selection processes for iPad trials, suggesting that not enough attention is paid to implementing a strategy around sourcing relevant software. As a result, the more commonly used apps are those recommended through the distribution channel which perform more generic tasks, resulting in a dissatisfaction particularly in specialised study areas.

1.33 Existing apps

In the search for the 'killer app', there is an inherent trust that comes with the purchase of an app that it will deliver an experience beneficial to teaching or learning. The App Store offers an education category which touts subcategories such as 'Apps for Teachers', 'School Toolkit', 'University Survival Guide' and 'Best New Education Apps'.

The apps themselves make claims about their benefits for education, for example, the Nearpod app (2014) describes itself as a "magical educational app". The Edmondo app (2014) promises that is "makes a teacher's daily life easier by providing a safe and easy way for teachers and students to engage and collaborate…"

The Substitution Augmentation Modification Redefinition, or SAMR model developed by Puentedura (2008) offers a way to describe the levels of technology use and examine what type of effect technology would have compared to the previous technology or analogue equivalent. The model describes how technology is used to substitute, augment, modify or redefine a task (Puentedura, 2008) and suggests that it is at the redefinition level technology enables new tasks that were previously inconceivable.

A few of the studies from the previous section did identify specific apps that were employed and these will be analysed against the SAMR model, comparing user expectation against delivered benefits. Our understanding of a killer app is now consistent with what is suggested by the SAMR model at the 'redefinition' stage. Ten apps have been selected for review, either because they were specifically mentioned in a study, or because it was prominently displayed in the education category of the App Store.

As shown in Table 1, 'off the shelf' apps are currently performing substitution and augmentation level tasks. It can be seen that there was a lot of overlap across apps in the tasks they focused on. Already the conclusion can start to be drawn that existing apps drawn on tasks associated with the instructivist and information delivery models of teaching, perhaps to be perceived by those removed from the context as beneficial to education. These tasks focus on document management and delivery of digital media and classroom content. Though substitution of these tasks and previous analogue tools can enhance productivity, it doesn't necessarily translate to a redefinition in the educational experience in the original task or activity, let alone the experience of education as a whole. This is consistent with the findings of the dissertation thus far.

The following sections discuss the common themes which have arisen from the field and literature reviews.

The perceived affordances of the iPad identified in the previous section suggests that basic substitution level tasks are being fulfilled, but substitution alone does not address the greater need for something new that justifies the use of mobile devices over previous hardware.

Table 1

Apps Evaluated Against SAMR Model

App	Study / Reason for choosing	Claims from App Store description	Main task / functionality	Main category in App Store	Previous technology or analogue equivalent	How does the app substitute the previous technology?	How does the app augment the previous technology?	How does the app modify the previous technology?	How does the app redefine previous technology?
Keynote	The app is referenced in a study by Mitchell (2014).	"Keynote is the most powerful presentation app ever designed for a mobile device."	Presentation / delivery of classroom content	Productivity	Computer / overhead projector / smart board / whiteboard / blackboard / slideshow	Presentations can be created and presented directly from a mobile device.	Multimedia, such as videos and photographs, can be added directly from the device and with AirPlay mirroring can be wirelessly presented.		
Nearpod	The app is referenced in a study by Newman and Ventel (2014). The app is prominently featured in App Store education category: 'Teacher's Starter Kit'.	"...magical educational app used by more than 2 000 000 students around the world." "The Nearpod platform enables teachers to use their iPads to manage content on students' iPads, iPhones or iPods. It combines presentation, collaboration, and real-time assessment tools into one integrated solution."	Presentation / delivery of classroom content	Education	Computer / overhead projector / smart board / whiteboard / blackboard / slideshow	Students can follow along with a lesson on their own devices and do not have to be in the same classroom space.	Quizzes with multiple choice questions and polls add interactivity for students.		
iBooks	The app is referenced in a study by Cidre (2014), Burden and Hopkins (2014), Newman and Ventel (2014), Murray and Saavedra (2014) and Altena (2014). The app is prominently featured in the Education category of the App Store.	"iBooks is an amazing way to download and read books."	Access to and distribution of digital books and other epublication formats.	Books	Books, paper based text	App offers easier access to books with the added convenience of being able to carry around countless publications. Often used as a place to store and organise class notes.	Some books come with interactive features, such as the ability to change font and text size, add notes and bookmarks, view rich media (images, videos, audio).	Capacity for content creation where students and teachers can create their own iBooks using other apps.	
Myscript memo	The app is referenced in a study by Harvey, Leah, Masters and Morrison (2014).	"With MyScript Memo, take your notes on the go using your handwriting and convert them to digital text."	Handwriting conversion	Productivity	Note taking	Hand written notes can be converted to digital text which can be stored, replicated and shared.			
Explain Everything	The app is referenced in a study by Newman and Ventel (2014), and Altena (2014). The app is prominently displayed in the App Store's education category: 'Teacher's Starter Kit'.	"Explain Everything is an easy-to-use design, screen casting, and interactive whiteboard tool that lets you annotate, animate, narrate, import, and export almost anything to and from almost anywhere." "Explain Everything has been a top paid education app since its release in United States, United Kingdom, Australia, Canada, Denmark, Finland, France, Germany and Turkey."	Presentation / delivery of classroom content	Education	Computer / overhead projector / smart board / whiteboard / blackboard / slideshow	Presentations can be created and presented directly from a mobile device.	Supports integration of various forms of multimedia, supporting lesson creation. Lessons can be recorded and shared and reviewed later.		

App	Study / Reason for choosing	Claims from App Store description	Main task / functionality	Main category in App Store	Previous technology or analogue equivalent	How does the app substitute the previous technology?	How does the app augment the previous technology?	How does the app modify the previous technology ?	How does the app redefine previous technology ?
AirSketch	The app is referenced in a study by Baab and Bansavich (2014).	"Turn your iPad into a wireless whiteboard!"	Presentation / delivery of classroom content	Utilities	Computer / overhead projector / smart board / whiteboard / blackboard / slideshow	App acts as a substitute for drawing diagrams on a whiteboard.	Diagrams can be drawn on the iPad and shown on any other device on the same network wirelessly.		
Dropbox	The app is referenced in a study by Baab and Bansavich (2014), Altena (2014) and Backhouse, Mackley and Wilson (2014).	"We build apps for people who change the world." "Dropbox lets you bring all your photos, docs, videos anywhere and share them easily."	File storage, resource access	Productivity	USB drives / discs	App makes the transfer and storage of files easier as they can be saved and and accessed wirelessly from any device.			
Goodreader	The app is referenced in a study by Baab and Bansavich (2014) and Altena (2014).	"Soon you'll be wondering how you ever managed to go mobile without GoodReader."	Document annotation	Productivity	Paper based text and stationary, desktop / laptop computer based software.	Notes and documents can be stored and edited on a mobile device and accessed across multiple devices.			
Evernote	The app is referenced in a study by Baab and Bansavich (2014).	"Stay organised, save your ideas and improve your productivity."	Note taking	Productivity	Paper based text, desktop / laptop computer based software.	Notes can be created, stored and edited on a mobile device and accessed across multiple devices.			
Notability	The app is referenced in a study by Backhouse, Mackley and Wilson (2014). The app is prominently featured on home page of education category of App Store and in the collection: "Teacher's Starter Kit'.	"…a powerful note-taker on iPad and iPhone: sketch ideas, annotate documents, sign contracts, complete worksheets, keep a journal, record a lecture, jot travel notes, or teach a class."	Note taking	Productivity	Paper based text, audio recorders	Notes can be created, stored and edited on a mobile device and accessed across multiple devices.	Notes can be embedded with audio and played back to show context for when different parts of the note were created.		

1.4 Discussion

1.41 Existing solutions offer only substitution

One of the common themes emerging from the literature review is that both the expectation of what the iPad enables and what it actually delivers acts only as a substitution of the previous technology.

Portability is quickly becoming the norm; mobility, convenience and accessibility are not affordances: they are a given. Research has proven time and time again that mobile devices deliver these logistical benefits as a result of portability, regardless of platform and context.

Mobile devices are the next evolution from the chalkboard, to the whiteboard, to the smart board: each evolution added convenience by changing the vehicle and medium. 'Off the shelf' apps deliver only these base affordances already inherently offered by the hardware itself and at best, augment the tasks that were already possible with the previous technology. Simply but, these apps are still adhering to the "Chalk and Talk" model.

The catchphrase 'There's an app for that', which has since been trademarked by Apple (Apple Inc., 2013), implies that this app should exist. No matter what task you need to accomplish, there is a tool that can help you achieve it. Even with thousands of apps listed under the education category of the App Store, the field review indicates that these apps offer only substitution to traditional tools and reinforce the instructivist model of education.

A 'killer app' is the software that justifies the need for the hardware. Education is still searching for a way to justify 'needing' mobile devices in an education context, to find what is so necessary about the mobile devices that will revolutionalize the education industry. The literature suggests that this has not yet happened and part of it is a perception problem: the focus has been on the hardware, rather than the software, and the misconception that portability and mobility offered by mobile devices are justification enough. To a developer outside of the education context, it is easily perceived that this is what educators want. More generic tools become a way to target a broader market for greater sales and profit, rather than targeting more niche markets through specialised tools.

1.42 Generic tools versus specialised solutions

The easy access to apps resulting from low cost and large number available means that it becomes hard to gauge what is suitable, let alone transformative, for an education context. Though most research does find a range of benefits to be gained from the introduction of iPads, these conclusions are often followed up with suggestions for further research or the caveat that it is too early to draw firm conclusions (Harvey et. al, 2014; Burdens & Hopkins, 2014; Procter & Taylor, 2014; Mitchell, 2014).

Mobile devices are designed as a blank slate with the capacity for third party applications making them adaptable to any use case. Mobile devices not designed with formal education in mind and likewise, the most common apps which are utilised in tertiary educations are not either. Very little of the research on mobile devices talks specifically about what apps have been selected, why they have been selected or what

they hope to achieve. Additionally, it cannot be assumed that the intention of a developer is solely to deliver an engaging education experience, especially given the financial incentive of creating a 'killer app'. It is important to note that there are no specific criteria a developer needs to meet to be able to sell an app through the education category of the App Store: apps are reviewed by Apple prior to being put on sale and an app needs to show some relation to education, but the claimed benefits are not substantiated.

Despite the lack of 'off the shelf' solutions catering to specialised disciplines, only one paper mentions exploration of custom solutions using development tools. The study by Newman and Ventel (2014) found that it is difficult to source suitable apps that would enhance the curriculum and facilitate understanding of the topic at hand. The authors suggested that app development tools could provide a way to create apps as custom solutions with specific goals relevant to the learning outcomes and with a focus on the curriculum. This approach would put the control into the hands of education as a way to bridge the 'killer gap'.

There are some examples where this approach has been taken. At AUT University, an app was developed with close consultation between the developers and the physiotherapy department to develop an app called Dynamic Spine (2014). The purpose was to assist in the teaching of musculoskeletal disorders of the spine. Explain Everything (2014), one of only two apps specifically targeted at education that was reviewed, is a general tool that aims to capture informal conversations. One of the co-creators is a both a teacher and an app designer whose frustrations with assessment procedures informed the creation of the app (Richards, 2013). Explain Everything is a successful app with over 1,000,000 downloads (Mastalerz, 2014) and highly commended in education circles (e.g. Landis, 2014).

