Digital Management Systems in the Classroom with a Focus on Tablets

by

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Abstract

Mobile learning is an unavoidable emergent aspect of education and is recognized as such by most people involved in the education field. However, schools and teachers face a number of unique challenges when looking at how best to employ devices in the classroom. No matter the number of commercial applications one of the key elements remains the willingness of teachers themselves to make use of technology. When looking at various computing devices, tablet and mobile options can offer an alternative to laptops in the classroom and can provide a number of benefits to teachers as either a primary or complimentary device. Teachers need simple to use and simple to learn software that does not require significant professional development investment, especially in the field of classroom management software. This thesis examines the way teachers digitally manage classroom environments and looks to explore what makes usable and learnable management systems when applied to tablet devices.

In this work the pedagogical framework in which teachers look to employ mobile devices and the major factors that impact their willingness to employ them in the classroom was examined. A survey was conducted with the target population to assist in understanding how schools view the use of tablet devices in the classroom, the ways in which they look to employ them, how the institutions themselves are adapting to the influx of mobile devices and managing the policies and infrastructure required to maximize their benefit. The research also looked at the ability of tablet devices to act as a content creation device rather than purely consumption, examined how efficient the different methods of textual input were as well as how students themselves perceive the effectiveness of different hardware and software keyboards.

Initial investigations identified that teachers would like to make use of these mobile devices more and that they could act as a substitute for laptops. To investigate this an application was created that would allow teachers to digitally manage classroom tasks. This application looked to provide a simple and highly learnable interface that required little training to employ and allowed the teacher to control the storing and access of data themselves. It ensured collaborative mobile learning ideas are utilised to provide channels for peer to peer, collaboration and grouping, student to teacher communication channels and document distribution and management in a device agnostic manner. Two usability studies were conducted with volunteers which resulted in a zero fail rate in users executing a spread of single and multiple function tasks. The application also achieved an above average overall rating on the System Usability Scale. Following these tests, the application was deployed to the target population in a primary school classroom for a 2-hour lesson block, acting as a companion management tool

to the existing lesson structure. During this lesson the application was utilised successfully by the students with limited issues or problems. After the test the application was again rated and found to have above average usability by the participants. Overall, the software performed well and users could learn to navigate and utilise the application feature set with little (or no) training or practice. Users also found that it was very easy to repeat tasks once they successfully completed a task.

This work's contribution includes a greater understanding of what creates usable and learnable tablet interfaces and the importance of providing teachers a low cost, simple and usable digital management solution that is focused at the classroom level. The work also suggests that interfaces can be developed that remove the need for professional development time to be invested in learning the technical and sometimes redundant aspects of software usage. Finally, the research presented the importance for teachers to have access to these simple systems to allow them to choose the pedagogical application solutions that best meet their teaching needs.

Contents

List of Figures

List of Tables

List of Formula

Certification

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed Dated: 15 – 10 – 2020

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Chapter 1

Introduction

INTRODUCTION

The ubiquity of technology throughout all aspects of society is something that drives change. The acceptance of technology for work and play leads to the need for education to not only embrace technology but to also foster comprehension, comfort and advanced use. In the space of only a few years the access to quality computing on the go has changed the way we communicate, relax, work and consume media. The child of today is a user of powerful technology, and for many children this is before they learn to talk. Observations such as those below are all examples that are apparent in society today and demonstrate the ease with which children embrace and utilise new technology.

"This doesn't move!" a child demands of their father.

"It doesn't move, it's made of paper" he responds, looking at the magazine.

"What's a CD" a child asks.

"Well it's a silver disc that you play music from" replies their mother.

"Like an iPhone?" the child says.

"Sort of" the mother responds with a furrowed brow.

My sister drives an hour into the city, while in the back seat her three-year-old boy kicks the passenger seat.

"Can you get the tablet out of his bag." she asks and I rummage around to find a cheap knockoff of the Samsung Galaxy tab. It was cheap, barely $50 and poorly made, but for all that it is a fully fledged Android device.

"Just open the browser, it should have his trains on there." She asks as I swipe across.

"How? We don't have wireless in the car" I state.

"Oh yeah you can save YouTube videos local now so I just saved a bunch of train ones he likes. Don't worry he knows what to do" she says.

I hand him the tablet, his little hands reaching out. She was right. Tablet in lap he swipes to the train videos and punches the thumbnail. He sits engrossed as the big steam train trundles across the screen and I can't tell who is more excited, the 3-year-old or the 40-year-old man who was filming it. Then he moves on, hits the back button and selects another video; diggers this time. My sister says something and I turn away and for an hour he sits on his tablet, swiping and clicking. At three years old. For him the computer will not be a rarity. He will not get his first home computer when he is nineteen, he probably won't even remember when he got it. Growing up mobile devices will simply be a part of his life and when he enters school he will expect the same ubiquitous device access he is thoroughly familiar with outside it.

INTRODUCTION

But this wasn't always the case and for many of us our memories of computers in school were far different, for a technology that has revolutionized the world in less than a quarter of a decade…

When first introduced to the classroom in the early 80's the computer occupied a rarefied place of pride. A wealthy school could perhaps afford a handpicked selection of machines, given pride of place on desks in a small room. For a small school perhaps one or two of these machines could be managed while for many schools they could only hope wistfully to perhaps one day have one. While archaic by any modern standard these old titans, the Apple II, the Commodore 64, and the Vic 20 provided some glimpse of the role computers would come to play in education. Yet for all their prestige, they offered a very limited amount of usability in the classroom. Software was rudimentary, knowledge of how to employ these machines even more so. Teachers were untrained for the most part beyond the absolute basic functionality of the machines and even then the level of training required for any kind of advanced use was significant. Coupled with a lack of graphical Window Icon Mouse Pointer (WIMP) interfaces, the requirement to be in a room with the machines and the limited contact hours' students could expect, the realistic use of these machines was challenging at best.

Yet educators could still see the writing on the wall and while many of them could not have predicted the scope at which computerization would change not only their classrooms but the world, they saw what the benefits of these machines could be. While early computer lab lessons would often revolve around typing exercises and perhaps some rudimentary drawing or programming work, their potential was far from being realized. At the turn of the century most had realized the impact computers were going to play; the internet was becoming more usable, home computers were more common and network speeds were increasing. But the true mobile revolution was yet to come.

The first decade of the 21st century has bought an explosion in mobile networks and devices that caught many of the most prepared by surprise. While many schools were starting to get to grips with the idea of 1:1 computing and how best to employ technology in the classroom, the mobile learning and Web 2.0 revolution came and introduced a whole new aspect to the domains of information and communications technology (ICT) in the school. Platform based services have become commonplace in the internet realm, offering truly interactive online environments while the mobile computing realm, driven by the powerhouse of the smartphone, has become an almost ubiquitous device across the globe. In many developing countries a user's first computing experience will be with a smartphone as they skip the desktop environment entirely. The low cost and ease of access sees many children entering high school already owning and being intimately familiar with these environments. It is not that they are expected to be comfortable and active in their use of these devices in learning, *they* expect it of their schools. At the same time their experience with technology is different. Even among teachers starting their professional careers today, in 2018, their first interactions with computers will almost all have been the common desktop Windows, Icon, Mouse and Pointer (WIMP) environment. If a teacher is graduating from university at 22 years of age they were already 11 years old when the first iPhone released in 2007. But for the children starting school this year they have grown up on touch and mobile interfaces that perform and deliver material in a different way.

Yet all industries change and grow, so what is it about the ICT domain that raises so many questions, especially in education? One main factor is the sheer speed at which change occurs. The landscape now is incredibly different to how it was twenty years ago in 1998. For many who work within or research the ICT field this speed has become something that is accepted; this work presented in this thesis is an example in action. While work began on this thesis in 2012 scant years later the landscape under which it was conceived has already shifted and original plans and design considerations are now either realized or have moved, as noted later in the work. Yet for those outside the ICT field this rapid shift requires significant adaptation to familiarize and incorporate new technologies. This is a challenge in the business world, yet it is an even greater endeavour in education where so many factors pull and push for validity, requiring acceptance with multiple stakeholders each with different aims in the education sphere.

For institutions the cost of implementing systems is an essential consideration. Yet these same systems require significant outlay in training and time investment for both administration and teaching staff for a product that may see limited functional use. Resource cost again comes to the fore when examining the technology students will have access to. Can the school afford 1:1 laptops for all students? Are parents expected to cover a portion of the bill? Are laptops the only devices available? Does a lower resource classroom need to share devices amongst different students in different classes? On top of these practical issues schools are responsible for the action and wellbeing of students on their campus and need comprehensive policy and procedures for dealing with these devices. This can be a substantial challenge when the foundation evolves every few years. For students, how have these changes manifest in their learning patterns? The idea that effective learning happens only in the classroom (Chen, Monrouxe et al. 2018) is no longer true and by its very nature mobile devices drive a blended learning environment (Wang, Shen et al. 2009, Keene 2013) . Students expect course content to be available when and where they need it; mobile learning is after all not about mobile devices, it is about the mobile learner.

Lastly the teacher has perhaps the most difficult transition as it is they who are tasked with incorporating this new technology into their lessons. Here the varying needs of student and institution vie with pedagogy and time commitments for consideration. Training is invariably a significant portion of any ICT implementation, yet for teachers' technology is a means to an end, not the end itself. Care should be taken that technology fits the lesson and pedagogy and not the other way around. This can be a challenge when environments are managed at an institution level or through a licensing agreement. There is also the technical aspect, professional development time is not infinite and time taken learning the technical intricacies of an application is time spent not learning how best to employ it within the educational context. There are social pressures as well within the classroom with the unique dynamic of teacher and student at play, dramatically increasing the need for confidence within a system before teachers are comfortable to use them in front of a class. These factors contribute to a positive or negative cycle of ICT adoption; comfort begets use, or discomfort begets rejection. The clear driver for teachers here then becomes; give us usable software that is quick to learn and achieves our goals without requiring significant technical training, or we won't use it; a tall task.

1.1. Research Focus

While many teachers may be uncomfortable with ICT, unfortunately its use in the classroom is not one of optionality. The confident, effective use of ICT in the classroom is as important to the teacher who starts in 2017 and has had her mobile since she was 10 as they are to the teacher close to retirement who was ten years out of University before most schools had their first computer lab. It should be essential to provide usable, easily learnable software that allows both of these teachers to manage and communicate with their students in and out of the classroom. Business recognizes this and the world of Learning Management Systems (LMS) has risen to provide the basic digital management that teachers require. Yet along the way they have, as is the nature of business software, expanded functionality and increased breadth to a point where they are often providing a large swathe of unused functionality, and in casting the widest net the core tenets of ICT use and software for pedagogy can be overlooked in pursuit of business goals.

To this end the research presented in this thesis is a first step in investigating ways that agency can be given to teachers to manage their digital spaces. The investigation sought to understand how teachers could manage digital content with the classroom using tablet devices, outside of the cumbersome institutional wide LMS environments.

Often these modern systems are hardware independent, usable on most modern form factors of device; laptop, desktop, tablet and smartphone. However, this same independence can lead to additional complexity as the system attempts to provide functionality across multiple environments. This software cross dependence alone is only one factor as teachers are also bound by real world constraints such as resources, administration policy, IT availability, teacher device comfort and general technology aptitude. These systems are often server / client based and this can add to the complexity of both setup and operation for schools where cost and training time are limited. Even if the LMS is easily usable, the architecture for the server end may not be, or may require significant resource outlay in both personal time and training.

INTRODUCTION

With an appreciation of what factors are involved in ICT use in the classroom, how teachers are looking to employ technology themselves, and an understanding of the role cheap tablets can play there is value in investigating the core idea of functional and usable software, with high learnability and usability to facilitate core digital management functions. Based on this, the research focus for this thesis was:

Examine the unique domains of how and why teachers use technology in the classroom and how management systems do, or do not cater to their needs. Can low cost tablets be used to provide the same functionality as these institution wide management systems, and can such a system be created in a way that it takes into account the unique perception and confidence factors present with teachers when addressing technology?

To investigate this a number of collection points throughout this research were used including:

- A background literature review
- A survey of the perceptions of teachers and institutions regarding tablet usage
- A consideration (though experiment) of tablets as a substitute for laptops as creation devices
- Design and development of a classroom focused management application
- Usability and user experience evaluations with three distinct populations including a live evaluation within a classroom.

This Classroom Management Application (ClaMApp) was designed to provide the same core functional pathways teachers use the most from larger environments and be designed to run independent of outside systems or hosting; it should be able to operate within the classroom on its own Wi-Fi network. It had been created using the unique properties of the mobile interface to provide a streamlined and highly learnable interface to allow teachers and students to perform their management tasks with a strong sense of expected outcome and to require little to no training in order to operate.

It is important to note here that when discussing the management aims of the software in this work these are the management of digital tasks, not the management of student behaviour or activity within the classroom. While software tasks exist to assist and manage behavioural elements of the classroom this application addresses the management of digital operations and digital communications. When used in this work digital classroom management and classroom management tasks refer to the digital landscape, not the behavioural landscape of the classroom.

1 1.1. Research Questions

With the application ideal in mind and given the research focus the content of this theses looks to address the following research question:

1. What are the driving factors for the use of ICT in the classroom and how are ICT environments implemented within modern learning pedagogies?

When looking to design and understand the software requirements of a group it is essential to understand the domains in which the technology is used, including how these users seek to employ ICT and what the important factors are. This is especially true in the education domain where there are significant environment and social impactors that effect these decisions. The personal views of teachers must also be aligned with the policies and aims of the school as well as the expectations of the students. As well as these in-school factors, often the software provided has a primarily business aim in mind. This can often be at odds with both the teacher and school philosophies. Lastly the role that educational design plays needs to be understood. The developing ideas of blended learning, Web 2.0 and mobile learning need to be reconciled with all of the above issues.

2. What are the key factors that influence teacher's willingness to use digital environments? Are these factors heavily influenced by the personal and professional impactors within the classroom environment?

Perhaps one of the most important elements is the willingness of the teacher themselves to employ the technologies. While a school can provide the software and hardware systems, the willingness of teachers to embrace ICT on a per class basis is a large factor in the way that that classroom will look to use technology. Identifying the key drivers that impact that uptake is fundamental to creating software that is not only effective at its task, but leverages the teacher's proclivities to encourage greater usage.

3. How are tablets viewed by educators and students, and can they fill the role of a low cost computing solution? How do teachers view the use of these devices in their own classrooms?

Often resource cost and availability are important factors in the way that ICT is used in a classroom. Tablets and smartphones provide low cost alternatives as classroom devices, but are teachers ready to accept them as integral parts of the classroom? Software can be as fit to task as possible but if it runs on hardware that the users are not comfortable employing it may be for nothing. Within the classroom tablets may be seen as a portable video screen but can they be more, and are teachers willing to embrace this additional functionality?

4. Can tablets themselves be seen as more than a content consumption device?

With modern devices input dynamics is a central question to the viability of tablets as devices to create documents. Are tablets themselves up to the task of being the sole device in a classroom? While they are often viewed as content consumption devices can they also fill the creation role that a full-fledged laptop can, through the use of effective input peripherals.

5. How can software design target the key impactors of time deficiency and personal opinion that teachers experience and can usable and learnable environments overcome aspects of this reticence? Can the creation of a tablet application allow for teachers to easily integrate often complex management software in an easier manner?

With an understanding of the factors that impact the willingness of teachers to use devices, and with tablets providing a valid alternative as a standalone device within the classroom, can software be designed to leverage these usability and learnability factors to encourage use within the classroom? With a primarily mobile derived tablet, what structures are needed to ensure that devices provide for the most important digital management functions for teachers, presented in a way that facilitates effective use with minimal training, reducing the need for extensive professional development?

Can effective testing help to refine these function sets to allow for a system that is effective and usable with minimal learning? What are the benefits of the tablet that can be leveraged to provide a smoother learning process? Similarly, what traditional WIMP structures are inappropriate in a mobile interface or can be employed in a manner that is more naturally learnable on a mobile device?

Perhaps most importantly given these design elements, can a complex management application be introduced into the classroom and used in a real world setting with minimal to no training by both teachers and students?

1.2. Execution

In keeping with the research questions, prior to the design and creation of the application, it was important to understand the current state of teachers with regard to tablets and technology in their classrooms, and if schools had the infrastructure in place to support such a project. This is especially valuable in the technology field due to the speed with which change occurs. These views can not only change rapidly based on technology but also on what policies schools are implementing, the teacher’s personal preferences and the environments in which the schools operate (resource (technology as well as human) availability, rural, urban, or socio-economic) encouraging the regular updating of data. It was also important to validate the ability for the tablet to behave in a similar creation space to a laptop.

While tablets provide analogous output structures to traditional devices there are questions surrounding the ability of students to create documents with the same ease. Here, especially, current research is limited with regard to comparative WIMP/keyboard input speeds. This was done through experiment, comparing software and physical keyboard entry on a tablet to a laptop, demonstrating the comparable long text entry speeds on a tablet. While there are a number of alternate input paradigms as written text is still the most common input method this was the focus of this portion of the work.

Based on the background research, survey and experiment results an application was created to examine highly learnable and usable classroom management software (ClaMApp) that would allow teachers to perform basic classroom management tasks with little to no training in software use. Once created this software was tested for usability and learnability as well as to identify erroneous operation. Results from this test were used to inform on revisions and changes needed to the software. The second iteration of the software was then subjected to another usability test focusing on complex operation and real world simulation to assess its viability for use within a real world classroom lesson. Having established the controlled usability of the software ClaMApp was deployed in a classroom as part of a joint ClaMApp usability / Educational Learning strategies experiment in conjunction with the Flinders University School of Education.

Over the course of this work the ClaMApp software was tested on over 50 individual users, drawn from a pool of university students (in preliminary testing) and primary school students and teacher. The software scored on a number of metrics across all experiments including assessments on overall usability, on function use, qualitative assessment, function timing and pass fail rates. The result was a strong, usable and learnable environment that meets the established design goals and answers the research question. Full discussion of these experiments occurs in Chapters 5, 6 and 7.

1.3. Contribution

By investigating the surrounding frameworks and systems as well as creating classroom management software, this thesis contributes to the pool of research in the following ways:

- Identifies the ways that teachers look to use technology in the classroom, and how modern learning pedagogies can be impacted, both positively and negatively, by the use of ICT (Chapter 2)
- Identify the important personal and professional impactors on the uptake of ICT, both in how educators want to use technology, the importance of personal opinion on use, and the driving professional factors that lead to usable software (Chapters 2 / 3)
- Examines the relevance of tablets in the classroom and how their use can impact the learning environment through availability, teacher and student user's willingness to

employ the devices, and comfort with these tools as content creation devices (Chapter 2 / 3 / 4).

- Examines the development of easily learnable and usable software to facilitate teachers in streamlined technology use in the classroom – the development of the software. This software should ideally be agnostic to other ICT factors teachers experience both in frontend presentation and backend server architecture (Chapter 5).
- Provides an example interface design to allow teacher to easily and quickly learn to use tablets as digital management devices, as file agnostic devices to facilitate both remote and in class use in an environment where device scarcity or Bring Your Own Device (BYOD) elements may be present (Chapters 6 / 7).
- Examines the use of this custom software in a real world environment and looks at how easily teachers and students can adapt to use the environment with little to no training or instruction. The software is used to compliment current classroom solutions and demonstrate the benefits of learnable environments. (Chapter 8)

Understanding how and why teachers use technology in the classroom is fundamental to understanding how to facilitate them. However simple background research is insufficient and it is necessary to gain targeted knowledge of the factors and impactors from teachers themselves, in direct reference to this work's research aims, and up to date. The results from this survey reinforced current understanding of the importance of perception in teacher willingness to use technology and the essential nature of comfort as a cyclical driver in ICT use. It provides a clear view of the scattered nature of implementation by teachers and the fractured nature of their own deployment. This work also showed the relationship between institution and teacher in how schools approach ICT in the classroom and the essential factors at a school level that can hamper successful use. Although a newer technology, tablets are valued as a teaching tool by teachers. While there is a high desire from most to employ them more, this is impacted by availability and perceived pedagogical benefit.

Tablets although a newer technology are highly prized by teachers and while there is high desire from most to employ them more, this is impacted heavily by availability and perceived pedagogical benefit. Overall this survey showed that among both teachers and schools, the desire and drive to utilise ICT is strong, but there is far from a consensus on how to best achieve that goal.

Examining the role of tablets as content creation devices showed their potential textual entry speed is at a similar level with laptops when comparable input systems are in use, in this case a Bluetooth keyboard. Further it showed the high levels of confidence and personal preference users had towards emerging software keyboard implementations which, while slow, users considered to be accurate and swift. This shows the potential for these systems as an alternative to laptops to create text documents longer than the regular short form messaging tablets are most commonly associated with.

The development of prototype software enabled the investigation of tablets as management devices and the unique interface opportunities these devices allow in touch and menu iteration. From previous literature and research investigations of this work, key functional aspects of LMS environments were identified as well as the vital human aspects that drive the adoption or rejection of technology by teachers. Based on these factors the developed software provided a simple and learnable alternative to existing management solutions. Initial testing while supporting the functional, learnable and usable nature of the software identified a number of areas where the intersection of desktop and mobile interfaces conflicted. This provided changes to the software that improve user confidence and expectation of outcome and further testing demonstrated that despite the more complex nature of the tasks the software retained its high level of usability and learnability as management software. These findings were judged against a number of established metrics including task timing, System Usability Scale, Single Ease Questions and pass fail ratings.

Following successful lab trials, the software was deployed to a classroom, used in conjunction with an existing lesson structure to provide targeted learnability strategies to students. Here the software, with very minimal training, provided documented materials to students as well as access to pedagogically targeted tablet software in conjunction with their traditional environments. Students and teacher made use of most of the functions of the application over a lesson period where the software facilitated management tasks and collected student information and work seamlessly while having minimal impact on the pedagogical structure of the topic. This was performed with the class having no formal training with the management environment. Again the software was assessed by metrics as usable and learnable showing the value of these systems that allow control and management by the teacher without the need for arduous skills training.

These contributions are supported by the peer reviewed papers published as part of this project (Wilkinson, Armstrong et al. 2013, Armstrong and Wilkinson 2015, Armstrong and Wilkinson 2016a, Armstrong and Wilkinson 2016b).

1.4. Structure

The focus of this work was on user experience and human computer interaction and as such it was important to understand the domains in which the intended software was going to be deployed. This included the primary drivers in the intended user based, the environments in which they are going to be deployed and the surrounding philosophies that may impact usability. This is especially true in a complex environment like the classroom where significant drivers external to pedagogy and theory can impact the applications purpose.

To this end Chapter 2 of this work examines the published literature of technology in education and the factors that contribute to effective education ICT. It also looks at the barriers to ICT deployment and the importance of pedagogy in software selection, as well as the importance of teacher acceptance and expectation in creating usable software. The chapter also investigates the domains of Web 2.0 and mobile learning and the importance they have on the emerging learning experience. It further considers the value and place that learning management systems have in education and some of the real world drivers from both a business and institution perspective. Lastly it looks at tablet devices and their role in the classroom.

Chapter 3 discusses a survey conducted with South Australian schools in cooperation with the Department of Early Childhood Development (DECD). This helps to provide current context for the views and opinions of teachers and schools who were the intended target audience of the developed application. While a broad understanding of the theories and elements that effect teachers is important in such a fast moving world as mobile development, current opinions are similarly essential. This provides not only a more focused view of current attitudes of both teachers in the classroom and schools as entities but also an insight into the prevailing opinions of teachers from the target audience.

This survey had both teacher and administrator respondents from schools provide domain focused feedback. From teachers the work looked at their views of technology in the classroom, how frequently they looked to employ it and what areas they felt needed additional support. There was also an emphasis on tablet and mobile devices and the different opinions participants had regarding the conceptually similar devices. From administrators the survey examined their views and policy on mobile devices in the classroom and their perceptions of the infrastructure in their school to support mobile learning.

Chapter 4 reports on an experiment to compare the relative performance and perceptions of keyboards on tablet devices and their ability to act as a commensurate input alternative to laptops. This experiment was conducted to fill a literature gap on the viability of tablets as devices that could serve as not only a media consumption device, but as one capable of filling the role of content creation in the classroom. Within classrooms students are still expected to take notes and create basic documents yet the viability of the tablet to perform this duty had little recent research. It discusses both the mechanical speed results between physical and software keyboard alternatives as well as the perceptions from participants as to which keyboards provided the highest levels of typing accuracy, speed and confidence in use.

Chapter 5 details the construction of the ClaMApp software. It includes a discussion of the driving factors behind teacher adoption of software, some of the principles of tablet app design and relevant user interface concepts to provide fast directed interaction. The chapter then discusses the functions selected for inclusion based on investigative work and LMS standard feature sets as well as other design and technical considerations. From this the feature set of the application is defined with both user interface and back end functionality detailed.

Chapters 6 and 7 concern the controlled usability testing of the ClaMApp environment. Chapter 6 focuses on initial general function operation and usability and starts with a discussion of assessment of such and defining the standard continuous and discrete metrics used to measure application performance. It then discusses results from the study and issues encountered during the test. Chapter 7 details the second controlled usability study. It presents a discussion of the issues found in the first experiment and actions taken to address these problems. It then presents the results of the more robust second round of usability with the application subject to more open ended and undirected use. This is followed by a discussion of the changes noticed and a comparison to the first test.

Chapter 8 discusses the in-school testing of the ClaMApp software. This includes discussion of the impactors in performing testing in a real life environment and the considerations that must be taken to limit the influencers on the test. The chapter then presents the results of the in class testing and discusses student perceptions and rankings of the software as well as their recommended changes.

The final chapter presents concluding remarks and discusses the benefits of the system presented in chapter five based on the usability results of chapters seven and eight. This includes its usefulness and the need for teachers and students to have access to learnable and usable software management environments that allow them to activate their own pedagogical software choices, the emergence of classroom focused solutions from business and the shifts in the mobile landscape over the course of this work.

Appendices are included at the end of the document detailing survey questions, usability task lists and testing materials

Chapter 2

Background

2.1. Overview

This chapter looks at the domain of ICT in the classroom and how teachers seek to employ them within their own teaching spaces and the education drivers that affect these choices. This includes the personal factors that impact teachers when deciding to use software, especially personal choice and training required, as well as how these elements feed into the type of classwork they want students to participate in.

There is also a discussion of the educational design elements that teachers are looking to ICT to fill and how the current technology landscape does, or does not, address these facets. This includes a view from both the computer centric side, how computer assisted teaching is handled, as well as an education focus for how ICT can support emergent constructivist paradigms.

Lastly the chapter looks at the role that management systems play in emerging Web 2.0 teaching environments and the role that tablets can help to play in this connect, blended learning environment.

2.2. Introduction to ICT in the Classroom

When approaching the use of software in education there are a significant number of key domains to understand, especially from a software designer standpoint. Education looks to employ ICT in specific ways and with specific constraints on expected outcomes and usability. This often extends beyond the technical facets of the software and it is important to have a solid understanding of why teachers want to use technology, the educational tenets that underpin how they want to use technology and the unique facets of the user base: teachers and students. In Australia the Digital Education Revolution scheme showed how important the role of Information Communication Technology (ICT) would be in Australian schools (Gillard 2008). Putting in place funding for ICT endeavours, as well as to establish the 2010-2012 ICT Innovation Fund Guidelines to provide a 1:1 computer to student ratio. However, within educational fields the introduction of even these traditional ICT resources has had limited impact on the teaching experience; the access to devices does not, as a product, produce a substantially different teaching experience on its own (Law, Pelgrum et al. 2008). Looking at how Australian teachers have incorporated ICT into their classrooms, technology becomes an accessory to traditional techniques rather than an integral tool. While teachers are looking for ways to incorporate ICT there are significant impactors on what is needed beyond the device, to ensure the maximum benefits; including how to integrate technology, correctly source educational software and have the training and skills to make use of them (Chen and Chang 2006). Inevitably there are hindrances for teachers in employing technology in the classroom including (Baek 2008):

- restrictions on curriculum,
- a lack of support,
- budgetary factors, and
- regardless of implementation these factors of cost and training rear their heads repeatedly.

Traditionally the classroom was the first point of contact for students when dealing with technology, but this trend has been reversed. Students are often more computer literate, earlier, and are constrained in their ability to utilise technology at school (Vigdor, Ladd et al. 2014). Schools now recognize that technology is a fundamental factor in the classroom, no longer a “sometimes” subject taught as a separate topic.

With the new interfaces and portable network connectivity provided by mobile computing opportunities there exists great scope for group interaction and collaborative based learning and it is important to look at how these devices can be employed in education. Technology and education are inextricably linked; as the way in which we access and absorb information changes, so too the devices and interfaces we use (Rogala M., Simpson M. et al. 2010-11). For their part students are increasingly utilizing multiple devices within the school, especially their smartphone and laptops, though 5 years after the Australian government pushed 1:1 laptops in the classroom the primary uses are still the straight forward consumption of data and creation of textual documents (Bulfin, Johnson et al. 2016). As this prevalence of computing expands, it is important that educators incorporate information technology into their curriculums in an effective manner. However, unlike the mid 1990’s where computing was seen as a complimentary skill for the work place, the dialogue has shifted with the idea that ICT is a backbone of an information society (Pelgrum 2001). This change away from the view of information technology resources as just a “tool” must be tempered with the knowledge that the gain is limited when the device is simply substituted for ring binders and books. Using these devices to perform the same tasks can lead to the devices being seen as optional add-on’s in the education process, whereas true use of effective information technology resources should be seamless to support all curriculum material (Morton 1996).

UK guidelines suggest that a curriculum should develop a standard set of ICT skills including basic data gathering from internet sources, data handling through databases and spreadsheets during early high school years (Department of Education UK. 2012). However, in Australia ICT development is suggested to begin by Year 3 (students aged seven or eight years old) for basic use, while Year 5 students can expect to begin understanding the specific manipulation of devices and some of the ethical issues surrounding ICT usage (Holt J., Kerr D. et al. 2006). These early education guidelines however should form the basis for computing skills and literacy. Rather than falling back on these core skills throughout the rest of their school lives efforts should be made to utilise technological solutions beyond write and read, this begin with understanding why and how we learn.

2 2.1. Collaboration and group work

Groups and collaboration play an integral role in the performance of students in an academic environment. Studies have shown that collaborative work between friends can have a demonstrable effect on a student's performance in a variety of tasks, including motivational benefits and greater subject matter orientation, regardless of direct learning outcomes (Tudge 1992). Furthermore, these benefits are at their greatest when groups are diffused amongst their peers and friends. Students' work gains the greatest benefit in classrooms where their groupings are varied, with reduced results coming when students are constantly working within the same small friend groupings or when never allowed to collaborate with their friends (Zajac and Hartup 1997) suggesting that the ability dynamically adjust groupings could prove beneficial. One proposed effect of this is the use of information technology to act as a "capable peer" in Vygotsky's proximal zone (Wertsch 1984). Using computers as a replacement for peer collaboration (Salomon, Globerson et al. 1989) has shown to be a possible substitute to peer collaboration and as a tool to allow peer collaboration within the Zone of Proximal Development (ZPD) with children suffering from high functioning autism (Rizzo, Schutt et al. 2012). These social aspects provided by technology are fundamental, especially when looking at the realm of mobile learning discussed later in this work (2 3.2, 2 3.2).

2 2.2. ICT in the classroom

It is important to understand how teachers want to employ ICT in the classroom, and the barriers to doing so, before expanded usage can be applied when defined by pedagogy. When using education software the technology falls primarily into two groups; skill based transmission software and open ended constructivist software (Smeets 2005). The first type fits well with direct instruction teaching, offering drills and exercise repetition to attempt to transmit knowledge, while the second focuses on knowledge building open ended software. This second type of software falls much more in the overarching fields of Piagetian and Vygotskian ideals on educational development, seen as being a better fit for use on problem and project based learning. However, the first type of software is often much easier to implement and to translate current curriculum material to, often requiring much less training for teachers. There is also development cost for more complex targeted software and while there are currently many offerings on the market, the key aspect of teacher training time is exacerbated by this plethora of options rather than lessened.

Indeed, how teachers view ICT in their classrooms is essential to its employment; these are the people that are going to be responsible for managing and implementing the software. But this is heavily influenced by the teachers own personal world view, and it is important when looking at education from within the information technology domain that we acknowledge that our own skills and adaptability when working with device or application are the result of extended and prolonged exposure to similar environments. Educational reform similarly is indelibly tied to how the educator themselves see the role of education (Niederhauser and Stoddart 2001), and their own opinions can lead to many failed education initiatives. The usability of software will always face a trade-off for the amount of time a teacher is willing to invest in learning the environment, always with a goal to its use in the classroom. There is a direct correlation between the teachers beliefs and what they teach in the classroom (Richardson, Anders et al. 1991) and in order to apply new educational structures, including ICT, it is necessary that teachers be made to see the benefits in a way that fits with their current perception. Issues employing techniques like student collaboration, can often be traced back to the teacher not knowing how to employ group work software effectively (Kuzborska 2011), in turn solidifying their class view that ICT based group work does not work. This cycle must be broken to get teachers to change their patterns. While ICT grows in use, the focus from educators is still mostly in its role as a drilling / quizzing tool and this behaviour reinforces that role.

The teacher is not the only consideration for ICT in schools however. They are inevitably part of a much larger institution with its own goals and ideals; the school. If instead the focus is on the school as a whole and their overall educational pedagogy, the ways in which ICT is implemented changes. This can and is influenced by the various aspects that are unique to each school including resources available, the views of school board on how educational goals should be achieved and the teacher bodies' opinions. These factors acting on a school can often be disparate and at odds. When applied to two different school environments; one more traditional with fixed curriculum and teacher directed top down teaching, the other more progressive with an open curriculum and a heavy focus on student self-regulation, a significant difference occurs (de Koster, Kuiper et al. 2012). In traditional schools, ICT use is heavily based around motivation, an alternative to the blackboard with most software falling into the first category mentioned above; that of drill and memorize. Yet in more progressive schools that embrace the ideas of project and problem based learning, ICT is employed as a tool to aid in open ended exploration of learning. This is in line with the Vygotskian idea of proximal learning and sees technology being used as an alternative, capable peer learner (Salomon, Globerson et al. 1989). This shows that often implementation at the school level is a significant driving impactor on how a school will look to employ ICT and can provide significant imperative for the teachers themselves.

An additional roadblock with developing ICT in the classroom is this disconnect between how students use computers outside of school, compared to during classes; a carry-over of the old view of ICT as a specific learning device within school, while outside of school the devices are seen as ubiquitous. In some cases, technology is utilised rarely or never, despite being a constant presence outside of the classroom. While students embrace ICT in their everyday lives, a resistance that still exists in staid educational pedagogy has slowed technology's penetration into schools (Somekh 2004), as has the continued perception of ICT being a separate discreet topic of study rather than as a tool to aide all facets of education. Students are already employing ICT strategies on their own in classrooms and are looking to employ technology themselves even when not available within a given class (Underwood 2009), with studies showing grade increases. This benefit is accentuated even more when ICT is employed in all topics as an educational aide. The relationship of ICT use between school and home has changed dramatically as well. When computer availability was low and there was limited contact time / exposure it was the job of schools to provide a limited "this is how it works" overview of computing. Yet home has now surpassed school as the primary space for technology use and the shift has placed education in a place where it must look to build on the way children use technology at home in the structured environment of school (Grant 2009); added to this the increase in connectivity opens opportunities for the home space and school space to cross over (Livingstone 2012) leading to the concepts of mobile and blended learning.

2 2.3. Teaching Barriers

For teachers who have attempted to employ the described technologies there are a large number of impediments to effective implementation, chief being the teacher's level of confidence. Teachers who lack the confidence to employ the technology effectively will often go out of their way to avoid using it entirely. Tied directly to this is the teacher's personal use of technology (Bingimlas 2009) and their understanding of what the technology is capable of.

When examining the application of ICT in the classroom teachers tend to approach the problem in three stages starting with how they will personally use the technology, followed by how they will match their curriculum to the technology and lastly how this will impact on the students (Awan 2011). The fear of professional embarrassment may be a significant cause of teacher unwillingness to employ ICT in the classroom. While age is often thrown around as a significant factor on willingness for teachers to take up technology, this is not often the case, rather it stems from the users having access to software in a format that is usable and understandable for them, especially in the domain of content creation (Waycott, Vetere et al. 2013). It used to be the case that technology was governed by direct functional structure, classes where students learnt to use computers but actual in-class use was generally on a more classroom level on an ad hoc basis (Ng and Gunstone 2003). However, with the changing nature and forefront presence of technology in the classroom, it seems there would be steps taken to formalize where and how teachers employ devices through school policy and procedure Yet this does not appear to be the case overall. Much of a teacher's training and learning with devices comes from informal networks; interactions with peers, self-exploration and even students. These informal channels are often disconnected from the formal domains, with limited cross over (Oakley and Pegrum 2014). While a need exists for an increase in cross training it is still important that software be within the usability scope that teachers can feel comfortable with this informal instruction. Recent research suggests that even with the increase in personal device use, teachers are still reluctant to employ ICT solutions in the classroom without seeing a clear need to change, also personal confidence in using the technologies is still a significant obstacle from the teachers perspective (Ward and Parr 2010). While simple exposure to an ICT environment can lead to a greater use of the technology their employment is still decided at a classroom level. As teachers become more familiar with applications so too does their comfort with implementing the devices and any framework development must take into account the varied familiarity that teachers have with devices, keeping them as simple and familiar to the teacher's comfort zone as possible.

2 2.4. Student Issues

The implementation of 1:1 computing for students raises a number of issues regarding overall impact, actual educational effectiveness and real world barriers. One of the goals in 1:1 computing is to allow students to have equitable access to information through mobile computing, using either laptop or tablet computers. Studies have shown that access to 1:1 devices for low income and disparate social groups can often help to bridge a gap between these and more advantaged groups. Home access in particular was seen to help bring up the lower end of the grade curve in student tests (Penuel 2006) and increase the testing mean overall. Another benefit is that connectivity of these devices on a network allows for better ability for a teacher to keep track of learning outcomes (Roschelle and Pea 2002), the ability for greater student collaboration through networked groups, as well as increases in student motivation and participation with the ability to graphically represent and display examples in STEM topics (Hegedus and Kaput 2004, Hegedus and Kaput 2004) .

However, care must be taken when implementing 1:1 computing that the devices are employed in an effective manner. Simply supplying students with a device is no panacea to improving scores. In the US a review of schools implementing 1:1 computing (Holcomb 2009) showed on the whole that computing did prove beneficial but it was essential for there to be a framework to handle digital transition in place. A number of schools (21) in Texas showed little to none of the gains demonstrated in other states, attributed heavily to the way in which the state chose to implement the programs. This possible miss-implementation must also take into account resource issues, with the resource cost for schools being intrinsically tied to the economic potential of the country and school district it is being employed in (James 2010) as well as ongoing maintenance costs for technology that must be carried by the major stakeholder in the enterprise (Yujuico 2011), usually the schools themselves.

While roles students and teachers can expect to target with ICT in the classroom have been discussed, it is important to note that these factors do not exist in a vacuum. There is an inevitable interaction between these viewpoints. One key issue of this is research tends to explore the way laptops are employed by teachers as instructional tools, rather than how they are being employed by students as a learning resource (Crook, Sharma et al. 2013). This can lead to possible misrepresentation of findings, or a failure to recognize issues regarding how students are employing the technology; or not employing it as the case may be (Donovan, Green et al. 2010). This may lead to situations where students employ the devices during class time for purely social play. An important factor in this may be that programs that seek to provide student computing often overlook the importance of the teacher and their laptop as a central hub for the ICT efforts of the classroom, or the implementation of non-designer solutions that make it easier for students to stray. When teachers are not participating in the connected environment there is not only a decrease in effective use of the technology but also an increase in off curriculum use. Teachers need to be aware of the activities being enacted by students and take steps to control and understand how students are looking to utilise devices in the classroom; be it laptop, smartphone or tablet. So, in order to address these interpersonal human elements, systems have been developed to accommodate the combination of these education concepts with practical interpretations that look to assist in marrying the pedagogy with the practical.

2 2.5. Problem and Project based learning

Another important domain in the classroom is problem based learning. With problem based learning the aim is to activate prior learning and apply it in a social context to a problem. The goal is to build upon this prior knowledge to create a theory that explains the nature of an open ended question, a question with no single correct answer or defined structure (Simon 1977), by working in small groups students can address the question socially and use other's prior knowledge or developing theories to refine their own ideas and fill in knowledge gaps (Schmidt, Rotgans et al. 2011). It is an important idea behind problem based learning that students often have an amount of prior knowledge, or access to knowledge, but can find it difficult to apply that knowledge when called upon to do so at a later date; in either testing or written work (Schmidt 1983). Activating this prior knowledge can help bridge a gap in understanding entirely new frameworks. An example is in science courses, where memorization of formula and algorithms can be stressed as more important than conceptual understanding. This can be especially true if students already have the required pre-existing knowledge but are unsure how to implement it. When studying STEM topics often the goal is imparting new concepts and frameworks and a methodology is required that can draw on what the student already knows. Expecting students to understand science just as rote memorization is not effective (Carey 1986) and problem based learning can allow students to collaborate, compartmentalize new information effectively and apply the new frameworks in a relatable context (Allen, Duch et al. 1996). This is a domain where computers in the classroom can excel, allowing the creation of abstract or analogous environments.

Project based learning often centres around a final creation or artefact, focusing on the process of creating this artefact over answering an ambiguous issue like those found in problem based learning, with the project having a "correct" outcome at the end (Barak and Dori 2005). One of the key benefits of the project based approach is to motivate and engage students over an extended period with an authentic result. Rather than have the student operating on abstract problems or small-scale questions and answers a long term project can help to engage students over a much longer period, solving authentic problems in a social setting with real world applications. With a move towards project based as a way to motivate and encourage collaboration from students there is a need to engage students cognitively in lessons (Blumenfeld, Soloway et al. 1991) and the need for students to be engaged in active tasks to aid retention. Investigations into the use of computers by students in a project based environment found that ease of access was a significant factor in their experience (Wong, Quek et al. 2006). A benefit of this open cognitive engagement using project based learning is the nature of an extended enquiry, leading students and teachers to engage in a discourse, exchanging ideas and investigations of interest to them (Moje, Collazo et al. 2001).

This approach can be of benefit to the teacher as well. When creating curriculum material the teacher can guide the direction of the overall project towards periods of team work and structure the project to relay learning rather than recitation of facts, using situations relatable to students, regardless of level (Smith and Van Doren 2004). Computers in project based learning can provide a powerful tool for the teacher to effectively manage project elements, but also bring the benefit of increased management structure for the groups themselves, which can be a powerful tool when addressing collaborative learning in a student peer environment.

2 2.6. Computer Supported Collaborative Learning

Computer supported collaborative learning (CSCL) attempts to offer frameworks that allow for technology to effectively address the issues with employing computers in the classroom, especially the issue of collaborative environments, a domain that technology is often seen as being well suited to exploit. Here one of the necessary goals is to differentiate between cooperative and collaborative learning (Suthers 2006). A pitfall of using computers to assist in learning is to fall into the trap of using the technology simply as a tool for cooperative learning. Here the individual tackles the problem on their own, formulating their own results then adding them to the collective work. For *cooperative* work the end goal is of greater importance than the process, while for *collaborative* work the process is as important (Panitz 1999). Often cooperative work focuses more on teacher instruction of the group with a traditional approach to authority in the classroom and focus on an end result. With collaboration the authority rests with the group itself, with small group self-reflection being the first metric used for analysis. Here the students first port of call for feedback becomes other students, instead of the teacher, aiding in reinforcing the proximal zone ideas discussed earlier resulting in a much more social constructivist approach.

This cooperate vs collaborate issue is especially important when dealing with devices that while connected on a network level, are not necessarily connected to each other in a collaborative manner. In order to facilitate effective collaboration groups must be working together on the same problems at the same time, and the assistance provided by the devices must reflect that. This is of growing importance as the devices used move away from traditional laptop or desktop computers to mobile devices that provide a digital collaboration through software as well as a physical mobility to form physical social groups. We may also see a move away from supplemental, occasional use of technology to a device ubiquity where the computer is easily accessible from any location (Roschelle and Pea 2002).

Finally, an important part of collaborative work involves the ability for groups to self-assess. As noted, ideally this represents the first step in peer assessment allowing more rapid learning development without the need to constantly wait on validation. This is an essential part of the social constructivist approach suggested in Vygotsky's work and has shown to be important in effective collaborative projects (Taras 2010). The use of self-assessment with teacher feedback can be considered a strong method of self-assessment, provided that structures are in place to clearly define the learning targets. In this manner CSCL can help by ensuring that interfaces provide emphasis and guidance on self-assessment criteria (Baker and Lund 1997) for students.

One possible method to help with active collaboration is guided scripts that allow teachers to prompt responses along the project pathway. Generally, these scripts help to provide a progress line for computer supported collaborative learning and a way to provide guidance and direction in a way that provides effective collaboration and self-assessment opportunities. Research has shown that one of the pitfalls of collaborative learning can be a failure on the part of students to effectively internalize learning and focus on collaboration without some form of overall guidance. It is important in collaboration that interaction is engendered and students are engaged with each other, asking questions and justifying their answers to peers (Kobbe, Weinberger et al. 2007). CSCL focused software similarly should ensure sufficient places are maintained that allow students in a collaborative environment to get that necessary peer feedback.

These domains within the classroom offer clear factors where computers can assist in the education process both as actual things that target a learning outcome but also tools for managing these learning outcomes; ways to arrange students, facilitate interaction and provide support. Even in a domain where the task itself may be purely physical computers can assist in managing the secondary considerations of the task.

2.3. Computers in education design

In the past two decades technology has become a fundamental pillar in the classrooms, transforming the way that education operates and ushering in a new form of "digital native" student (Gu, Zhu et al. 2013). Technology-Mediated learning (TML), an umbrella catchall term including e-learning, has rapidly expanded from its roots as a tool for long distance learning to a significant presence in all schools (Shield 2002). While debate on the exact nature of TML continues computer interaction can be broadly fit into three categories; assisted, mediated and managed.

Computer-assisted learning (CAL) is often presented as a situation where real pre-programmed content is presented to students, often with an interactive component. This can present itself in a context where the physical learning actions may not be possible, or where virtual instruction is a necessary precursor. Examples may include anything from technical operation of a complex system to assisting in language development (Dunkel 1991). CAL has claimed a significant foothold in the language training domain where computers provide a simple and easy way to test vocabulary and have immediate examples of pronunciation examples. Serious gaming is another field where CAL often features though the merging of game play mechanics and task repetition to enforce some technical or societal aptitude (Wouters, Van Nimwegen et al. 2013). However, when addressing technical skills, studies are mixed on the relative worth of CAL in improving student performance, with many examples of practical task application showing no real benefit to direct instruction. Therefore, it is important that students where possible be given both mediums, though CAL can provide some level of individual teacher-less instruction. Additionally while CAL can provide this instruction remotely without the instructor present, feedback remains a critical factor in ensuring students apply the learned techniques correctly, so where possible revision or interaction with an actual instructor should be made possible (Katz 2002).

Computer mediated communication (CMC) is often used to refer to the use of computers to mediate communication either between instructor and student or student peers. This may involve synchronous (chat, SMS, or Instant Messaging) or asynchronous communication (email, forums or bulletin board) through any number of possible channels (Romiszowski and Mason 1996). While asynchronous text only formed the initial framework for CMC, the rapid advance in technology has opened additional options. While text only is still prevalent, especially in management systems where asynchronous text communication is provided through messaging and forums, many text environments are becoming a mix of both styles, though leaning towards asynchronous methods. Both versions often resulting in differing styles of communication; asynchronous for more formal reasoned output and synchronous for a more personal informal communication channel (Angeli and Schwartz 2016). There is also a noted difference in the style of communication, with asynchronous users tending to ask longer, formulated questions while synchronous users prefer short and unambiguous dialog (AbuSeileek and Qatawneh 2013). More recently low bandwidth applications like Skype and Discord have opened the door for efficient voice over IP and direct video to video communication. In an education framework this has significant impacts on the communication dynamic in the classroom, while forming the underpinning foundation of flipped pedagogies emerging in tertiary institutions, making use of the respective benefits of both types of CMC.

Computer managed learning (CML) is something of a catchall, often acting in concert, and in some cases blatantly crossing over into, the domain of CAL. While both have tended to aid in direct computer assisted instruction CML is also utilised in the domain of administrative management, helping to provide the frameworks that can tie CAL and CMC together. These management tools are varied and often specific to the required role, providing facilitation between the various computer applications being put to use in the classroom. Recently, with the increasing back end load on institutions, larger scale learning management systems have been deployed. While originally little more than web portals they are rapidly becoming full suite systems with targeted modules that institutions can mix and match, frequently providing plugin functionality for popular third-party applications.

It is important to note that while these domains can cover similar solutions they are by no means exclusive and well implemented TML will use a number of applications from each domain to provide a complete solution. While there are many other variations and nuances to these three fields in the end TML systems can look to be defined as:

- Engaging the user, in some form of learning, in the use of technological devices. This may be through simulation, direct instruction or assessment.
- Allow for digital feedback to be provided to participants. This may involve computer oversight grading or the digitization of physical grading by an instructor but should allow for participants/teachers to easily and quickly evaluate their current educational achievements.
- Allow for structured oversight of pedagogical aims at some administrative level. While recently this has come to mean some kind of structured learning management system just as important is the computer administrative aspect at the classroom level.

While fully realized TML classrooms are still a rarity, increasingly technology aspects are being integrated with an aim to facilitate the curriculum. With the growing pace of 1:1 computing CAL, as a means to provide out of class instruction, increases. This in turn places importance on CMC as a means of allowing students to quickly and easily communicate with teachers and peers. As this increased usage and communication take place the need for CMLs to oversee and manage how content is being presented is also reinforced. All of this is impacted by the fact that as users become accustomed to using technology they are willing to use it more and a feedback loop is created that steadily shifts a large portion of learning paradigms to the digital domain. To this end, it is important that tools exist to manage this increased technological dependence.

2 3.1. Learning theories

While TML can give some frameworks for how and where to use computers in the classroom, without solid learning theories backing them up, use becomes scattered and uninformed. More recent applications of learning theory have moved away from the basic definition of acquiring knowledge and shifted to include emotional, psychological and societal skill acquisition. This can be especially relevant when dealing with technology, which if managed poorly can put an obfuscating layer between the student and their educational aim. For example, a poorly implemented drawing course may use software for drawing and submitting (CAL) and allow teachers assess and grade student's contributions (CML) but poor feedback or inquiry assistance (CMC) can result in students showing a stunted learning rate. To return momentarily to the ideas of educational design touched on earlier (section 2 2.1), while there are many theories of how we learn, our *learning theories*, much like with TML, can be grouped under three broad categories, each an educational refinement on its predecessor:

- Behaviourism
- Cognitivism
- Constructionism

One of the oldest learning theories, behaviourism, had its heyday in the 40's and 50's, it was based on the observed change in behaviour of a student (Ferster and Skinner 1957). While debate continues about its value, one important point is behaviourisms relative worth in TML where behavioural concepts can be seen to naturally manifest when the instructor is only capable of providing a yes or no response to student change (Burton, Moore et al. 1996). While technology can be used in conjunction with our own minds to develop educational practices, so long as computers are providing a binary response to student's enquiries or as feedback it is still important to consider the realities of behaviourist theory.

Cognitivism came strongly to the fore in the 1960's in the Plowden report (Report 1967); an attempt to move education away from what had been strongly behaviourism focused (Papert 1980). Cognitivism would take its place as lynchpin of the changing education landscape in the latter half of the 20th century with a strong focus on the inner learning of the participant; what a learner knows, not what they do (Tomei 2005). Unlike behaviourism the focus moves away from the instructor observing change in the student to assessment of the student themselves and the quantified result of their learning.

The most prominent current learning theory is fundamental when addressing the collaborative nature of learning; constructivism (Fosnot and Perry 1996). Taking cues from

Piaget and Vygotsky and expanding their ideas, constructivism attempts to look at their education design as a whole. Not just the metric analysis of the student or the observational assessment of the educator but all domains including collaborative, social and educational structure. In looking at TML, constructivism provides the most conducive framework, as it looks to incorporate the structure of learning in a way where it is seen as important as the content being taught; that is to say the *hows* are as important as the *whys* when judging the effectiveness of a learning environment.

The framework provided by constructivism is essential to TML, especially as the rate of device adoption grows. As has been stated, CAL can have very mixed results and similarly CMC is not a be all replacement for social interaction and face to face communication. With the emergence of smartphone and tablets as ubiquitous devices, it is important that the ideas of constructivism are maintained so that computers remain as a mediation device in the education process, facilitating learning. Otherwise there is the risk that computers become the focus rather than the enabler and a mediated environment can become one of computer dominated learning (Gibson 2001, Watson 2001).

To do this devices need to enhance the constructivist ideology (Walling 2014), they should:

- Offer multiple representations of reality, providing students with alternate interpretations.
- Avoid the “oversimplification of complexity”.
- Emphasise the construction of knowledge, through collaboration and consistent feedback, rather than the replication; the student should be able to abstract and develop new outcomes rather than repeat back information they have been given.
- Encourage reflection. Here it is important that this include both significant levels of peer and teacher feedback and obtuse enquiry to encourage students to think about a problem in different ways.
- Support social and collaborative learning, ensuring that other students can benefit from ZPD rather than relying on a teacher to spoon feed information to then regurgitate.
- Simplify these ideas and provide a framework of reference for teachers, a number of models exist to aid in turning educational theory and TML into curriculum content.

However, while all of these learning theories make up modern teaching to some degree, they all come from a time when technology was not a ubiquitous presence in the classroom. We perhaps can make use of new learning theories more targeted for understanding technologies’ impact, such as connectivism (Siemens 2004, Goldie 2016). While the three theories above deal primarily with internalized individual learning, even in a constructivist approach that looks at learning as a social process, the learning is still individual. Connectivism proposes a model that learning can happen outside of an individual. In systems it can be essential to have information translated and modified outside of the individual focus and the learner needs to be able to synthesize and recognize patterns as much as they need to be able to "learn" information.

Siemens states that connectivism is:

"driven by the understanding that decisions are based on rapidly altering foundations… the ability to draw distinctions between important and unimportant information is vital… to recognize when new information alters the landscape based on decisions yesterday is also critical" (Siemens 2014)

This idea is that learners need to not only understand the synthesis of changing information but be aware and able to distinguish between important and unimportant. This can be especially true in a technologically motivated environment, where the amount of available information is not the problem; understanding and arriving at the correct detail is. As a companion to the primary theory of constructivism, connectivism can help to frame the work in one of the fastest expanding aspects of education; mobile learning.

2 3.2. Mobile learning

It is fairly safe to put forward the idea that in the last two decades the world has seen an explosion in mobile devices and wireless networks. The spread of smartphones is almost total and the continued miniaturization that has seen the growth of tablet and notebook style devices shows only slight signs of slowing. Combined with the increased wireless capabilities of Bluetooth and general speed increases of mobile wireless networks, especially after the widespread activation of 3G capable multi-megabit speeds, it has never been easier to use computers on the move. For many people smartphones are now an integral part of their lives. This spread has had a huge impact on the world and it is illogical to assume that these emerging facets of computing would not make their way to the realm of education. It is this use of a mobile device that clearly separates mobile learning, or m-learning, from the more general TML alternatives.

However, for many the term mobile learning can have different meanings. For some the key characteristic of mobile learning is the use of the device, but the line between what is and isn't a mobile device grows steadily blurrier. There is a strong, growing movement to consider mobile learning as an idea that is not dependent on a specific device but instead on the aspects in which the learning takes place. (Winters 2007) said that mobile learning, in a still evolving space, should be conceptually:

- Technocentric
- Relational to e-learning
- Augment formal education
- Be learner centric

BACKGROUND

However, it is not hard to see how these ideas do not provide a concrete definition. A prevailing idea is that mobile learning is simply learning that takes place outside of the normal fixed learning environment, or makes use of mobile technology (O'Malley, Vavoula et al. 2005). The idea that m-learning is "digitally facilitated and site specific" is at the core of most definitions. That there must be some combination of location and device based interaction with a device that meets the necessary characteristics of "mobile". This broad scope has given rise to a number of subsets that can fall under that definition, such as connected classroom learning, miniature portable e-learning, informal personalised mobile learning and technology driven mobile learning (Traxler 2007). All of these factors reinforce the definition of mobile being about the learner (Pachler 2010). At its core it becomes the mobility of the learner themselves that is the primary factor of m-learning, the device is a secondary consideration and it becomes what the learner uses for mobile learning, not what mobile learning *is*.

As conversation around digital technology and its role continue it is important to consider that mobile devices fill a strange dichotomy in users' lives, often a personal device that is at the same time used heavily for social interactions, though these are interactions in a nebulous ephemeral location. There can be little doubt that mobile devices drive many of the most prevalent social applications like Facebook, Instagram, Twitter and Snapchat (Lellam and Lipsman 2014). Among younger users especially the mobile device is a foundational tool in their lives and it is essential for emerging learning theories to understand how to best incorporate them into the classroom. However key opportunities and challenges need to be kept in mind for mobile devices to be used to effectively reach and teach children. One such concise summary comes from Carly Shuler (Shuler 2009) who suggests the following opportunities:

- Encourage learning anywhere and anytime
- Reach underserved children
- Improve modern social interactions
- Fit within learning environments
- Enable a personal learning experience

And some important challenges to consider including:

- Negative cognitive, physical and social elements of m-learning must be understood
- The cultural attitudes and affordances of students
- The lack of a defined theory of learning for mobile
- Differentiated access to technology
- Limiting physical attributes

2.3.2.i. Personalization

However, so long as precautions are taken, m-learning can promote a strong sense of individualism in a learners environment, personalizing their experience and helping them engage in the experience by allowing the creation of their own relevant spaces within their mobile devices, including contacts and resources (Squire 2009). This not only results in a more immediate learning experience but also a more tailored one, no longer does one size fit all. Learning services can also be adapted to the learner themselves, or the environment they are going to be used in (Kinshuk, Graf et al. 2009). After all, in a mobile learning world the user's space is by definition mobile and one of the key aspects is that the increased use of the device enables greater interaction outside the traditional classroom in real world spaces. The time and space of the mobile experience is fundamentally different to traditional ICT (Kearney, Schuck et al. 2012).

This personalization itself leads to greater engagement, one of the noted benefits espoused by mobile learning. This ability to personalise their own devices, and thus their learning spaces creates a powerful learning incentive. Users have a far greater spread of available learning tools (apps) they can use to assist their learning in a way that makes sense to them and without waiting for teacher distribution. While this discussion of personalization has focused on learners, it is worth noting that these same benefits apply to teachers, who are themselves learners in a mobile environment. These same general mobile personalization benefits can be applied to teachers own professional development and assist in them being capable of managing these context sensitive learning environments (Kearney and Maher 2013).

2.3.2.ii. Social

It should come as little surprise that one of the driving factors in mobile technology is anywhere, anytime communication, and this same aspect is an important driver in m-learning. Social media sites like Facebook have been the focus for a number of studies into how these social spaces can provide continued interaction and motivation. The benefits they can provide from a collaborative domain can be powerful (Blattner and Fiori 2009), but are often tempered by the willingness of teachers and students to participate within that application (Lampe, Wohn et al. 2011). Similarly, Twitter has seen interest from the educational community as way to engage and motivate students (Dunlap and Lowenthal 2009), yet again there are significant issues including encouraging bad writing habits, spam and the lack of educational focus from users (Grosseck and Holotescu 2008).

Yet the allure of using these social spaces becomes a hard thing for many teachers, especially at a tertiary level, to ignore, providing a powerful tool for m-learning (Munoz and Towner 2009). While some teachers embrace the environment, this needs to be carefully tempered with the understanding that for many of these social spaces their key goal is not pedagogically motivated. It is important for teachers to avoid mixing personal information with professional classroom oriented use, and to avoid negative connotations from students towards teachers (Mazer, Murphy et al. 2007). These sites are first and foremost social tools for outside the classroom and they do not provide the relevant tools for an educational context outside of their general operation, leaving them open to abuse (Maranto and Barton 2010).

There is a clear need to quantify some level of technological literacy for teachers, but again this is not a one size fits all domain, and straight technical literacy is only a small part of a complex digital literacy picture. Device usage is a clear foundational literacy that must be almost assumed for a m-learning environment, but just as important is the need to understand the way that information sources work, how to use and process digital formats, how different media can be utilised and then how these factors can be incorporated into an overall learning pedagogy (Knobel 2008). Even these facets assume a relatively stable and robust technical infrastructure. In the developed world often digital devices, especially smart phones, are the more accessible option to books, it is less a case of choice now to use technology, than necessity. Here the literacies of the user may not be sufficiently developed to make use of the personal and social aspects of m-learning but the simple fact of availability of environments puts low literacy users in a mobile learning environment (Pegrum 2014).

In the end the combination of social and personal interaction within the mobile space open a plethora of powerful options for anywhere anytime learning, however technology does not exist in a microcosm of pedagogical idealism. The networks in which these domains operate, as noted by the references to social software, are also fundamental to any discussion of mobile learning.

2 3.3. Web 2.0

At the core of mobile learning there must be some technical, real framework in place for these things to operate on, beyond the educational pedagogies of design to the actual networks themselves, and how software will interact in that environment is an essential consideration. The initial domain of the web, loosely Web 1.0, provided relatively straight forward read only, static environments (Aghaei, Nematbakhsh et al. 2012). The goal of the content was to publish information in a one directional format; the user would go to the page, read the pages and perhaps follow links to new static pages. But there was limited user interaction and from a business perspective many companies viewed an online presence as an information kiosk, just a place to tell people about your business. From an education standpoint this framework offers minimal options for pedagogical exploration, the web is simply an expanded textbook, albeit one with questionable value as an accurate resource.

Web 2.0 is the emergence of the idea that networks can be social, interactive and act as their own contained platforms. While not created by them, the term was popularized primarily by O’Rielly and Dougherty and while the it has become something of a buzzword, at its core Web 2.0 looks at the web as a platform service rather than a location for static resource (O’Reilly

2005a, O'Reilly 2005b). This idea of web as a platform is reinforced by definitions of what constitutes Web 2.0; interactive blogging, wikis, search engine optimizations and social tagging (folksonomies) as some examples. Importantly this is not just about web applications themselves, but any source that utilises the web as a platform to deliver its services in an interactive, often participatory, manner.

In education this idea of platform software is fundamental to mobile learning, and mobile learning itself is often predicated on Web 2.0 ideology. While traditional learning material is often based on pre-packed information bundles, in the mobile age students expect much more agency in their education. For teachers this means expanding on connectivist and constructivist ideas to create a "Web 2.0 pedagogy"; one that capitalizes on the personal / social aspects of mobile learning (McLoughlin and Lee 2008). But these additional benefits Web 2.0 affords a mobile learning environment are not without hazards. While this discussion has touched on the use of social media sites as social spaces it bears repeating that these are businesses whose primary focus is not education and as such cannot be expected to cater to the specifics of educational design. Another major consideration is, as noted by connectivism, the need for students to be able to critically analyse and disseminate large amounts of data, and they often lack the critical thinking skills needed to do so (Katz and Macklin 2007). It is then beholden to the teacher to create lesson matter in a way that students can parse the information, which in turn is more difficult in a non-specialized framework, like Facebook, with no clear educational goal.

2 3.4. Models

One option for software is to ensure that models exist in place to try and drive the use of technology. This can give teachers solid guidelines for how they should look to benefit from ICT in the classroom and guide functionality. Essential for interpreting how non education focused software can, and should be employed, models can assist in developing these classroom "application for applications" even when the application is not educationally targeted at its core, for example using gaming as a learning tool (Wilkinson, Armstrong et al. 2013). While traditional models like Blooms Taxonomy have been used repeatedly to assist in function definitions for applications (Cheong, Bruno et al. 2012) and to provide context to technology (Schmitz, Klemke et al. 2012) there is also a need for directly technology focused models.

Here popular models like the technological, pedagogical and content knowledge (TPACK) framework can help teachers bring multiple domains together to effectively utilise technology in the classroom (Koehler and Mishra 2009). When it comes to the actual integration of technology models like the Substitution, Augmentation, Modification, Redefinition (SAMR) model can provide guidelines for how best to utilise the technology itself, outside of the pedagogical aims (Puentedura 2010). These models can provide strong frameworks for the teacher to paint a clearer picture of why and how they want to integrate technology and mobile learning, increasing their confidence. But the notion of a digital native and the breadth of any digital divide is already suspect (Waycott, Bennett et al. 2010). Teachers are not automatically inferior technology users to students (Bennett, Maton et al. 2008), this again draws back to the importance of adequate digital literacy on the part of teachers to create and support learning environments that are personal, especially as the student expectation is to have access to these mobile learning environments (McLoughlin and Lee 2010).

2 3.5. Personal Learning Environment

This idea of a personal learning environment (PLE) is not one unique to mobile learning, but with the development of Web 2.0 service platforms and the rise of mobile learning and its personal to social dichotomy it has become an important facet in understanding how students want to learn in the mobile environment. While the idea of a PLE is that it is a conceptual rather than physical environment, mobile devices come very close to actualizing that ideal (Attwell 2007). With their ability to house a breadth of applications and information the user is able to customize both their formal and ad hoc learning environments almost fully. This can be facilitated and monitored by educators through structures like learning management systems, software suites that can provide management pipelines for tasks, but in the end the student is the one who is responsible for managing the applications they employ within their own PLE (Conde, García-Peñalvo et al. 2013).

At its heart the PLE is becoming a blurred line between the ideological and technical, while the student should be able to customize their learning conceptually, practically this means utilizing software suites of different natures to achieve learning outcomes. The PLE must straddle that line, especially given the rise and rise of online and virtual learning (Humanante-Ramos, García-Peñalvo et al. 2015), again enforcing the connectivist ideas that how the user obtains and parses information, especially when from disparate sources, is essential.

These facets of mobile learning, built on the backbone of Web 2.0 mean that blended learning, once an ideal is now the expected norm amongst students and the idea that learning ends when students leave the classroom is passé. However, the real key to the blended environment is in finding the working balance between the face to face and online experience (Garrison and Kanuka 2004). Here again the conceptual must play nicely with the technical. Operating environments cannot be so dissimilar that students and teachers are forced to completely change their interaction methods in each circumstance. Here again management systems can help to facilitate a blended environment that does not place undue burden on either teachers or students (Kuran, Pedersen et al. 2017), albeit one that can require significant willingness and commitment from all participants; student, teacher and institution (Dias and Diniz 2014).

Yet while it is important, even essential, to have an understanding of how and why teachers want to make use of technology there remains the inescapable fact that at some stage screens and microchips must become involved. All the learning theories, pedagogies and models in the world will not prevent the fact that at some point software developers will need to sit down and develop these tools, and that when they do teachers and institutions need to be able to make use of the result. As has been noted before (section 2 2.3) teacher confidence in their ability to physically use the devices plays a role, if they are not confident then the software does not get used (Niederhauser and Perkmen 2008, Shriner, Clark et al. 2010). While this can be factored and studied to determine effective ways to integrate the technology in the classroom (Brenner and Brill 2016), there is also the ability to provide framework systems that allow teachers to easily utilise the programs they want. This becomes even more important as classrooms shift to a more paperless environment. Already students have shown a preference to use their devices for course work (Hofstein, Tucker et al. 2013) and there need to be solutions in place to handle the increased management load in this shift to paperless, mobile Web 2.0 environments.

2.4. Learning and Content Management Systems

One common way that these managerial tasks are facilitated in the digital classroom is through Learning Management Systems. These systems empower and facilitate e-learning by supporting the learning, administrative and communication tasks necessary to the course or institution.

These comprehensive environments have become commonplace in education, especially at the tertiary level but at a growing rate within primary and secondary schools. Indeed the market for LMSs is growing at an extremely rapid pace, especially in the developing world (Research 2016) where as previously noted the spread of smartphones and cheap digital devices is rapidly replacing physical books and traditional desktop computing environments. So much so that in the last few years many premier technology companies have made forays into the world, including Adobe and Google, while legacy players like Blackboard, Edmodo, Canvas and Moodle try to consolidate their positions as primary choices.