These findings suggest the need to look beyond 'off the shelf' solutions and examine the possibility for the development of custom solutions where educators have had input into the development process or have led the development process themselves.

Ultimately, it is hard to imagine an app that is revolutionary or transformative. The thousands of apps that perform substitution level task have their purpose but until education understands more about app development and visa versa, the 'killer app' cannot exist. This contributes to the 'killer gap'. There needs to be a greater understanding of the role of the software in a research context.

1.43 App development as a possible solution

There is a need to look at the underlying process of app development. Software is an abstraction: code, at its simplest definition, is a mode of communication, a means of transferring information (Petzold, 2009). In a technology context, code is the language of computation necessary for communicating with computers because they cannot directly interpret human communication (Williamson, 2013).

What was so revolutionary about VisiCalc that led it to become classified as a 'killer app' was that it appealed to people who previously had no interest in computers and offered the power of computing to non programmers (Zynda, 2013). In the late 1970s when it was released, it was one of the few applications available that added a layer of interactivity that removed the need for complex low-level programming knowledge (Zynda, 2013). VisiCalc was the first program that was responsible for sales of an entire system (Ramsdell, 1980).

Software is what makes the abstract into the tangible. Education is a broad, complex and abstract thing that software aims to make tangible. As the hardware is increasingly interactive, portable and directly manipulated with touch input, the tasks they enable begin begin to provide an increasingly tangible experience of education. However, educational theory rarely engages with the code and visa versa, software developers rarely engage with education theory.

Coding is a means of problem solving and finding a way to deliver a solution. Every app started with an identified problem which it aimed to solve. It can be assumed from the review of apps that software developers are only able to conceive logistical problems and therefore only provided substitution apps.

Developing apps is the process of encoding and enabling interaction not just with the technology, but through the technology. The behaviours enabled by an app and what is afforded by the device is not dependent on the hardware but the decisions made by a programmer at a software level. Though it is no longer necessary to interact with the underlying layers of code to make an app work, understanding how an app comes in to being could enable education to better utilise the technology and allow us to think of new ways, previously undiscovered.

1.44 Summary

It has been four years since the release of the first iPad and the tertiary education sector is still dissatisfied overall with the results. The conception and expectation of the 'killer app' in an educational context represents an ideal: a silver bullet or Holy Grail that will answer the questions still asked of educational technology. Both directly and indirectly, users are still being promised this while neither developers nor educators fully understand what this expectation implies. There has been little evidence in practical research to show that mobile devices have improved student achievement. This contributes to what this study refers to as the 'killer gap'.

The review found that research into the impact of iPads in tertiary education tends to overlook the software entirely, focusing only on the capabilities and behaviours afforded by the hardware. Research that does discuss the use of apps has found that these rarely meet the needs of the context within which they have been implemented.

Education looks to the existing apps as the starting point and does not see the gap, when in fact these 'off the shelf' solutions are the end point. By the time the app is in the hands of a user, the decisions determining the interaction have been set. There needs to be an intersection between a technical and education perspectives: this is the starting point for bridging the gap.

As a result of the findings in the review, the research will investigate what can be revealed through the process of programming and suggests that the key to understanding how to utilise mobile devices lies inside this gap.

The idea for an app is the starting point and the code is what bridges this gap: the process through which an app comes into existence. By investigating what lies inside the 'killer gap' can we understand how to get to the 'killer app'.

The next section of the study will outline the implications for research design, where a practice based methodology will be employed as a way of bridging the 'killer gap'. Through having defined the terminology and field of knowledge, both the technological and educational perspective are to be incorporated into the practical component.

Chapter 2: Plan of Study

2.1 Research Design

The literature and field review set out to understand from the existing field of knowledge why the 'off the shelf' solutions have not been fulfilling the expectations of iPad users in an education context. The literature indicated that the iPad adds a level of augmentation to traditional classroom tasks: the affordance of mobility applies to both the device and the way it handles data transfer, as well as wireless connectivity which enables both the curation and presentation of rich media. Despite the millions of 'off the shelf' apps available that utilise these affordances, whether an app substitutes, augments, modifies or redefines an activity lies in understanding what happens inside this gap. These tasks are the starting point for the practical research to establish the validity of the process of mobile app development as an influential - but overlooked - factor of previous studies.

The question being asked is what can be revealed from the process of developing a tablet-based app that can be applied to utilising mobile devices in tertiary education? To answer the research question, a practice-based research methodology was deemed most appropriate. This section will describe the overall methodological approach for the practical component of the study and identify appropriate methods for data collection and analysis.

2.11 Required knowledge

An app is the end product of the software development process. The practical component of the study will begin with the proposal for an app that is informed by the findings of the literature review in regards to the education context. By building on the field review of existing apps, the aim is to create a unique app informed by the researcher's industry experience across both fields.

In order to answer the research question, it is important to ask whether the final outcome can deliver that ideal 'killer app' or does something get lost in translation? What falls into the 'killer gap'?

It has been argued that apps currently utilised in tertiary education are not designed with the purpose of creating an engaging learning experience. In this case, the intended users of the app are not specific to any discipline and the focus is only narrowed by specifying higher education as a target of the study.

A preconceived notion of who the potential users of an app are and what is most important to them may not be the most apparent to a developer who is removed from that context. By undertaking this research in an academic context, the methodology enables a design strategy specifically for the tertiary education context. This is not to discount the existence of technology in other fields of education, however those are beyond the scope of this research.

2.12 Required Data

The 'data' needed in order to gain knowledge of the mobile app development process emerges from the process itself, where the knowledge is gained through practice. With an understanding of both the technical

and education field, the documented process can be explained and demystified in everyday non technical language in relevance to the education context.

The aim is not to make a 'killer app': by any definition it would be beyond the scope of the study to develop an app and take it to market as a means of evaluating effectiveness. Nor is the aim to develop an app for the purpose of evaluating its effectiveness in user trials. The aim is to deliver a practical outcome, rather than a theoretical framework, where the process of practice based research reveals the knowledge that arises from the production of an artefact, more significant than the artefact itself. In this case, the study proposes that the development process of an app will reveal more than an app itself will.

Previous research has focused on evaluating an existing app after it has been through the development process and distributed for sale.

2.13 Data Collection

The process of app development is a creative one as much as it is a technical one which can pose problems in capturing the process and translating that as 'data' in an academic sense. Versioning software offers a way to document the process of regularly committing code to a repository. This is an important part of software development as it offers a way for developers to back up and restore code from the history, known as a 'branch', or to work collaboratively with other developers and be able to seamlessly integrate different sections of code.

These logs are accompanied by commit messages explaining what has been changed. Therefore these can provide snapshots into the development process as the app progresses. The user interface is also an important part in determining user interaction and experience and as this emerges, it provides a visual way to demonstrate the development process.

Early interactive prototypes can be used to demonstrate the intended outcome before any code is written. Prototyping methods offer a way to communicate in a visual way what the ideal end user experience is. Prototyping is an important part of the software development process as it allows the testing of ideas quickly, which saves time and money by ensuring that development time is spent building the right things (Bernstein et. al, 2014) because it is about testing the experience, rather than feasibility.

While the notion of "If you can dream it, you can build it" is often touted in software engineering, in reality, limitations in the the programming interfaces often sway the design of the software from the original vision. It is near impossible for an original prototype to look and behave exactly like the finished project. Commit messages in version history allows an observe decisions and the reasoning behind them step by step.

Through the collection of this development and creative process viewpoint 'data', the study aims to reveal what is usually an invisible process, demonstrated through practice.

2.14 Data Analysis

The theoretical component of the research serves as the starting point of the practical, where the findings of the literature and field review informed what the functionality of the app would be. The main user level features of the proposed app will be decided with the aim of reaching the 'modification' and 'redefinition' scale of the SAMR model. To interpret the 'data', the resulting features and functionality of the feature complete app will be evaluated against the intended user level features to analyse any changes that had to be made during the development process that impact on the end user experience. Put simply, did the original idea for the product behave anything like the final product?

2.15 Methodological Framework

To develop an app is a costly process, either in monetary investment to have someone else make it or time to learn and make it yourself given the required technical knowledge. Institutions have publicly released solutions they've invested in and made**,** for example, the previously highlighted Dynamic Spine app**,** which offers a way to recover development costs, but often it is hard to know what apps have been designed and made by someone in that education context. Custom app solutions are rarely an option, where as 'off the shelf' solutions are cheap and readily available. Solutions such as Blackboard, Moodle and WebCT are such off the shelf modular solutions whereby an educational institution can purchase a costly licence and then pay to activate additional features.

The suggested 'best practices' that emerge out of previous attempts at understanding how to utilise mobile devices are formed around the tools, this study aims to create the tool to fit the context.

Within the context of 'creative technologies', we look at how the boundaries of disciplines are converging. A practice based methodology is appropriate because even though the fields of technology and education are converging, those in the field of education do not necessarily have an understanding of how the technology comes into existence. Those in the field of technology do not necessarily have an appreciation of the educational context. Not enough is understood by either educators or programmers of the needs of the other.

The process of mobile app development is important because "how code comes into existence, how it is written, who produces it, how it works and what it does when it is set in action remains largely invisible, unquestioned, and taken for granted" (Williamson, 2013), all of which acts in reconfiguring learning as the codes are set into action.

This study is unique in its approach to undertaking the process of app development as a way to address the gap in knowledge. The practice based methodology is appropriate for this topic as the process between 'we set out to create an app that does X' and 'we have released an app that does Y' is often undocumented publicly, or hard to understand without specialised technical knowledge.

2.2 Introduction to practical component

2.21 Proposal of practical outcome

This section introduces the practical component of the research and the starting point for the mobile app development process, including the chosen platform for development, the purpose of the app and major user-level features. The findings from the theoretical research so far will be used to determine the problem the app is solving and the target user for the app.

The overall ideas are informed by the theoretical component of this study, the researcher's previous study (Klein, 2012), and also the creative process of the researcher which is informed by industry experience in working with lecturers and professors at a tertiary education level, experience in software development, and experience as a student using an iPad in a tertiary education context.

2.22 Choice of Platform

A tablet, akin to its name, is a blank slate, a piece of hardware, an empty tool box which could be used for anything. The apps are the tools, but all mobile devices are attached to a corresponding ecosystem and development platform.

The two dominant players in the tablet field are those running Apple's operating system (iOS) and those running Google's Android operating system. Each platform is different and can determine whether certain features or functionality can be incorporated into an app. However, very few have features that the other does not parody. Because software is the key focus of this research, it is accepted that the choice of hardware is irrelevant.

For the purposes of this research, the Apple iOS platform and associated iPad tablet was chosen given the researchers' prior experience and technical knowledge in the area.

2.23 The starting point

The starting point for the app was to look at the identified affordances that were already being taken advantage of, as identified in the literature and field review:

• Rich media: utilise the device's inbuilt hardware which affords the ability to capture, curate and create images, photographs, audio and video without any extra peripherals.
• Internet access: connectivity affords the ability to access vast amounts of resources, constantly growing and 'always on'.
• Communication: Cellular, wireless and mobile network capabilities affords the ability to communicate, work together, leverage social networks to share content and collaborate.