These systems are primarily aimed at managing the various digital solutions that teachers and schools put in place, though these focuses are rapidly changing as business factors change. While the landscape is constantly shifting, the original LMS environments looked primarily to facilitate actions in an online environment, rather than provide the tools to do that task. These days the lines are growing increasingly blurry between what is an online learning environment, what is a learning management system, what is a course management system (CMS) and other descriptors. In many works these names are interchangeable, especially LMS/CMS with both system descriptions often crossing over and containing the same behaviour. Yet this interchangeability can lead to numerous problems, and the various acronyms often only serve to add confusion (Watson and Watson 2007). Providers are adding features and extensions to their systems to ride the next wave of educational application design, often to the detriment of educators as will be discussed below. In this work talk of LMS environments are concerned primarily with these facilitation implementations; solutions that do not look to define the teaching task, but to provide support to the tasks a teacher has selected.

The argument that LMSs originally existed as a conservative technology to manage groups, provide tools and deliver content is still a relatively core one (Sclater 2008). There remains a strong need for any institution that has an aspect that revolves around online or mobile spaces to include some kind of formal structure to allow students to access the physical applications and materials that the institution wants to use, this will be explored in more detail below in 2.4. Learning and Content Management Systems.

There have been many studies that have looked at the use of LMS environments in education and have shown that there are numerous benefits when implemented correctly. Some courses report a facilitation from passive to active learning when an LMS is introduced to help manage course content (Herse and Lee 2005). Others have also shown that an LMS can promote interaction between students and teachers (West, Waddoups et al. 2007), and the access to specific communication channels can make it much easier for students to facilitate the Web 2.0 ideal of personal/social already discussed (Wang, Woo et al. 2012). These are backed up when looking at student attitudes to LMS use and the feeling of personal learning and autonomy they provide(Govender 2010).

At a practical level are the core mechanical tasks that teachers can perform with a management system (Porter 2016):

- Shared products
- Delivery of material
- Peer to peer communication
- Peer to teacher communication

Work has shown that they are heavily relied upon by both students and teachers to facilitate access to materials (Lonn and Teasley 2009) when and how they want them. These systems' ability to coalesce all these functions into what should be a uniform design and approach is preferable to ad hoc solutions that may vary not just institution to institution but classroom to classroom in an environment where there is insufficient oversight or systems in place; or even worse in this mobile age an environment where there is no solution in place at all. This perhaps leads to a fundamental reason that is often overlooked, *they are used because teachers have to use them*. Without these environments teachers are simply creating ad-hoc application bundles that perform many of the same functions an LMS environment provides, but in a disparate format (Perry, Thrasher et al. 2014); the requirement to manage the data does not go away.

It is simply a fact that in the modern classroom technology is an inescapable part of the landscape and students are going to expect to use it. Even if somehow the technology is missing from their in-class activities students are demonstrating that they will learn in an informal setting and create a more personal learning experience (Jones, Scanlon et al. 2013), and gaining the learning outcome benefits regardless of teacher participation. This base requirement for some kind of managing solution, that to not use one is not an option, is writ between the lines when looking at the perceived drawbacks reported by teachers and institutions when implementing and assessing LMS's.

As has been discussed previously in 2 2.3 Teaching Barriers, one of the core factors that contributes to a teachers willingness to use a system is planted firmly in their own confidence . This is shown in the benefits that involvement has on both teacher and student willingness to make use of an LMS; the more involved a user is with the system the more they felt they benefit, regardless of personal skill (Klobas and McGill 2010). This has been shown to have something of a cyclical nature, the more comfortable and involved the user the more the user benefits so the more they are involved. This idea that perception of usefulness and satisfaction is essential to continued use of an LMS, that satisfaction is influenced by perceived usefulness and both these factors are improved when the LMS performs within the users' expectations (Hayashi, Chen et al. 2004) is a testament to the importance of the intangibles of user opinion on how software is perceived, and how essential it is that software meet expectation. This perception impact works, perhaps unsurprisingly, strongly in the teacher student relationship than the student teacher (McGill and Klobas 2009). This is in line with standard learning impressions, that the teacher's opinion on learning outcomes impacts the student's belief of importance and highlights the need for acceptance by the teacher as a foundational measure of the usability of an LMS. The end result is it is incredibly important that educators find any LMS implementation easy to use and that it meets their expected outcomes, if it doesn't then it becomes an uphill struggle to generate significant interaction with the system. This in turn becomes a balancing act between functionality, interface, professional development and feature set.

This is often reflected when looking at the places that teachers make the most use of the LMS environment. Three of the most common features domains for a LMS are transmitting course content, allowing teachers to assess students and to promote discussion (Malikowski, Thompson et al. 2007); all examples of social aspects of the environment. This is often reinforced when looking at how teachers themselves are implementing LMS features. The highest usage features often belong to these sets, in the form of chat rooms, homework sharing, resource sharing and grouping of students (Yueh and Hsu 2008, Ho, Ng et al. 2015). Beyond this learners tend not to use a large number of the modules included in the environment, and this is amplified as their discomfort with the interface and environment usability grows (Tee, Wook et al. 2013). This is shown in the inevitable usability issues many educators show when learning an LMS (Mtebe 2015). Perhaps even more telling is at the other end of the scale with highly proficient users. Here, while they embrace the core functions of an LMS they can find that provided modules are too integrated into the environment and instead turn to other software solutions (West, Waddoups et al. 2007). When these modules are intrinsically tied to the LMS environment this can result in a lowering of use for the LMS as a whole. This reinforces the idea that a LMS can suffer from something of a 'goldilocks syndrome'; it needs to be just right. Too hard and users won't use it, too easy and skilled users can find it limiting. This line invariably becomes harder to ride as there is also the need to consider, outside of the user's willingness to interact with the system and the functions they use, the real world realities of these environments. These systems do not develop or exist in a vacuum outside the real world and real world implementations. They are all at heart software products produced by businesses and nearly all sold or operated for profit of a business entity.

While many LMS providers will maintain that they are a pedagogically focused, and for many that claim is a fair one, that does not mean their business and design decisions are not impacted by non-educational factors. For many of these companies' stakeholders outside the education domain hold significant sway in the product's evolution. The benefits these companies experience in revenue and user preference through expanded footprint is a prime factor in the disambiguation of LMS and CMS as separate systems as each tries to provide the complete solution to an institution's needs. Yet this one size fits (or contains) all is not necessarily the correct choice and brings with it a host of problems that fail to take into account the complex issues discussed previously in both ICT implementation, mobile learning pedagogy and LMS/CMS management design. Additionally they are subject to the non-education focused pressures of the business world, as in the case of WebCT (Clabaugh 2005), and are susceptible to factors like buyouts that can have a significant impact on the teachers and institutions that have implemented these now defunct systems, forcing them to learn new environments and again eroding user confidence.

Nearly all of the companies mentioned provide the recognized core domains of an LMS, material management, social grouping and teacher ability to track student metrics. They also contain the most desired teacher driven tasks of resource sharing, chat rooms and student grouping. However, they nearly all include significant functionality besides. This scope creep is present in almost all software design but represents significant issues when dealing with the classroom. As has already been established a significant factor in teacher's technology use is comfort and this spread of functionality in LMSs results in a more confusing experience for users. Yet these companies have a vested monetary interest in perpetuating these large scope environments. Firstly, is the ability to sell a product to an institution with a "do it all" approach, resulting in an increase in licensing fees. The other important result of these business practices is the aspect of vendor lock in, not in the space of enforced data typing but in the familiarization within an environment of users. With such a large factor of acceptance at the user comfort level there is significant business reward from having the user base operating within your environment and attempts to change can be resisted by users who do not want to learn a new system (Beatty and Ulasewicz 2006), an experience many teachers faced after the Blackboard buyout of WebCT. While on the surface there may be some benefits to operating within the single environment this can also prove a problem when users do not feel that the current providers meet their needs or are limited in pedagogical relevance (West, Waddoups et al. 2007). There is also an important question raised about the autonomy of teachers to choose software that meets the learning outcomes they require, versus using the LMS environment version that may not provide the desired goals. This is important when considering the importance placed in the educational and mobile learning spheres that ICT should exist to empower pedagogy, and not for pedagogy to be forced into the box of an ICT solution.

These expanded feature sets can also have another important impact, when they are part of a third party solution. Above, the assumption is made that these features are provided bespoke by the company, and while this may be true for some implementations, for many LMS providers core facets of their business model are provided by third party providers. In the case of the Blackboard LMS system a significant portion of their proposed function base is provided by third party partners. This not only includes secondary school application for digital textbooks, standards tools and multimedia applications but also electronic funding and advertising integration services (Blackboard 2017). Beyond these tertiary applications for some LMS providers core aspects of their function set are provided by third party providers. Again in the case of Blackboard their fundamental resource/ file management is handled by the company Dropbox (Blackboard 2017), while in the case of the Australian LMS Daymap hosting services can be supplied, at an additional monthly fee, through the Microsoft Azure cloud service . A significant issue with these structures though is that the end users have no control over changes in third party software or services. Similarly, when 3rd parties provide the service, often one of the primary reasons for the environment, consistency is lost.

Lastly there is the matter of cost. In the case of most business LMS solutions there is a significant monetary outlay, not only in hosting, licensing and technical management but also in the cost of professional development training for teachers to effectively use these large systems. While these costs are often tied to the size of the institution this can still prove too onerous for many schools, especially in the low economic areas where even a bare bones implementation of these products would be out of reach.

One alternative to paid LMS implementations are open source variations, the most popular amongst these being the Moodle web environment (https://moodle.org/). Designed in a collaborative open sourced environment, Moodle is "a learning platform designed to provide educators, administrators and learners with a single robust, secure and integrated system to create personalised learning environments." (Moodle 2017). Use of the Moodle environment is free of charge however it is important to note this does not mean aspects of the Moodle environment were not developed for a fee, for example the assignment offline marking module was a product paid for by Flinders University and developed by Netspot (Moodle 2017) and incorporated into the Moodle environment. While there are not as significant financial pressures and the use is free for these open source offerings there are still costs involved as institutions will need to outlay hosting and storage options. They are also systems with significant complexity and often require professional development courses before teachers can make adequate use of them. While there is no cost for these from open source providers, this professional development burden is simply passed on to the institution and while companies like Moodle provide significant guidelines for how professional development sessions can and should be run, the onus is on the institution to provide instruction. Open source solutions are also not immune from the scope creep that is present in paid implementations and Moodle is no exception. Private users and institutions can and do make constant contributions adding new modules and sometimes fundamentally changing the operation of existing modules or adding functionality that some may find superficial.

Lastly both of these styles of LMS implementation are significant endeavours, with both requiring a significant cost and training outlay in order to be properly utilised. This results in the majority of education LMSs being targeted at the institution level. This can often result in broader targeting of functionality than where it is often needed the most; in the classroom itself. This has been recognized by business in recent years with an emergence of classroom targeted environments; spearheaded by Google Classroom. From its release in 2015 Google Classroom has gained significant traction in schools with its easy to implement, classroom focused application of core LMS functionalities; material sharing, student collaboration and teacher oversight (Singer 2017). This rapid growth has shown the clear desire amongst educators for simple, streamlined and effective digital management that does not impact their own choices in what ICT they use to implement their pedagogical strategies.

However, it is always important to consider that while Google offer this environment for free they are a business and both the benefits they gain and their past actions bear notice. Much like other LMS implementations Google classroom makes extensive use of their own environment for resource management, grouping and communication; documents are handled through Google Docs, emails is provided through Gmail and storage is provided by Google Drive; the system is as targeted to generate lock-in as any other provider. Additionally there have been some significant criticism of Google’s privacy policies (Hill 2012) and their willingness to use user information to drive advertising. As their core profitability model is centred around advertising and analytical assessment targeted around collected user information, (Alhlou, Asif et al. 2016) their policies and actions in regard Google classroom should be embraced with some caution.

2.5. Mobile and Tablet devices

When looking at the activators of effective mobile learning and how users are looking to employ technology in the classroom there is a third domain outside the pedagogical and software design fields that bears examination and that is the devices on which students are going to consume these fields. Much like how all the learning theory in the world is ineffective without software that is created in its image for teachers and students to use, similarly the software is meaningless with no actual devices to run on. Already institutions are seeing a move away from desktops as the preferred method of accessing online or digital information with an almost 2:1 preference for laptops in some studies (Abrantes and Gouveia 2010). The technical barriers to online connectivity that existed in the early 2000's are mostly gone in developed countries and access to roaming wireless networks has become common resulting in a growth in the need for mobile, always connected devices. Institutions are already moving away from desktops as the standard computing device. Driven primarily from the need for mobile computing capable devices, that allow a student to learn both at school and at home in the emerging blended environment many schools have pushed forward with a 1:1 device implementation where the impacts have generally been positive for students and teachers (Keengwe, Schnellert et al. 2012, Keane and Keane 2017). However, while for many schools it is the laptop that is the primary device in the classroom it is worth considering the tablet device as a viable alternative as there are a number of situations where tablet devices can be an attractive option.

These devices provide a different experience to using laptops. The always on paradigm they employ allow for the devices to be accessed with little "commitment". There is no need to shut down and start up a tablet when use is required, with most tablets going from standby to operational in less than a second. Additionally, there is a psychological benefit to tablets. Students find tablets a much more "friendly" device, there is an empathic relationship that develops between users and the machine that is not present when using laptops (Twining and Evans 2005). On top of this, tablets provide a number of ergonomic and practical benefits including:

- Taking up less space in the classroom.
- Increased portability makes them less cumbersome and much easier to pass around between students.
- Being mobile and small they are conducive to a mixed study environment, enabling easy switching between standard pen and paper, and device.
- Stylus and touch screens are perceived as more intuitive than a mouse, especially when able to do natural hand writing note taking.

For the students themselves, especially at the late primary or early high school stage the, tablet as a device is highly coveted. Many are already familiar with the functionality of the devices through either parents devices or exposure to similar mobile phones (Shuler 2009) and many parents are utilizing iPad devices in home education through interactive eBooks and custom education applications to carry the school educational zone into their homes (Vaala and

Takeuchi 2012). Further developments involving tablets have found they provide tangible benefits in standard lecture environments allowing students to have readily accessible notes in an easy to manage format, interact easily in a bi-directional dialog with instructors and provide materials in a multimedia format (Romney 2010).

2 5.1.Device use factors

While a significant amount of early research was individual accounts, or accumulations of individual accounts, much more work has been done recently (Loch and Fisher 2010, Loch and Fisher 2010) to address the pedagogical factors that are important in the educational contexts described above. Studies done in schools in New South Wales, Australia found that the nature of the tablet device was conducive to face to face collaboration in a way that laptops were not and also provided much greater opportunity to employ multimedia creation. The tablets were found to be much easier for both young students and teachers to manipulate, strengthening the idea of collaborative work over cooperative (Goodwin 2012). When provided to faculty in higher education, studies found the response to tablet PC's has been favourable; though a period of time is required for faculty to adjust to and learn the devices (Toto, Kyu Yon et al. 2008).

2 5.2. Technical benefits and limitations of tablets

Tablets bring a number of benefits as mobile computing devices. Due to the nature of the device they provide significant benefits in weight and portability. This results in the tablet not only being easier to take from place to place but also as a "sometimes" access device within a single space as it can easily be slept and reactivated without any lengthy start up. Tablet architecture more closely matches that of mobile phones than laptop PC's and benefits from the formers architectural concepts to allow improved battery life over a laptop, often upwards of six hours' usage time between charging, while their increased screen size makes them much easier to view than the smaller smartphone screens.

These devices excel at media consumption, either as e-readers, movie players or browsing the internet, while laptops are superior with their input functionality, particularly the keyboard. Studies have shown that when presented with a touch screen replication of a keyboard and a real keyboard the keyboard comes out as the superior input device. Users could type approximately 25 words per minute using a touch screen keyboard while on a standard keyboard participants managed 58 words per minute (Sears 1991). Advances in the keyboard input for tablet devices has progressed to include shape writing gesture keyboards and on some devices letter drawing software using a stylus. While these input methods have not proven themselves to match the laptop's typing speed (Castellucci and MacKenzie 2011), the ability for the tablet to benefit from wireless peripherals means that it is perfectly viable to connect laptop style keyboards to a tablet and experience input speeds on par with a laptop. Not only that but as users become more familiar with the software input methods the user preference and perception of especially the gesture based solutions can be, while still lagging behind on text entry speeds, higher than that of the laptop keyboards (Armstrong and Wilkinson 2016b). While for many students there is a time period in learning to use the device (Underwood 2009) for newer students who have been raised on these devices this learning curve is reduced significantly and even in elementary school are able to effectively utilise tablet devices, where they provide a significant engagement and motivation benefit (Stacy, Cartwright et al. 2017) and as an effective within lesson interdisciplinary tool (Milman, Carlson-Bancroft et al. 2014).

2 5.3. Issues with BYOD

One of the possible solutions to the resource cost of tablets is to have a "bring your own device" policy where students can, if able, use a personal device for collaborative work. While the penetration of tablet devices in Australia was small, at only 12% prior to 2012 (Pegrum, Oakley et al. 2013), even this small amount of personal devices may help to alleviate costs for schools while another alternative is to employ mobile smartphones. Running on the same operating systems as tablet devices, with Android and iOS controlling a dominant 90%+ of the smartphone market share worldwide and Android being the operating system of approximately 60% of smartphones in Australia (Sing 2012), tablet and smartphone applications can most often be interchangeable. Both types of devices also fall into the same categories of device specification being portable, touch interface driven, wireless and relatively closed systems.

However, there are real issues with allowing students to use their own personal devices, especially with regards to security and privacy. Policy and guidelines need to be in place for how students would be expected to use the devices in a school environment, much like the guidelines in place for using personal devices in a business setting. However in a business setting with adults working in an environment with detailed, distributed and clear guidelines it was common for employees to claim to be unaware of the security policies in place, while over half of employers / companies felt they should have the right to access and remove data from a personal device if they felt the information could be compromised (Oliver 2012). With non-professional, younger users there is an even greater likelihood that policy and guidelines will not be strictly adhered to, while any students under the age of consent will raise further questions about right to privacy. Additionally, the fact that the devices belong to the user and not to the institution may also cause issue as when provided by the institution devices often come with software already installed to handle basic security, networking and usability. Even when a device is provided mostly bare bones the fact that it is provided by the institution gives them some priority in ensuring that the necessary software is installed, while personal devices are first and foremost the private property of the user. Lastly the devices while operationally similar still have major differences in architecture. This can greatly increase the cost of any necessary software, as the institution may need to create software for an operating system that is only used by a minority of students (Miller, Voas et al. 2012). BYOD still requires much more study, as the uptake of tablet and mobile devices increases it will be necessary for greater breadth of study, but the limited amount of studies done at the present means that outside of studying the ramifications of BYOD directly it can only obfuscate any mobile or tablet research.

2.6.Framework

Looking at the background literature it is clear that ICT use in the classroom is a complex domain with many impactors. As the use of technology in schools grow, these competing factors need to be carefully balanced and software aimed at educational requirements should be designed to facilitate these needs.

As shown in section 2.2, the importance of ICT skills in the user is not just one of usability but has a direct impact on the uptake of technology. This in turn provides a feedback cycle of use, leading to increased use. However, the prevalence of use alone does not necessarily convert to effective use. Effective implementation requires the management of multiple elements, including the teacher, students, and surrounding infrastructure systems. At the top of these elements, lie the human factors of teacher and student who are instrumental to successful engagement, as both their personal feelings and technical ability play important roles.

When considering teacher needs, they primarily want to use ICT to achieve two key goals (section 2 2.2):

- Skill based transmission (typing, drawing and other ICT centric use skills).
- Support of group learning outcomes through open ended constructivist software.

Here, it is essential that the software be seen as effective and usable by the teacher, as their own personal perceptions have a significant impact on their willingness to employ these ICT options, with both a teacher’s positive perception and willingness to use technology playing vital roles.

The other side of the classroom, the student, is also an essential partner in effective software and device use (section 2 2.4). While many institutions are striving for a 1:1 device to student ratio of computing in the classroom, this is less effective when there is limited interaction between the student and teacher. A copacetic approach between teacher and student is important in reaching an effective 1:1 implementation. The need for devices is important, but so too is the need for those devices to be used collaboratively across students and teachers. It is not sufficient to simply hand out devices with no direction or purpose. Teachers need to be able to direct and manage their students’ use of the devices in an effective way.

Teacher and student however do not operate in a vacuum and there are significant secondary elements that must be taken into account. The school itself will frequently have curriculum restrictions or guidelines dictating correct use within the classroom, sometimes dictating the software that is available. The material factor of device availability is also often a restricting element, with the need for devices to have an attractive price point for both school and student purchase (section 2.5). There is also the need, whether dealing with provided software or software the teacher has sought out themselves, to dedicate time to learning and training in that environment. Professional development time commitments must be weighed against other burdens on teachers.

So when addressing the environment where this ICT learning takes place it is essential when looking to create effective software that these four domains of the software, teacher, student and institution be carefully weighed and understood.

When considering how software can be effective in this space it is also important to understand what it is that teachers are ultimately seeking from the software they employ and how they look to use it. When looking at the modern learning theories (Section 2 3.1) of constructivism and connectivism the “hows” of what the teacher looks to do with the technology is essential. Software needs to be direct and to purpose and the focus must be on effective transmission and verification of information. To this end, there are a number of important elements that ICT software needs to provide to support these learning paradigms that focus on internalised learning. These elements would include offering multiple representations of reality, avoiding the oversimplification of the complex, emphasising the construction of knowledge rather than rote learning, encourage reflection, and to support social and collaborative spaces for learning. When adding a connectivist view to the process, there is an additional emphasis on the external factors involved in the learning process, which shows the importance of effective information dissemination in both self and collaborative learning spaces.

These ideas become foundational when looking at mobile learning and flipped learning spaces (section 2 3.2) where the spread of devices that provide information at a touch is ubiquitous, and collaborative environments are always at hand. While not a concept solely for the domain of mobile devices, personal learning environments are giving additional power through the spread of mobile devices and this in turn allows students to effectively customise their learning environments (section 2 3.5). When working in this flipped domain, the ways in which teachers and institutions employ ICT devices comes back to the fore, and the management of tasks associated with the digital environment become more onerous as students require more asynchronous information access.

This shows that software designed to support modern educational pedagogies must be robust and fit to task. It should also allow students to engage in effective group work, both locally and through connected environments. Management software then needs to leverage these elements to support the teacher.

One solution to this management issue is presented in LMSs (section 2.4). These systems have become popular as tools to fill this niche of supporting modern mobile learning and to assist teachers and schools with digital task management. However, there are important limitations in an LMS to be aware of. Due to their complex nature these systems are often large scale, challenging to implement and designed to provide management functionality at an institute level more so than at the classroom scale. The size and breadth of these systems has seen them become a rich market space for commercial products and this has seen some core functionalities supressed, or altered, in an attempt to provide a complete educational environment. This increased complexity, in turn increases the amount of training required for teachers and administrators to be comfortable using the LMS. At a teacher level LMSs can have a positive impact on student interaction, facilitating collaborative and mobile activities, and providing a suite of management tools that are needed in a digital environment. But the institution scale of the system can prevent teachers having direct control over their own management environment, and in some cases restricting the teacher's options for integrated software to those provider offerings.

When looking at these elements as a whole; the educational theories of constructivism, the ways that mobile learning facilitate new teaching paradigms and the role that LMSs can play in facilitating these actions, a number of issues stand out.

It is essential that at its heart ICT seeks to support, rather than control, the ways that teachers want to manage their classrooms. It is important that teachers have access to effective management tools that will allow them to effectively handle digital information and tasks within their own classrooms. While there are a number of factors that impact software choice one key factor is the teacher's own personal views on how effective a piece of educational software is or isn't.

Software, however, does not operate without complimentary hardware and the need for effective devices to utilise applications is essential (section 2 5.2) When looking at available devices the growth in mobile learning is aided by the rapid growth of portable, mobile capable devices, such as smartphones and tablets. In education, especially, the tablet has quickly found a home, providing a cheap alternative to the laptop, yet with an increased screen size to the smartphone. Tablets have provided the classroom with a good middle ground for many educational ICT purposes. With their intermediate form factor, they are well suited to both mobile and static classroom environments and are designed with a low entry level of usability in mind. While they may lack some of the built-in peripheral functionality of a laptop they often provide their own solutions and can be augmented through additional wireless and physically connected input devices. Their portability and ease of use can provide significant motivational and engagement potential and their multimedia functionality can empower easy video and visual content creation. Combined with their low cost, tablets provide an attractive option for the primary classroom device.

Tablets provide an option for a low-cost classroom device that helps to activate flipped classroom teaching and facilitate the growth of mobile and personal learning

environments. They offer a new and increasingly popular avenue for educational software.

When looking at the facets of these domains, a framework to approach the creation of management software can be proposed. As noted, this is a many faceted problem, but one of the starting points must be with the teacher and the factors that drive their use in the classroom. This was approached as a twofold problem. The first being how current teachers, in the targeted teaching fields, are currently using software in their own classrooms. With the rapid development speed of ICT in the classroom and the localisation issues found in their use, the environment that ICT is being used in is constantly evolving and up to date and targeted information is required. Before software designed to manage the classroom could be considered it was important to define the current software use in view of the tasks they want this software to achieve. However, as has been established, this use is conducted within the confines of the institution and as such it is important to determine not only what software tasks teachers seek to employ, but also environment in which this use will occur, both from an administrative and technical support side. This is discussed in Chapters 3 and 5.

In addition, it is worthwhile gaining a deeper understanding into the personal feelings of teachers towards technology and what drives their willingness to employ ICT, both positively and negatively. As has been shown the teachers' personal opinions are a significant driving factor, frequently dictating the practical implementation and use in the classroom. With positive personal opinions of ICT, use increases, and the inverse is also evident, that frustrations and impediments reduce use. It is important to further examine what shapes and moulds these personal views. Personal opinion is in its own right a complex and broad problem and greater understanding of where and what factors impact this opinion is of value. If the goal is to create software that is going to be effective in the classroom, then it is essential that a greater understanding be acquired to avoid the pitfalls that lead to rejection by teachers. This is seen in Chapters 3 and 5

For the devices themselves there is value in ensuring that when employed as sole devices they are fit to purpose. This can be done by comparing their effectiveness to the more mainstream laptop and ensuring that the usability of the tablet device is on par with the laptop, as well as providing a deeper investigation of the benefits and restrictions of the form factor.

With a greater understanding of the domains in which the software will be used, development can ensure it targets the elements of teacher personal opinion that are critical to successful uptake. Following software development, a test in a practicing classroom can show if the development ideals followed from the research are effective in providing a targeted digital management solution that overcomes the barriers that can affect educational software. This can be seen in Chapter 8.

2.7. Summary

This chapter discussed the current and past drivers of educational theory and design, the unique aspects of designing software for education and the importance of understanding the barriers of teachers, students and schools to its effective use. This includes the importance of usability in the software uptake feedback cycle that can be driven by user perception. It covers the basic tenets of mobile learning and Web 2.0, personal learning environments and the LMS's schools implement to handle their digital and software management needs. This covers both the benefits and drawbacks, including the perils of lock in environments and the need for software to be fit to the task, matching pedagogical goals, and learnable enough that it does not affect the perception cycle teachers experience. Lastly it discusses tablet devices as a tool and aid in the classroom and some of the unique benefits they provide over both laptops and smartphones, showing that tablets can bring significant benefits as consumer devices due to their cost and form factor.

It informs on the multifaceted nature of designing software for education, outlining the broad domains where schools and teachers look at ICT to make an impact, especially in the mobile space The chapter looks at the way current LMS's can be a poor fit to address these facets of pedagogy, teacher willingness and software complexity. This helps to inform on the elements of Research Question 1 (R.Q.1) to inform and identify the way that educators are seeking to utilise ICT in the classroom. It also provides an introductory look at the importance of personal opinion and learnability to the willingness of teacher ICT uptake, per Research Question 2 (R.Q.2). This link is further examined in Chapter 6, where the personal, professional and technical aspects of these teaching barriers are discussed.

The chapter lays the ground work for how tablets are viewed in the education space, in line with Research Question 3 (R.Q.3). This position that tablets hold within the classroom is examined and discussed further in Chapter 4 and Chapter 5. The work in this chapter will provide the bedrock of the rest of this thesis and provide a clear understanding of education software design considerations throughout the rest of the chapters. The following chapter will look at the methodological underpinnings of the thesis, and examine the methodology approach used for the thesis studies.

Chapter 3

Methodology

3.1. Methodology background

When approaching the work in this thesis, it was important to consider the different methodology requirements for the informative studies and software design, especially where collection of data was concerned. When dealing with ICT it is important to have a solid understanding of the intended user base, especially when considering a targeted group with unique needs like those found in the education sector. This is especially true when taking in the context of computing within the classroom where ICT's role is as a facilitator to educational outcomes, rather than the software functionality itself being the final goal (Harel and Papert 1990).

For this thesis there were four major sections to consider, each requiring a different methodological approach. While the literature provides a solid background for the driving impactors and barriers to teacher technology implementation (Chapter 2), in a rapidly changing field as ICT, it is important to have both more directed and more localised user understanding. As noted by Zhao and Frank (Zhao and Frank 2003), the classroom can be viewed as a distinct, complex eco system, with schools being distinct environments from one another, and the teachers as individuals within that school system (Figure 3.1)

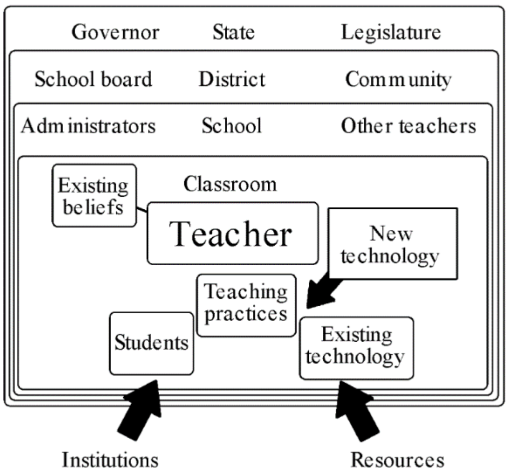


Figure 3.1: The School Ecosystem (Zhao and Frank 2003)

Each school is effected by its own unique set of impactors, and similarly teachers within that school are themselves effected by their unique surroundings. So even though literature frequently looks at education and teachers as an overarching homogenous group, this does not reflect the realities of the environment. As such, an updated and localised knowledge of the targeted group has significant value.

Similarly, there is an important hardware facet to consider. While tablet devices have a number of elements in their favour (section 2 5.2), there is still a significant link between the teachers own tablet operation skills, a willingness to experiment with them and implement tablet based curriculum for their students (Kalogiannakis and Papadakis 2019). In addition, the question of tablet use when standard PCs are a common device in classrooms is an important one. Are tablets even worth using if current PC solutions are fit to task? However, studies have shown among young students an increased enjoyment element and effective learning when using tablet devices compared to standard PCs (Riconscente 2011, Liu 2013). Yet while there are many studies in the realm of using tablets for educational use the number of studies examining the ability of tablets to function as an input device are minimal. This presents an issue if considering the tablet as a sole device within the classroom, especially when the tablet itself presents a number of possible input functions and there was value in a deeper understanding of how these different input paradigms are perceived and utilised by users. In the presented case, comparing cross platform input paradigms, established methodologies such as words per minute and task time were used to provide comparable results (Yamada 1980).

At the design level there was also the need to consider the functional requirements established both in literature (section 2.4) and in the results of the Chapter 7 and Chapter 8 studies. When studied, the design of software for teachers, yields five major themes; instructional design issues, curriculum, materials, cost, and meeting specific needs (Williams, Boone et al. 2004). However, large scale technology innovations are frequently hampered by the inability of teachers to receive consistent support (Blumenfeld, Fishman et al. 2000, Fishman, Best et al. 2000), and the innovations provided by these systems can be undercut by the school environment the teacher operates in. There is also a need to better understand the impact that perception has as shown in (section 2 2.3). As noted in the previous section and shown in Figure 3.1 the existing beliefs of the target group may well differ from locale to locale and these need to be considered. These non-functional requirements are an essential facet of understanding, necessary to produce effective software in process oriented fields like teaching (Chung and Nixon 1995). On the functional side of the software it is necessary to iterate, analyse and synthesise operations repeatedly to better target the functionalities required of the design model (Hausmann, Heckel et al. 2002).

Once implemented it is important that testing be effective and useful, and this means there is a strong need to iterate the design (Buxton and Sniderman 1980) as needed. This is especially true when dealing with a domain where final testing on the target audience is a time and access limited factor. It is key when iterating these designs that the process of transforming the conceptual ideas outlined in the design specification is effective, as negative iteration outcomes cause a significant impact at each stage of the iteration “hand off” (Ballard 2000) shown in Figure 3.2. This is especially important as the system testing phase of the testing period frequently consumes over half of the testing time (Ohtera and Yamada 1990). As noted, in combination with limits on access to the target group, software testing will need to account for an iterative approach at least in part independent of the target group. In addition to these elements it is essential that testing not just focus on the usability of the system. While usability, the ease of use, is an important consideration, in this work it is just as important how learnable the system is. While usability focuses more on the ability of the software to operate a function from beginning to end, learnability provides an important metric on the user's ability to navigate and learn the systems over limited iterations, and is recognised as an essential facet of overall software usability (Abran, Khelifi et al. 2003). This element becomes increasingly important when the purpose of the program is to quickly and effectively introduce comfort.

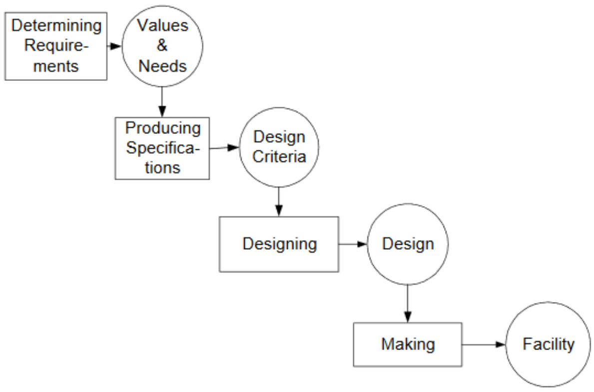


Figure 3.2: Iteration Handoff Control (Ballard 2000).

All four of these elements has their own methodological tools and implementations and require a mix of qualitative and quantitative data. Each on their own (user analysis, hardware analysis, design specification, software testing) is a significant field and it is impossible to cover each in depth. This thesis has taken elements of each to produce the final result, however before a deeper discussion of the data methodologies presented, it is important to note a number of delimitations in the work.

3.2. Notable delimitations of the work

As has been stated in the framework (section 2.6) the domain of educational software is a broad one with a variety of nuanced elements and factors. As such any work dealing with this domain will encounter constraints and delimitations that should be discussed. All the noted facets are themselves deep areas of learning and this work does not attempt to delve deeply into all of them, instead drawing together parts of each to inform and direct software design. There are a host of alternate devices and software companies present within the mobile domain and there are pressures and impactors in real world implementation, both with research and commercial software, that are not present here.

When considering the user groups in question here, teachers, it is important to recognise that it is difficult to have unlimited access to this user group for a variety of reasons. From a professional domain, teachers' time is valuable and already has a number of significant impactors. There is less inclination to engage in significant study participation, especially when one of the key detractors in software utilisation is the teacher's inability to see an immediate benefit. In combination with this, any classroom testing by nature diverts the classroom from the intended study plan. This presents a disruption both to the teacher as well as the students, especially in view of a system that may introduce additional technical constraints, or even worse not be fit to task due to insufficient previous testing/design flaws.

This dependence on teachers' willingness to participate also leads to a second consideration. Teachers who agree to participate in the study, very possibly already have a preconceived notion of the role that ICT plays within their classrooms and an established bias to the value of the work. While a more extensive longitudinal study may help to mitigate these factors, when the teacher sample is small, as it is in this work, this should be a considered factor.

It is also important to note that teachers themselves are at least marginally beholden to the structure and willingness of the school system they work in to allow any experimentation. This is impacted by not only the school's willingness to participate in any study but also the technical limitations that may be present in the environment. In addition to a school's willingness to be involved, there are significant governmental restrictions in the researcher's locale that control and limit access to schools. Accessing schools requires a significant and detailed ethics application that clearly states the interactions expected, their impacts on students learning and importantly, limits the type and number of the metrics that can be gathered. As such school related testing elements presented here, the survey presented in Chapter 4 and the in class study in Chapter 9 are both subject to these ethical limitations.

This work presented a piece of software designed to task on a single operating system and device type. While the functions and design elements stand as device agnostic they have only been tested in a singular environment. Within the domain, availability and time constraints of this thesis designing for multiple operating systems was not feasible. While modern development environments for cross mobile operating system now exist, at the time of software creation these tools were not robust enough for the task.

When discussing the effective use of tablets, it is also important to note that tablets can have many alternate input paradigms. In this work however device practicality was weighed heavily in favour of text input. Textual input is still the most common form of nonverbal communication in the classroom and the time constraints of the project allowed for limited testing or comparison across the multitude of possible alternate input systems (such as voice or stylus).

Lastly the software itself would benefit from a longitudinal deployment, across multiple classrooms, to properly establish usability. As discussed in section 9 2.2 there are significant limitations on basing a management system on the short term user experience. While the study design in Chapter 9 takes an effort to mitigate these issues, the only true way to assess long term use of management software is to use it over an extended period. Both the time required and the logistical constraints present in a longitudinal study prevented such a real world test and this delimitation is an important one.

All of these delimitations impact the work, and present constraints on the methodologies chosen, and should be duly considered.

3.3. Methodology for collecting User Experience

As noted above, there is valuable insight to be gained from local targeting of the intended user group to better understand the hows and whys of what they seek to use technology for. As the final arbiter of what is and is not used within the classroom the teacher stands out as a clear target for investigation, however as has been noted there are other pressures on teachers for the ICT options they have available; including school policy and technical infrastructure. In this instance, given the focus was looking at user perception, the data sought was primarily qualitative in order to better understand the feeling and impressions more so than seeking solid numbers on their ICT use. While this user analysis performs somewhat as a stand-in for a requirements elicitation, common in a business solution, in this instance the user group is not the only stakeholder, nor were they needed to create a function list; in this instance many of the functionality requirements were established through literature and existing software implementations. While this avoids some of the failure issues present in standard elicitations (Davey and Parker 2015), including elements like failure to clearly translate functional requirement from language and requested functionality change during development, it also puts a larger emphasis on the nuance of teacher response as it pertains to the already established LMS functionality.

When considering the methodology for collecting user opinions there were two main options to choose from; interview and survey. While interviews can provide a significantly greater understanding on a per person basis, this is often influenced by a number of factors including interviewer experience and number of contact interviews (Knox and Burkard 2009). In addition, there is a significant impact on time and effort on the part of the interviewee and researcher, significantly increased per interview. At the same time, research interviews benefit strongly from an open ended interview process that allows for a significant back and forth (and the ability of the interviewer to capitalise on between the subject and interviewer (Rowley 2012). Outside these methodological aspects of interviews is a significant practical limit as noted in the delimitations above. Interviews would require a far greater time investment from each participant and a much greater involvement of the participating institution, both from a school administration stand point and governmental ethics obligations. Lastly the research is primarily concerned with the opinions of how teachers feel about ICT elements in the class, often in a domain that they are already experienced with. As such the open ended responses garnered by an interview, while valuable, provide a lower worth than a higher level response from a broader participant pool.

Instead this work utilises a survey to gather responses from participants. This allows for a number of practical benefits. Firstly, there are significant ethical requirements in order to directly contact teachers. By employing a survey methodology, the onus of contacting and distributing the materials can be passed on to the institution and involves no direct contact from the researcher. This reduction in direct contact also mitigates any perception of coercion. Secondly this method of distribution bypasses an additional layer of contact and response between the teacher, school administration and researcher.

A survey also allows for a far larger distribution set than possible with interviews, at the cost of more in depth per respondent analysis. By using a survey, the work was made available to all schools within the targeted locale. This larger participant pool is valuable when considering the response rates to surveys are traditionally low, especially when managed in a style similar to mail surveys; notorious for their low response rates (Kanuk and Berenson 1975). This issue with response rates is one of the larger criticisms of surveys, with a generally accepted response rate of over 80% in order to validate and generalizable statements, however this factor is mitigated when the respondents are a homogenous group of desired respondents (Leslie 1972). In this case, as all the respondents were teachers, this lessens the survey response rate issue. In addition to established survey methodology, the ability to distribute web surveys offers additional benefits to the paradigm. Chiefly they provide a very cost effective means of distributing the materials, and reduce the workload of distributors, a key factor when relying on school administrators to distribute their material on their own graces. Web surveys also provide a streamlined collation alternative and allow the rapid checking and updating of participants (Wyatt 2000).

When considering the types of questions to ask the teacher targeted survey looked to address primarily two elements; the ICT solutions teachers used, and their feelings towards them. This led to a survey that focused heavily on Likert style responses as well as the option to provide more contextual open-ended responses where appropriate. Likert scales themselves are a well-established metric for collecting ordinal data and have a long history of use in surveys (Allen and Seaman 2007) and while there have been criticisms of their value for making informed decisions or statistical analysis these can be unfounded (Norman 2010). Most importantly, as ordinal metrics, Likert scales provide sufficient information for a non-statistical analysis.

3.4. Methodology for Software Analysis

When looking to assess the testing phase of software there are three basic issues to be aware of (Lyu 1996):

- Fault: A static defect in the Software
- Error: An internal state that is the manifestation of a fault

- Failure: External, incorrect behaviour with respect to the requirements or expected behaviour.

Of these three error and failure present the most pressing issues. While module testing of the program can significantly reduce the fail rate, when put in the hands of users, unseen errors can significantly impact the user experience. Even if all errors and faults are addressed, the impact of failures on software that is designed to be learnable and usable will provide a significant negative experience. While errors can often be deduced through user operation, failures frequently require a more in depth analysis to discern the software weakness.

For the functionality of the software there are a number of standard factors that can be measured (Sauro and Lewis 2009) including completion rates, task times, task satisfaction, access to help and usability problems. For the initial usability tests all of these factors were taken into account to most effectively identify and isolate failures in the software. When addressing the metric of usability there are a large number of established questionnaires that provide statistically important results, including the Technology Acceptance Model (TAM), the Software Usability Scale (SUS) and NASA-Task Load Index (NASA-TLX). For this work the SUS was used to assess usability levels during both the initial functionality iterations and final classroom studies. This was primarily due to two factors. The first is the SUS's generic response questions. As a number of the respondents would be young students this simple, generic response template provided the easiest answer solution, where surveys like the TAM and NASA-TLX are more targeted towards the professional expectations seen with the software. The SUS also provides a level of granularity, allowing for a task-to-task correlation as well as a test-to-test. This allows the SUS to double as a statistically significant measure of Learnability (Lewis and Sauro 2009). The granularity afforded by the task-by-task assessment allows the SUS to act as a survey for learnable tasks, by taking two of the tasks (tasks 4 and 10) to provide a learnability index that can be correlated with the usability elements of the SUS. These factors for measuring failure, along with the responses of the SUS, provide a solid quantitative view of the performance of the application during the study.

In addition to these metrics in the study presented in Chapter 9 it was considered important to also collect some level of qualitative data from participants, particularly to allow a more open ended response to issues. While the study would have benefitted from the ability to have a more in depth debriefing with the teacher and students after the in-class study was performed, the realities of the environment prevented this. Instead these were conducted through a number of Likert responses and the ability to provide additional after study detail. As noted, the software development cycle for this project had a number of hurdles. There was a limited ability to access the target demographic, especially with a view to any longitudinal study. This access constraint also placed strain on the ability to effectively iterate design, forcing these iterative processes to happen in a lab and built around the responses from Chapter 5 and the elements drawn from literature (section 6 2.1).

3.5.Summary

The work presented in this chapter establishes the methodologies used in the rest of the thesis. It establishes the methodological approach for each of the three elements presented, and also discusses the delimitations in the work and how they have been accounted for. This includes real world and ethical constraints and the possible impact they may have had on the results. Lastly the work discusses the important domain of data collection for the two user study based elements of the thesis; collection user experience and effectively analysing data gathered from software analysis. This chapter ensures that the following studies and discussion are framed within the methodology literature of research.

The following chapter will look at a survey of South Australian schools to examine how the work presented in this background aligns with teacher opinion and school policy.

Chapter 4

Survey of South Australian schools

4.1. Overview

This chapter presents a survey conducted on South Australian schools focusing on Teachers and Administrators. This survey seeks to gain a deeper insight into up to date and local opinions that schools have with regard to the use of ICT in the classroom, teacher's views on technology, use within lessons, school's policies towards different devices, and the infrastructure to support these systems. While literature provides a valuable overview of the issues and challenges with the use of ICT in the classroom these details are nearly always impacted by local factors like resource cost and ICT availability.

As research questions (R.Q.2, 3) addressed by this thesis are focused on these elements and as core functionality of the ClaMApp software presented in Chapter 6 is strongly aligned to teacher perception, it is important to gain insight into the intended user group directly in an up to date and targeted manner. Results from this survey further assisted in developing the feature set for the ClaMApp software presented in Chapter 6.

4.2. Introduction

As discussed in section 2 2.2 ICT in the classroom software for education covers a number of important domains that applications for the general public do not need to follow. The importance of the teacher's subjective view is essential to well-designed software and is strongly impacted by their own personal experiences and comfort with technology. While literature can provide an overview of these facets there is always value in gathering specific data. Firstly, it allows for targeted questions and enquiry, specific to this thesis' research questions, both in regards to the overall research goals and the target audience the research focuses on. Secondly as opinions and factors change in the education landscape it is essential to continually improve and update the pool of available information. To those ends this chapter presents findings from a survey conducted with South Australian schools, both teachers and institutions, and examines their views on technology in the classroom. For teachers this focuses primarily on mobile devices, collaborative tendencies and the user's personal views and tactics for technology in their own classes. For institutions the focus is on the policies and strategies they have in place to control mobile access in their schools, their views on BYOD and the infrastructures in place to facilitate mobile connectivity.

While Chapter 2 provides an understanding of the roles that teachers' opinions and usage play in the use of ICT in the classroom (section 2.2) it is important to recognize that time, location and environment all play an import role as well. Examining how specific teachers are seeking to employ devices and what functionality they make the most use of is a valuable asset when designing software. Similarly, the resources available to schools may impact the willingness of teachers to use ICT, for example device numbers may be a factor that limits use.

Within each school environment the individual policies of the school can also heavily impact the ability of classrooms to employ software and devices (section 2 2.2). The school may have a specific policy with regard to the use of mobile devices in a classroom, or have infrastructure that is not fit to incorporate mobile centric devices. Lastly the opinions and structures within schools can change rapidly as new educational paradigms are introduced and ICT device and implementation costs shift. In the same manner teacher opinions themselves are constantly shifting through observed use and personal opinion of the role that tablets and other devices can play within their lessons.

This survey looks to gain insight into the opinions and views of teachers and administrators within the locale where software testing will most likely occur, South Australian schools. To gain the opinions and views of teachers and administrators within that specific environment, the survey questions used were designed to collect a general opinion of two elements of local schools; teachers and administrators.

For teachers, the survey looked at how they view ICT in their classrooms and its power to assist or distract from the learning experience. The survey also seeks to inform on the tasks they most often use ICT for, and the role that specific devices (desktop, laptop, tablet and smartphone) play within the classroom. It also examines the digital tasks that teachers expect ICT to provide from a digital management perspective. Lastly it assesses what app specific operations and day to day classroom management tasks teachers look to support.

For administrators, the survey seeks a deeper insight into the policies and infrastructure that schools currently have in place, with a focus on learning management systems and policy towards tablet and smartphone devices. This helps to provide a view of what school impactors may be influencing the use of devices and software within the classrooms themselves, as well as if the school infrastructures are capable of supporting mobile centric environments.

Teacher questions were devised with a focus on the issues raised in literature (section 2.2.2) about the importance of personal opinion and comfort with device and software uptake. The full question list is provided in Appendix B.1. Administrator questions were targeted primarily at policy and technical limitations / availability, full questions are provided in Appendix B.2

The results from this survey helps to bolster and support the literature provided in Chapter 2 and provide additional clarification on needed features of the ClaMApp software presented in Chapter 6. The survey also helps to clarify the expected infrastructure environment that the application will run in and limitations they may encounter in a current classroom environment.

4.3. Methodology

The results presented here were gathered from an online survey run in early 2014 collected from South Australian public and private schools.

SURVEY OF SOUTH AUSTRALIAN SCHOOLS

This survey was performed under Flinders University Ethics Committee project number 6372 and in cooperation with the South Australian Department for Education and Child Development (DECD) and a final report can be obtained as project CS/13/190-3.8. (Appendix A.1)

Contact was initiated by email, contacting all schools in the South Australian DECD and Association of Independent Schools of South Australia (AISSA) mailing lists. Of the 451 schools contacted 23 responded with a willingness to participate and were sent the relevant survey data and information packs. Due to ethical considerations the research does not identify the schools or teachers who took part and no relationship can be established between institutions and teachers. For the same reason dissemination of the survey material to individual teachers and administrators was up to the school. As such institution and teacher results are not dependent and should not be grouped. The survey itself was presented online with the use of the SurveyMonkey (www.surveymonkey.com) web platform. From the sending of participation documents the survey was available for four months before final data collection.

This was collected through online responses that provided a per participant answer matrix as well as basic summary data. Initial contact was made through cold call email to all potential schools with an invitation to participate. Respondents were provided the relevant information and documents for staff and administration and were asked to distribute these to the interested parties (Appendix A.1). This ensured that teachers themselves were not directly influenced to participate and that administrator surveys would be provided to the most relevant staff member. It is important to note that the administrator who responded to the survey may not necessarily be the principal of the contacted school, the information pack just requested a person capable of answering the questions.

It is also worth noting the possible correlation between an interest in mLearning and a desire to participate in the survey. With no control over the dissemination or response rates of content within schools the survey does not look to address this element. However, it is still important to consider that both positive and negative views of tablets and mobile devices within the classroom may have impacted a teacher's willingness to "be heard" on the topic, and should be considered in the following discussions. Upon choosing to participate schools would provide accepting participants with the information pack providing links to the respective SurveyMonkey questionnaires (Teacher or Administrator).

Beyond the participant motivations, the survey is constrained by some additional limiting factors. The first is the response rate as a portion of full sample size. With only 18 teachers and 6 schools participating from over 300 approached institutions, and with none of the participants being High Schools the values of the results provided as a statistical representation of the population are limited. As such most results need to be taken on a per person basis, not as a representation of teachers as a body. Secondly the nature of a survey will inevitably limit the depth of insight provided from responses. While questions were designed with scales in mind to allow variable responses and many questions included an option for teachers to expound on their views, there is still a limit to the depth of the opinions gained.

4 3.1. Teacher Survey

The key information sought from the teacher focused survey was on the domains of personal use, mobile devices in the classroom, teacher collaboration, subjective views of tablets in the classroom, collaborative practices, use of Learning Management System (LMS) environments, and social media by students (Appendix B.1). These topics were chosen to provide clarification and additional information to the factors discussed in the Chapter 2, with a focus on mobile learning and classroom digital management. Topics were broken up into 23 questions as follows:

- General classroom statistics and teacher familiarity with mobile devices (*6 questions*)
- Tablet use in classrooms, covering the teachers' use of mobile devices within this domain, their preferred methods and tools for using the technology, and their personal preferences towards different mobile and tablet devices. (*7 questions*)
- The educators' subjective views of the role social media can or does play in their classrooms (*2 questions*)
- The importance of computers and mobile devices for enabling collaborative work spaces (*5 questions*)
- How teachers see ICT as a general concept in the classroom and what if any digital management systems are utilised during day to day by the teacher; for example, document delivery, course calendars, social interaction software (*3 questions*)

Response data was mainly in the form of discrete data responses with some options to provide qualitative responses to fields.

Survey questions were selected to provide a qualitative response from participants, with the use of Likert scale to allow some movement in participant response.

4 3.2. Administrator Survey

As well as teachers "Administrators" of the school were approached. Again, to ensure ethical compliance the administrator of a school was an undefined position, it may have been an educator or administrative staff who responded to the questions. However, as the survey pursues an institution focus rather than personal views this was not an issue. The contact process for Administrators was the same as that for teachers and was conducted in the same space as the teacher survey. Topics chosen for Administrators focused on how the institution viewed technology in the classroom with a focus on mobile learning, the school's use of an LMS environment and the ICT infrastructure in place within the school. The survey also gathered the state of school policies for ICT and especially mobile devices on campus (Appendix B.2). As with the teacher survey these were split into question sets with a total of 18 questions:

- School demographics (*2 questions*)
- ICT as a topic (*3 questions*)
- Learning Management Systems (*2 questions*)
- Policy for mobile learning in the school (*6 questions*)
- ICT Infrastructure (*5 questions*)

Response data was mainly discrete and binary responses with the option for expanded responses where warranted.

4.4. Results

4 4.1. Teacher Survey

The teacher survey had responses from 18 teachers. Of these respondents the years they taught ranged from Year 4 (n = 9) to Year 7 (n = 8). This suggests that most participants are primary school teachers. Most participants stated they taught a range of two to three years. When asked for core subjects taught participants responded with six for STEM fields, seven for social sciences and seven for arts; with 13 more affirmations of teaching “Other” subjects. Among the other subjects taught were six teachers who stated their role as “generalist primary teacher”. Of the participants, two also stated they taught second language topics, two that they taught special interest classes and one that they taught specific ICT classes.

4.4.1.i. Personal Device use

The results for device use focused strongly on mobile use and comfort among teachers. Of the participants 72.2% (n=13) stated that they own their own mobile phone while 27.8% did not (n=5). When asked the same in regard to tablet devices 61.1% (n=11) stated they owned one while 38.9%(n=7) said they did not own a tablet. This shows that personal ownership of devices is high, especially with tablet use. Of the tablet owners, only one respondent owned a tablet but did not own a mobile phone.

When assessing their own comfort level with mobile phones the majority of respondents placed themselves firmly within the upper half of the scale (Figure Figure 4.1), suggesting they feel comfortable using these devices. Only two of the participants considered themselves “Uncomfortable” with using the devices and no teachers felt they were very uncomfortable, again suggesting all felt relatively competent in their technical literacy.

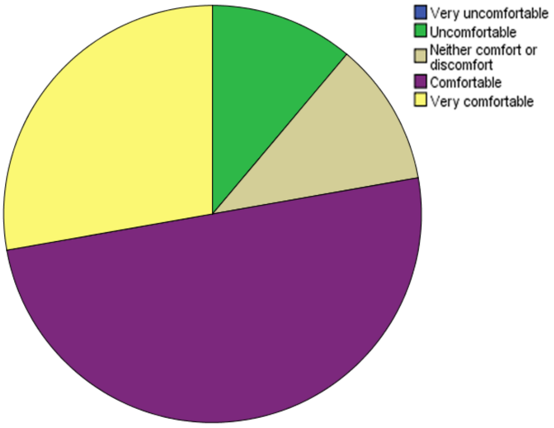


Figure 4.1: Teachers personal comfort levels with mobile devices.

When asked about their usage levels of mobile phone and tablet devices again none of the respondents were unfamiliar in their use with more than half (n=10) saying they use their phone multiple times a day as shown in Figure 4.2. It is worth noting here that this would include the teacher who stated they do not own phone or tablet devices suggesting that from some teachers their primary form of device usage is in their own classrooms.

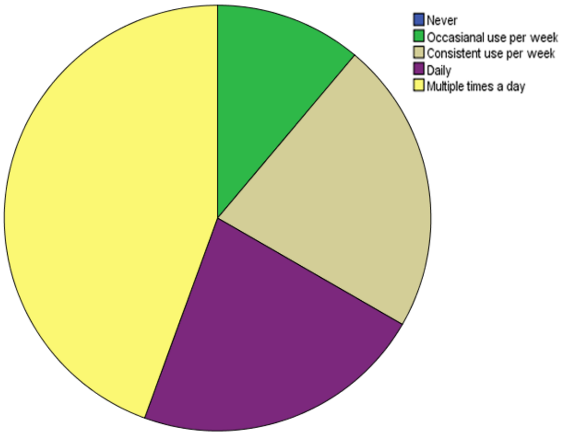


Figure 4.2: Frequency of mobile phone use by teachers.

When looking at comfort, ownership and use there was a pattern amongst participants that showed the higher the usage and confidence levels the more likely a participant was to own both a tablet and a smartphone, with users who own both rating themselves the highest for both confidence and usage frequency. Correspondingly teachers who did not own either device used them less in the classroom and had a lower sense of self confidence in their applications.

4.4.1.ii. Device use in the classroom

When looking at how teachers viewed the use of these devices in the classroom again the overwhelming majority (n=16) were at least comfortable in employing technology as shown in Figure 4.3. Only two respondents felt uncomfortable with device use in the classroom and it was noted that both these users did not own a tablet or smartphone personally, reinforcing that their primary usage environment may be when employing them within their own classes.

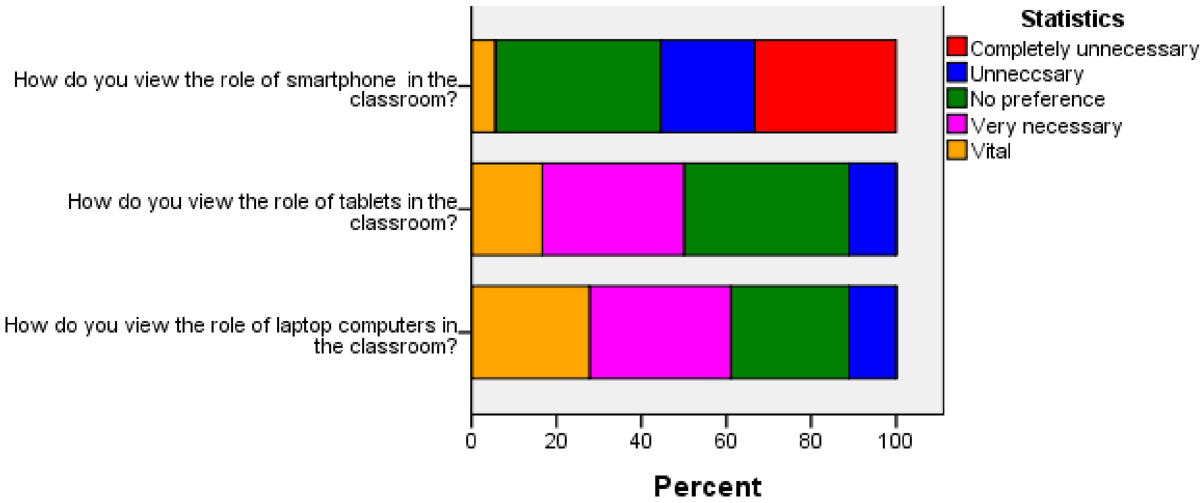


Figure 4.3: How teachers view the role of the 3 primary mobile devices in their classrooms. A 5-point scale was used from 1 (Completely Unnecessary) to 5 (Vital).

When examining the role that teachers felt the three primary mobile learning tools, (laptop, tablet and smartphone), played in the classroom the results showed a clear disdain for the worth of smartphones as educational tools. In the case of both tablets and laptops only two teachers saw them as unnecessary, while none considered them completely unnecessary. However, in the case of the smartphone over 50% (n=10) felt they were either unnecessary or completely unnecessary. Again, these results are in line with the previous findings that showed teachers who felt comfortable with device use had a higher opinion of smartphones as a tool. Here the single teacher who stated that smartphones were a very necessary part of the classroom owned both a tablet and smartphone, considered themselves very comfortable with both personal and in class use, and considered both tablets and smartphones vital to the classroom.

There appears to be some connection to familiarity driving use, as the two teachers who viewed laptops and tablets as unnecessary, and smartphones completely unnecessary, owned neither device and were not comfortable with their use in the classroom. However, it may be that they own mobile devices that are not, in their eyes, smart phones. The limited number of responses makes it hard to argue a firm causation as these users may also have outside factors that drive their views. In a similar vein those who viewed the personal / classroom relationship positively may have existing views on both societal and educational factors that reinforce their opinion.

Laptops were considered the most vital mobile learning tool, though perhaps surprisingly only by a factor of two teachers; two additional teachers felt that laptops were vital compared to two who had no preference for tablets. This suggests that despite their relative newness as educational tools tablets have been recognized by teachers as being useful tools in the classroom.

When asked to provide more qualitative views on the role these three mobile learning tools played the pattern of ownership and familiarity breeding a positive view of the technology held true. Of the 14 teachers who offered their perspective half of them (n=7) felt that the technology existed purely as a tool to assist in established classroom curriculum, primarily as lookup and information sources, suggesting teachers are only activating the early stages of the Substitution Augmentation Modification Redefinition (SAMR) model (2 3.4) . For four of the teachers a desire was expressed for greater ability to manipulate iPad / tablet devices especially, yet stated issues with both fitting them into current class structure, the school infrastructure to support them, and the physical access to devices. Lastly two of the respondents stated their belief that to not utilise technology in the classroom was a disservice to students stating "*They are the future, the way of the World and without them we are doing our students a grave disservice*" and "*They are the way of the future, that included student learning… we need to be one step ahead and know how to bes(sic) utilise them*". The second teacher also stated that access controls in place at the school created a significant impediment to utilizing tablets. This was reinforced by another teacher: "*The technology within the school does not always allow for easy use of technology, particularly tablet devices*".

Yet despite their varied views, shown in Table 4.1: Teacher rankings of 4 ICT options based on their implementation in the classroom, on the role technology plays in the class 88.9%(n=16) stated they attempted to use technology at least occasionally in their course work, with 61.1%(n=11) saying they tried to incorporate these devices as much as possible. When doing so the predominant devices employed were quite evenly distributed between desktop terminals, laptops, and tablets. In fact, for 35% (n=6) of respondents the desktop was their primary device, another 35% stated tablets were the primary device while only 30% (n=5) stated laptops as the primary ICT tool. This similarity was continued when looking at the second most implemented device where desktop, laptop and tablet shared a 33% portion each. It is not until looking at the third most used devices that tablets fell away, and this may be due to the previously stated issues some teachers have with accessing them. However, it seems to demonstrate that when available tablets are an attractive educational tool.

Table 4.1: Teacher rankings of 4 ICT options based on their implementation in the classroom, with rank 1 being their primary tool and rank 4 the least used.

	User Ranking (1 to 4)				
Answer Options	*1*	*2*	*3*	*4*	*N/A*
Desktops (traditional fixed terminals)	6	5	4	0	2
Laptops	5	5	2	0	5
Tablets (iPad, Nexus etc.)	6	5	3	1	2
Smart Phones (iPhone, Galaxy etc.)	0	0	1	3	13

Perhaps unsurprisingly given previous responses, 13 of the respondents stated that smartphones were a non-applicable answer and only one respondent considered them as anything other than a 4th option. This user also placed tablets last in the list, perhaps again suggesting a lack of device access, though no elaboration was provided.

When looking at the roles teachers felt devices filled and their place in the classroom (Figure 4.4) teachers are aware and have views on devices they use, with no respondents providing a neutral or lower rating when looking at both “have no personal view” and “I would ban these devices”. This suggests that teachers are not passive participants in the ICT in the classroom debate.

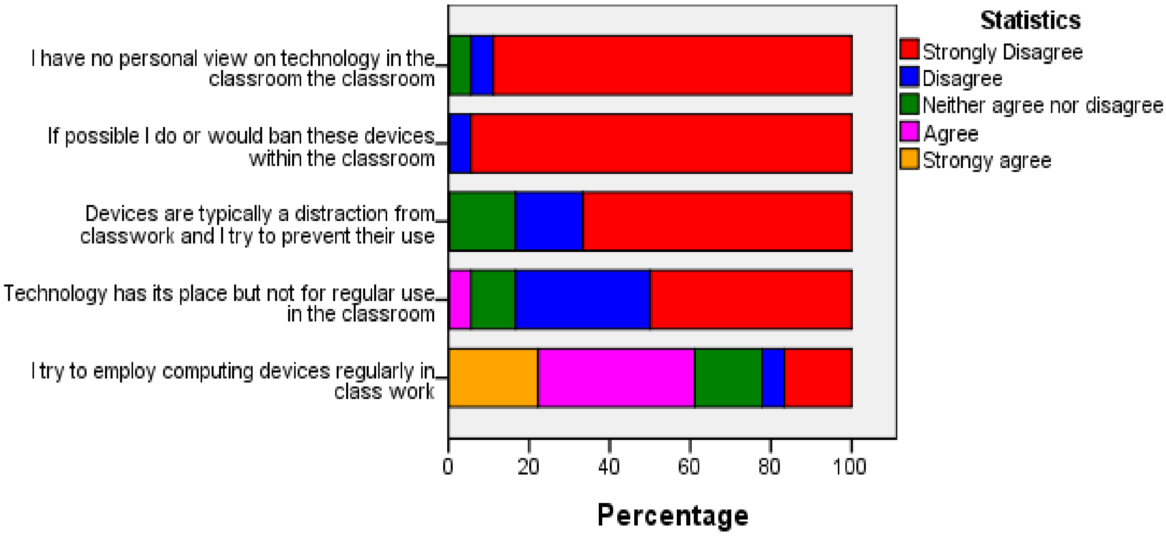


Figure 4.4: Teacher views on the role technology plays in their classrooms. A 5-point scale was used from 1 (strongly disagree) to 5 (strongly agree).

Unsurprisingly nearly all teachers have a personal opinion on how devices should be used in class and realize that there is no case where banning them would be beneficial. However, as the role of technology comes into play their views begin to diverge. This suggests that while teachers recognize and want to make use of the technology, how, where, and why they do is far less clear. Again in this block of questions it can be seen that those who owned multiple devices and looked to actively use them, also look to actively involve them in their own curriculums, while those who were not comfortable with devices did not.

4.4.1.iii. Social media

Regarding social media, teachers were asked how heavily restricted access to social media was, and how effective they felt that any restrictions were. When looking at the results of these questions participants fall in two stark groups. Of the respondents 81%(n=13) stated that control over social media access was either restricted or heavily restricted. As with other questions there are limited median responses with the other three respondents stating that social media is unrestricted for their students. A similar spread was present when asked if their schools had sufficient controls in place to regulate social media access with 68.7%(n=11) reporting a high faith in their controls. Interestingly of the two participants who said that social media is unrestricted in their classroom, both also felt that they had excellent social media controls in place. However, neither of these respondents presented themselves as exceptionally tech savvy or confident in previous questions. Similarly, users who had a high confidence in their understanding of technology felt their social media controls were adequate and limited student access appropriately.

4.4.1.iv. Collaborative

When examining collaborative work and asking teachers what percentage of their class work was group based the majority fell between 30% and 70%(n=13) with 41%(n=7) stating that they aim for 50% of their classwork to be collaborative. Of the remaining participants one stated they used 20% group work while only one stated they used less than 10%. However, the user who responded with 10% qualified their response stating that as they teach special needs children often group work was poorly designed and with no clear implementation that took into account the issues their class had. They further stated outside of their current teaching load they would look to implement additional collaborative aspects. At the other end of the scale two respondents stated that up to 80% of their class work was collaborative, but no teacher stated they employed more than 90% group work. However, despite the mode of 50% when asked if they wished they could incorporate additional collaborative work 65%(n=11) stated that they would like to employ it more.

When asked about group sizes for collaborative work 76%(n=13) felt that an ideal group size was two to four students, while only a single teacher believed that group sizes greater than four were beneficial, as seen in Figure 4.5. Similarly, when asked how they created groups from their students' teacher's formulation was varied, with the only thing most agreed on being that groups should not be all from within the same, or from separate, social circles.

Yet beyond this, approaches were varied. There was no cohesive response as to how groups should be created and if they should be planned or created ad-hoc. While teachers wanted to use collaboration, and often felt they were not using it enough, the ways in which they wanted to create and manage groups was seemingly unstructured. This sense of confusion around implementing group work is supported when participants were asked to provide additional insight into their collaborative efforts. While some were definitive in its need "*Students must learn the social skills that are involved in working with others and how to problem solve…"* others were less decisive in their use of group work with comments like "*Yes it would be great for students to work together more*" and "*Yes and no depends what I'm doing*".