These capabilities are afforded inherently from the nature of the inbuilt hardware. In a previous study by the researcher (Klein, 2012) it was proposed the following functionality as a way of taking advantage of these affordances:

- Dynamic interaction space: this related to how an app displays content. There is limitless possibility as to how information can be presented digitally, an app should be able to go beyond the simple rectangular organisation of pixels on the screen to give a sense of depth and space, even externalising beyond the device with connection to multiple displays.
- Real time collaboration: an app should be able to accommodate multiple participants working together and reflect this in real time.
- Location awareness: an app should be able to detect and respond to its geographic location and be able to present contextually relevant data.
- Seamless fluidity of content across multiple devices: Devices do not sit in isolation and so content should not be stuck on one device. Sharing and moving media around should be seamless, multiple users should be able share content as a cohesive unit. This means taking advantage of networking technologies and frameworks to move content 'over the air'.

2.24 What is the purpose of the app?

The purpose of the app is to create a backchannel of discussion within a classroom space. The app facilitates real time collaboration on the iOS platform between users working on a common topic or idea. The primary functionality is to curate and create content which is used to generate a montage of images, text and web clippings around a common topic between users in a shared location. As the intended use is for education context, it has an emphasis on adding and exporting citations.

The purpose of creating a backchannel is to support and contextualise the main topic of discussion during a lecture or to facilitate initial brainstorms in a group project or other collaboration.

2.25 Major user-level features of the app

The key affordance of mobility, as identified in the literature review, applies to both the device and the way it handles data transfer, as well as wireless connectivity which enables both the curation and presentation of rich media. Therefore, mobility has been the key consideration in all the major user level features.

The underlying premise is that of a collaboration and mind-mapping or brainstorming app with several points of difference. The app has been designed to target the current version of the mobile operating system of the iPad (iOS7) to take advantage of the newest technologies and frameworks, as reflected in the major features and functionality:

- Micro locations: When entering a space, users are put into groups based on their location and proximity to other people within the classroom. The collaboration is represented as a dynamically generated montage of visual material and concise statements around a topic or idea. A classroom or even tables within a classroom can become a micro location where the spatial arrangement can be determined by peripheral bluetooth hardware known as beacons.

- Focus on content: Users add images, text and web clippings to a canvas. The presentation of visual information does not act as a barrier - when users contribute content, it is automatically geometrically arranged in a scrollable view. Users do not have to worry about design or layout - they can focus on the content. This happens on their 'personal view', where they see only their own content, and on the 'shared view' where a montage is generated with the content of all users in the group. Individual elements can be tapped on to get extra options.

- Dynamic / Temporary media: Shared views are updated dynamically if users leave or move between groups. The shared montage brings together each user's unique contributions in real time on a shared canvas that only exists dynamically while collaborators are in the same space. Users are prompted to export a static PDF version when any participant is about to leave the beacon region or disconnect from the session.

- Academic validity: When adding any piece of content, users can add citation material which is later used to generate a bibliography. While users are able to add content from a variety of sources, they are prompted to add reference information to each piece of content. This can be added at a later stage and users are prompted to fill in missing information before exporting to static PDF.

- Dual screen capability: When connected to a secondary display, the content displayed on the iPad is updated to make use of the extra screen real estate. Utilising the existing key elements of a typical classroom space, the screen at the front of the class becomes a space for interaction, not just delivery of static information. When connected to a secondary display, the app displays the shared montage on the 'public' display, and the user's own personal contributions on the screen of the device. This is necessary when sharing content with the class given the relatively small screen size designed for the personal device.

2.26 App Purpose and Target User

There is the opportunity to add greater value to the face-to-face component with an app designed specifically around the considerations of the physical classroom space.

The proposed app addresses three expectations of mobile devices in tertiary education as highlighted in the literature review. However, these expectations create a tension with the generally accepted notion of 'teaching' used in the context of this study, where a teacher is at the front of the class delivering the information. The target users are both teachers and students. This app does not adhere to the accepted notion of teaching, nor does it intend to do so: it is not designed to be used to support chalk and talk style teaching.

1. *Expectation: Virtual 'spaces' become the new 'place' where learning occurs, replacing the physical classroom.*

Schools and institutions still invest a lot of money into the physical building and classroom as the place for learning. Mobile apps cannot yet afford to disregard the importance of the geography of the classroom. Making an app location aware and responding to that location enables new kinds of behaviours and interactions with people and content. However, the design of the application would allow it to scale for larger areas if needed.

The proposed app aims to examine the ways in which we share and exchange ideas which are often spontaneous and unstructured and to capture those fleeting moments and interactions which take place in class discussions and group work. This kind of interaction is still what cannot easily be replicated in a virtual space.

2. *Expectation: mobile devices enable more collaborative ways of working.*

The iPad makes it easier to share and exchange information, as per the current conception of collaboration on the iPad, but what is still missing is real time collaboration where users can see the contributions and actions of other users in real time. Some apps start to demonstrate this, such as Google Drive (2014) and Popplet (2014).

3. *Expectation: The role of the teacher will change as more students have devices - they each hold in their hands the access to the same information.*

The iPad is a tool capable of both consuming and creating content. However, education apps are still very teacher-centric (for example, the top recommended apps on the App Store for education focus on 'Instructional Tools' and 'Classroom Management'). The focus is still on one person at the front of the class with the information delivering it to be consumed by the students.

In higher education, investigation, research and self directed learning are more appropriate to encourage. The proposed app still enables the teacher to act as a facilitator, to guide students through the sea of information that is available to them, to filter out what is useful and guide in the direction of valuable resources. Students can use the app as a secondary layer of interaction with the topic at hand, while also embedding academic citations which are critical at tertiary level of education but often overlooked when pulling sources off the internet.

2.27 Project GeoStorm

In summary, the overarching problem is the tension between new technologies and established practice: the physical space of the classroom will not yet become obsolete, its role will just change and this app is aiming to address these ideas of what that interaction can look like beyond simply substituting previous technologies or analogue tools.

This app aims not to introduce a paradigm shifting 'killer app', but simply to encourage a backchannel of discussion, to make tangible the conversations and interactions which already take place in the classroom spaces and capture them in a way that is valuable for both students and teachers.

This was the goal for what became known as Project GeoStorm, 'geo' meaning location based and 'storm' meaning brainstorm to represent the idea of collaboration. This is a working title and the process of finding a more appropriate name is outlined in the next section.

The next section documents the process of turning the concept into an app, as described in the plan of study. It is documented through working drawings and sketches, screenshots of user interface elements, and the version history of the development process which highlights features and functionality as they are added.

By revealing this process, it is hoped to give insight as to what decisions were made along the way and why. Decisions made when implementing functionality impact upon the final product and this highlights that those who develop software will make these decisions not knowing enough about the end context that the app will end up used in.

Chapter 3: Practical Component

3.1 Supplementary Material

The next section of the research documents the practical component of the research. This has been done in iBook format so as to best communicate the development process through a medium that is relevant to the product itself.

The iBook format was created by Apple as an extension to the ePub standard to add interactive features specifically for the iPad. The research has aimed to utilise these as a way of presenting content and hence, some of the supporting diagrams and images cannot be reproduced in this printed version or in a PDF file. These elements have been listed in the list of figures.

Ensure that the iPad is running iOS 7 or later and the latest version of iBooks 3.2 (downloadable through the App Store). Though it is encouraged to view on the iPad, it can also be viewed on the iBooks app on an Apple computer running OS X Mavericks (10.9).

To download the iBook for an iPad, go to the Safari app on the iPad and type the following into the URL bar: **http://bit.ly/geostorm**

This will redirect to a Dropbox page. Tap on the 'Download' button and wait: it may look like it is doing nothing as it downloads. Due to the large file size, this download may take a while and it is recommended that a Wi-Fi connection is used to ensure a faster download and avoid incurring high cellular data costs.

Once it has downloaded, it will give you the option to 'Open In "iBooks"'. Tap on this and the book will be opened in the iBooks app automatically.

If you encounter difficulties downloading on the iPad, download through desktop or laptop computer, import into iTunes and manually transfer it to the iPad.

If viewing on an Apple computer, download through in a web browser of your choice and open in the iBooks application.

A static version of this book has been included in "Appendix A: Static version of supplementary iBook documenting the practical component of the research" on page 47.

Chapter 3: Results and Findings

3.1 Results

This section will discuss the findings that emerged from the development process. User testing of the app is beyond the scope of this study as the focus is on the process through which an artefact is created, rather than the artefact itself.

The app was developed to the point where it was feature complete. The findings from the process will indicate whether the intended functionality was able to be implemented as originally intended, or whether design decisions had to be augmented due to technological limitations.

Where the previous chapter was the data collection, this chapter aims to analyse that data. Analysis will take the following format:

1. User level feature as highlighted in 'Project GeoStorm Chapter'.
2. Intended functionality enabled by feature.
3. Limitations: was this feature able to be implemented?
4. If not, what design decision was made as a compromise?
5. What effect would this have on the end user experience in regards to the functionality?
6. What was the expert feedback?

The collected data reveals what lies in the 'killer gap', the disconnect between an app idea and the final outcome. The analysis aims to demystify this process by explaining in a way that is understandable by non-developers. In some cases, technical terminology is necessary and these have been defined in the glossary.

Major user level features:

Micro-locations

The intended functionality was to use iBeacons to determine a user's location within a classroom and use that to assign users to a group of nearby peers as a way of facilitating group projects and collaborative activities. Within this intended context, iBeacons can be installed for facilitating group projects and collaborative activities.

While iBeacons supplement the application they are not required for its use and users can still collaborate without them. This makes the app usable for smaller study groups outside of the classroom.

iBeacons are still a relatively new technology and as such not all mobile devices support it. While this will change in the future, it was decided that if a device did not support iBeacons, it would create its own fake beacon to allow it to communication with other users whose devices also lacked the capability. In addition to this, all devices needed a way to trigger a search mode for when the user moves location. After consulting with Apple engineers on the matter, it was decided that using the device's accelerometers to detect movement of the mobile device would trigger a search to determine whether the user's location has

changed. This represents a utilise the inherent mobility of the device in a way that goes beyond simple substitution level tasks. It is a behaviour the user may not be directly aware of, but it will impact the end user experience.

Focus on content

The intended functionality was to allow users to contribute images, text and web clippings and the app would handle layout automatically. The aim was to ensure that the visual content took up most of the screen real estate by geometrically arranging and sizing elements without cropping.

An open source third party library was used to handle the display of content. It had to be modified to incorporate text and logic had to be put into place to determine the sizing of the cells which were created for content. For images it is based on the ratio and for text it is based on the length in characters, with a maximum of 250 characters.

The decision to use this library was to save the time it would have taken to implement the same functionality. The use of open source libraries is common in development processes.

Adding web content was considered a low priority in the initial development time and has not yet been implemented. This will be an important feature as it will enable users to browse for relevant images and text on websites without leaving the app so as to not disrupt the workflow. Without this feature, users can still leave the app to source additional content.