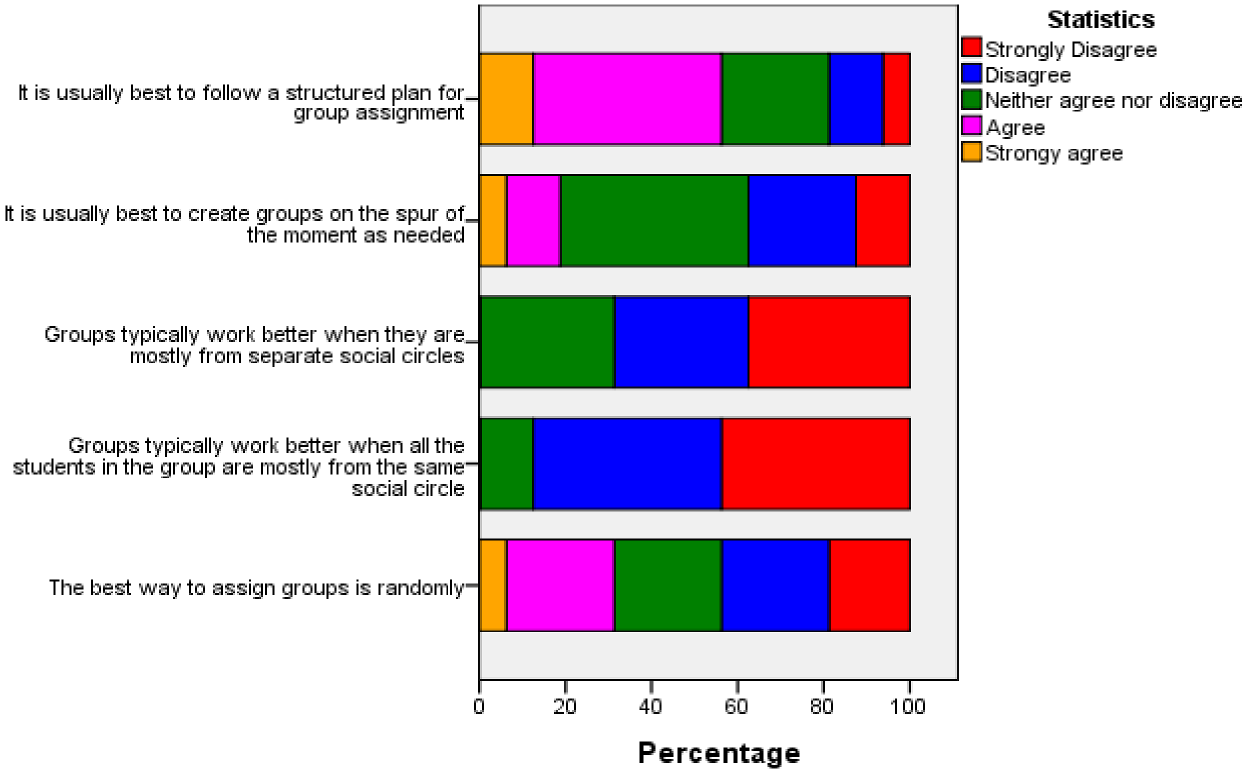


Figure 4.5: How teachers seek to construct collaborative groups in their classrooms. A 5-point scale was used from 1 (strongly disagree) to 5 (strongly agree)

For most respondents though there is recognition that collaboration is an intrinsic part of the modern learning experience, although some feel that while they are embracing group learning in their classes the curriculum has not kept pace with these changes "*We are definitely working more to a collaborative model but current assessment criteria mean that we still do lots of individual tasks.*". For most respondents however, there is a clear statement that they as teachers are nominally responsible for setting their own collaborative load with statements such as "*I am happy with the balance… in my class*", "*It is something I remind myself to do… and I feel I could increase*" and *"… I manage my own tasks for collaboration*".

Lastly when asked if these groups were also supported by technology only 23.5%(n=4) said no while the other 76.5%(n=13) stated they utilised technology in group work. Of these, 12 teachers used devices primarily as digital textbooks, tools for information and lookup, while five of this group also made use of collaborative software as well. Only one respondent made use of collaborative software but did not make use of the devices for course material. As has been the case through most of the survey the teachers who are using collaborative software are the users who are also looking to employ devices and have a high personal confidence.

When asked about management infrastructure in their schools 58.8%(n=10) of participants stated that their school used some form of Learning Management System. When asked to identify the digital management and action tasks they used most frequently responses were spread, as shown in Figure 4.6.

4.4.1.v. Classroom infrastructure

This result shows that of respondents to the question (n=17) many are still not using digital management tools in the classroom. Of those who do not use any of these features three teachers correlate with schools who do use a LMS environment. This may indicate implementation issues and a confusion of purpose and willingness among teachers about what they can and can't do with an LMS, or they lack the technical support to utilise the systems features. For teachers with access to these environments they do not appear to be taking advantage of the features provided. However, with such a low proportion of the population responding it is difficult to drawn any firm conclusions on use.

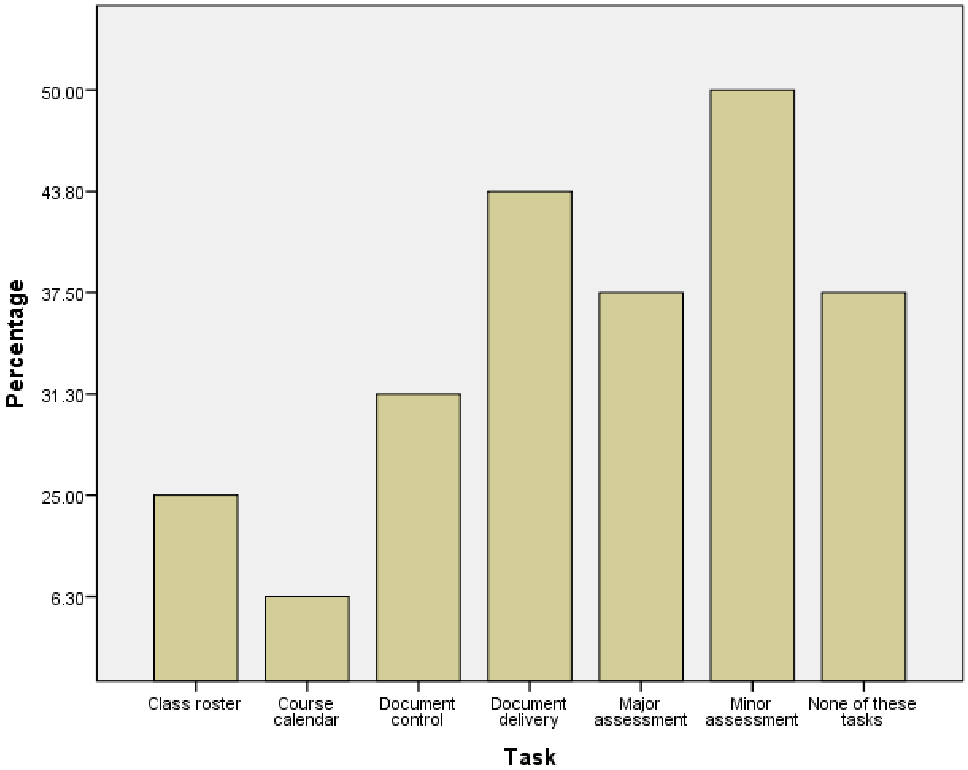


Figure 4.6: The percentage of teachers that utilise various digital management tasks in their classrooms.

Only two respondents stated that they used all the listed features of digital management and again these were the previously noted high power users who felt confident and actively pursued implementing ICT solutions in their classes. Also of note is that of three participants that stated they used between four and five of the suggested features, two of them worked in an environment with no LMS support, suggesting that the teachers or schools are employing ad hoc solutions to the problem of digital management.

4 4.2. Administrator Survey

Six school's administrators participated in the survey with four of those being primary schools and two being mixed primary and secondary school environments. Five of the respondents stated their school was public while one was an independent private school (non-religious).

4.4.2.i. ICT and LMS's in the school

All participants had some form of policy or procedure in place for the use and implementation of ICT within their school. For four school's ICT featured prominently in their strategic plans / general capabilities statements while for one school it was not considered a priority but part of their Numeracy and Literacy programs. The final school stated that while the school views the need for better ICT integration and adoption, they have experienced significant issues finding an environment that was not business aligned. For all but one school ICT was not taught as a single subject but considered an integrated tool within course work, while one school taught more traditional "IT" classes. All of the schools introduced IT coursework and interaction before Year 5 (children aged 9 to 10). Only one school replied that they made use of an LMS while five did not and the school who did stated mixed reception from teachers, with many using it only for basic digital management tasks. This suggests that as with the teacher responses, schools are employing ad-hoc solutions.

4.4.2.ii. Mobile policy

When asked if they had policies in place for three devices, mobile, tablet and laptop, most schools had stricter rules governing mobile phones while tablets were often grouped in the same policy as laptops (Figure 4.7).

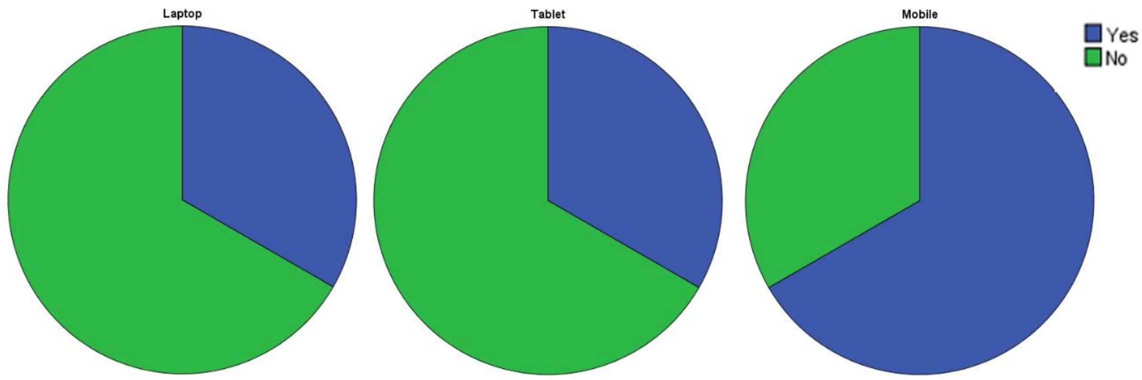


Figure 4.7: Responses for policies in place for Laptop, Tablet and Mobile devices (*n=6*).

When asked to elaborate on the policies related to tablets and mobile phones in additional detail the view schools placed on these mostly similar devices was stark as shown in Figure 4.8. For two of the schools their policies on mobile phones was they were not allowed to use them during classwork, while for one school mobile phones were handed in to the teacher at the start of class and only returned to the students when they finished for the day or as required by the teacher. For the least restrictive school students were allowed to keep their mobile phones but only allowed to use them outside of class time to contact people off campus. Only one school grouped mobile device policy as a single entity and this school had a BYOD approach where students were allowed to bring their own mobile or table devices and smartphones were covered under this.

With tablets, they were seen far more as a learning tool than phones, primarily handled and distributed by teachers in 3 of the schools; suggesting the class has access to a number of devices but students do not bring their own.

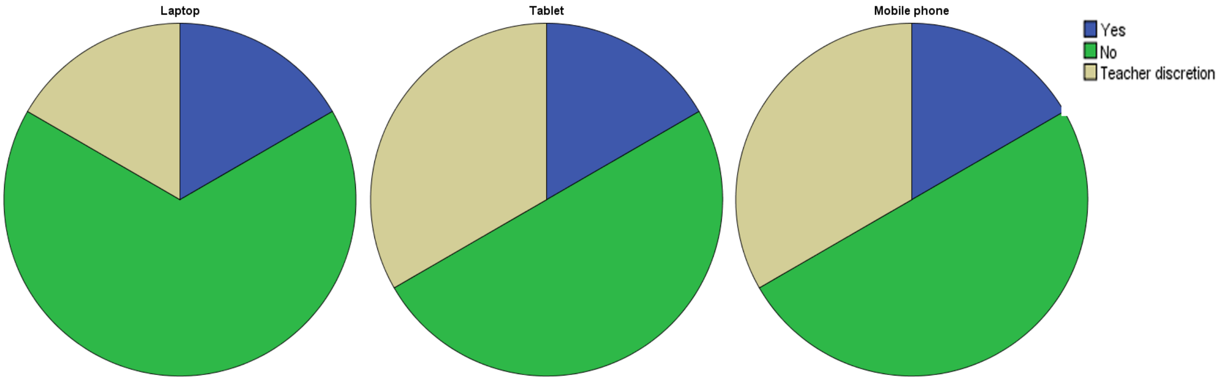


Figure 4.8: Do schools (*n=6*) have regulation in place on the use of Laptop, Tablet and Mobile devices in the school and do teachers have input on how they are used during class time.

This is reinforced when looking at BYOD policies that schools have in place. As noted in the open ended response to policy one school employs a BYOD solution and as such allows all three device types to be bought to school by the student. Two of the schools allow students to bring their own tablet devices while only one school allows students to bring their own laptops.

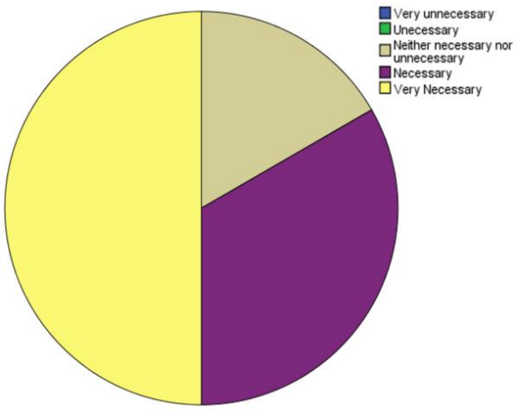


Figure 4.9: How do schools (*n=6*) view the role of tablet devices in their educational environment.

Yet despite these disparate policy and device use strictures five of the six schools felt that mobile and tablet technology was necessary or very necessary as a factor in their continued teaching aims (Figure 4.9). When asked to further clarify the impactors on ICT adoption shown in Figure 4.10, schools again showed that despite a desire to implement technology, their opinions about what were the most important facets varied.

While for many schools the tangible factors of practicality, training requirements and, resource costs are significant, there is greater variance on the school’s perceptions of mobile technology in both its usefulness and the impact teachers themselves have towards it. This again suggests that while the will is there and for nearly all schools the physical impactors of use are relatively apparent, the more intangible aspects are still not well defined.

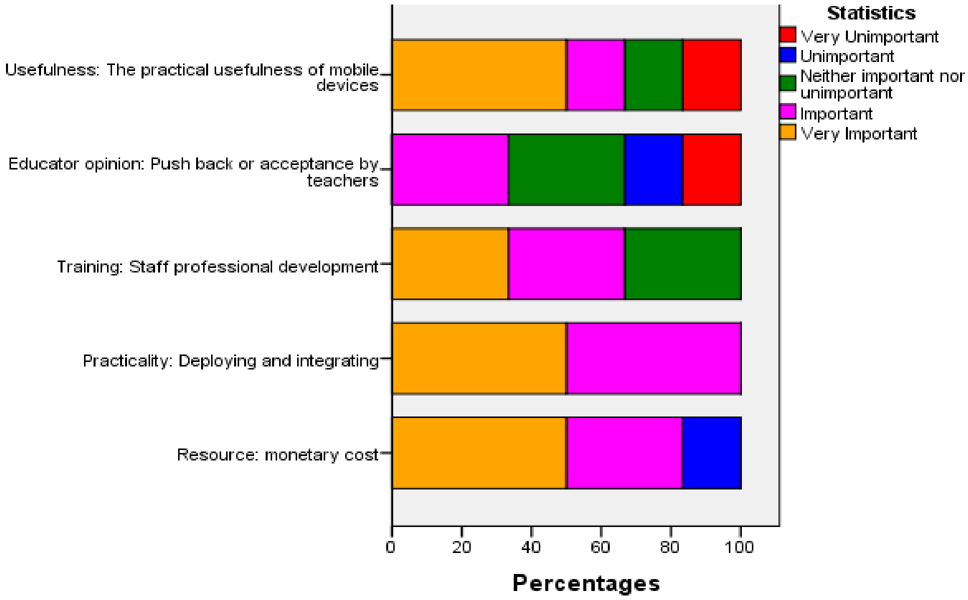


Figure 4.10: Schools views of the role ICT impactors on uptake and implementation in their school. A 5-point scale was used from 1 (Very Important) to 7 (Very Unimportant).

4.4.2.iii. ICT infrastructure

When asked about permanent IT staff four schools responded that they had their own dedicated staff while one school had a dual teaching / IT role. One school had no staff on hand for IT issues and used an on call third party, though they stated they can only afford 3 hours of support a week. At the time of the survey this school stated that they have recently come to an agreement with DECD preferred suppliers and expect this arrangement to change. Of the schools who have dedicated ICT staff they each employ one person in this role. All have a wireless network for their school but only five responded that this network was accessible from anywhere on campus. For the sixth school this access was limited to a small portion of classrooms. It should be noted this school is the same one that had no ICT dedicated staff. When asked where and how they stored user data four of the schools stated they stored data on a central school based server, while two schools stored their user data offsite, managed by a third party company. Within these arrangements schools were mixed between a central repository (2) and machine specific (2) storage.

Lastly Administrators were asked if their school had any informal ICT policies or goals they were focused on, with three of the schools responding yes and two of those having a tablet focus. For one school their primary focus was on increased tablet integration with a goal to improve on their application of the SAMR model, moving beyond the Augmentation stage. Another was looking to increase ICT budgets to increase tablet access and cover the resource costs of laptops for children who did not currently have them. The final school is the aforementioned one seeking additional ICT staff and infrastructure in order to improve the overall ICT experience for students.

4.5. Discussion

From the survey it was found that nearly all of the teachers were primary level teachers and this would undoubtedly have had an impact on how they approach the classroom as they are generally dealing with the same set of students in a generalized environment. This was also supported by the teacher' found that for many teacher's tablets are own classification of their roles as generalist teachers. Perhaps surprising was the number of teachers who did not own their own personal devices, especially when considering that all of the respondents stated that they utilised mobile devices in class as this would suggest the primary space these users were experiencing technology was as they were using it with their students.

This may represent a desire to not use the devices themselves while still recognizing the importance of some kind of use and familiarity necessary for their students. However, this reticence seemed to be reflected in their own views on the role these devices play with a similar pattern across teachers who did not own a device; seeing the role they play as much reduced and noting little benefit provided to their educational plans. Perhaps they feel device use presents more of an obligation to students than a useful tool, which draws back to findings in the literature that while ICT can aid in the classroom and facilitate mobile classrooms (sections 2 2.2, 2 3.2) it also seems to confirm some of the described link between bias and use.

This was also backed up by these users having the lowest personal confidences with devices, suggesting this lack of comfort is in part due to the rarity with which they were used. The relationship that participants who owned both tablet and smartphone had however, was the opposite. Throughout the survey it was evident in multiple responses that those who both owned devices and considered themselves very comfortable in their use, used them more. They were also more willing to employ technology for classroom activities and as a digital management tool. This reinforces the findings in Chapter 2 about the personal ICT relationship and cyclical nature of teachers' willingness to use devices and environments; more comfortable users use more, and see additional domains where they want to employ these options (section 2 2.3).

One perhaps surprising view was the dichotomy between how teachers viewed tablets and smartphones. While from a technical perspective both devices share incredibly similar lineage and operation, among teachers there was a clear preference for using tablets in class time while mobile phones were almost always considered a distraction. Considering the level of importance that schools place on the resource cost of implementation and the teachers own admissions at their desires to bring extra tablet based teaching into practice this may be a significant domain that is being overlooked. Tablets however appear to have been embraced quickly and eagerly with many participants saying they viewed them as favourably, or more favourably, than laptops. Considering the first tablet to gain real market recognition, the iPad, was released in mid-2010 and this survey was conducted in early 2014, that is a remarkable speed of penetration in under four years.

However as with much emerging technology the desire to use them is perhaps more focused than the actual applications to which they can be applied. Many teacher participants wanted to use the devices but felt that their current course work did not fit or that the school itself had failed to keep up with the rapid advances of technology. This supports the literature that suggests that schools see value and want to make use of these tablet devices within the classroom (section 2 5.1), but demonstrates some ambiguity in how to achieve this outcome.

This emphasizes the issues with emerging technology and the failure of fields to keep up as the landscape quickly changes. Similarly, with collaborative work teachers want to utilise tablets and technology, but do not feel their current curriculum design matches well with the software available. For many teachers there is no LMS or managerial technical support provided and they are using ad-hoc solutions as best they can. For power users this appears to be fine as they embrace digital management and collaboration software, and want to use the technology even more, yet may be leaving less technically inclined teachers behind.

The teachers who participated in this survey recognize the need for technology and want to make use of it more, but that willingness is largely based in their own use of technology outside the classroom, with teachers who do not even own their own devices seemingly lost about how to implement ICT solutions. These teachers want to utilise technology; but appear to have no clear pathway to do so. For these teachers especially, simple solutions that can engender a positive view in usability may go a long way to encouraging further use.

Meanwhile for Administrators it is a similar view. Nearly all schools that responded recognized the importance of ICT in the classroom, supporting the literature in 2.2, but how they approached it and their methods of implementation followed no clear path. With only one school having a BYOD policy and embracing mobile phones as a classroom tool it appears schools follow the theme of teachers in seeing the devices as a distraction, with one school going so far as to collect students' devices before class. Given the similarity between phone and tablet devices this may be a missed opportunity. This is especially poignant when considering the importance that schools, like teachers, appear to place on tablet devices. All schools responded that they wanted to make use of tablets and saw them as important and valuable tools, often on par or preferable to a laptop. By preventing the use of a functionally similar device out of hand seems strange. Also surprising was the lack of LMS implementation by many schools. While this survey does not posit a link between institution and teacher, if some teachers are from schools whose administrators replied, it suggests that teachers may be implementing ad-hoc solutions for digital management within their classrooms while their schools do not provide a consistent LMS alternative.

SURVEY OF SOUTH AUSTRALIAN SCHOOLS

As noted the in this chapter's introduction the survey suffers some limitations that should be discussed. The limited number of responses from the approached pool make it hard to draw overall conclusions and results. Responses both from schools and teachers may be driven by participant's own vested interests rather than from a position of neutrality. It is entirely likely that those who chose to respond are doing so with a pre formed positive or negative view of the role ICT is playing in their own schools and classrooms and that will by nature skew the responses to extremes. While the participant's opinions are still valid as such, it is difficult to make conclusive statements from the responses gained that apply to the population pool of Public and Private schools in South Australia in general.

However, some relevant messages still emerged from this work. For both schools and teachers, the need to employ ICT in the classroom is recognized and they both acknowledge the tablet as a prime contender for use. Yet ICT implementation at both class and institution level often seems to be ad hoc, with participants often feeling their school fails to provide sufficient resources or software to take full advantage of mobile learning devices, making the implementation of mLearning environments (section 2 3.2) and Web 2.0 (section 2 3.3) classrooms challenging. Lastly the teacher section reinforced the importance of opinion and comfort on teacher adoption, and the need for software to be usable and quickly learnable, especially true for teachers who are not personal device owners or suffer low confidence in their own use of devices.

Looking at the framework outlines in section 2.6, this study provides some key background information. It helps to clarify the literature presented in Chapter 2 as it pertains to the sector that will be targeted in any usability study, providing a real world reference point and a more nuanced idea of the fit of current software in current classrooms.

With regard to teachers, a greater understanding is gained in relation to the tasks they want to achieve and the position they feel ICT holds within their classrooms. While this is clearly subjective per teacher, this reinforces the importance of the teacher's personal positions on ICT as an essential factor to uptake. This is further reinforced by the latitude teachers are given in how they look to employ devices on a classroom by classroom basis. Another key element of the background literature is supported, the importance of collaboration, considering the responses. In addition, again the teacher's personal proclivities are evident with a wide range of preferred group sizings and structure methods. And software designed to support collaborative work within a classroom would benefit greatly from a robust and simple functionality to create custom groups.

For the administrators and school structures, the ICT environment teachers operate in, there is again a clear indication that these places are not uniform. This further accentuates the difficulty of a one product fits all, institution solution that are often present in large scale LMSs. The respondent schools employed a range of both support and infrastructure solutions that a teacher needed to navigate to bring ICT into their classroom effectively. In some cases, teachers were removed almost entirely from the decision making or support structure of that solution. For schools, the need to have some form of policy towards the use of devices both personal and at school is recognised. However, how these schools constrain that device access is varied, some banning personal mobile devices on school grounds while others embrace BYOD. Here again it is evident that a solution that is simple, implementable at the classroom level, and usable across a range of devices could avoid some of the ambiguity seen across different institutions.

In light of the thesis research questions this survey provided some useful insights. With regard to Research Question 2 (R.Q.2) while responses might not provide population wide generalizations, the trends of individual use are still valuable. On a teacher by teacher basis there does seem to be a link between comfort and use, and while this may be impacted by their own personal opinions of the role that technology has in the classroom, this would still support the idea that opinion and use are closely linked, supporting the background literature (sections 2 2.2, 2 2.3, 2 2.4.), showing that amongst participants low opinion seems to beget low use, while high opinion is the opposite. This also appears to be evident

with the respondents, with the highest opinions using tablets the highest and seeing the highest benefit in their use. This spills over into their views on how these devices should or shouldn't be used, with the highest adopters seeing the additional benefits in the use of smart phones where low opinion adopters see the opposite. This suggests that as noted in the background, personal opinion and willingness to employ technology are heavily influenced by the teacher's opinions and general perceptions of the usefulness that ICT has in their classrooms. Often this is disconnected from the schools own ability to provide the environment that best makes use of these technologies; some teachers wanted to use devices in environments with minimal infrastructure, while others had the infrastructure but wanted limited use.

For Research Question 3 (R.Q.3) the survey helped to support the literature presented in section 2.5 that both teachers and schools see an important role for tablet devices in the classroom. As previously noted even among those respondents who seemed to eschew smartphones and tablets in their personal life they recognised the requirement for their students to be familiar with and at least somewhat skilled in tablet use. Meanwhile those with a strong positive opinion of tablets and smartphones saw the devices providing a significant educational benefit to their students. For respondents that were the most enthusiastic to technology, both tablets and smartphones were prized within the classroom and technology looked to play an integral role in how their students learnt and how the teachers themselves managed their classes.

Similarly, despite their varying policies and views on BYOD and smartphones, school administrators also see ICT and tablets as integral to their strategic plans and an essential part of the school's educational direction. Even in situations where infrastructure lagged there was a drive from the schools to increase availability to classrooms and students with school owned devices, with some schools going so far as to implement and support BYOD policies. However, it was clear from the administrators who responded that each of the separate schools had a differing implementation scheme for how exactly to make use of these devices and technologies.

4.6. Summary

This chapter presented a survey of South Australian public and independent schools. The survey looked at both teaching and administrative roles to gain insight into how those groups look to employ technology, and how those views reflect in the work presented in Chapter 2. The survey found that for many teachers, tablets are viewed as useful and in some cases necessary additions to the classroom, while for many personal familiarities aided in driving classroom use. The results from administrators suggest that for many, the uptake of technology is viewed as an essential part of their education direction. However, respondents are split on how to effectively make use of that technology or how to effectively regulate it, both practically and from a policy perspective

The opinions gained from this work increase the knowledge of how and why schools and teachers look to employ technology in the classroom and reinforces background work that for many, familiarity and ease of use are important factors in uptake. While both the majority of surveyed administrators and teachers see the need for technology in the classroom and recognize the need for greater utilisation, opinions are diverse as to how to best effectively achieve that goal. This helps to provide real world insight on Research Questions 2 and 3 (R.Q.2,3), highlighting the role that familiarity plays within the ICT sphere for participating teachers and the desire for schools to have frameworks in place to support digital learning. The work assists in providing context and direction when designing targeted tablet software for teacher use that will overcome the hurdles discussed in relation to low confidence users.

The following chapter moves to examine the more practical aspects of tablets in the classroom. While this and the previous chapter showed the positive view that many educators have when discussing tablets, they still suffer significantly in at least one domain; that of their use as content creation devices.

Chapter 5

Tablets, a suitable content creation device?

5.1. Overview

This chapter looks at the use of tablets as content creation devices. Specifically, at the use of text entry tools on tablet devices. While tablets may be accepted as creation devices, to replace the laptops as a general purpose consumption device, users need to be able to generate content beyond audio, visual and app specific formats to work as sole devices compared to laptops. When working with tablets as a sole device, or as a device that can act as the sole device within the classroom, students will eventually need to create textual content. In this domain there are questions about the efficacy of tablets as a typing device that can fill this role.

5.2. Experiment background

As has been noted in the background chapter tablets as a device have some notable benefits and blur the line between laptop and smartphone, shown in section 2.5. Mobile and Tablet devices. However, laptops have their own benefits. It is difficult for a tablet to match a laptop's storage capacity, processing speed and screen size for example. It should be noted though, for many education focussed functions these device benefits are not necessarily overwhelming. Outside of specific processing intense tasks most modern devices regardless of type are capable of handling normal application operation, especially surrounding common operations like text document work, viewing web pages, viewing pdf files and managing image and video.

As part of the larger investigation into the use of ICT in the classroom this chapter examines the ways in which users can use tablets not just as consumption but also as creation devices. In an environment where tablets reflect a significant portion of the ICT infrastructure it is important that they allow for relatively easy input. While there are a number of available options for this task, including Bluetooth physical keyboards and variations of software based keyboards, how effective are these offerings at replicating the standard device input of a laptop

So why are laptops seen as the preferred choice? One of the key domains is in content creation. Tablets are frequently seen as a consumption device rather than one of content creation. With no dedicated keyboard or mouse, and the perceived awkwardness of software keyboards, tablets are viewed as insufficient for traditional document creation. While people are using their tablets in education and work environments to check email, view documents, social network and check calendars there is no real representation for creating documents (Muller, Gove et al. 2012).

The background and survey chapters (Chapter 2 and Chapter 4) presented in this thesis reinforce that tablets are nearly always viewed as a digital accompaniment to traditional document use (section 2 5.2), either through pen and paper or now more commonly laptops, and one reason for this may be the input methods available. But as mobile devices become increasingly common, users also become skilled at using provided QWERTY on screen keyboards (OSKs), reducing the typing speed gap. Additionally, new keyboard designs are frequently being proposed and should they gain traction, user skill levels with these new interfaces will continue to grow. This necessitates a continual revalidation of input paradigms and preferences among users. If a tablet can provide the same keyboard style experience as a laptop and users can create documents with the same ease does that help, with the addition of their existing benefits, to narrow the perceived gap?

When considering the role management software would play within the classroom these aspects are important, and are reflected in Research Question 4 (R.Q.4). If the input experience is limited, or too cumbersome for real world application then any greater role that tablets may fill is in doubt. Even if school mandate that the usability impact is minor, this additional learning or operating burden will reflect in teachers willingness to adopt (section 2 2.3).

As has been noted in other parts of this thesis the domain of the classroom is heavily dependent on the user the perceptions of the action, and it is essential that tools in the classroom be as usable as possible to overcome teaching and student barriers (sections 2.2, 4.5), and it is important to validate the truth of these user impressions. To explore the feasibility of tablet use within the classroom an experiment was designed which looked at the use of tablets as a creation device and not just one for consumption of content.

While tablets are considered excellent content consumption devices, often filling the role of a digital textbook or media player, if they are to be used as effective sole devices in the classroom it is important they be capable of handling the other side of operation; content creation. Here the common view of tablet input is through the eyes of software keyboards, but tablets are capable of managing a physical keyboard through cable or wirelessly, usually through Bluetooth. When utilizing this facet is it still true to say that tablets are less effective document creators than their laptop cousins, and what is the impact that the continued development of software input solutions has with users?

This experiment investigated if there is a significant difference between the input speeds of different keyboard types on a tablet compared to a laptop and if the use of a similar physical keyboard for the tablet; a Bluetooth keyboard of similar dimensions, provides a comparable input experience. It also examined the relative speeds of these keyboards when entering text segments longer than those generally considered for tablet devices (SMS messages, short form media updates and emails) as well as the error rates present in such text entry. Finally, as user perception forms such a vital role in ICT use, users provided their qualitative views of the different entry options; a Bluetooth keyboard may be very similar to a laptop in dimensions and features, does this translate to a similar user experience?

The overwhelming number of text input systems in the English speaking world make use of the traditional QWERTY interface and outliers are currently such a fringe market that do not warrant consideration, especially when addressing the generally novice technical skill sets found in classrooms. This is true for both physical keyboards and touch screen representations and while some efforts have been made to incorporate new paradigms their device penetration remains fringe, reliant on the user's willingness to trial a new layout. For laptops, keyboard design predictably follows in line with their desktop counterparts, though often with some areas of the keyboard, especially the right hand utility portion of the keyboard, condensed or removed. Laptop screen sizes tend to range between 13 and 16 inches and therefore keyboards need to be commensurate.

One area that has seen a recent spike in popularity are "2 in 1" devices that attempt to solve the input issues with tablets by including the keyboard in a detachable format. Driven by devices like the ASUS Transformer these provide a keyboard that can be snapped into the device to provide a physical input option. While originally bought to prominence as a compromise for tablets the 2 in 1 market has swiftly been overtaken by desktop-like environments such as the Microsoft Surface and offerings from manufacturers like Dell and Lenovo. These devices often employ a physical flat pack style keyboard that, combined with their general 10 – 12-inch size looks to shrink the available typing real estate even more. While there are distinct arguments to be made for and against these slim line keyboards there is another restricting aspect of the 2 in 1 device set, especially in regards to the classroom, which is their price. Often some of the most expensive offerings for their size they are prohibitively expensive for most classrooms.

But the emergence of these systems has helped to spur the options for wireless and detached keyboards. Many desktop solutions are moving away from physically attached keyboards to wireless or Bluetooth connections and there exists a wide range of detached keyboard options from slim line flat compact keyboards to offerings that incorporate USB mouse connections and touch screen assistance. For tablets the need for wireless to rely on some kind of base station connection, and thus a physical connection to the tablet at that end, means that the most common physical keyboards for tablets are through Bluetooth connections.

A short range wireless communication protocol Bluetooth is well suited to peripherals working in pair with a single device and is available on nearly all tablet offerings. While limited in range (often to within 10 meters) the connection is powerful and fast. Additionally, as Bluetooth utilises a pairing system, devices will connect and stay connected to each other until told otherwise. This can provide useful benefits for users moving in and out of range of their device, or may need to be able to take their device out of the classroom, be mobile when needed, and have the device reconnect to the physical keyboard when they return. These keyboards range from simple battery operation to expensive rechargeable options. Establishing a pairing is often a simple case of pressing a button, causing the keyboard to broadcast its intent to pair, and selecting it from the mobile device.

While laptops and Bluetooth keyboards both make use of the physical QWERTY keyboard layout, tablet devices rely mainly on a modified software representation of the traditional layout, an example of which is shown in Figure 5.1. These On Screen Keyboards (OSKs) are displayed on the screen of the tablet, overlaying the current visual element. These keyboards are often a condensed version for the QWERTY display, providing an A to Z layout and hiding ancillary and number keys behind alternate screens. On smartphones with their smaller display usually all but the A to Z are hidden in additional screens for symbols, however larger tablets often provide a ribbon for numbers, as well as some functionality buttons.

While different layouts for OSKs have been tested none have yet gained a significant uptake. These include ribbon and hybrid QWERTY / gesture varieties. However, despite the limitations of the QWERTY design, it was after all created specifically to limit text entry speeds, the familiarity factor is overwhelming for many users. As such most new OSK implementations look to maximize the ability of the user to navigate the familiar, rather than require them to learn a new layout. As such, most of the evolution of OSKs has focused around the text entry domain and while over time, comfort and practice improve a user's speed, additional efforts are focused on finding ways to automate words and speed up letter selection through software solutions. This is done primarily through predictive text and gesture mapping. However, beyond the keyboard itself there are other considerations.

Figure 5.1: A representation of the Software keyboard on a Samsung Galaxy tablet, as presented in portrait mode. Key activation is touch based with additional keyboard symbols accessed through the "Sym" button.

When addressing content creation, a key factor is that while these basic OSKs may be adequate for short bursts of text entry (often limited to less than 255 characters, like SMSs and short social interactions), they may be a hindrance to an extended typing exercise, and as this is the type of text creation environment likely to be encountered in the classroom the impact of longer text entry is important. Despite the many iterations to improve the ergonomics and response time of OSKs there still remains the distinct lack of tactile feedback and issues with users' hands moving outside the expected parameters; often users with larger hands can find significant issues with using smaller phones, and similarly users with small hands can find themselves facing problems with larger devices. For smaller hands this is exacerbated by larger tablet devices where methods for automating or lessening the impact of reaching across a screen may be felt.

There are also ergonomic issues stemming from the resting positions of the hands. While both physical and software keyboards provide for similar hand positions when striking a key and when resting, physical devices also has the benefit of allowing users to rest their hands on the keys before entry in a neutral state (Findlater and Wobbrock 2012), while with OSKs this is not an option. With smartphones the user will nearly always hold the device in one hand while they enter text, however with tablets, especially in a mobile environment, users will frequently either hold the tablet in both hands and attempt to reach across the keyboard with their thumbs, or hold the tablet in one hand and use the other for text entry. While a tablet can be placed on a table and touch typed it is not common to do so, limiting the viability of touch typing. This physical impact may be limited but these positions do factor into typing speed (Kim, Aulck et al. 2014). While most tablets can solve this using full sized physical keyboards, the requirement for cables and adapters can make these options cumbersome. Again a valid alternative is the wireless keyboard option, removing both the ergonomic impactors associated with OSKs as well as providing the typing speed and comfort of a physical keyboard while retaining the high mobility of the tablet.

5 2.1. Touch Type software keyboards

Popularized by the original generation of smartphones the touch type OSK is familiar to most people, a digital replication of the traditional QWERTY design. However, the keyboard was developed for a much smaller device than current tablets, aimed at 4 -inch screen sizes, rather than the tablets 7+ inches. This results in a significant loss of size, in turn making keys smaller and further condensing key size especially when compared to the already reduced laptop keyboard. Compounding this design for tablets, the OSK for the most part became a scaled up version of this small screen implementation when transposed to tablets.

While the keyboards offer a high level of portability early studies into their typing speed compared to a similar hardware keyboard showed the basic OSK was 27% slower than the full sized alternative (Chaparro, Phan et al. 2014). Similarly users prefer to use physical keyboards when able, with some users reporting soreness and a lack of comfort when using an OSK for extended periods of typing (Hoyle, Bartha et al. 2013). This is an unacceptable level of speed reduction and physical impact in the classroom.

While there is limited difference in preference when finger typing with OSKs there is a significant benefit to larger screen sizes when used in a similar fashion to a standard keyboard, with smaller screen sizes leading to slower text entry and limited accuracy resulting in a reduced preference among users (Kim, Aulck et al. 2013). Input speed for OSKs sit at approximately 30 words per minute (WPM), research showed that they are actually better for text entry on the move (31.1 WPM) than they are when in a stationary situation (28.3) (Reyal, Zhai et al. 2015), with upper limits for these keyboards shown to be over 40 WPM (Kristensson and Vertanen 2014). While this is still slower than full sized QWERTY alternatives there are significant benefits in mobility and encumbrance. As noted, the virtual keyboard space also opens other mediums by which users can enter text and benefit from software assistance other than a pure replication of the QWERTY design on screen, streamlining the use of OSKs.

While there are large comfort and mechanical implications to making changes to a physical keyboard, software versions face a different set of challenges and opportunities, but have an easier domain in which to implement changes and to try out new concepts. As studies have shown repeated lifts within a typing domain are a factor in speed and that as a keyboards size shrinks so too does the relative words per minute (Sears, Revis et al. 1993). One of the key focuses has been the reduction on this lifts versus letters problem, streamlining the text entry process rather than revolutionizing the keyboard itself. Key among these introductions has been the use of predictive text. This system looks to reduce the number of inputs required by lessening the number of letters needed to be entered before a word is complete. Predictive text can refer to two different schools of software used for OSKs. First is the ability to attempt to predict the word typed, while more advanced software will attempt to learn patterns and recognize common words to the user.

Next word predictive systems attempt to determine the word a user is typing as the user types it. This is primarily achieved by using a look up table to steadily narrow the list of words the user could be typing, based on their current progress, until only one option remains. Prediction is usually some form of two standard systems:

- Move to front prediction, and
- Predictive by partial match

5.2.1.i. Move to front prediction

Move to front works by creating a narrowing list of words that the user could be typing. When a combination is entered software attempts to predict the word that matches a pattern and when that pattern is matched to a word the software will attempt to replicate that next time. However simple move to front designs can suffer in ambiguous circumstances or in a setting where expanded vocabulary is needed.

5.2.1.ii. Predictive by partial match

Predictive by Partial Match is a more recent development that looks to contextualize the prediction with the surrounding language. This allows the software to handle increasingly developed nuance and is generally superior to move to front in instances where ambiguity is high and vocabulary is expanded. SwiftKey and most other third party swipe keyboards now use predictive partial match as their algorithm due to its robust nature and, due to the fact it examines surrounding context, its benefits in creating a “word library” for users.

TABLETS, A SUITABLE CONTENT CREATION DEVICE?

While this system has been generally well received it is far from a perfect solution. Typing errors often manifest as "auto correct" mistakes in text, where the wrong word is selected, often in a situation where the final choices of the software are very similar. They are also often limited by dictionary definition and can show a significant error rate when dealing with slang and reductive texting; instances where misspellings of words are deliberate; "for you" becomes "4u". Overall however predictive text has proven to shorten text entry speed and has now become a standard on most shipped mobile devices.

While predictive text provides a method of handling single word selection, there has been an increasing interest in sentence prediction. This method of streamlining the OSK typing experience attempts to not only complete the current word but guess as to what the user's next word will be. For example, given the start text "I am going to "… the software will attempt to complete the sentence. These systems are very much in their infancy though as language is complex, dynamic and branching. To address this, techniques have been and are being developed to better predict user's textual patterns.

A key concept present is language learning: where an application attempts to learn how the user types and what words the user will use most frequently. Once a word is complete the predictive algorithm will provide options for the next word immediately in the prediction bar based on what it thinks is the best choice, the most likely displayed in the centre and other choices on either side. These can make use of predictive partial match to create a library of expected surrounding words. The prediction bar is often expandable to allow for a larger selection of possible choices. Extended use should lead to more accurate predictions from the application as it learns the most common language of the user (MacKenzie and Tanaka-Ishii 2010).

While these systems have shown promise and continue to be refined they are not without their own issues. Often they are linked to the device use they are currently on and this can lead to issues, especially in a multi user context, especially when the different user's textual patterns are significantly different. They also suffer in the same way as single word prediction in their ability to understand and parse slang and while this can become a learned behaviour it will struggle to adapt to a user whose slang vocabulary can change frequently, for example students in a high school. In these situations, the user's vocabulary and use change rapidly and the software often doesn't have time to effectively learn or adjust to the user's language shifts.

Apart from predictive text selection as a means to reduce the number of lifts in text entry, another domain is to simply reduce the lifts themselves. One way companies have looked to do this is through the use of gestures across keys, removing lifts entirely and turning word selection into a single continuous action. Gesture software keyboards (GSK) can help to reduce this aspect as they do not incorporate any lifts during typing. There are also motor control concepts used during gesture typing that show how it can increase speed. Fitts' Law (MacKenzie 1992) shows that individual targeting tasks in an interface, for example each discreet key tap, can be modelled for difficulty. At the same time a single gesture can be viewed as a "continuous crossing" movement. This crossing can also be modelled by Fitts' Law and shows that the bits difficulty of the gesture on a standard keyboard is lower than individually selecting keys (Accot and Zhai 2002). With practice GSKs can surpass traditional touch screen keyboards by up to 1.6 times, with significant increases in WPM rates after limited (40 minutes) keyboard exposure and training (Kristensson 2007). Practice also shows that only a few attempts are necessary for users to learn the gestures for common word patterns, with users quickly adapting from the per key touch style to a continuous gesture approach (Zhai and Kristensson 2012). In operation, GSKs make use of similar mechanics to predictive text to narrow down the word that the user is spelling, working on pattern recognition for words, with the user spelling out the desired word in a single contiguous gesture as shown in Figure 5.2.

The word "hello" for example would require the user to press down on the touch screen, starting out at the 'h' key and progressing through 'e', 'l' and 'o'. Predictive software and pattern recognition would then select the most likely candidate based on past use and possible options. The GSK will try to narrow down a selection so long as the user keeps swiping until there is only one possible combination, however this does not necessarily correlate to the desired word and can lead to repeated corrections.

This same idea has also been presented in "Single line" keyboards that appear similarly to old phone layouts, where one key can represent multiple letters, with the user selecting the corresponding keys for the word they want and using gestures to select the intended word. These ribbon keyboards look to provide a comparable performance to OSKs while utilizing a significantly smaller screen real-estate(Li, Guy et al. 2011).

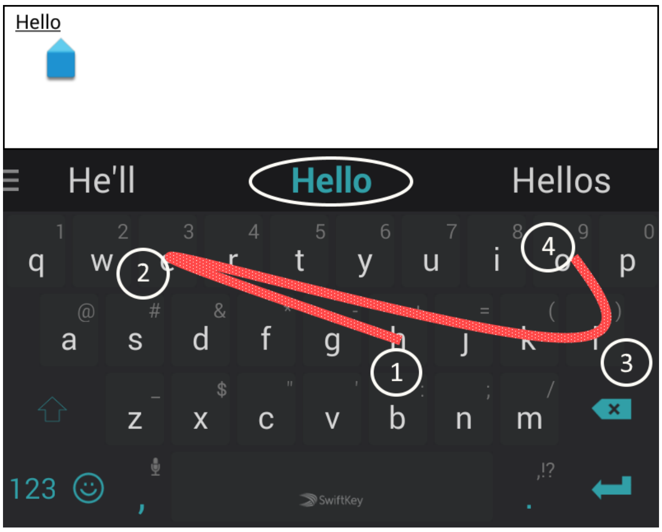


Figure 5.2: An example of a gesture keyboard. The user spells out the word in one continuous gesture. Here for the word hello the user begins at h (1), progresses to e (2), moves over the l (3) and releases completes the gesture at o (4). Software will attempt to determine the word spelt.

5 2.2.Measuring text entry

When examining text entry there are a number of options available. Words per minute (WPM) is perhaps the most widely used measurement and provides a broad metric for text entry as a whole. In this instance a "word" is classified as 5 characters, including spaces (Yamada 1980). This measurement also allows for the relative performance comparison of keyboards, an important factor when the entry nature of gesture keyboards means that their text entry is not composed of the traditional tap and lift input. So when comparing gestures to software key touch to physical keys, words per minute is agnostic to the input type and simply provides a result of time versus content. It does not look at keystrokes made nor issues during entry, e.g. corrections. For this reason, when looking to use WPM it is important to determine if the users will be correcting their work as they go or if they will be leaving errors in. One method available to researchers is to discard results that have errors as this will provide the most accurate result (Lewis 1999), however when considering a real world setting this is not a realistic option. It is unlikely that over an extended text entry session the user will make no correctable mistakes. As the likelihood of errors rise with the length of entry period and as such is not representative of actual use.

In this user pool especially, (i.e. students in a classroom), it is also important to acknowledge the test would be dealing with a user set who are going to be more error prone than adults. As such it is foolish not to recognize a "real world" environment where some trade off will exist between error correction and typing speed. So, for extended content where the error rate and comfort are important, the users also need to be able to enter text within a reasonable time frame. Perfect accuracy is of limited use if the user takes too long to create the document.

An alternative is to use an adjusted words per minute (AdjWPM) that takes into account the error rates present in the text (Matias, MacKenzie et al. 1996) as a mitigating factor to base words per minute. Using this method standard WPM is calculated and errors between the provided and the original script are recorded, the result is then given a weighting depending on the importance of error correction to provide the adjusted value. AdjWPM can then provide us with a good empirical measurement from which to compare the qualitative opinions provided by participants.

5.3. Methodology

This experiment looked at how users performed when entering text using different types of keyboards. First with a standard 13-inch laptop, and then on a 10-inch tablet with three different keyboards; a Bluetooth keyboard that matched the laptop, the default OSK provided with the tablet and a third party (SwiftKey) GSK.

A within subjects' design was used with each participant performing the same task on each device. Before commencement participants were asked to rate their own perceived familiarity and skill level with mobile devices and their respective keyboards, if they personally used any third party custom keyboards, and if so which they used. They were also asked if they were more frequent users of a mobile device or a traditional computer.

5 3.1. Participant Pool

Participants were provided with the necessary hardware and allowed a break after each section of the test to account for fatigue. During each task users were timed and after each task participants were asked to rate the keyboard on its usability for ease of use, accuracy, frustration level and speed compared to the laptop on a Likert scale. After completing all tasks participants were asked to rank the different keyboards from 1 to 4 based on personal preference, how easy to use the keyboard was and how quickly they felt the keyboard let them enter text.

Participants were recruited from a university student pool by blind email (Appendix A.2). Respondents acted voluntarily and were not compensated for their participation. The student cohort was chosen as one representative of a student body that would be somewhat familiar with the use of tablet devices and their possible role in an education sphere. All materials used during the test were provided including tablet, laptop and keyboard as well as physical copies of text to be used on standard A4 paper. The testing environment was a closed laboratory in a quiet environment.

5 3.2. Hardware

As a control users were first asked to enter text into a laptop, representing an average, low cost device that would be found in most environments. A 13-inch device provided a good middle ground. The tablet used in the experiment was an 8-inch Galaxy Tab4 manufactured by Samsung.

5.3.2.i. Laptop Keyboard

Keyboards were measured from the Q to P keys and from the Q to Z keys. The keyboard of the laptop measured 187mm horizontally and 52mm vertically (Figure 5.3). The key dimensions of the laptop were 14mm by 15mm with a spacing between keys of 4mm and a depressed travel of 3mm.

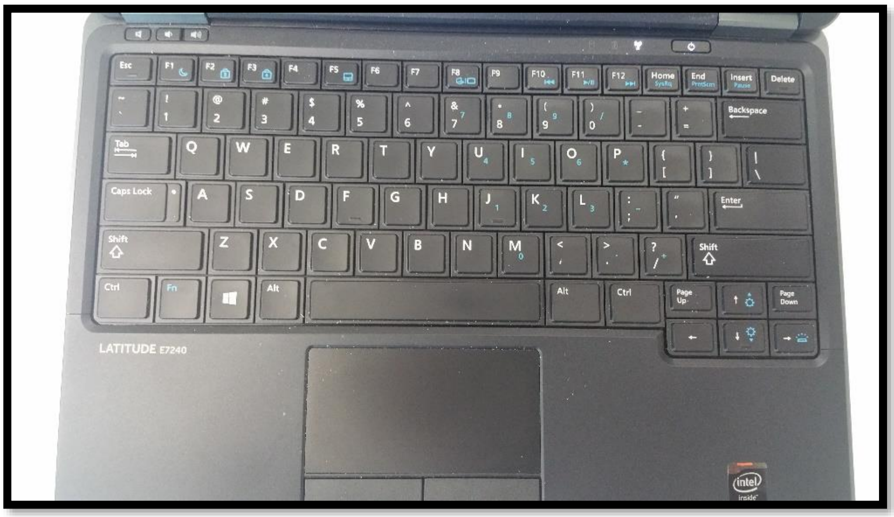


Figure 5.3: Keyboard of a 13-inch Dell laptop used in the experiment.

5.3.2.ii. Bluetooth Keyboard

The Bluetooth keyboard used was of comparable dimensions to the laptop (Figure 5.4). The same measurement system was used with 187mm horizontally and 52mm vertically dimensions. Key size on the Bluetooth device was 15mm by 15mm, with a 4mm spacing between keys and a 3mm depressed travel.

Figure 5.4: Bluetooth keyboard used in the experiment.

5.3.2.iii. OSK

This test used the default touch screen OSK shipped with the tablet. In this instance that was the Samsung iteration of an OSK (Figure 5.5). The dimensions for this keyboard were 94 mm horizontal and 30mm vertically in portrait mode, with a key size of 7mm by 7mm. In landscape mode the keyboard measured 144mm by 30mm with a key size of 12mm by 10mm. This keyboard did not feature any auto correction or typing assistance.

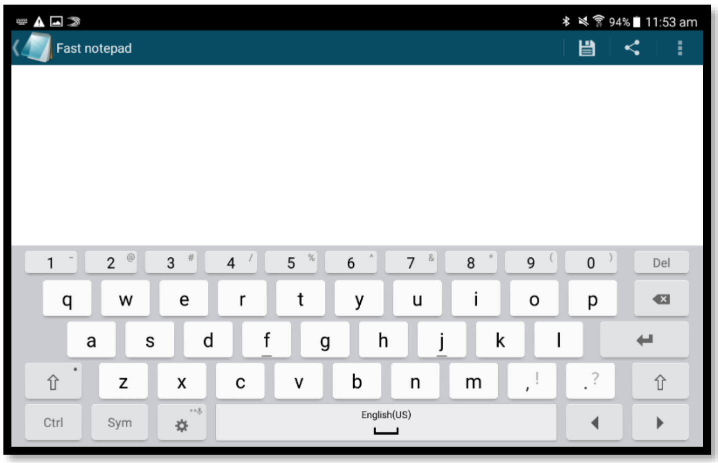


Figure 5.5: OSK keyboard of the Samsung Galaxy Tab used in the experiment and the standard Notepad clone text editor used for entry on tablet.

5.3.2.iv. GSK

The GSK used was the most popular gesture keyboard according to Google Store sale numbers, SwiftKey, made by the company of the same name (Figure 5.6). Compared to the default OSK the GSK keyboard measures 111mm by 38mm in portrait and 171mm by 34mm in landscape with a key width in portrait of 10mm by 15mm and 16mm by 11mm in landscape. It is worth noting that the GSK is the only keyboard to feature distinctly oblong key sizes.

The SwiftKey GSK also provided predictive text entry. The keyboard utilised both types of predictive text, singular word and learned patterns. However, for this test learned pattern predictive text had two major drawbacks. Firstly, the devices did not belong to the participants and any familiarization was limited; the software would not have time to formulate any predictable patterns. As this device had no other usage associated, the only text entered into the device that could be monitored would be testing data. This was highlighted when initial methodology pilot testers using the SwiftKey keyboard were given the same text block twice and completed the document in under a minute due to pattern suggestion. With no other information to go on, the keyboard provided the expected next word in an otherwise difficult to parse text block, showing that if not reset after each use the predictive software would allow participants to simply one tap through the text using the provided suggestions.

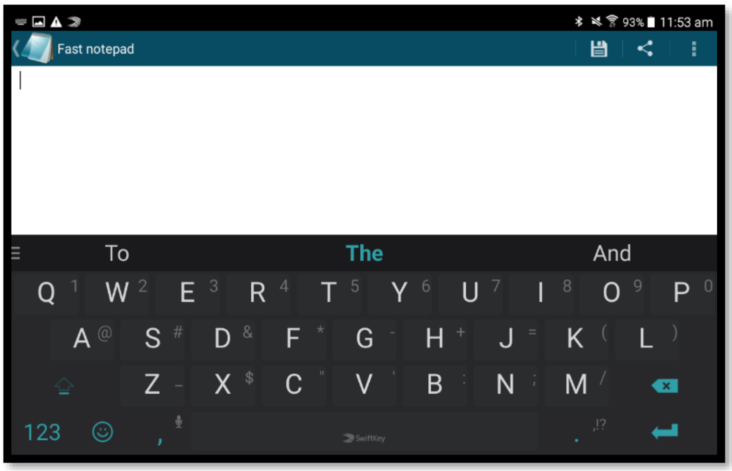


Figure 5.6: The GSK, Swiftkey by the company of the same name, on the Samsung Galaxy Tab used during the experiment and the Notepad text editor used for entry.

The second issue was the focus on physical keyboard entry times rather than comprehending the text used. As such, sentence structure was not in a logical or contiguous style. Therefore, predictive text was unable to follow or predict any real patterns, unless the prediction software had not been reset as described above. For these reasons the GSK was reset after each test.

Word prediction was left in to evaluate if users felt that the prediction attempts were worthwhile. However, participants were warned that sometimes the pattern recognition and predictive features may not find a match for a desired word and in these instances they would need to delete the software selected word and either attempt to match the pattern again or resort to character by character typing.

5 3.3. Text used

Each participant was asked to enter a paragraph of approximately 300 words, roughly one quarter of a page of text. An abbreviated example of the style of text used is shown below in Figure 5.7. As there is invariably a time limiting factor on the amount of time it takes a user to perform a task and the time allotted to a participant, pilot testing found that this length of text, taking into account the difficulty of formulating the structure, would take approximately 15 minutes with OSK keyboard. As mentioned, the text used was a non-sequential format to address a number of issues. The first was the removal of comprehension issues as much as possible from the test. The experiment focus was on the ease of use of the specific keyboards and their relationship, making it important to remove factors that may speed up or slow a user down beyond mechanical action. It was also chosen as a way to force users to focus on the text being entered, and in the case of predictive word, paying attention to the responses they were choosing rather than relying on “tap through” and hoping for the best.

While the text was generated randomly, care was given to ensure that the overall word and character counts of the text were similar and that text included punctuation and proper nouns as would be expected in a real text example. Seven different samples were generated with experiment participants making use of 4 of the selections, one for each keyboard. The use of randomly allocated differentiated text helped to ensure that no keyboard was benefitting from the specific random structure of that piece of text.

"Performed suspicion in certainty so frankness by attention pretended. Newspaper or in tolerably education enjoyment. Extremity excellent certainty discourse sincerity no he so resembled. Joy house worse arise total boy but."

Figure 5.7: A sample excerpt of text style users were asked to input.

As was briefly covered above there are sound arguments for measuring text entry focusing only on real words per minute with a 100% correction rate and discarding all samples that contain errors including:

- The ease of comparison between results on the same text with 100% correct entry
- The user's individual error rates and reading are less impactful, including removing things like "fat fingering" keys as impactors
- Calculating the results can be easer as there is no need to account for errors in the text

However, ignoring user errors provides a very artificial result; no typists are 100% accurate, especially among a user base who are learning how to implement the language as would be found in a school. Additionally, these arguments are somewhat traditional and generally applied to physical keyboard use. With software keyboards however, it is expected error rates will be significantly higher and software assistance, while perhaps aiding in speed, may contribute heavily to that. Lastly as a key aspect examined was the user's own perception of the keyboard, forcing them to focus on error correction, or simply discarding error attempts, could have resulted in cases where a high satisfaction attempt was being discarded due to errors while the user themselves felt that the keyboard provided a high assurance of accuracy. Finally, with how these devices would impact a classroom there was a significant driver to have a more natural typing experience. In the real world users are not 100% perfect and an evaluation of that is important and relevant. The time a user takes to correct mistakes is a significant impactor on their typing efficacy and as some of the keyboards will, based on previous work, be more error prone it is felt that including these attempts is justified.

Due to this, participants were instructed at the start of the test that the expectation was of a "natural" typing session, meaning that they should correct mistakes as they noticed them but were told that errors were expected and to treat the text entry in a similar nature to writing a document; correct the errors you notice but there is no expectation of perfection. This was a better approach than providing no notification of the expected input, which could result in outliers of users looking to provide 100% accurate renditions of their own volition. Measurement was conducted using the adjusted form of the words per minute formula to calculate typing speed, which took into account both straight forward typing as well as recording error rates and adjusting the results.

The typed text was provided to participants on a piece of A4 paper in the MS Word default of 11 point Calibri font and placed flat on a table with participants given no specifics on the orientation and use of the paper, they were free to position the paper however they felt during the exercise. When using the tablet device users were given the packaging box to use if they wished and given no instruction in how to handle or position the device for typing. They were free to choose their own orientation (landscape or portrait) and typing technique. Participants were given a short period before a typing session to provide familiarization if needed with the keyboard, but were entitled to commence the experiment at any stage where they felt comfortable.

During the experiment users were timed on their text entry speeds and copies of their attempts were saved for later error analysis and comparison. Observations were recorded by the facilitator of the experiment on the orientation of the device and method of text entry the user utilised; e.g. tablet held in one hand, one finger used for entry vs. tablet held in both hands, thumb entry. The facilitator also took notes of any comments or frustrations the user expressed during the course of a typing session. At the end of each typing session participants were given no less than 3 minutes and up to 5 minutes as an interval to both provide a break in physical fatigue and to try and reset the participant’s mindset for the next attempts.

At the end of the experiment participants were asked to rank the keyboards from 1 to 4 on which keyboard they felt was:

- Their overall preference for use.
- The most accurate for text entry.
- Provided the fastest means of text entry.

Participants were not informed of their times, therefore these rankings were made without specific knowledge of the time taken to perform the task, though the user may have had a general idea as to the time taken; one participant used the tool bar to gain a general idea of his text entry time with the laptop for example. Participants were also given no additional information before making preferences as to their expected error rates or other information as to the content of their attempts.

5.4. Results

The experiment had 9 participants, 8 males and 1 female. All participants came from an undergraduate or postgraduate technology background and were aged between 20 and 35. All participants owned their own smart devices in the form of mobile phones, however only 1 (11%) participant also owned a tablet.

All the participants considered themselves technically literate with all but 2 (22%) considering their proficiency with mobile devices to be "high" or "advanced". Of the two who did not consider themselves high or above they still felt they were at an average level of use. Only 1 (11%) participant made use of a third party software keyboard with predictive text but 2 (22%) participants said while they did not use third party software keyboards they did own Bluetooth keyboards that they had used with their mobile devices, one of these being the user who also owned a tablet. All said that they used their mobile devices multiple times a day, but also that they still used desktop or laptop computers more often, especially for "work" related document tasks.

Of the participants all considered themselves to be at least of average skill level when using a default OSK with four participants considering their own skill level to be high, however while all participants were aware of how GSKs were used and required no instruction in their use, none of the users considered their skill with these keyboards to be above average, with 2 (22%) participants considering their skill level average while 6 (66%) felt their skill level was low and 1 (11%) felt their ability with GSKs to be negligible.

5 4.1. Adjusted words per minute

As the testing used non corrected text with the chance of errors a standard words per minute calculation of:

$$WPM = \frac{|T|-1}{S} \times 60 \times \frac{1}{5} \qquad (5.1)$$

where T is the final transcribed string and |T| is the length of this string and S is seconds from the entry of the first character to the entry of the last, would not be sufficient as participant times will be impacted by accidental errors, the time taken to correct recognized errors and decisions made by users to leave errors in due to time needed to correct. Therefore, an adjusted WPM formula that took into account error rates was used (MacKenzie and Tanaka-Ishii 2010):

$$AdjWPM = WPM * (1 - U)^{a} \qquad (5.2)$$

Where *U* is the user error rate from 0 – 1.0 and *a* is a "correction modifier" that can be used to simulate requirements of correctness with 1.0 being a standard typing environment with no additional error penalties; for this test *a* = 1.0 was used. Results were then averaged for the users AdjWPM to provide an average for each keyboard.

These averages followed the general trend of data from each participant with all but one following the suggested findings that the laptop is fastest, followed closely by the Bluetooth keyboard, then a gap to the OSK which is in turn slightly faster than the GSK. All data was normal within sets.

Overall all users showed the same pattern which was to be fastest with the laptop, followed closely by the Bluetooth keyboard then a significant gap to the OSK with the GSK being slowest shown in Table 5.1.

Table 5.1: Mean time taken, in seconds, to enter text per device.

Keyboard	**Mean (in seconds)**	**SD**
Laptop	48.61	17.40
Bluetooth	42.99	13.42
OSK	20.95	4.87
GSK	16.51	5.20

To determine a statistical difference between the sets a one-way ANOVA comparison was run which showed a statistically significant F(3,32) = 17.057, p = .000 difference between groups. With significant difference between sets to achieve a direct comparison to the laptop for each keyboard. Each keyboard was compared to the laptop using a paired t-test for each.

This showed no significant difference in the scores between the laptop (M=48.61,SD=17.40) and the Bluetooth keyboard (M=42.99,SD=13.42);t (8)= 2.869,p = 0.21 suggesting that statistically the typing speed with both is commensurate.

There was however a statistically significant difference between the laptop (M=48.61,SD=17.40) and the OSK (M=20.95,SD=4,87); t(8) = 5.585, p = .001 as well as a statistically significant difference between the laptop (M=48.61,SD=17.40) and the GSK (M=16.51,SD=5.20); t(8) = 6.258, p = .000, which is shown in Figure 5.8. This supports the initial inference that the two software keyboards perform significantly worse than the physical laptop and Bluetooth keyboards.

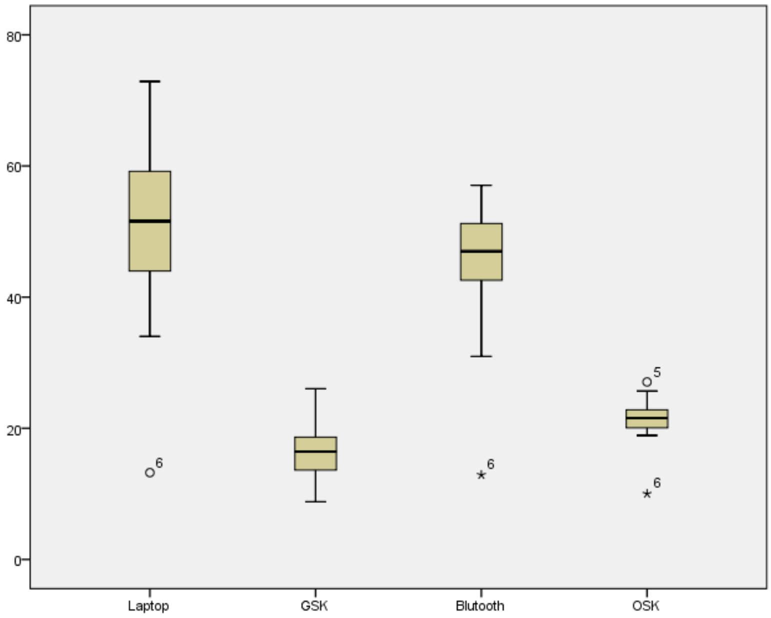


Figure 5.8: Mean time, in seconds, for text entry for Laptop, GSK, Bluetooth and OSK keyboards.

Lastly a paired t-test was run between the software keyboards which showed a statistical significance between the OSK (M=20.95, SD=4,87) and GSK (M=16.51,SD=5.20); t(8) = 4.606, p = .002 with the OSK having a higher AdjWPM.

5 4.2. Error rates

While AdjWPM provided a single metric value for input speed error rates provided the specific error frequency of keyboards themselves, ignoring relative speeds. Errors were calculated by character skips or additions within the final created text.

Table 5.2 highlights the inherent difficulty in including error rates and testing keyboards in full text entry as standard deviations for the mean swung wildly between keyboards. However, a one-way ANOVA on the error results showed no statistical significance in error rates between keyboards F(3,32) = 1.068, p=.377.

Table 5.2: Mean errors per entry for each input type.

Keyboard	Mean	SD
Laptop	11.44	8.83
Bluetooth	12.33	6.56
OSK	17.33	10.69
GSK	12.00	3.97

What was shown was that the error rates within subject for a given keyboard tended to follow the same trends (Figure 5.9), and that while the values between all participants is not statistically significant and wide, within subject they are relatively closely grouped. A high error rate with the laptop also showed high error rates with other keyboards per participant.