Dynamic / Temporary media

The intended behaviour was that contributed content was automatically shared with connected peers on a shared canvas which only exists while the users were all present in the same space.

To enable such an experience typically relies on a client-server model of networking and requiring users to create an account before they can use it and constant internet connection, which is the approach of most existing collaboration software. The proposed app aims to use a peer to peer model which can bypass the need for an account and even Internet access. Given the personal and personalised nature of mobile devices, this approach is appropriate as it is assumed that it will always be the same user on the device. Combining the new Multipeer Connectivity framework for networking and iBeacons for location, groups and interactions can be dynamically created based on location and proximity.

This functionality was implemented using the Multipeer Connectivity Framework offered by Apple. This provided a way to handle networking in a simplified manner, including connecting and disconnecting to peers and sending data between peers using Wi Fi and bluetooth capabilities. Once implemented, the app was able to handle connecting to and disconnecting from nearby peers, adding and removing images and text (known as contribution items) in real time and removing all objects for a peer when they disconnect.

A few issues were encountered in implementing this capability:

- Connecting to peers was not always successful. No error message would be given and the app would have to be relaunched to try again.
- Sending large amounts of data, such as large image files, would be slow and sometimes result in peers disconnecting.
- Peers would randomly disconnect and other peers would not always be notified.

These issues have major implications for the functionality of the app so changes in design were necessary as connectivity and transfer of files are a major component of the functionality. Possible solutions and alternatives include:
- Still attempt to connect to a session with nearby peers automatically but offer user interface elements (e.g. buttons) to facilitate connection functionality, such as connect, disconnect, reconnect or search for a session.
- When someone new joins a session, send items one by one rather than all at once to avoid large data loads.
- Compress images to reduce file size.
- If a user has not contributed in a certain period of time, kick them out from the session. This eliminates the problem of 'dead peers' (which results from a disconnection notification not being sent) and as a design decision, penalises peers who have not been contributing content.

Apple engineers who were involved on the creation of the Multipeer Connectivity framework were consulted on these issues. The issues are caused by software bugs in the framework itself rather than issue with the implementation, meaning that there is no immediate fix in the near future.

This caused major challenges in the development process as any design decision would have a major impact on the end user as this functionality is critical to this feature and the intended functionality of the app as a whole. By continuing to use Multipeer connectivity, the end user would be impacted with these bugs which would result in a frustrating experience when sessions with peers would not be created or maintained correctly.

The other solution as suggested by another Apple engineer was to create the same functionality offered by the Multipeer Connectivity framework using the lower level code that the framework abstracts upon. Multipeer Connectivity is not the only way to access peer-to-peer Wi-Fi and Bluetooth capabilities: such facilities are available using networking protocols such as Bonjour TCP/IP. This would in fact solve the identified issues while providing the desired end user experience, but to write that code would be a time consuming and complex undertaking.

Academic validity

The intended behaviour was to enable users to add content and have any associated metadata automatically included as citation information, and allow the user to populate this information manually as well. This would mean users could export the content of a canvas with an accompanying reference list.

Due to the limits of development time allowed within the scope of the research, this has not yet been implemented. When the web clipping capability is implemented, this feature will be critical to be able to track the sources of contributed content.

This design decision was made because the app can still function completely without the feature and the impact on the end user is minimal.

Dual screen

The intended behaviour was to make use of the existing features of a classroom by using the data projector and screen at the front of the class as an extension of the iPad screen when connected wirelessly. Rather than the default 'mirroring' behaviour, the app treats the second screen as a secondary display and displays the collaborative content on the public screen while the user sees their own local content on the iPad screen.

This feature was implemented slightly differently than intended: rather than showing all the contribution items, it highlights the newest contribution item in real time. The user connected to the display can also choose to highlight specific contribution items to show. It is not possible to create a queue for managing people wanting to connect to the display as this is a function offered system wide and not by individual apps. Upon consultation of Apple's AirPlay engineers, some workarounds were suggested but not recommended so this feature was not implemented. It is difficult to predict what difference this would make on the end user because this capability is not vital to the core functionality of the app. It is possible to use the app without these features.

3.2 Findings

Through the practice based methodology it was revealed that there are many influential factors that emerge during mobile app development that impact on the end user of an app.

Certain features were not implemented in the development time due to complexity and relative low priority. It is normal in mobile development to release regular and modular updates to users as the platform allows app developers to release new versions which are automatically downloaded and installed on users' devices. It is common to release new features and bug fixes in future updates.

What this means is that an app's functionality may change over time: the apps which were critiqued against the SAMR Model in the field review of this study at a later date could rate differently in the future.

It has become evident that it is important to target specific devices and operating systems: there is always going to be a compromise between how much backwards compatibility can be enabled while still making use of new frameworks and capabilities. This is a different issue and beyond the scope of this study. In the case of this app, the target was limited to newer devices to take advantage of certain hardware and software capabilities. This however does suggest that perhaps existing apps have targeted older hardware and software to make an app available to a greater number of users and therefore have not made use of the newest capabilities.

In instances where design decisions had to be changed, this shows that what is imaginable from an education perspective is limited by the capabilities of the frameworks and the technology. Often a problem can be solved conceptually from a high level, but cannot be recreated from the lower level through the programming language.

One significant challenge in delivering a feature complete application in this study was the limitations of the networking framework. Upon consultation with the Apple engineers, it was confirmed that these were known programming bugs in the underlying framework and beyond the control of software developers.

Apple too often releases updates to its frameworks so as these tools continue to evolve as well, there's always the likelihood of new capabilities being added. As is the case with many of the features incorporated into this app: many were only announced in June 2013, only months after this study commenced, as was the case with iBeacons and Multipeer Connectivity (Bruins, 2013; Klinc, 2013).

Without these frameworks, many of these capabilities are still possible but a much lower level understanding of programming concepts is required. For example, the network capability could be rewritten using lower level network programming code. However, that is beyond the scope of this study and requires more specialised knowledge in network programming.

The development process and the resulting app demonstrate that even where the desired features and functionality of a perceived 'killer app' can be imagined and prototyped, it often requires specialised technical knowledge and extensive development time to be implemented. A custom app is likely outside of the scope of many university budgets which is why a study with a practical implementation such as this one is unique.

Compromises can be made along the way where the intended functionality is not feasible within the timeline and budget of a project, but throughout the development process, these design decisions will impact on the final functionality and ultimately on the end user: the teachers and the students and the way that they use it, and what the learning experience is.

Without conducting user testing, it can be difficult to know exactly what the impact on the end user is but the purpose of the chosen methodology was to highlight these conflicts that emerge between the desired outcome and the feasible outcome. The purpose of developing this app was to demonstrate and explain in non-technical language how an app idea can result from identifying a problem from an understanding of the education context, but a technological understanding of the development process is required to implement it in such a way that the end goal is not lost along the way when compromises and design decisions need to be made.

The next section discusses the implications of the research and contextualises the findings based on the theoretical fields and the original research question and hypothesis.

3.3 Discussion

This study set out with the aim of assessing the importance of the mobile app development process in understanding how the affordances of mobile devices can be utilised in tertiary education. It was hypothesised that not enough is understood about what decisions have been made by software developers who are generally removed from the education context.

The results of this study indicate that previous trials of mobile devices in tertiary education have overlooked many influential factors that come into play well before an app is even in the hands of teachers and students. This section will discuss those key factors in relation to an education context and the notion of the 'killer app'.

It is again stressed that the scope of this project did not include user testing and the focus of the practical implementation was on the process, rather than the resulting product.

One of the most significant findings to emerge is the need to compromise on functionality. This is an ongoing process as an app is being developed as decisions need to be made to counteract constraints in time, budget, expertise, or even flaws in the underlying programming frameworks.

Another issue not yet explored in the scope of this study is that of targeting multiple hardware platforms. This study used only Apple's iOS platform for development but it is possible to implement a cross platform solution which would make it available on many more devices. Some schools, institutions and students often choose Android tablets because of the reduced cost.

There currently are few apps available that can communicate with their iOS, Android or Windows counterparts. All platforms have different capabilities, less so in terms of the hardware but rather the programming languages and frameworks available to utilise. What might be simple to implement on one platform, could be more difficult on another. For example, the Multipeer Connectivity framework is specific to the iOS platform, limiting interaction to be strictly between iPads only. What this would result in is more compromises and design decisions to the lowest common denominator of capabilities, perhaps limiting functionality and capability.

High turnover of technology will constantly pose a challenge for schools as older models of hardware are no longer able to support newer features and functionalities: it is at the discretion of each developer whether these are made available. Usually it is not a problem as users can continue to use older versions of apps on older devices and older versions the operating systems, but with a networked app that relies on multiple participants, bugs can occur if participants are using different versions. Backwards compatibility becomes a huge issue.

These results provide further support for the hypothesis that both developers and educators to be involved in the development process so that when compromises need to be made, design decisions are well informed with the needs of the end user kept in the forefront. This study has proved that the process of app development is an important factor of how mobile devices are used in education contexts, where previous studies have focused only on hardware and apps once they are at the end of this process.

The inherent disconnect resulting from the 'killer gap' is that apps are still being designed for a model of education located in an information scarcity model, where knowledge was locked up in books and in people and teaching was about getting that knowledge out to the students through a formalised process.

Technology has brought about a different paradigm of information from 'what is the information?' to 'what information is true?'. The value of a teacher is no longer content delivery, but rather in contextualised and personalised meaning making. Though technology has caused this change, it has also prevented it. Use of technology in education has so far been about efficiency enhancing tasks such as writing, communication and research. The recorded lecture online is not 'teaching' and portability and efficiency is no longer an affordance (Landis, 2014).

Education and learning are separate missions. In its simplest form, education is the transfer of knowledge. Learning is the ability to take the knowledge, interpret it and put it to use. Hence the notion of a 'killer app' for 'education' is flawed; rather a 'killer learning app" that is needed - an app which facilitates the understanding and interpretation of the knowledge. Existing apps, by substituting existing classroom tasks, only emulate the processes of 'education': it can be argued that they do not facilitate 'learning'.

The findings indicate the notion of the 'killer app' is not applicable in a modern content due to the greater availability of a larger range of hardware than ever before and the fact that technology evolves at an exponential rate. What might not be 'possible' now could be a reality in a matter of months. When this study began, iBeacons and Multipeer Connectivity were not publicly known or available to use. Towards the end of the study, Apple added 4000 new APIs to their development framework, enabling new possible functionalities (Apple Inc., 2014b).

These findings help us to understand why a killer app cannot exist. Mobile devices have already reached mass adoption, with or without a killer app. We have reached a tipping point where the technology is put before education. Even by evaluating apps against the SAMR model, whether they reach that redefinition level depends solely on how they're used in that setting. An app is just a tool that can facilitate a behaviour: half the challenge is in knowing what the implications of that tool are, and the other half is knowing how to apply it effectively. In order to utilise educational technology and the affordances of mobile devices, how the education intersects with the technology needs to be taken into account.

The problem identified in this research is not just a technology problem, it is a creative problem: just because a creative solution can be conceived, does not mean that the necessary people will have the technical skill to implement it. Without the technical skill, there is a need for a budget to hire someone who does have the technical skill. Someone who has the technical skill might not have the knowledge and experience of a field to see a problem or the creative skills to conceptualise an appropriate solution.