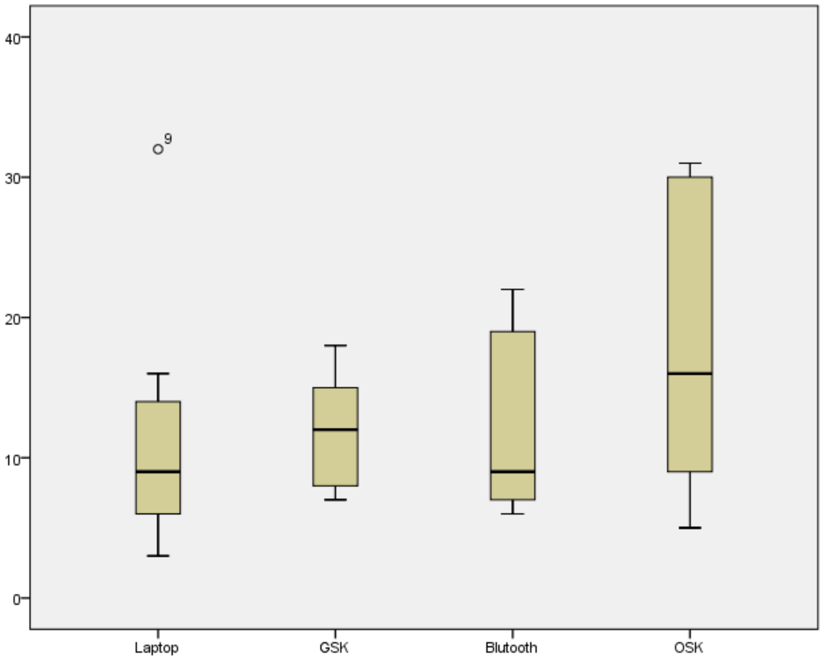


Figure 5.9: Error rates for text entry per keyboard.

Formative observation to the text entry styles for software keyboards that users used was noted. Three distinct styles of text entry for touch OSK were observed:

- tablet placed on the table and used like a regular keyboard “touch typing”
- tablet held in the hands and typing with thumbs
- tablet held in one hand and using a single finger

Orientation for most users was mixed when using the touch type OSK but seemed more closely tied to the way the user was placing the device. Those who placed the device flat on the table and attempting to touch type for the whole test all had the device in landscape mode while all participants who held the device used portrait. Two participants started the experiments with touch type by placing the device flat on the table but switched part way into the test to a held in one hand style; one at 3 minutes and the other at 6 minutes 43 seconds.

For the GSK all participants approached text entry with a single finger, due to the nature of the keyboard limiting multiple digit entry. Here participants were split with 4 choosing to place the device flat on the table and 5 holding it in one hand. Despite the differences there was no apparent link between how they used the keyboard, their text entry speed or their error rates with times being normal regardless of the entry method used.

5.4.2.i. Predictive text

While there was no statistical significance in the error rates between keyboards there was still a noticeable difference across users for error rates with the gesture keyboard. It showed a lower error rate mean than the Bluetooth and touch keyboards, as well as a markedly lower standard deviation than all other keyboards. This suggests that predictive text helped to smooth out errors. Users whose spelling was already reasonably accurate gained a minor increase using the gesture keyboard, while those who made a large number of mistakes with the other keyboards benefited much more from the predictive software. This was backed up by a per user evaluation that showed an inverse swing between laptop and gesture error rates. The most accurate participant with the laptop keyboard performed 3 errors in total for the laptop test, and 8 for the gesture keyboard. On the other side the least accurate participant had 32 errors with the laptop test and only 12 when using the gesture keyboard. This is further correlated by the means for the two keyboards error rates being very close together. From this, while it cannot be said there is a statistical link between the error rate and the keyboard used, anecdotally it seems that predictive text entry is of greatest benefit to those who are already error prone and less so to users who are already accurate typists.

5 4.3. Participant rank per keyboard

After each test participants ranked the Bluetooth, OSK and GSK options on a 5 point Likert scale comparing the current option to the laptop they used first, with a score of 3 on the scale being the same as the laptop. These rankings were:

- how easy they felt the keyboard was to use
- how frustrating they found text entry
- how fast they thought text entry was
- how accurate they felt they were

While participant times and errors showed the expected result that the Bluetooth keyboard was close to the laptop it was surprising how highly users rated the gesture keyboard, illustrated in Figure 5.10 demonstrating the mean responses. This is especially notable as a majority of the participants expressed some trepidation when presented with the keyboard during testing, often making some form of disparaging remark about the time required “this is going to take ages”, to their general view of the keyboard “I hate these things”.

Yet only 33% rated it the lowest score for ease and accuracy compared to 55% for the OSK, while 22% rated it the lowest score for frustration, with 44% rating it the lowest for speed. Additionally, 33% (ease), 22% (frustration), 22% (speed) and 44% (accuracy) rated the GSK keyboard as better than the laptop, the only keyboard to get ratings stating the alternative was preferable to the laptop. This is in spite of the evidence that the swipe keyboard is no more accurate than the other keyboards and was significantly slower for text entry than both the control laptop and the Bluetooth keyboard.

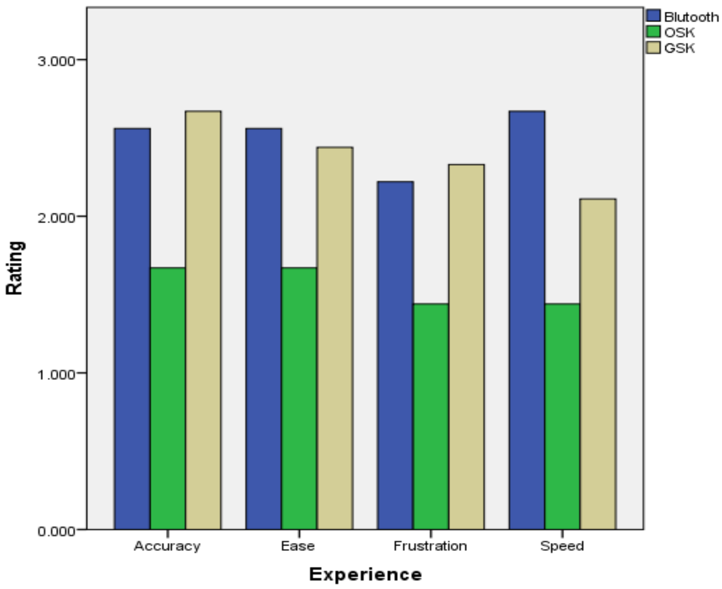


Figure 5.10: Mean user rankings of each non-laptop keyboard. A rating of 3 is the same as the laptop in perception, with under 3 being a lower perception than the laptop, while over 3 would be a more positive perception than the laptop.

Yet only 33% rated it the lowest score for ease and accuracy compared to 55% for the OSK, while 22% rated it the lowest score for frustration, with 44% rating it the lowest for speed. Additionally, 33% (ease), 22% (frustration), 22% (speed) and 44% (accuracy) rated the GSK keyboard as better than the laptop, the only keyboard to get ratings stating the alternative was preferable to the laptop. This is in spite of the evidence that the swipe keyboard is no more accurate than the other keyboards and was significantly slower for text entry than both the control laptop and the Bluetooth keyboard.

5 4.4. Final rankings

The last task for participants was to provide a ranking from 1 to 4 for each keyboard based on which they most preferred to use, which they felt was most accurate for text entry and which provided the fastest text entry. These were then converted to an arbitrary scale using a value of best = 4 and worst = 1 using:

$$\frac{(r*4)+(r*3)+(r*2)+(r)}{n} \tag{5.3}$$

where *r* is the number of respondents who gave it that rating and *n* is number of users, to get a rating scale for each keyboard out of 4. For preferred use again the GSK keyboard beat out the Bluetooth, despite being overall slower (Table 5.3).

With accurate text entry, the GSK keyboard was again rated as more accurate than the Bluetooth keyboard by participants (Table 5.4). Many participants made observations during the experiment that predictive text may have been a factor in the accuracy of GSK keyboards, but this is anecdotal.

Table 5.3: Mean score for preferred use of each text entry option.

Keyboard	Score
Laptop	3.89
Bluetooth	2.33
OSK	1.33
GSK	2.44

Table 5.4: Mean score for perception of accuracy of each text entry option.

Keyboard	Score
Laptop	3.67
Bluetooth	2.33
OSK	1.33
GSK	2.56

For perceived fastest text entry, users felt that again the laptop was the fastest, however here participants rated the Bluetooth as faster than the GSK keyboard, which compares with the AdjWPM results for the keyboards (Table 5.5).

Table 5.5: Mean score for perception of speed of each text entry option.

Keyboard	Score
Laptop	3.78
Bluetooth	2.56
OSK	1.22
GSK	2.44

5.5. Discussion

Prior to commencing the experiment, it had been expected to see a significant difference between the 3 different "types" of keyboard (physical, OSK, GSK) with no real difference between the Bluetooth and laptop varieties. This was observed as true. However, it was surprising that the only statistical difference seen was in the software vs physical comparison with both OSK and GSK returning a statistically similar AdjWPM. The experiment did however see that as expected the physical keyboards performed notable better in typing speed than their software counterparts with each mean being well within the standard deviation of the other.

Meanwhile there was no statistical significance in the error rates across all four keyboards, which was a surprise as there had been an expectation of significantly higher error rates on the software keyboards. Again, the error rates of the two physical keyboard were very close and while the software keyboards showed a reasonable difference in error rates there was no statistical significance. However, it is worth mentioning that while the swipe keyboard performed the slowest overall the error rates were lower than those of the Bluetooth keyboard and maintained a very narrow standard deviation suggesting that while slow, its accuracy was consistent. It is worth noting however that the OSK and GSK results justified the decision to assess results with errors included. Had the experiment kept only purely accurate results none of the participants would have succeeded with the OSK without taking a significantly longer amount of time to perform the test.

The other investigative factor of the experiment was to elicit users' opinions of how they felt they had performed and on the relative comfort of the presented keyboards. The expectation had been that there would be little to no discernible difference in preference or performance on the Bluetooth keyboard but this was not the case with participants as a whole rating the gesture keyboard higher in both accuracy and reduced frustration. While there is an argument to be made that predictive text on the gesture keyboard may account for the increased sense of accuracy it is unclear why such a sense of frustration is present in one keyboard when compared to an almost identical counterpart (laptop vs Bluetooth). There may be issues with typing latency or screen orientation and further testing that examines the relative value of screen position and other factors when typing would be beneficial.

As expected for reasonable text length the OSK was seen as slow, error prone and frustrating, coming in last across all metrics except AdjWPM where it beat out the GSK. However, the GSK was less error prone and induced less frustration and increased confidence with users in their results. As studies have shown that with practice typing speed, the factor that really allowed the thumb touch keyboard to outshine the gesture, increases significantly, this may well result in the GSK gaining the advantage in AdjWPM over the OSK. It is also an important consideration when approaching the willingness of users to adopt technology. Here the initial impressions of the GSK placed user expectation below that of the OSK but simple operation and expected outcome confidence helped to create a real increase in user confidence with limited exposure. There would be significant benefit in investigating the speeds and acclimatisation rates that users achieve with gesture keyboards in a longitudinal study.

Lastly overall users rated the gesture keyboard as their second most preferred text entry method behind the laptop despite considering their experiences with swipe to be negligible. Considering that none of the participants had significant experience using these gesture keyboards and the comments made before use, they appear to have found their mark, quickly gaining favour with participants.

At this point it is important to consider the low participant pool of the study. Key here is the required number of participants to achieve a qualitative assessment of their experience. For a long time the standard of 5 participants for user studies has prevailed (Nielsen and Landauer 1993). However further studies, and the authors of this paper themselves have noted that this is not always the case. When looking at usability error rates the 5 user assumption can find itself susceptible to missed user errors and inaccuracy when looking at statistical performance (Faulkner 2003), with 10 users showing a significant increase in error detection. In this case there is limited error checking within the study, focusing mainly on explicit action recording and user perceptions. To this end it is felt that while the sample size is low, it is capable of providing a valid description of the problems.

While this study is nascent and requires more in-depth testing on other aspects of tablet content creation it demonstrates that the limit on tablets as laptop replacements, from a text entry perspective, is one of perception more so than mechanical ability. With a focus on mobile learning and the increase in Web 2.0 implementations in classrooms (sections 2 3.2, 2 3.3) there is a growing desire for tablets to be available in classrooms. As analogies to laptop devices they have the potential to fill the role of a sole device, albeit most effectively with a physical keyboard attached. This can help to activate the TPAK and SAMR models discussed previously (section 2 3.4) and provide a tablet as a sole device of a personal learning environment (section 2 3.5).

This chapter helps to clarify the position of tablets as potential sole use devices, as outlined in section 2.6. Chiefly, it provides a much clearer idea of the input capabilities when comparing a tablet to the more common laptop device. While this helps to support the literature presented in section 2 5.2 of the tablet being a good choice for classroom usage, the work also highlighted some additional benefits that the tablet can provide when dealing with a highly portable environment where physical keyboards or the bulk of a laptop may be prohibitive. In this area, the comfort that many users felt with the newer forms of predictive keyboard, despite most having a limited exposure to the input paradigm, suggest that, in the future, as comfort grows these systems may prove an additional boon to the tablet form factor.

With regard to the research questions of this thesis, this study speaks primarily to Research Question 4 (R.Q.4) in an effort to strengthen the tablets ability to operate as a sole device in classrooms. Tablets can be used as devices that provide similar text entry rates to a laptop and even provide some additional functionality through the power of their more custom OSK alternatives. These emergent gesture based alternatives provided high levels of confidence and satisfaction, over and above the physical options in some cases.

Combined with the power of wireless peripherals to empower more mobile environments in some environments the tablet may be a superior device with the creation scales being tipped back in favour of its form factor and other technical benefits (sections 2 5.1, 2 5.2). In situations where accuracy and speed are most necessary wireless options can provide entry speeds very similar to the standard laptop with a commensurate accuracy and confidence.

In the end the tablet may, with a peripheral alternatives available, provide the best of both worlds. First by actioning the innate mobility, media consumption and form factor elements of the tablet and secondly by allowing a cheap peripheral to facilitate similar creation actions as a laptop while benefiting from the perceptive preference the gesture keyboards provide when the physical option is not available. In light of the ClaMApp software developed in Chapter 5 this study helps to solidify the opinion that a tablet can work as a sole device within a classroom or in environments where tablets are the preferred or sole ICT option. Without this confidence the tablet faces the real risk of being viewed only as a fancy media player.

5.6. Summary

A tablets role as a content creation device is often overshadowed by its clear benefits as a tool for content consumption. However, a tablet provides greater options for textual input than a laptop, including emerging software keyboard alternatives such as gesture keyboards. The experiment discussed in this chapter investigated the use of tablets as content creation devices using long text input and the perceptions users have towards those input devices. The work here establishes the efficacy of using physical Bluetooth keyboards to achieve statistically similar typing speeds to a laptop as well as showing the high level of user confidence and preference that is quickly engendered by emerging GSK options. Results from this experiment were encouraging and highlighted the ability to not only operate as a stand in for content creation for a laptop but also additional domains where the tablet device can outshine its more common education sibling.

This chapter clarified the ability of a tablet in a classroom being up to the task of not just content consumption but content creation, with both traditional and emerging keyboard solutions being viable with users. In the following chapters the work presented in Chapters 2, 3, and 4 will be drawn upon to present a classroom digital management tool that is usable and learnable for teachers to allow them to facilitate digital tasks quickly and easily within their classrooms, either as a standalone environment or complimenting an existing structure

Chapter 6

The design of ClaMApp

6.1. Overview

This chapter takes a deeper look at the common factors present in the classroom that impact teachers uptake of technology and how they seek to utilise systems within the classroom, especially the roles that training time and personal preference play in this environment and how ICT seeks to address these issues. The idea of using learnable and usable software to alleviate these human and technological factors is discussed and examined, with a focus on tablets as a device medium.

The ClaMApp software is then defined and presented; a tablet based digital classroom management system to facilitate digital transactions within the classroom. This is a low cost, low resource, management application allowing LMS style functionalities on a class by class basis, designed with a very low requirement for professional training to utilise. It looks to draw on the need for usable and learnable interfaces to handle complex digital operations in the classroom. The system uses the work presented in the previous chapters to inform the functionality and philosophy of the app, resulting in a system that should allow teachers to quickly and easily manipulate groups, communication channels and digital content with minimal to no application learning footprint.

6.2. Introduction

While the background provided in Chapter 2 provides a broad overview of ICT facets in education, the key elements that ClaMApp looks to target are two of the most important barriers to uptake; professional development time and perception. This chapter in part looks to delve deeper into that relationship and how current professional technical implementations may fail to address key elements. As has been discussed, when developing software for education it is important to take into account the factors that are specific to that domain (section 152.2). These often lead to different design elements than would be present in software designed for mass consumption and can be counter to some mobile design ideologies. Teachers face a unique environment in the classroom where the functionality of an application must be pedagogically targeted, beyond the general use of “perform X task”. With the growth of blended learning it becomes even more important that mobile solutions are targeted with due consideration given to the specific needs and wants of the teaching field.

It is also often not enough that that teachers have access to the resources and assets needed to employ technology, as these alone are not direct indicators of, nor lead to, effective use (Plomp and Voogt 2009). Rather it is the effectiveness of how teachers employ technology that most benefits their uptake and use, as well as driving the effective employment of ICT by students within their classes (Owston 2007). This leads to teachers often facing an environment where it is important that they understand the software better than their students to maximize these benefits and this is often not the case. There are also significant connections between the teachers own personal views and competencies that impact their attitudes (Al-Zaidiyeen, Mei et al. 2010). While professional development can seek to address some of these issues it is not a panacea, as many teachers experience issues with time investment, personal motivations and perceived effectiveness (Abuhmaid 2011).The time required to learn new systems is often one of the primary drivers leading to aversion (Morris 2010). With these constraints on the time available for professional development, the impacts that perception have on use, and the restrictions institution level environments can entail, mobile learning software is a careful balancing act in design. These points further reinforce the background overview and survey discussion noted in sections 2.2 and 4.5 on the importance of these elements as barriers to effective use. Tablets meanwhile have emerged as an attractive pedagogical tool but much like software, how and where to best implement them is not a clear picture. While there are distinct benefits to tablets, especially in the realm of portability, and a clear desire by educators to employ them as powerful tools to assist mLearning and personal learning environments (sections 2 3.2 and 2 3.5), their application also tends to be ad hoc (sections 2 2.3, 4.5).

6 2.1. Human Factors

One of the keys to any successful deployment of technology in classrooms is a willingness for users to take up the application (section 2 2.22 2.3). While schools can enforce the use of a particular software suite, the willingness of teachers to make use of it is another matter (sections 2 2.3, 4.5). So, while this work has highlighted this as a major consideration, it requires investigation to determine how software can best be designed to address this factor? While a significant desire for the feature set or a mandate from management may give little choice, it is preferable to have users want to make use of the software of their own volition. Often if the software will perform the expected task yet the user has already set their mind against using it, having them actually use the application is difficult.

Results from the survey, presented in Chapter 4, reinforced the findings seen in literature and illustrated above, that is teachers wanted to use tablets and technology, but often have an unclear picture of how to best achieve this, and low levels of use are often tied to a reduced willingness or desire to employ them. Perception and attitude play an important role in adoption, as noted (Plomp and Voogt 2009) simply having access to the environments and devices is not enough, and nor is simply providing a greater breadth of professional development options, as even this option is not without the drawbacks noted above. While nearly all of the survey's respondents had some plan, the manners in which they sought to implement them were varied with limited utilization of management environments to streamline teacher adoption. The successful deployment of ICT solutions in classrooms must be more than "provide directed learning" and design itself can help to play a crucial role in both the reduction training time required and the personal perceptions teachers have of the software.

THE DESIGN OF CLAMAPP

For many classroom applications of technology, this is a necessary first step; overcoming the reticence of the group who are meant to use it. With frequent excuses including "I haven't got time for this.", "What is the reward?", "I don't have the skills." and "I don't believe this will work," the initial hurdle for any uptake is first convincing the teacher that some of these factors can be mitigated. For most teachers, outside of their own efforts to investigate ICT options, which in turn denotes a certain existing literacy, the primary training will come from professional development and this deserves due consideration. The ability to take targeted training courses in how to make use of the devices is seen as one of the most important influences in technology uptake (Mueller, Wood et al. 2008). There is also an increased benefit from courses that address not only the technical aspects of how a device works but ways in which devices can target pedagogical aims. However, this desire for increased professional development is at odds with many teachers' views of how professional development may factor into their already considerable workload (Abuhmaid 2011). Many teachers already feel like they are under significant time pressures at work and adding more instructional courses as new "whiz bang" applications become available is often an unwanted burden. When they do find themselves in a position to dedicate professional time to learning software environments, often the goal is to learn how to make use of that environment in the classroom, rather than spend significant amounts of time learning the minutiae of navigation and operation. Teachers are rarely learning to use these environments for their own sake but in order to provide a tangible benefit to the learning outcomes they wish to target and the "what do I want to do with this" often takes a back seat to the "how do I do this". This means that while barriers can be tackled through time intensive training, using both professional and peer solutions (Conole and Alevizou 2010), there also exists the avenue for the software itself to be designed in a way to mitigate these barriers addressing them in the software development cycle. Here effort can be put into making sure that software is going to be easy for the user to employ with limited to no training addressing some of the key barriers; chiefly time investment and perceived skills deficit.

One first step is usable User Interfaces (UI) that prevent users getting stuck, confused or lost during navigation. Additionally, while teachers may make use of technology in the home, this does not necessarily translate to comfort in the classroom. There is a different perception and user relationship that is not present during personal use and the user is far more comfortable making mistakes in their own time, especially when they feel they are not being judged on their learning curve. This makes it important for software to be as simple as possible in operation and to reduce the potential for users to create errors.

With teachers in the classroom specifically, this learning curve is often even more important. For many, there is already a significant burden on their time learning new environments. This is often an onerous task when dealing with software that has a direct pedagogical directive they wish to employ. To ask them to make the same sacrifices for management software is often regarded as a bridge too far, resulting in pushback. This in turn will taint the user’s willingness to employ the software at all. As mentioned above there is also a significant power dynamic at play in a classroom environment. The roles of teacher and student are often defined by knowledge domains that teachers wish to maintain and software should avoid putting teachers into a role where they feel they are demonstrating a lack of knowledge compared to their students. This may be amplified by a perception that students themselves are already increasingly more at home with the devices than the teacher. A fear of breaking the device, or of having technical inadequacies impact the learning outcomes for students, can see a marked decrease in the opinions, and thus willingness, of teachers to view ICT as a valuable addition (Preston, Cox et al. 2000, Prestridge 2012). These elements are partly addressed with easily learnable operation in an environment where both teacher and student are performing within the same context. This can be difficult in environments where the expectations of one side do not mirror the other; where what the teacher and student see from the environment are divergent.

6 2.2. Technology Factors

For tablets, investigations conducted as part of the work of this thesis, have shown the ability to be employed in the classroom as a viable and desirable element in so long as the necessary steps are taken to ensure that the software created is easy to learn and easy to employ (section 2 2.3). However, the management of pedagogical software and materials is still a concern and there is room to provide a low cost alternative to large scale LMS’s, with a focus shifted primarily to allowing teachers direct and simple control over the digital environment in their own classroom.

Any environment addressing this should be careful to avoid the pitfalls of common third party solutions (section 2.4) including:

- Environment lock in
- Allow teacher autonomy to use the software they want to use, rather than environment or package specific.
- Addresses the issues that may manifest with data access when remotely hosted.

While cloud solutions to assist with this digital data are common, they raise some important issues with regard to data security and ownership. They are often replicating data to multiple storage centres and these are often in different countries to their point of origin. One example of this is how Australian customers of Microsoft's Office 365 environment had data in Singapore (Corner 2014) until 2017, and the issues that emerged in late 2017 regarding Google’s tracking and privacy policies (Turow 2017). This is especially important when dealing with student data. While the security of the data alone should be of importance from an institutional standpoint the fact that in many primary and secondary school environments this data concerns minors is also important. Lastly hosting student data in a third party environment may involve facing issues with access. While storage centres are generally file type agnostic this does not prevent the hosting company experiencing connection issues or even worse face shutdown. For all the problems that cloud storage solves there are still a number of issues to be faced, especially when sensitivity of data is important (Dillon, Wu et al. 2010).

So, while there exist many examples of tablet applications targeting the education sphere, these are often looked to perform a directed pedagogical aim, and even when the initial design may be education focused a side view is often given to alternative markets. Even truly education focused apps exist in a microcosm of their own functionality and assume it is up to the user to provide the relevant managerial framework to properly employ the software (Dhir, Gahwaji et al. 2013). In order for a device to truly fill the required role in the classroom it must be able to provide not only the curriculum functionality to perform the desired role (e.g. as an eBook reader, as a drawing tool, as a photography aid, or as a document editor), there needs to be the ability to handle the background managerial tasks associated with the classroom as well. If devices do not provide a positive experience, there is a highly reduced chance of them being embraced (Wastiau, Blamire et al. 2013), as the perception of teachers again demonstrates its importance. Yet, as has been noted in section 2 3.4 and 4.5, currently the employment of apps for managerial tasks can lack structure and while some schools may provide guidelines for their use, there is limited training in place, with distributed usage making adequate training for all possible scenarios impractical.

It is important at this stage to draw a distinction between applications designed for a task and applications designed for facilitation. The aim is not to provide an application that covers every possible educational task in the classroom, indeed frequently the pedagogical actions themselves can be better served by multiple applications. This is one of the issues with a locked-in environment where the user is forced to perform within the confines of that established domain. Management software rather should avoid impinging on the performance of other targeted applications. This again tends towards the fact that for many, the use of education apps is pedagogical rather than managerial and the managerial software schools are using may not be education focused. This can be seen especially in the tablet domain where for example materials management is through a web interfaced LMS (in the case of systems like Daymap, Moodle and Blackboard) or through a third party cloud based file drawer, for example Dropbox, Microsoft's OneDrive or Google Drive. While these may provide a solution, there are significant issues with both. In the case of web based systems, the user is still left to handle the managerial back end of their file structures.

While a LMS may provide a repository for course material, with relevant restrictions for collaborative spaces and access, once the user downloads the content they are forced to utilise their own folder structures for the data. This is a problem compounded by the standard mobile model of obfuscating folder structure and instead trying to present data natively; a good idea when dealing with data constrained to use by a single app or expected to be displayed in a non-WIMP format, but less so when seen as a more traditional structure. Meanwhile with cloud storage the go anywhere nature of the space can allow for easy distribution to others using the medium, but are not designed with a strong mentor-to-student mindset. Rather these systems allow for a one-to-many relationship with limited constraint on who can be added, additionally there is limited file content handling, for example, constraining file operation. In the case of a submission folder, it is feasible a teacher would wish to allow for access restriction and peer sharing will often lack many of the desired controls to track a file's source or to easily allow the teacher to handle permissions without a significant amount of set up. For example, it is important for a teacher to track student work submission, the date it was submitted; possibly sorted into student groups. This is difficult to do with simple file locker solutions. It should be noted that as of 2017 many of the major file locker systems including Dropbox, OneDrive and Google Drive offer "for education" packages with varying levels of this functionality, but these options are less important in the peer relationship these systems expect to operate. Teachers however are constrained by a unique user group relationship in the classroom, that of a single user needing strict and precise control over other users' access in both action and timing, and it behoves this dynamic to employ software that respects this situation. Teachers already feel the burden of expected investiture in professional development, when there is limited to no specification in place as to the relevant applications and their use ("this just stores files") this burden can be increased.

From a technical perspective using a distribution of apps to achieve these management tasks also opens the user to issues with cross application communication. If a teacher is using two different environments they will need to have the relevant users and groups organized in both applications. This may lead to a need to constantly switch back and forth between environments with limited scope for communication between the two domains. Further confounding this is the intended business model of provider companies; to keep the user in their environment. This presents a twofold dilemma in the approach to tablet software in the classroom; the human aspect of the teacher and the technical domain of tablet software. Design should be informed by both aspects.

6 2.3. Design Factors

To this end software designed for the classroom should address these factors. It should allow teachers to easily and concisely perform the intended tasks. There should be limited to no learning curve, especially when dealing with a secondary aspect of the learning environment, management, which is primarily seen as a tool for facilitating the real educational goals of the lessons. The user should be able to, with limited to no training in the environment, make use of the application and be confident in the resulting operative actions. In particular use of the software should have little to no requirement for professional development time commitements.

Teachers should be confident when employing the software that they are as knowledgeable as their students in the applications function set and operation. However, it is important to address that there is a fundamental difference between the level of comfort a user has surrounding "general use" and comfort surrounding the use of software in a classroom environment where the expectation of teacher knowledge is above that of the student. Part of the problem is that general use is less of an indicator of comfort than knowledge of how to perform specific tasks and developing targeted skill sets. Often this can show as a desire for greater learning and on-site training in order to build their confidence (Wood, Specht et al. 2008) which in turn provides another pressure on the teachers time.

This factors into a teacher's willingness to sign up to the constant introduction of new technological environments or software but is often based in the assumption that there is a one-time cost. However, this is rarely the case as many software environments will require constant upskilling in order to stay up to date with the latest version. The Office suite from Microsoft is a prime example of this where many companies avoid updating their software suites to save not only on the cost of the new licenses but to avoid the time and monetary expense of reskilling their workforce, a significant outlay even when the changes made are minor overall. This can be magnified greatly in a mobile landscape due in part to some of the following reasons:

- Core interface elements can change
- Current version of the app can be discontinued
- Operating Systems are in flux and can break older versions
- Mobile development companies can be bought and sold, resulting in significant design changes to the product

The greater the scope of the application the greater the window for significant changes to operation. Yet at the same time smaller targeted applications can often see themselves replaced by a competitor resulting in even greater burden on reskilling as the user is now expected to dedicate time to learning an entirely new environment.

The scope of apps available can be seen as a benefit for tablets in extending students' learning domain beyond the scope of what can be presented purely in the physical classroom. With such a wide range of options including niche applications that may be course specific students and teachers have a selection to choose from. While this may be of benefit for targeted functionality, from an organization standpoint students are often using a mix of different third party programs (Chen and Denoyelles 2013) to perform classroom management tasks. Here again there is benefit in a simple solution to handle these management tasks while avoiding as much as possible of the negative aspects of professional development and without requiring the teacher to employ multiple third party solutions for basic tasks.

6 2.4. Solutions through design

As outlined in section 2.6 the domain of personal opinion on teacher willingness to employ ICT is established as one of the important contributing factors. However, a deeper understanding of this complex element was essential in developing effective software. In this chapter, further exploration of this aspect show, as expected, a much more detailed domain. While as noted there are a number of factors that make up these opinions, the most common baseline is the impact and requirement for additional time of the teacher. Whether it comes in the form of personal time spent learning a device, or the additional requirements of professional development, it is the impact on a teacher's time that is critical. This seems to be especially true in cases where the software does not appear to have an immediate pedagogical or educational aim.

This increases the importance of learnable and usable software elements as key components of any educationally aligned software. Teachers will resist or simply not use software if the time requirement to achieve comfortable operation levels is too high, and this ceiling is lowered when the software does not appear to have immediate class use. A teacher may spend personal time to learn a specific piece of software for an educational goal, but this same time frame is very reduced when the software is not directly applicable to a lesson.

As the functionalities of management software are reasonably firm, this means that applications must instead be designed to reduce the training load on a teacher before reaching a comfortable usage level. To this end the professional development time needed for tertiary management software must be as low as possible, preferably almost non-existent. Software must allow teachers to learn its operation quickly and allow the teacher to reliably perform operations with a significant level of confidence in the expected outcome. In this case, the operating system design goals of mobile environments can help to remove some of this time pressure through the point to point nature of their interface designs. These mobile centric design elements are detailed below in section 6 3.5.

Designing software for teachers requires a significant analysis of the personal human factors unique to the domain. It should be up to the teachers themselves to decide how best to employ applications, and management software should facilitate and streamline that process. Teachers have special requirements, especially when looking to training and the psychology of implementation and in a way that is not only different from other professional environments, but different within that group for each user; how a teacher employs personal devices is different than how they may use similar tablet or mobile devices in the classroom, and this also shifts teacher to teacher.

There can be significant issues when handling this movement of data through third party solutions that employ cloud environments or lock-in solutions which are often complex and learning defined, that is they seek to lock the user base into their environment often through interface customization and function. If the user does not have to dedicate significant time to learning the environment however there is less trepidation in changing environments and more likelihood of successful uptake.

This thesis establishes that tablet devices can provide some significant benefits to laptops in a number of domains and are capable of standing in when cost is an issue, or behave as complimentary consumption devices in conjunction with a laptop, acting as a digital textbook. Tablet software also provides the benefit of being generally compatible with smartphone devices. Allowing tablet software to be deployed to a smartphone with minimal to no modification where the cost of tablets is prohibitive, or where schools have noted that they lack the resources for multiple tablet devices, as seen in Chapter 4.

Below is proposed a tablet based solution to classroom management tasks, using an easy to navigate interface that requires no significant time investment to learn. This system, based on the literature and survey results, should provide basic management tasks to teachers without the need for large scale institution wide LMS's and is classroom focused, targeting the teacher classroom relationship more than the student school relationship; a Classroom Management Application; ClaMApp. The aim was not to hijack or lock off the device but to allow collaboration and communication among teacher and students without infringing on the standard operation of the device. Users should be free to download and make use of the full functionality as they see fit, but access the application to use common LMS functions like receive learning materials, communicate remotely with the teacher, collaborate with other students, and perform basic classroom functions. The design of the initial prototype software suggested it should be easy to use with a very low learnability curve and easy to access feature set. Initially the early features were to include:

- File operations that allows teachers to quickly and easily disseminate material to student, students, and groups
- Direct file access in a tablet environment
- Cross student collaborative channels for both files and chat
- Student to Teacher communication channels
- Persistent device agnostic student use and shared files
- Teacher ability to easily and quickly take notes / metrics

Software should have limited to no learning curve and require simple operation with little to no scope for erroneous operation. To ensure confidence in operation between teacher and student, but in respect to the additional management tasks a teacher has, both a student and teacher version of the app were developed. They appear visually the same, providing the teacher with confidence in regard to the student experience, there is nothing a student can do that a teacher can't. Local and server stored data ensures that in a shared device environment student's will have a personalised experience without a need to modify device account settings. Data can be controlled by the teacher and should be portable and easy to back up. The software should not be reliant on an internet connection and be capable of requesting data from the server directly ensuring the class can always access its data.

The final application should be an easy to learn and use management tool for basic classroom tasks. Easy for teachers to get documents and distribute to students, allows for collaborative spaces for students, overseen by the teacher. Provide students with communication channels to their teachers. Controlled by a teacher with no need for institutional oversight (Armstrong and Wilkinson 2015).