Programming languages, platforms and tools are becoming more readily available. To develop a custom app is a huge undertaking, but the barrier to entry is being lowered constantly. By understanding what happens beneath the sheet of glass of the tablet, education would be able to better take control of the technology and the affordances.

Further research is needed where a practical implementation of an idea is delivered, not just a proof of concept. It is hoped that future research on education technology and use of mobile devices will look more closely at the implications of the apps they are introducing. 'Off the shelf' apps can only go so far and the next step would be to conduct user testing as well as further exploring development process. This is what is needed to bridge the killer gap between the way we are using mobile devices and the transformative experience that has been promised.

Chapter 4: Conclusion

This research aimed to provide a practical contribution to the field of knowledge regarding the use of mobile devices in higher education where results of previous studies have delivered little more than theoretical frameworks. There is a disconnect between the game changing experience that has been promised by not just mobile devices, but every iteration of educational technology before it.

The conception has emerged of a 'killer app': a piece of software so necessary and revolutionary to an industry that it defined the reason for owning the hardware. Though there is a huge availability of apps claiming benefits for teaching and learning, it was found by use of the SAMR model for analysis that these apps offered only minor improvements, often efficiency, when compared to the previous technology or analogue equivalent.

This study took a step back and identified that by the time an app was in the classroom, it was at the end of an opaque process where the decisions about how it would be used and what behaviours it would enable for the end user had already been made.

It was proposed that not enough attention has been paid to the impact of the programming process on the end user of the product. Not enough is known about who creates an educational app or rather, software is taken in good faith that it has been designed with education at the forefront. With mobile development becoming an increasingly accessible and lucrative industry, it can be argued that developers with limited understanding of the needs of education could be the ones distributing 'education' apps.

Given the way the App Store is designed, it can be difficult to navigate through the thousands of apps available, filter what is appropriate and to validate the claims made by the developer in an app's description. It was found that many apps prominently displayed and recommended in the education category were generic productivity apps.

It was hypothesised that the mobile app development process held clues as to why there was no 'killer app' for education and a weakness of previous studies was in overlooking this as a valid influential factor on their results.

To investigate further, this study set out to reveal what happened in the process of taking an app idea informed by education through to a feature complete app. This study has demonstrated, for the first time, through the software development process that many technical constraints can come into play when implementing a desired functionality. Functionality enables some behaviour or task, and if that cannot be translated into a code level feature, compromises have to be made. This is the 'killer gap': the gap between the intended app, which could be designed with the best intentions for education, and what ends up in the hands of the end user.

Returning to the question posed at the beginning of this study, what can be revealed from the process of software development is that when creating an app for education, those who make those design decisions

throughout the development process may not be the best place to understand the implications on the end user.

With the tools increasingly available, schools and universities are able to take it into their own hands and create custom solutions better suited for their needs, whether it be for a specialised discipline or even a different locale, language or culture. The people who are located in that context are the best placed to make the design decisions along the way that impact the end users.

It can be an expensive undertaking to develop an app and the aim is not to create a 'killer app', and the needs of every school and institution will be different, so rather the goal should be to encourage the creation of contextually relevant content. The field of educational technology could benefit greatly if future research focused more on how the technology could be adapted to fit the learning environment from the code level, rather than adapting the learning environment to fit the technology. The latter approach has been proven in research not to work. The results of this study indicate that greater benefits could be had by investigating the creation of custom apps, by education, for education.

A practical artefact has been produced as part of this study and though the focus was not on the finished product itself, it was able to incorporate many of the features and functionality that were set out in the original design and prototype. Several of the features had to be modified or removed during the development process because of technical or time constraints. These are the decisions that would require input from educators to ensure that any change is still consistent with the desired end user experience. This is what lies in the 'killer gap'. In the context of this study, the researcher's own experience in the field informed the decisions that were made.

There is opportunity for research beyond the scope of this study for user testing to inform further development. User testing in an education context would work to further incorporate the voice of the end users into the end product. However, like any creative work, the product is never finished and can be continuously updated and refined to meet user expectations and needs, something that is particularly important with fast changing technologies, or even as the needs of education changes. We are seeing the end of software that is purchased in a shrink wrap box, evolving into something more dynamic and fluid that is more accessible than ever before. There is less of a barrier for the consumer to become the creator and this has huge implications for education that are not fully yet understood.

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Glossary

API: Application Program Interface, or, a set of functions that are used for building software applications by accomplishing specific tasks. Presented in a human readable format, and API gives developers the information they need for the protocols they can implement in a program to interact with different software components.

Framework: When used in the context of programming, a framework is an abstraction on low level code of a system that serves as a foundation to deliver a reusable and extendable platform for software development. Frameworks combine different tools, libraries, functions and classes, accessible using an API.

iBeacon: iBeacon is a registered trademark of Apple Inc. and refers to a indoor proximity system and industry standard set by Apple. A beacon is a device that emits bluetooth low energy that can be detected from another bluetooth capable device to determine relative location and proximity to the beacon.

Library: When used in the context of programming, a library is a collection of files, programs, routines, scripts, or functions that can be used to implement a behaviour.

Peers: In the context of this research, the term peer is taken from the Multipeer Connectivity Framework that is used to define any device that is present in the lifecycle of the app. Peers can be discovered, connected to and interacted with and includes the local user as a peer.

Appendix

Appendix A: Static version of supplementary iBook documenting the practical component of the research.

PROJECT GEOSTORM

Judit Klein

PREFACE

Project GeoStorm: Bridging the 'killer gap' by integrating developer and educator perspectives in the development of a tablet-based app for tertiary education

Judit Klein

This book accompanies the exegesis submitted to Auckland University of Technology in fulfilment of the requirements for the degree of Master of Creative Technologies (MCT)

2014

Faculty of Design and Creative Technologies

Colab: Creative Technologies

The content in this book represents the documentation of the practical process, as per the information outlined in the Data Collection section of the exegesis (2.13). Given that the nature of the documentation is not easily reproducible to the same extent in a print format, this format has been deemed appropriate as it provides a visual and interactive interface to the practical work when taken in context with the full exegesis.

1

PROTOTYPING
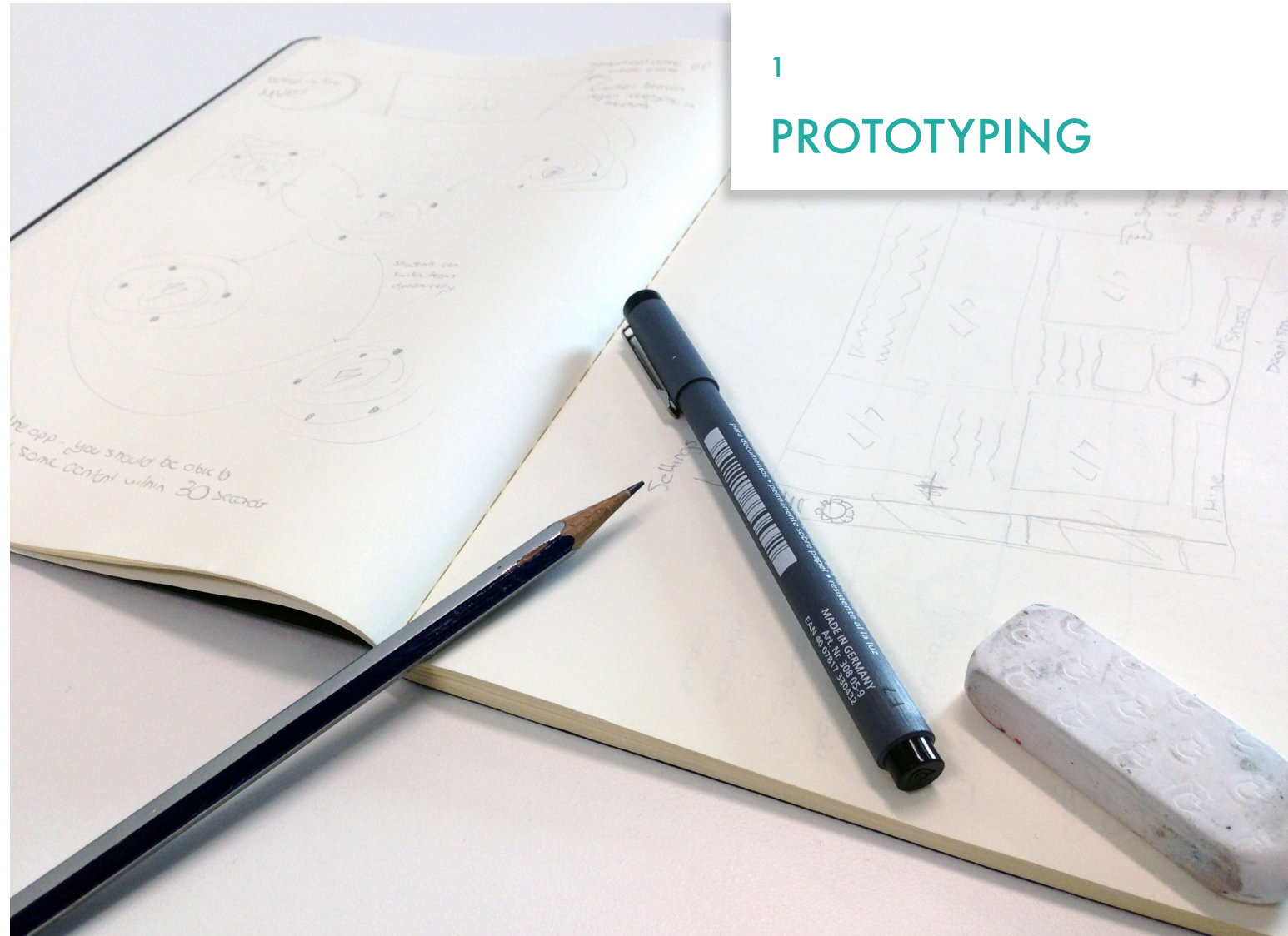
WHY PROTOTYPE?

This chapter introduces a variety of prototyping methods that were used in the original design of Project GeoStorm to demonstrate and determine the desired functionality.

Prototyping starts with low fidelity, hand drawn sketches and over several stages becomes something increasingly realistic, through to a high fidelity, interactive prototype.

This process enables the testing of early ideas, both in terms of visual aesthetic and usability, in a fast, iterative process to make sure that by the time development begins, there is a clear approach to how the app itself will be constructed.

Many digital assets used in the high fidelity prototypes ended up being used in the final app. Not every single prototype is included in this section: a selection of images and other media were selected to give the best snapshot into every aspect of the process.

Many of the figures are interactive and instructions have been provided where necessary.

INSPIRATION

Early concept depicting multiple devices contributing ideas (images and text) to a shared canvas from multiple devices.

PAPER PROTOTYPING

Early sketches of desired interaction and user interface elements. Tap on images to view full screen.
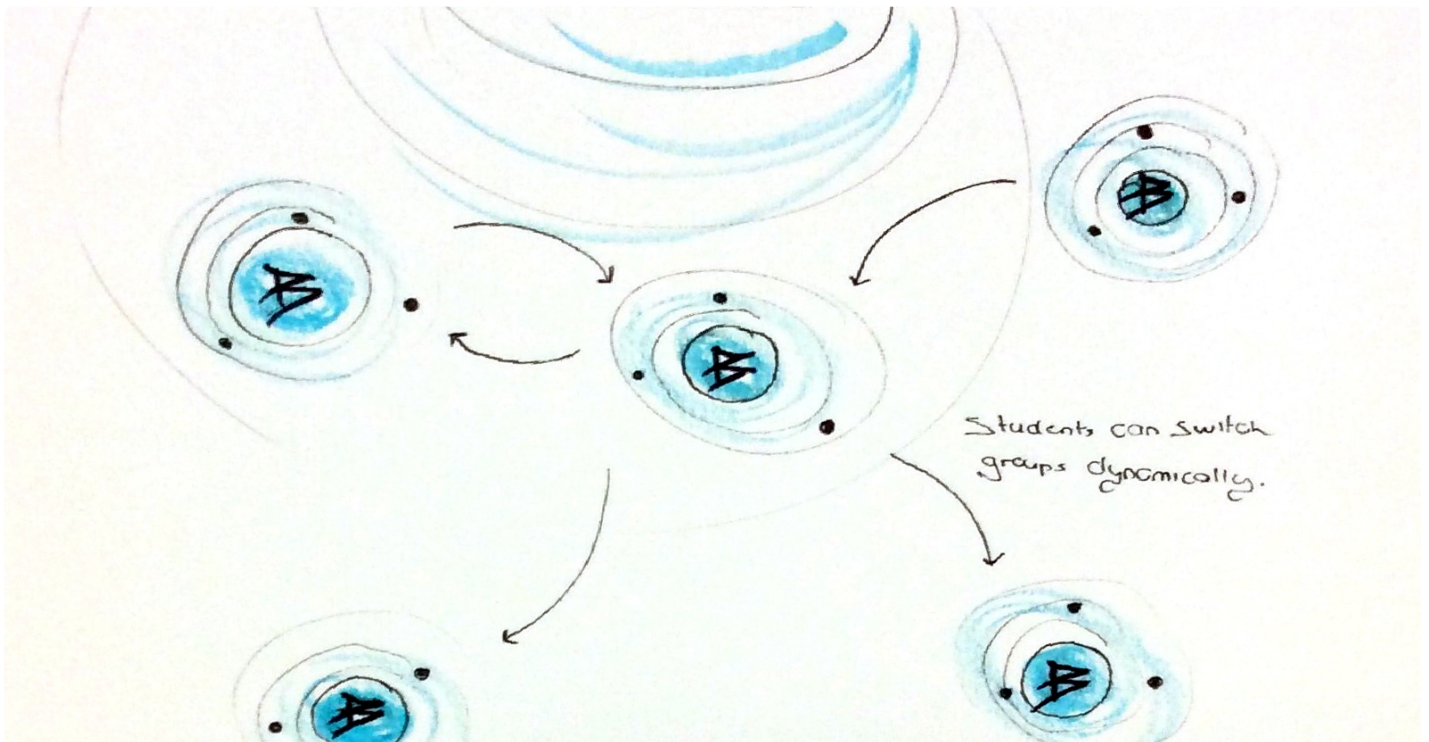
Early idea demonstrating intended user experience where the iBeacons are used to define locations within the classroom space. This lets users move through the space to switch collaboration groups dynamically.

Settings

Content Items

Shared content items

Local View

Shared view

MINE

Shared

◀ ● 1 2 3 4 5 ▶
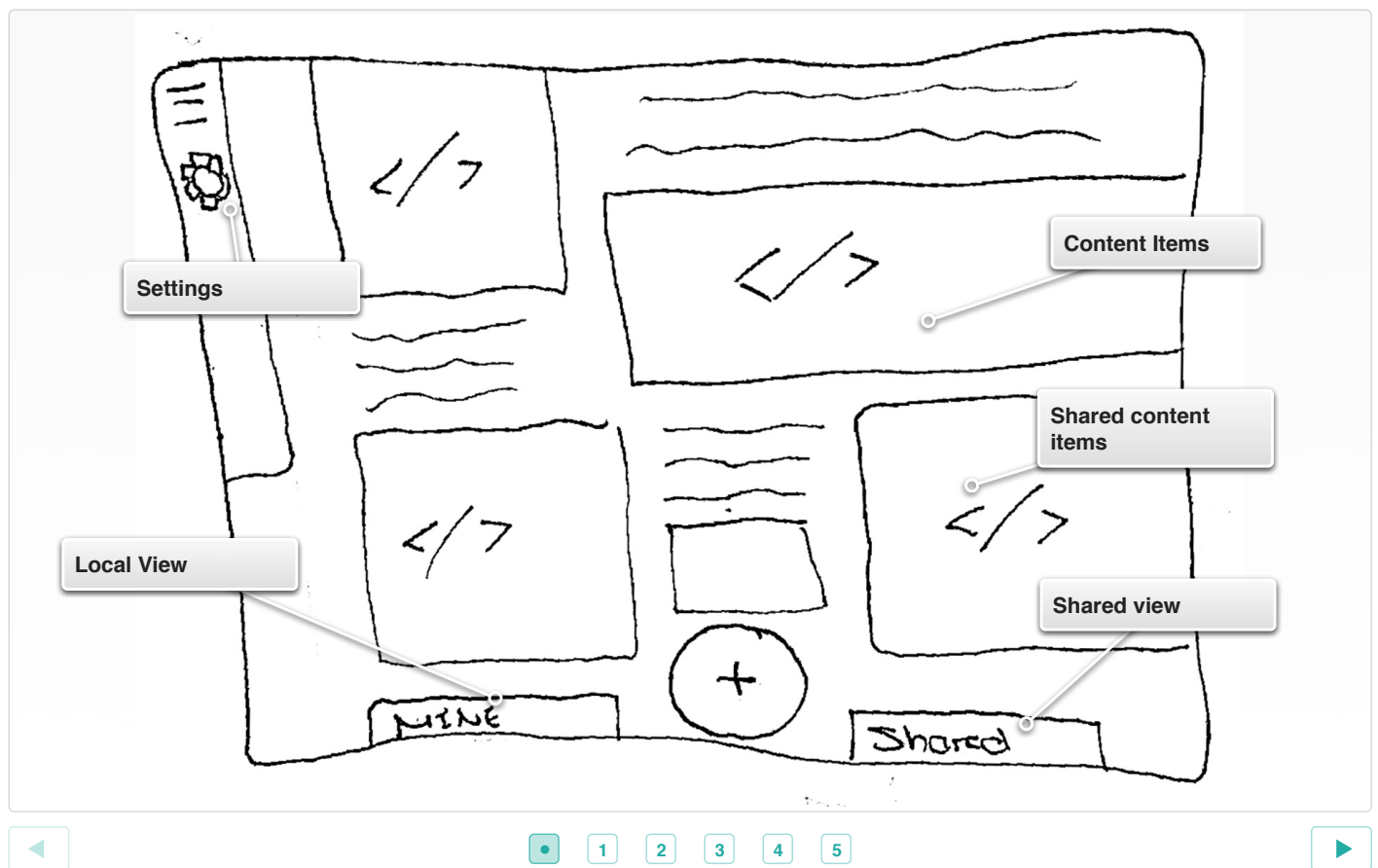
This interactive image shows the initial idea for the main user interface of the app. Tap on each label for more information.
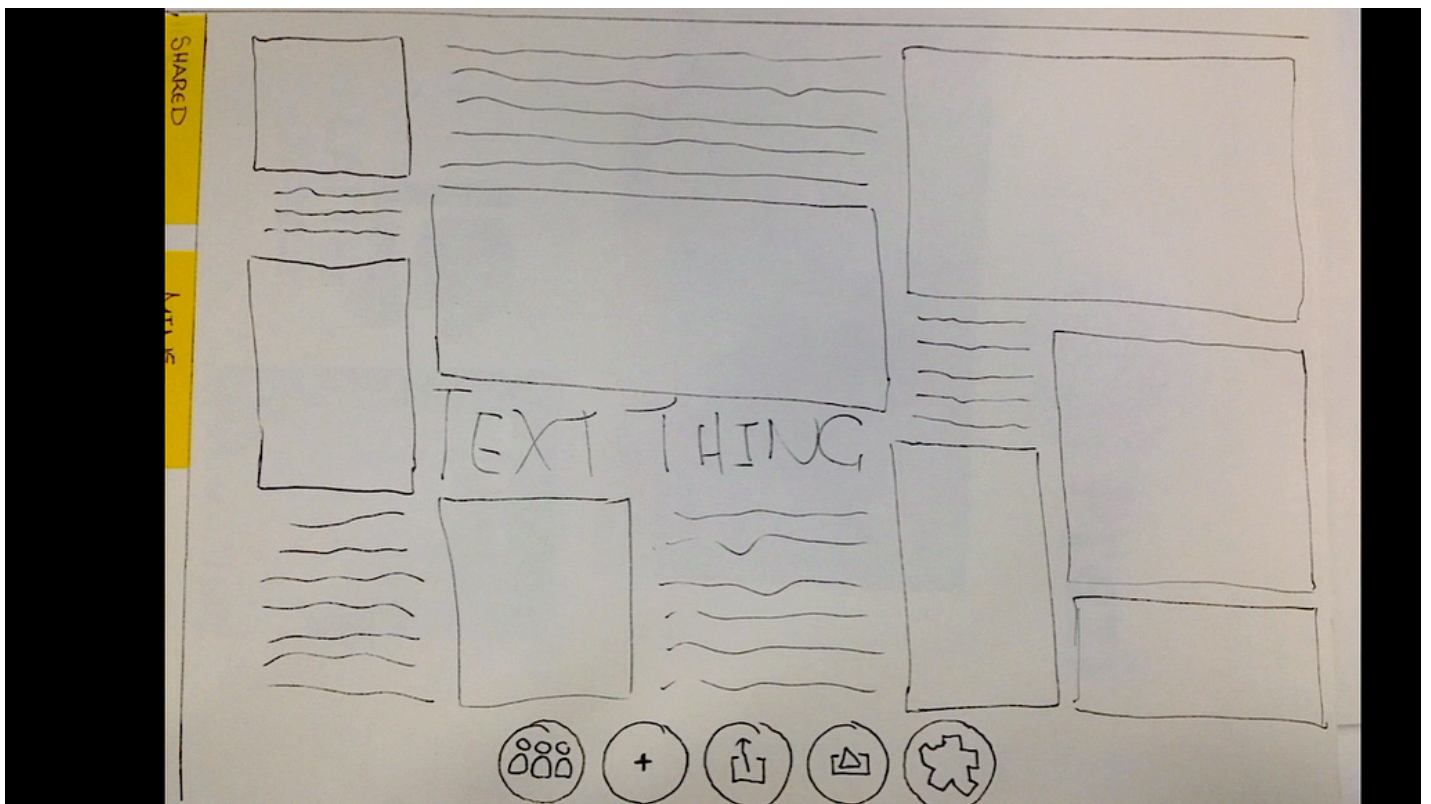
This video was created using an app called 'Prototype on Paper' that creates an interactive prototype from photographs of paper sketches. This is the first prototype that shows the intended user interface elements and some features.

APP FLOW AND USER EXPERIENCE

This section focuses on the app flow: possible courses of action that occur when different user interface elements are interacted with. By mapping these out, it can provide a clear visual way of seeing how an app functions which can also indicate key functionalities that need to be programmed.

Tapping on any of the circular icons in this section will reveal the flow diagram for that particular button in the app itself.

DIAGRAM 1.1 The 30 second test

A key aspect of creating a successful user experience is that a user should be able to launch the app and achieve something within 30 seconds. Tap on this icon to view the intended first experience is for this app.

All images and text have user interaction enabled.

Popover appears

Content becomes full screen

Different UI elements available depending on mode.

Individual mode/ own content

Shared content

🗑 Remove from montage

</> Get hyperlink (if available)

🎓 View/edit citation information

✏ Edit content

🚩 Flag as inappropriate

</> Get hyperlink (if available)

🎓 View/edit citation information

⬇ Save to own montage

DIAGRAM 1.2 This flow chart demonstrates the different ways of interacting with an item on the canvas.

DIAGRAM 1.3
Group Button
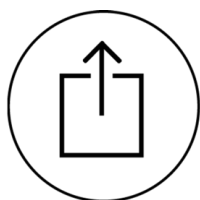
DIAGRAM 1.4
Share Button
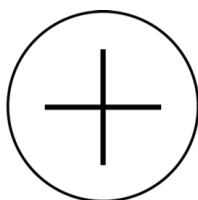
DIAGRAM 1.5
Add Button
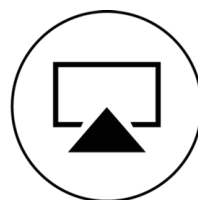
DIAGRAM 1.6
AirPlay Button

DIAGRAM 1.7
Settings Button

Tap on each of the icons above to reveal the corresponding user experience flow chart.

INTERACTIVE PROTOTYPES

INTERACTIVE 1.2 Functional Mockup
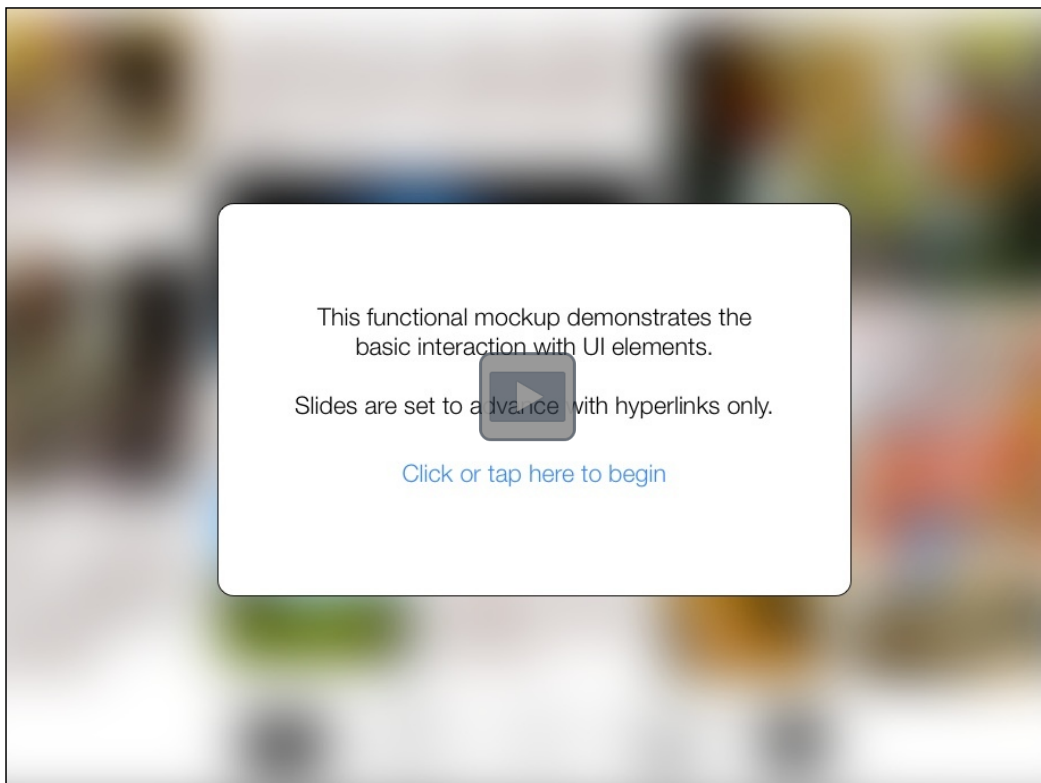
This interactive prototype demonstrates the basic interaction with the main user interface. Tap on different elements on the prototype.

User enters the classroom and goes to sit at a table.
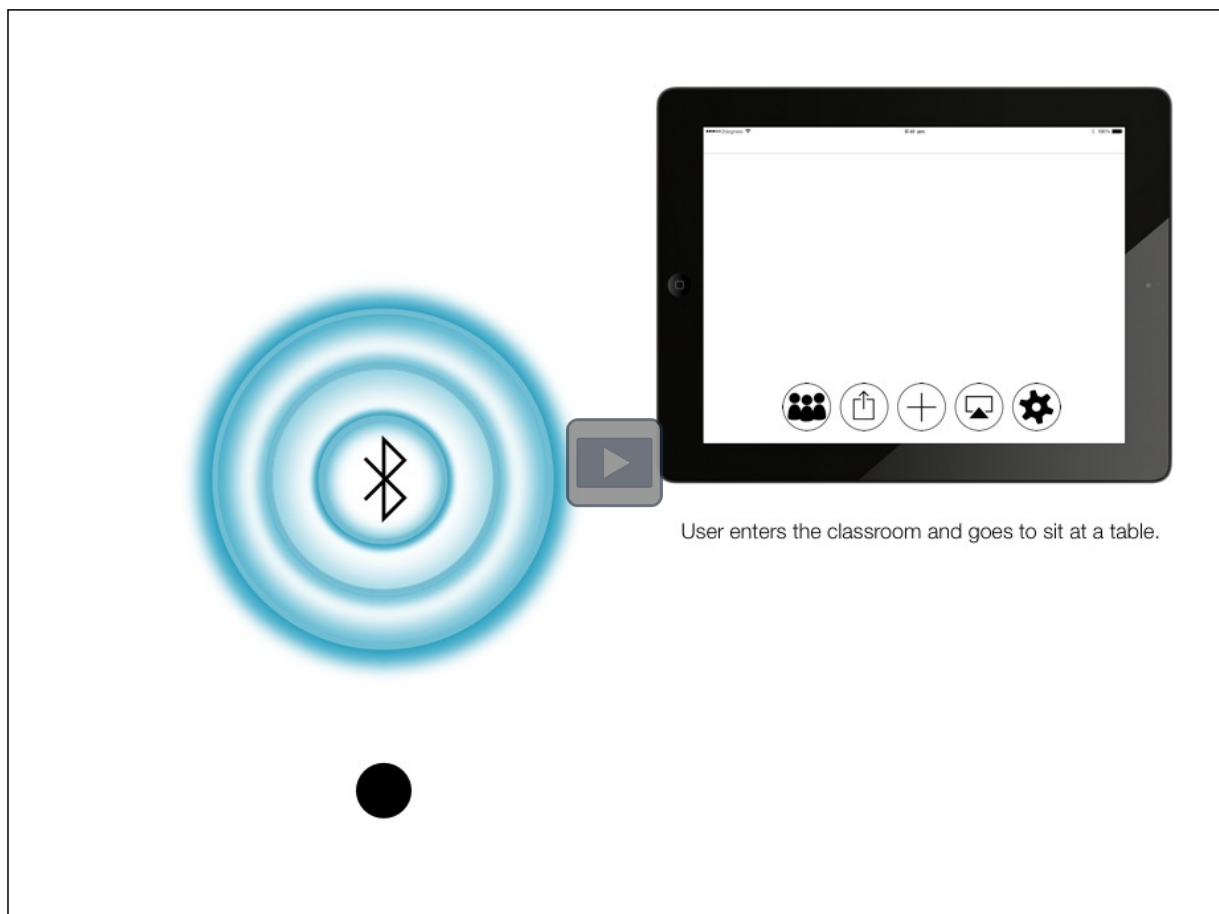
This prototype demonstrates the intended functionality when collaborating with other users. Tap play and slides will advance automatically.

USER INTERFACE DESIGN

This section shows the development of the user interface in a digital format, which was used to create a high fidelity, interactive prototype.

This is the final stage of the prototyping process in this study and many of the user interface elements shown in this section ended up being used as assets inside the app.

Stages of development of the user interface. Tap on images to view full screen.

Tuesday, 8 October 13

Digital Prototype of canvas layout and buttons.

The final prototype cannot be reproduced in this book and must be accessed via the following URL: http://invis.io/6KZ0WGEV

If viewing on a computer: the link will load directly in your default web browser. Click on the different user interface elements to use.

If viewing on an iPad: the link will load in the Safari app, as shown in the image to the right. Follow the instructions shown on screen to add the prototype to your home screen.

Tap on the share button and then the 'Add to Home Screen' icon, as shown below.

Tap on the newly created app icon on your home screen labelled 'Syncrasy' to view. Once launched, tap on the different user interface elements to use.
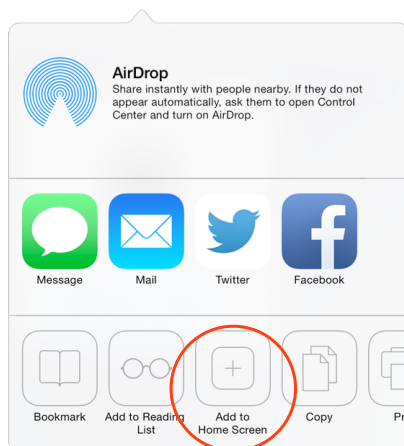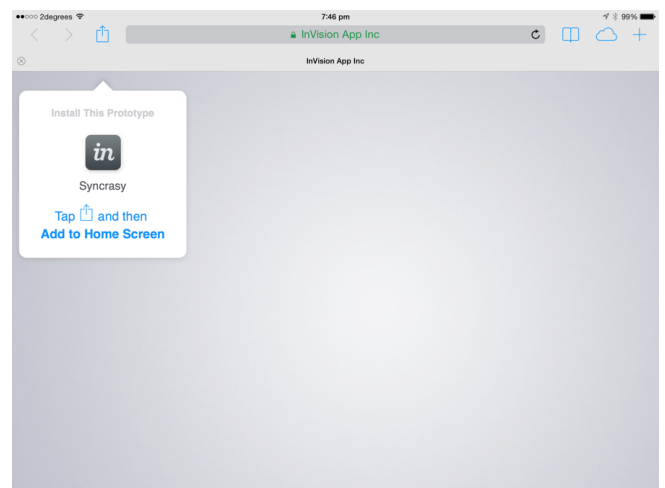
Note: An Internet connection is required to view this prototype.
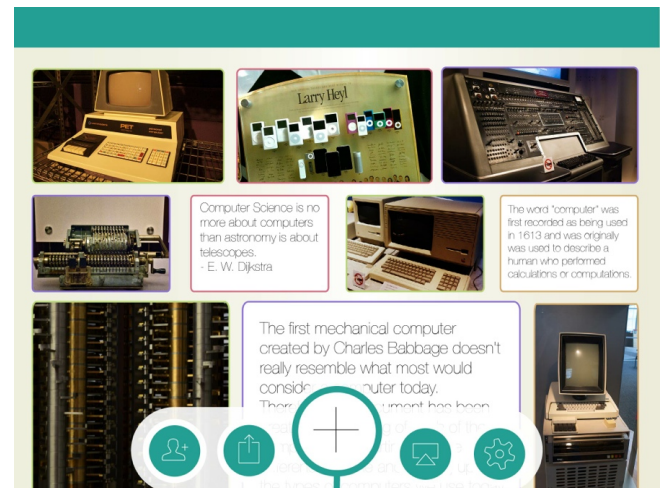
CONCLUSION

The purpose of this prototyping phase of development was to test ideas and to get new ideas that would make the experience of the product better.

However, there is a limit to what can be simulated using a prototype. In the case of this app, the simple interactive elements, such as the buttons, only go so far to convey and test the user experience. The main focus of the user experience is what happens when multiple participants are in the same place, and the type of interaction this enables. This is not something that can easily be faked or demonstrated in a prototype.

Because the scope of this research doesn't include user testing, this is another step that is usually part of the prototyping process to get feedback from potential users.

In this instance, prototyping played an important role in identifying key functionalities and beginning to understand how the project would come together. The prototypes will be useful later for comparison to the finished product as they represent the original idea for the app. The next section will document the development process and how this idea will change.

The prototype is one end of the killer gap. The fully feature complete app in chapter 3 is the other end. The next chapter reveals what lies in the chasm in between.

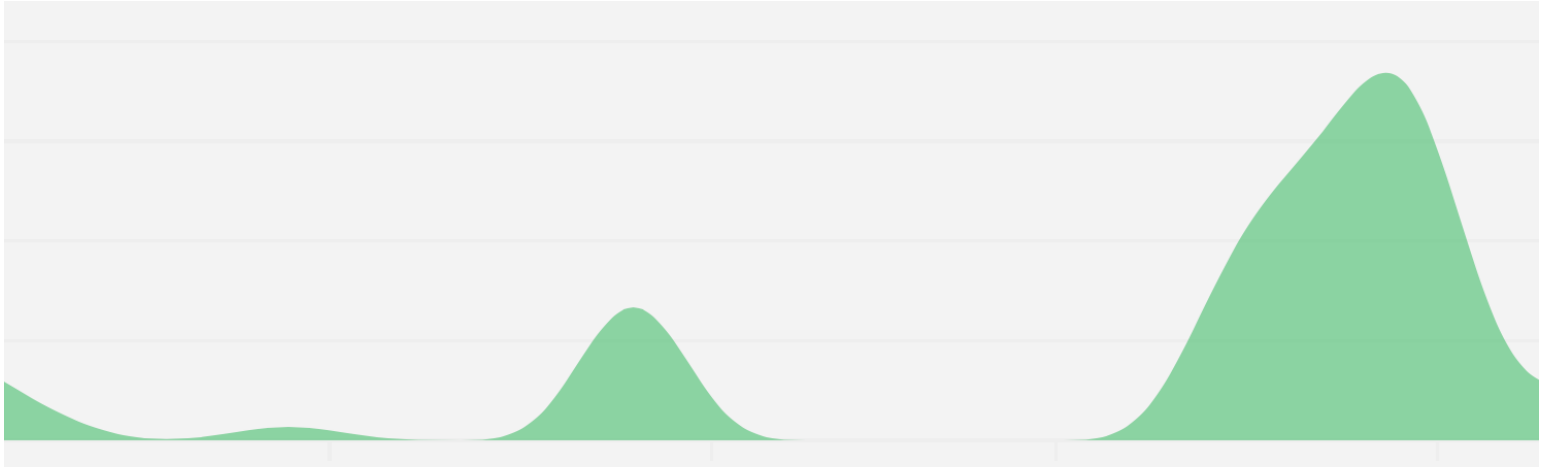GALLERY 1.4 User interface across different stages of prototyping. Tap on images to view full screen.

The first paper prototype.

DEVELOPMENT

DEVELOPMENT HISTORY

This section shows in several visual formats the development process of the app, through to a feature complete point. The most significant of this is the step by step documentation generated through the commit history: when a section of code is saved to the repository, it is accompanied by a commit message.

These commit messages have been put into am interactive timeline **(Interactive 2.1)** and at each step it is explained what the commit message means in relation to the scope of the project with the overall aim of demystifying how an app is made.
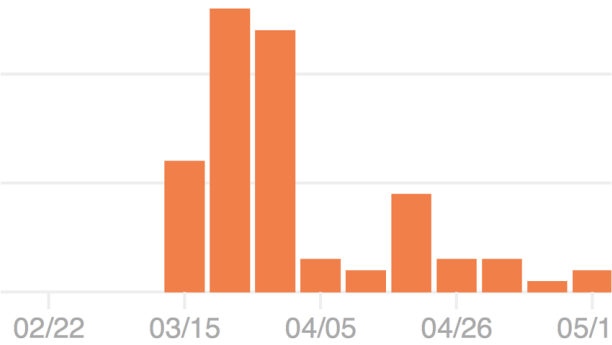
Further analysis will take place in the theoretical components of the exegesis.

INTERACTIVE 2.1 Interactive timeline of commit history. Tap image to launch.

This timeline depicts and demystifies every step of the development process of the app.
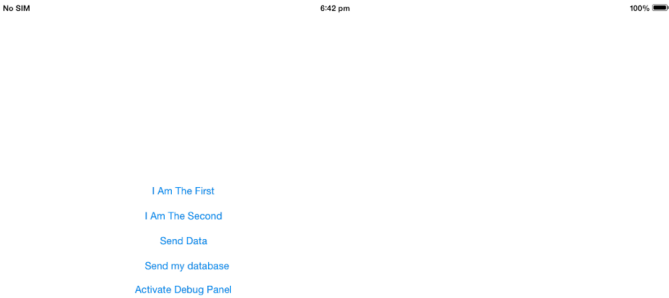
GALLERY 2.1 Visual representations of the app development process. Tap an image to view full screen.

Number of commits to the code repository over time.

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GALLERY 2.2 Stages of the user interface during the development process. Tap an image to view full screen

I Am The First

I Am The Second

Send Data

Send my database

Activate Debug Panel

1 of 15

SUPPORTING DOCUMENTATION

Feature list

Priority 1: This must be implemented, core functionality

Connectivity

√ Find other peers
√ Identify if other peers are associated with the same UUID
√ Connect to other peers
√ Send and receive data among peers
√ Handle peer leaving - if it is the peer advertising the session, someone else needs to advertise
√ Tap on group button to see who else is in the group with username and avatar
√ When connected to a new peer, remote peers send them their databases

Contributions / Adding content

√ Seed sample database
√ Send and receive database of objects
√ Set up cells for configuring layout
√ Add an image from camera roll to the montage
√ Add an image from camera to the montage
√ Add text to the view
√ Content is removed from shared view when a user leaves

- Goodbye protocol

FIGURE 2.1 Feature list: this shows the list of features to be implemented, their relative priority, and whether or not they were implemented.

Test Plan

Standalone mode

Adding content

- Add local contribution item - photo
    - front facing camera
    - back facing camera
    - add from device without camera (button should be disabled)
    - cancel adding photo from camera roll

- Add local contribution item - image from photo library
    - add large photo that needs compressing
    - add small photo that doesn't need compressing
    - add very small image smaller than cell
    - add horizontal panorama image
    - add veritcal panorama image
    - add landscape image
    - add portrait image
    - add square image
    - cancel adding image from photo library

- Add local contribution item - text
    - add text of different character lengths
        - 0 characters should have add button disabled
        - 1 to 20 characters
        - 21 to 50 characters

FIGURE 2.2 Test Plan: This shows the list of test cases that need to be run through to ensure that all features and functionality work as expected.

SYNCRASY

operam

pro tempore

ephemeral

fleeting

talk

ad hoc

chat   discuss

dynamic   # temporary

collaboration

transient   real time

active within a space | physical
virtual

come together

syndetic

muster

complect

alloy

Synactic

corrivate

adj. - acting in addition or together; cumulative.

To cause to flow together, as water drawn from several streams.

WHAT'S IN A NAME

*Syncrasy: The blending, harmonising, or massing of
different or antagonistic elements.*

Project GeoStorm was merely a working title and thus the
app will become known as Syncrasy. Careful consideration
was given to find a name that was unique, yet still
suggested what it's purpose and functionality is.

Words synonymous with collaboration and synchronisation
were important, as well as those prefixed with *co, col, con,*
and *sync.*

Syncrasy was chosen for it's definition and it's relatively low
usage on the Internet, which will optimise brand awareness
in the future upon app release.

Syncrasy

The blending, harmonizing, or massing
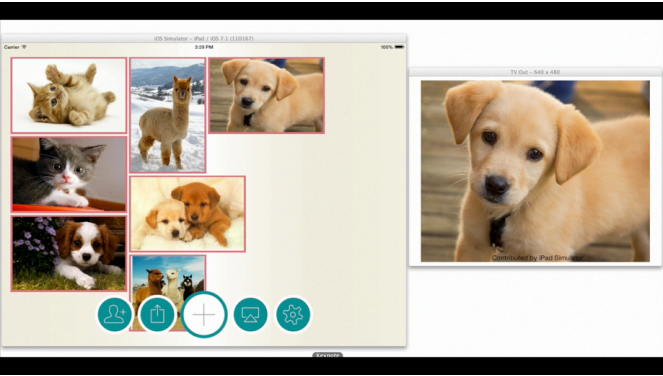of different or antagonistic elements.

Synectics

n. - problem-solving by creative and lateral
thinking among a diverse group of people.

Syntagma

n. - a systematic collection.

Systatic

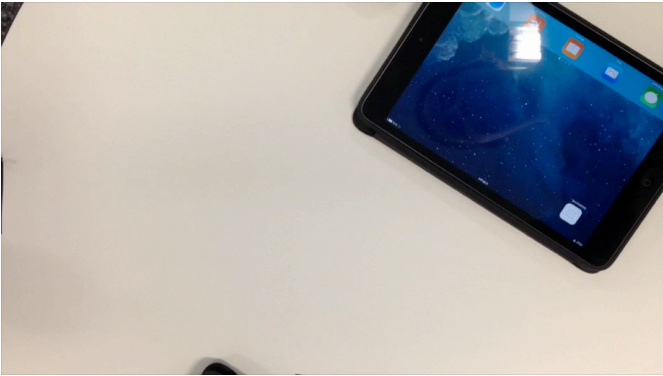adj. - bringing together.

20

THE END OF THE GAP

Movie 3.1 Video demonstration of feature complete app.

This video shows the completed app as demonstrated on one device only while connected to a secondary display.

Movie 3.2 Video demonstration of feature complete app.

This video shows the completed app as demonstrated when multiple devices are present with several users interacting.