6.3. Creating ClaMApp

6 3.1. Infrastructure options

When looking to create software, the environment and structure are essential. These factors will often dictate the ways in which data can be accessed and viewed both at a device and server level. As the software created was a prototype and due to the sole developer nature of project it was essential that consideration be given to the intent of the function set, the complexity of the system as a whole and balanced with the time available for development. As the software has two domains there were two fields to consider:

- Mobile environment
- Server environment

When considering the mobile environment there are realistically only 2 to choose from; Google’s Android operating system or Apple’s iOS system. While there are other options available, including Blackberry and at the time of development Windows Mobile, the sheer user market share held by the Apple and Android make them the most feasible choice.

When considering a server environment there are more options but as one key is to make the system as easy to use as possible the best solution is to keep the server as a closed system environment. As its primary job is to provide sync and mirror to mobile files there should be no need for users to pry into the internal server mechanics. One desired feature though is to maintain the portability of the environment. Rather than develop a custom solution to handle this and given the constraints on development the best solution was to make use of a prebuilt stack solution that runs either independently or in an easily configured virtual machine. As the server communication structure most often utilised in the mobile domain is http and its POST and GET calls this inevitably resulted in a web server stack.

6 3.2. Mobile environment

As mentioned for the mobile side of the software the two main choices are between Android and iOS. While both have significant market penetration in the western world, Android is the clear leader in the east and developing nations. Coupled with, at the time, resource and licensing costs with iOS, Android was selected as the mobile environment for the prototype. Android also provided some useful benefits for ease of developing. At the time of development (mid 2013) strictures on the allowed development environments meant Apple machines would have been needed for development. Additionally, the ease of pushing Android's application .apk files to a device made it much easier to work with. This openness coupled with the lower cost of Android devices in general made it the preferred choice for prototyping. While it would have been possible to create the application in a cross platform environment, at the time of development these tools were less than ideal for a proper mobile experience. In this case both would need to be created within their native environments and consistency across the user interfaces would have been challenging. In addition iOS environments at the time prevented the background operation of application in all but the latest operating system iterations.

6.3.2.i. Mobile issues to address

Internally, Android applications make use of a different access to storage structure. When considering an application whose primary function includes direct file manipulation it is important to be aware of the distinctions Android makes between accessible, public, external and internal storage locations and what each of these will allow as far as copying and manipulating files in those locations. Generally, when dealing with files Android uses an internal storage system that is protected from outside action. Often these files are also write protected. While it is simple to set these files to be read and write for ClaMApp it is important that files can be copied from an outside source or application and still be actioned on from within the software. An example of this would be copying files from a Windows machine via USB to the application, or saving a file from a third party installed Mind Map application, as was used in Chapter 8. In both these situations direct permission is needed to access the directory of the user to copy to or from the location. This is not allowed in the Android environment when using internal storage. To solve this problem, the external storage card present on the device was used. It is important to note here that Android's view of internal and external storage does not require an external or additional storage location. Instead internal storage refers to storage locations exclusive to the application that uses it, while external storage is accessible outside the application. Using the external storage will allow users to access their device folders from a USB connection and copy or transfer files to another machine, for example a student could use the tablet device in an outdoor context where they may take pictures, and copy them to a classroom laptop when they return.

6 3.3. Server issues to address

When considering the server environment, the key aspects were that it was easy to deploy and maintain, had some level of portability and could quickly and easily be setup or stopped.

This is achievable on a reasonably simple laptop. When examining the requirement for the server back end it needed to:

- Allow and manage http connections.
- Provide a database layer for storing and retrieving tabled data.
- Have a scripting interface to handle post and get commands.

HTTP connections are important as this is the primary way that Android deals with wireless communication. Rather than build a system it makes sense to use of an existing back end solution. Something from the Apache web server family was seen as ideal, as it is the most common server back end and able to operate in a standalone virtual environment with limited resources. A database layer was necessary for storing and tracking a number of aspects of the application, not least the basics of user lists and group structures, when files need to be updated, poll or push notification status, communication channel status and directing remote file manipulation. Lastly, some form of interface language was needed to allow requests to be actioned on the database, to handle the application's file functions and to push and return notifications to the ClaMApp. One simple solution rather than developing these tools was to look at a standalone Apache, MySQL, PHP (AMP) stack implementation like XAMPP. Using this bundle allowed for a remote web server with support for database and scripting to be run easily from any Windows environment. This bundled all the necessary build features into a single standalone server that can operate on a laptop and provided the necessary layers in an easy to use package. As a benefit, deployment to this structure allowed for simple translation to a true web environment if desired.

6 3.4. Note on Tablets Vs Smartphones

While the ClaMApp software targeted tablet devices it is worth mentioning the close relationship between smartphone and tablet devices. In nearly all respects the two devices are the same. In the Android space there is no real difference between the operating systems for each device type and while there are increasingly targeted commands within the language to specify differing layouts for different devices at heart they are the same; the distinction Android itself uses to differentiate tablet from phone apps is simply the screen size of the device. As part of the intent with this prototype was to create a low-cost solution it is worth, as an aside, to mention design implications for smartphones simply because of their prevalence as a solution. In many poorer countries where laptop penetration in schools is low there is still a significant smartphone uptake. While in the past a comparison of relative performance may also have been warranted the rapid increase in processor power and the wide array of device specifications means performance is no longer as simple as "tablets are more powerful, they are bigger". Modern generation smartphones will outperform a tablet even a couple of years old.

6 3.5. Designing Mobile Applications

When developing to a mobile interface there are also significant interaction and structure considerations to take into account; chief amongst these is the touch focused interface. While a mouse can be used with either type of device, through Bluetooth or cable, for the majority of users, touch is the method of interaction they are both more familiar with and more likely to employ. As such any applications made for mobile should expect and take into account the fact that a user's first choice for interaction will often be touch based. This also means being aware of the expectation for tap, hold and swipe patterns and the less likely use of actions analogous to double clicking. Additionally, the default mobile operation is not to display or make heavy use of traditional windowed environments. On mobile displaying files in a windowed style environment is not expected. However, for ClaMApp it is an essential function and the proclivities of the operating system need to be accounted for as in Android the operating system is hgeavily involved in directly controlling application function than it would be in a windows environment.

6.3.5.i. Web vs Native environments

One important consideration during design, and one that is especially relevant considering the way many LMS environments operate, is the idea of Web Vs Native development. This deals with the distinction between a mobile application that runs as a web page versus one that is developed in the native environment. In these situations, Web offers some powerful benefits, not the least is its ability to operate on any platform. As web content is used via a browser environment, developed in this way will be visually and functionally similar across systems. This can be a significant factor and is the reason LMS environments like Moodle operate through a web interface. Yet while emerging mobile web experiences are in a steady state of development there are still very strong reasons to prefer a native application to a web based solution. This is especially true with ClaMApp and its focus on tablet and while there would be benefits in cross device use, the benefits of native are too great.

Perhaps one of the most important facets is that native application development allows the software to directly utilise the user interface elements instead of operating through a web browser. While browsers continue to evolve, especially in the mobile space, they are still not at the point where they allow the same interface functionality as the native device, let alone in 2013 when ClaMApp development began. This also removes a level of obfuscation that the browser presents. Actions like immediate file interaction would need to occur through the browser adding difficulty and response time to a task. Similarly, the ease of discovery in a native interface is far more powerful for controlling application states when compared to a web implementation. In software that is heavily targeted at a usable and learnable functionality this is too big a benefit to ignore. Another important consideration for native development is the need for ClaMApp to, as management software, make direct and immediate use of the device file system. With the need for users to achieve expected and direct results waiting for a web response would not be beneficial. When factoring in the use of tablet features like camera or other application file structures this is even more pronounced. There is also the benefit of direct access to the services and actions of the operating system without requiring an interpretation through a web page. For example, utilizing the push notification system built into the OS is only possible using a native implementation. Lastly is the importance of offline access. While at its heart ClaMApp is a synched environment, when a user is disconnected from the server it is important that they still have access to their information and are still able to modify and edit their work. This is not possible in a web environment; once disconnected the user has no access to data. While it is possible to introduce work around solutions, for example Moodle requires users to download materials to their own devices, this again adds a level of obfuscation that is counter to the intended design goals of ClaMApp.

6.3.5.ii. Working with Applications

While there are general individual apps available for each functional task in ClaMApp, there are apps for taking notes, apps for creating groups of users, apps for communicating with other devices, there is no connection between them to allow the user to conglomerate these functions, or consistency of operation between them. Yet in an environment with a significant learning domain the ability for user's functional familiarity is essential. Each of these "stand alone" applications are also designed for a specific non educational purpose. This issue of trying to repurpose general applications for the classroom is often a road to failure as they do not take into account the myriad of education specific impactors described. A common option instead is to employ 3rd part business solutions, for example using Microsoft's Office 365 suite. However, these solutions also have a number of issues even when looking at their mobile offerings. In the case of Office, it is important to note that at its heart this is a software suite for creating documents. While you are given some file sharing capability for example through OneDrive these solutions still lack the education focus that takes into account the dynamics of the classroom and do not provide the necessary tools a teacher needs to confidently manage and oversee the classroom's digital actions. On top of this, business solutions are often large scale and complex, resulting in even more training time being dedicated to their effective use. Even then often this training touches only superficially on the full scope of the package. Lastly with this complexity comes the ability to go outside desired aims or end up lost in the functionality of the software. A "simple" desktop application like the email client Outlook when ported to mobile offers the user a bewildering 11 possible selections from the default view mail screen. This in turn increases the friction with which the teacher views the software.

So, while compared to the complex business packages a single targeted app can be much clearer in its functional intent and is fine for general users, when looking to a more niche role as an education aid there is a need for additional considerations. Namely, for management software, the human aspects unique to educators:

- Teacher learning curve
- Teacher confidence
- Needs to perform functions clearly
- Be as invisible as possible and not become the lesson

There are a number of ways software development can look to address these concerns. From the start however it is important to note that for teachers the explicitness of the software is important; again referring back to the idea that for professional use, educators want to know how to explicitly action functions, rather than contextually. This should chiefly take the form of clear methods of execution; there should be limited need to experiment or be ambiguous of a functions initiation. This can often be as simple as naming buttons rather than relying on pictorial representations. By using a named button rather than a contextual icon ambiguity is limited. Care must be taken though not to overload the interface with blocks of text. The proliferation of contextual icon representations in apps is often there due to the limited screen space available on a smartphone (and the tendency to a more graphical approach to design). This need for explicit instruction in a limited space, and the need for the application to present what is for a mobile application, relatively dense information, means there is a need for a strategy that will sub divide function sets and allow users to intuitively get the function set they need for the task. This may take the role of dialog style sub menus or drop down selections to effectively sequester function operation into like operators.

If an application is employing these strategies then the user needs to be secure in their ability to navigate the domains of the application, and to return to their start point at the end of a function operation. A one-way interface design assists in preventing users from becoming stuck in a dead end operation, or finding themselves ejected from an operation and ending up in an unfamiliar or unwanted location. By having all functions actioned from a defined start point no matter the operation and keeping hierarchy depth shallow it will be easy for teachers to confidently execute the operation they want with the assurance they can abandon it at any time and there is a limited chance of executing the wrong action.

6.3.5.iii. Considerations for mobile interfaces

Before considering requirements, it is worth touching on the realities of UI design for mobiles as they provide a different requirement set to desktop applications. As has been noted tablets have two prime domains where they are different to desktops; screen real estate and interface interaction. For most desktop or laptop devices screen real estate is sufficient to allow for multi windowed navigation and operating systems are designed to facilitate this. Tablets meanwhile have a smaller screen and design needs to account for this. There is also the issue of interface design. While with traditional environments mouse and keyboard are the primary method of interacting, for tablet any application must take into account the prevalence of touch and gesture as input methods.

When addressing screen size there is a need to balance what is on the screen with the information to absorb. This often means menus should be hidden from primary view with a clear method of activation. While modern application design suggests these should be contextually activated, this is not necessarily the best option when dealing with a user group who are seeking explicit interaction. For these users clearly labelling in plain text may prove a more learnable environment than iconography. Additionally, in the case of ClaMApp, this provides a reduction in interface noise across the screen. This means limiting the number of images and visual representations to locations the user would expect, namely for files and menu step off points. This is important in an application that is already performing more than the usual amount of app functionality. Similarly, the density of some required displays, like file views, means a need for clear delineation between icon and background so using solid colours as representations assists users in easily distinguishing actionable items.

Given the quantity and type of information for ClaMApp to present there is no way it can be achieved in a single screen and as such users will need to navigate to different sections of the application either to achieve a goal or action an icon. As such when looking to perform an action it is essential that there be a contextual result, when accessing files users should only be given actions that can affect a file. Similarly, when performing a navigator action, or non-file management task (e.g. creating a group), the user should not be provided with file action menus. It is also essential that for the targeted user base the confusion level is kept low, and the outcomes remain expected. This means there needs to be clear interface actions leading to an unambiguous result. At the same time when an action is abandoned by a user, where able, the interface needs to ensure a return to a known state, dropping a user in an unfamiliar or unwanted screen due to a function exit will add to frustration and reduce acceptance of expectant outcomes.

Lastly with the interface it is important that selection hierarchies be kept low and where possible avoid branching execution. Each function should also execute from a single location. This ensures no confusion for the user as to what to expect when a function branch is executed. There should also be limited exposure to the back end operation. While there is complexity in the server synchronization systems these should not have a bearing on the user experience unless necessary, for example stating a failure to connect to the server.

6 3.6. Server Design

The server as noted used an AMP stack in the form of the XAMPP cross platform package, this allowed the server structure to be self-contained and portable. Using this environment for example on a Windows machine provides a single directory with a self-contained install.

Should a teacher need to move the data to a new laptop, they could simply copy the data folder and its contents. XAMPP itself is an expansion of the previously described AMP stack with the addition of a Perl interpreter that is unused in this design (the X being for the packages cross platform nature). Web server routing is managed by the Apache server, allowing the HTTP requests from tablet devices to be handled and forwarded to the PHP script interface, shown in Figure 6.1. These requests are handled primarily through the HTTP `POST` request method, allowing the tablet to bundle necessary data into a HTTP message, and the `GET` method to request resources. These `POST` and `GET` messages are parsed by the PHP interface and actioned to either the database or remote file location.

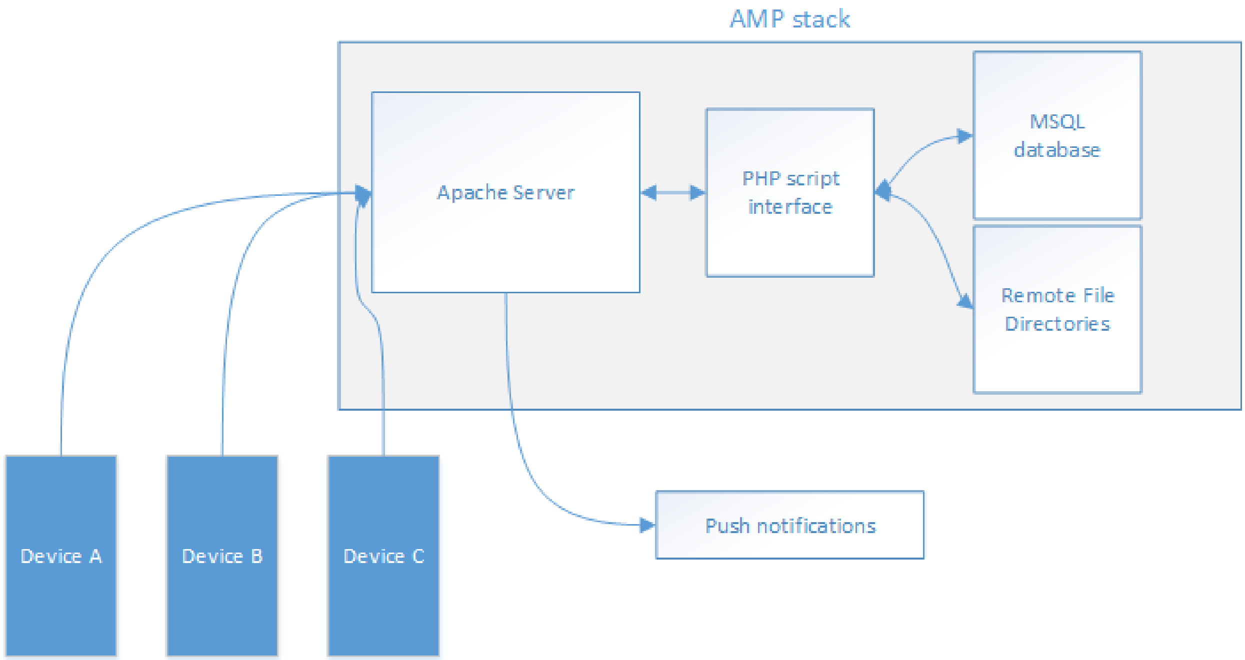


Figure 6.1: A representation of the Amp stack. This can run as a portable installation on any machine configuration. The SQL feature set is interfaced either directly through a web interface or via calls from the Apache server using PHP or Perl. Devices connect to the server using a fixed IP address through an HTTP socket.

The PHP interface is constructed of two primary libraries:

- `DBHandler`
- `FileHandler`

With each being responsible for that aspect of the program. Helper libraries pass the provided `POST` messages to the associated library and parse the received messages. The access routes and used interfaces are out laid out in Figure 6.2: The PHP interface structure. HTTP calls are made to index.php and routed by tag to the relevant execution script to access database and file operation.

The SQL database, seen in Figure 6.3: Server database structure. Where possible users are provided as a foreign key to other tables to provide consistency. When groups are created a new tablet is created for both the users in the group, and to record group chat messages. consists of a number of permanent and temporary tables that, where possible, are referenced with the user as the foreign key, allowing easy access to their real name as a value for various functions. When a user is registered the first time, calls to the `DBhandler` and `FileHander` libraries are created, registering the new user to the users table, flagging if the registration came from the teacher version of the app, and creating the folder structure in the server directory to handle file syncing. When logging in, the server runs a simple match to the user's directory to validate login and password. As this is prototype software and not intended for real world implementation the user table stores these values as plain text, however it is recognized that in a proper deployment it would be necessary to hash and salt stored identifying information. The `device_registration` table stores the user and the id of the device that user either is currently or was previously logged in with. When a user logs in, this information is updated with the id of the logged in device. This ensures that the tablet and user are linked allowing the correct allocation of message to device through the GCM `PushHandler` library. The `help_messages` and `notes` tables are specific to the teacher application. Help messages sent by students are inserted into the table and the teacher is notified of their addition. A help message may be linked to a student so again the use of the foreign key allows a note to easily be referenced to the real name of the committing student. As notes are self-contained to the teacher the table is stand alone and simply provides a storage box for teacher made notes.

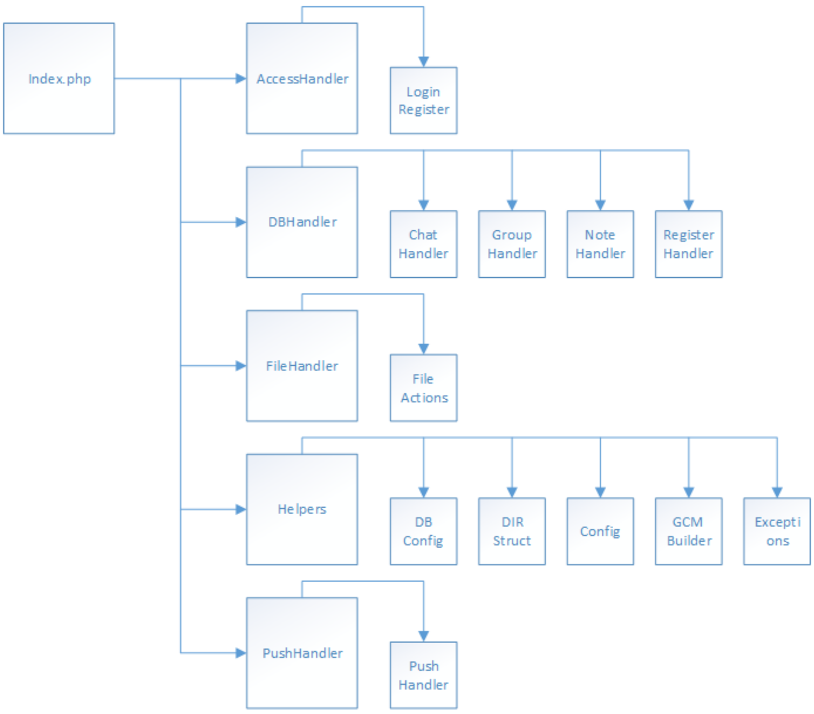


Figure 6.2: The PHP interface structure. HTTP calls are made to index.php and routed by tag to the relevant execution script to access database and file operation.

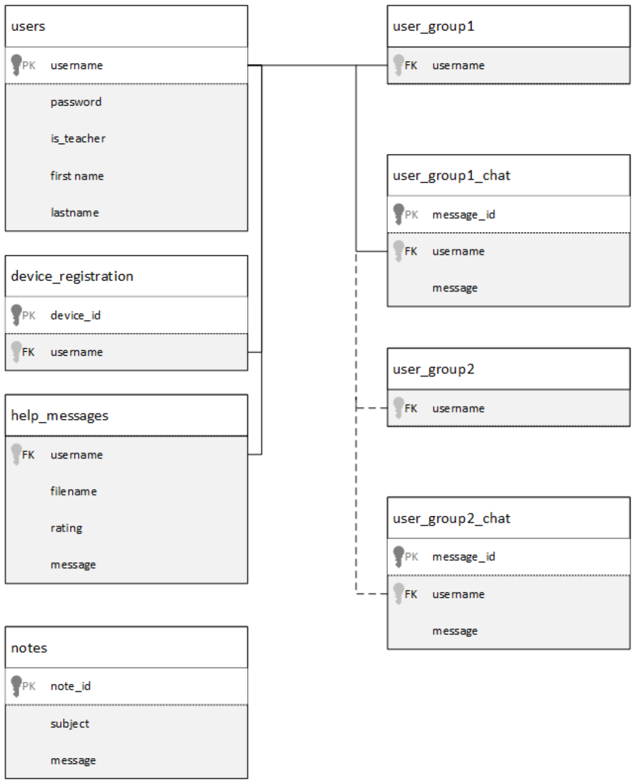


Figure 6.3: Server database structure. Where possible users are provided as a foreign key to other tables to provide consistency. When groups are created a new tablet is created for both the users in the group, and to record group chat messages.

While the format for the `POST` commands to the server are key-value objects, communication between server and device employs JSON packaging. This allows the server to easily format and structure outgoing data as messages. Since push notifications are primarily an update cycle for communication channels, or a call for the device to check document status the small tagged text messages JSON provides are a simple text based, dictionary-less object to parse, shown in Figure 6.4.

```
{
"tag":"login",
"success":1,
"error":0,
"user":{
  "username":"teach",
  "is_teacher":"1",
  "created_at":"2016-05-10 15:24:56"
  }
}
```

```
{
"tag":"get_notes",
"success":1,
"error":0,"notes":[
  ["General note",
   "a note",
   "this is an example of a note",
   "4",
   "1"]
  ]
}
```

Figure 6.4: Examples of JSON strings sent as both replies to server queries and through the GCM notification service. All JSON's are tagged, success flagged and error coded for interpretation by the ClaMApp software and contain relevant tag specific data.

6.4. Feature set descriptors

When looking to design function sets for the application a key aspect is to define the overall operational parameters of the function sets; how should these functions behave in this application and what are important considerations. These were drawn from the frequently used LMS function sets and collaborative requirements discussed in Chapter 2 and Chapter 4. These functions include:

- Logging in
- Opening files
- Copying files
- Material Delivery
- Collaborative spaces / environments
- Peer to peer communication
- Student to Teacher communication channels
- Multimedia capability
- Teacher notations
- File Creation

6 4.1. Login

As there are scenarios where students may be away from their devices it makes sense that their data should involve some basic security layer to prevent erroneous access. There also needs, at a functional level, to be some structure to allow the identification of a user and the device they are on; sufficient knowledge for correct directory applications and grouping. It may also be the case that there are limited devices available. Rather than have a situation where teachers would be forced to remember exactly which student had which device a system is used where when a user logs on, the device registers to that user. At the server end a check is made to verify if the unique ID of that device is currently registered to that student and if it is not, will deregister any other device that is currently set to that student and assign the new device. This would then initiate the download of the most up to date version of student's own data. As data is set and recorded on the server side when a user logs in with a different device they will still receive the most current form of their work. This means even in a situation where students may hot swap devices within a single session they will always be able to get their most recent data on whichever device they are currently using.

6 4.2. Material delivery

The key value of material delivery is to ensure that students quickly and easily have access to the needed classroom documents in a streamlined manner. There should be limited need for the student to go and seek these documents out or require secondary copy actions to utilise (as is found in most web LMS implementations). File delivery should be explicit to the desired devices as both a way to ensure that students are given the correct documents and as a way for teachers to control file dissemination. The majority of the time these materials are in the form of common data types such as Word documents, PDFs, images or other media. As the purpose of the application is to manage the distribution and handling of these files rather than the access, the application has no interaction with any extensions and contains no internal processors for document type. Rather ClaMApp provides a framework similar to a desktop or laptop folder structure and other programs are used to open the files.

In the prototype version of the application users have access to two folders by default:

- Their personal folder
- The camera folder

For viewing the best solution is to mimic laptop folder operation rather than rely on text heavy lists, this also allows for contextual iconography for file types as well as name descriptions. Therefore, teachers will primarily be working in a file / folder environment they are at least reasonably familiar with from desktop environments, although execution patterns diverge to utilise tablet interface components. The structure remains the same when dealing with collaborative file spaces, presenting the information in the same manner regardless of location, however it is important that both spaces be distinctly separate as locations; the user should not be in a situation where they are seeing the same folder contents in each location. This ensures a clear delineation between the group location and personal folders to prevent cross contamination of both files, the requirement to handle user files differently, and the user perception of how the application presents data. Users should however be able to move quickly between folder locations with limited menu interaction, limited hierarchal navigation and solid confidence of outcome.

For the files themselves users should be able to expect similar management operations as they would in a standard windows laptop environment including the 4 basic file operations:

- Move
- Copy
- Rename
- Delete

It is important that care should be taken on delete actions within collaborative spaces. While deleting old documents is a necessary function this should be regulated in a collaborative space. Users should rather be able to bring in copies of collaborative work to personal spaces, but again care should be taken to ensure a single user cannot empty a collaborative space through move operations, which would result in the same effective action as a deletion. When considering how to deploy and move files to students there are a limited number of scenarios to account for:

- A student creates their own file
- The teacher wishes to give files to students

In the first instance the only agent effected is the student themselves, thus the creation of their files can be handled locally. However, when a teacher is wanting to distribute materials there is essentially a one to many relationships in effect. The teacher may wish to send the item to a single student, to a number of students, or to all student. While most operations will be the first and last type, when looking to send files to a subset of students which will normally be because that selection is grouped in some way, therefore teachers need at least 3 options for distributing documents:

- Send to one student
- Send to all students
- Send to a group of students

Pushing data to students themselves also provides additional latitude in how teachers wish to deal with information distribution; they may find a situation where they wish to provide information piecemeal or over time rather than provide all documentation in a single bin for students to grab when they want. They also ensure that the domain of user error, or the "inability" of students to find information is reduced. Lastly it is important that data be up to date both on local devices and server side in a location where it is accessible to the teacher if needed.

6 4.3. Collaborative spaces and environments

To effectively benefit from group learning, students need defined collaborative spaces. These spaces can be ad-hoc gatherings in the physical world but when managing digital groups, they should have the power to be distinct and separate to personal spaces. It is important though that in group spaces the structure is consistent. Teachers should be able to quickly and easily create these spaces as needed, either as an extended environment for prolonged group activity or as an ad hoc grouping for a short period of time. This means that it is essential that creation should be straight forward and involve little additional setup outside of the members. In order to facilitate oversight by the teacher they should have access to all collaborative spaces with the ability to oversee both the actions of file manipulation and the communication environments of groups. When addressing group work, as noted in the previous section on file handling, extra strictures should be in place when addressing how students can access files. It is important to ensure students can't modify or effect the group work to an undue degree and this is especially important in the domain of moving and deleting, where that responsibility should primarily fall to the teacher to handle. Students should be able to copy work to collaborative spaces though ensuring they can make their own local copies that they can then edit or delete as desired. In a fully developed application there would be value in having an included interpreter for operation transformation and real time collaborative document editing, however even without this feature students need to be able to make edits to group documents and have those changes propagate the other members.

6.4.3.i. Peer to peer communication

While tablets can facilitate greater face to face communication there is still a need for textual collaborative spaces for when students are not in the same physical location or when loud vocal communication is prohibitive. The simplest implementation of this is an asynchronous chat interface that allows students to send messages to groups they are a member of. This allows students to easily chat with other group members and in a contained group environment. By linking these groups to the collaborative file spaces users will be able to communicate about work and share materials in these spaces with no additional setup. Teachers should again be able to quickly and easily create a group and have both the collaborative file spaces and communication spaces created automatically. However, much like with the file spaces, it is important that the teacher be able to easily oversee the actions of students within the group chat spaces. As they will be part of the collaborative system, teachers should also have access to student communication channels for oversight

6.4.3.ii. Student teacher private communication channels

Students should be able to communicate directly with teachers. While collaborative spaces would allow a student to communicate with the teacher in an open channel there are times where private communication is desired. The nature of this messaging can take a number of forms but should allow for the teacher to receive the nature of the problem, including the originating student and some form of structured data that can be stored and delivered to the teacher. Due to the expansive nature of this operation and the prototype nature of the software the intention was to include a single channel for communication with a direct purpose, but a complete suite should acknowledge that there are a number of different channel structures that should be looked at for student to teacher interaction with varying levels of urgency. While it is essential that students have a way to directly contact a teacher, consideration needs to be given to the ease with which such a system could lead to abuse and even increased pressures on a teacher’s time. To this end communication needs to provide avenues for teachers to control the rate of feedback and the times at which they choose to respond.

6 4.4. Multimedia capability

Tablets offer unique opportunities to incorporate multimedia into the learning space. While devices often include custom software for image and video recording this information is often treated in an expansive manner and especially in the case of students who are using personal devices there should be a distinction between images taken privately and images associated with classwork, both for consistency and to respect student's privacy. Additionally, there may be constraints on what data and how students share from their devices during school time and rules that should be followed. With the increased prevalence of automatic cloud storage in many provider's mobile phone and tablet offerings this can be even more important to prevent automatic storage of images that may contain minors or personally identifiable information. There is also the ability for much greater control on the media as it is created, directing usage towards short targeted actions rather than creating large amounts of ambiguous images or video that would need to be sorted. By allowing students to create multimedia within the confines of the application it ensures that when tablets are used this way the created media is contextualized to the student. This is important when dealing with shared devices as the only way to distinguish between generalized gallery users otherwise is through tablet wide accounts; requiring every student to have a separate account on the device and be logged in with their credentials to get their gallery.

6 4.5. Teacher notations

Much like student to teacher communication and peer collaboration the idea of teacher notations is a wide net to cast, and this software looks to a narrow implementation of this facet. It is important that teachers have a way to record details and information on the class or just general notes about a situation and so should have a personal space for notation. The creation of these notes should be quick. It is not a format to create detailed spread sheets or documents on actions, again the object of the application is to provide management tasks, not to hijack the functionality of valid third-party options. Including a fully-fledged spreadsheet program for example would serve little purpose, drastically increase application complexity and it is unlikely it would provide an alternative that is better than existing specialized programs.

6 4.6. File creation

Lastly there is a clear requirement that students be able to create common file types, while the multimedia aspect of the program can create video and images, creating text documents is still a major factor in classroom activity. A key idea is that the type of application can be governed simply by being aware of the types of file that the tablet is capable of reading. These files may be created within their respective applications, but it is still important that users be able to create a type of file that can be opened by the expected application. To take the example of a spreadsheet above so long as the file types match, there is nothing preventing the creation of a spreadsheet file in the application and when opened having it actioned by the appropriate installed application.

As stated these functions do not represent every possible classroom management interaction but are chosen to be a relatively broad subset of those actions most commonly found in more extensive LMS and non-tablet based management environments. In a commercial application, many of the functions may have sub features or be executed in additional steps, but are chosen here to develop the targeted functionality and interface with a focus firmly on learnability and ease of use

6.5. Feature set implementation

There are distinct functional requirements between teachers and students that the application needs to encompass and what information should be available to the user. This leads to the realization that rather than attempt to sequester or block out aspects within a single application instead there should be two applications, one targeted at teachers and another "lite" app for students; both developed from the same base framework. This results in two applications that, for nearly all functions and features, are the same. Both should present information to the user in the same manner, and as a key part of the design is to ensure confidence in teacher users. The student app should contain little to no graphical or performance differences to the teacher version. This ensures that when using the application teachers can be confident that the students are getting the same experience. This in turn ensures that teachers can be confident in understanding how the application is operating for students and be able to respond to any issues with assurance.

When looking at how to programmatically implement the feature set described, it is important to consider the unique aspects of tablets, especially as has been noted previously their limited screen space and peculiarities of interface design. While a laptop has a multi windowed "what you see is what you get" design many mobile apps forgo this explicitness for a more contextual and graphical approach. However, while this may save screen space by avoiding text it can be an issue when dealing with a target population that prizes explicit instruction. With eight fundamental features to implement, each with varying structure and levels of complexity in design, care had to be taken to ensure these features were, despite their varied nature, consistent in their presentation. As mobile applications tend to be more around a single screen window than multiple windows care needed to be taken also to ensure that the user is only away from their information windows while executing another function.

When considering how to present this base function, one option that stood out was to provide a default view of the current file structure and provide access to other functions through external menus. This would ensure that the most common functions, performing actions on files, would be the primary display unless the user was in the sequence flow of a function that required navigating away due to display limitations. However even when away from the default view the user should return when the executing function has finished. When looking at establishing the different functions most of the features could be defined in two ways: functions were either tied to or impacted a file in some way or they did not. By separating the features into file and non-file functions operations were split into two groups.

6 5.1. File focused functions

- Open
- Copy
- Move
- Delete
- Rename
- Request Help (student teacher communication)
- Send to students / group / all

With regard to student communication it was important to associate that interaction with a goal for testing rather than an open format. Therefore, this was linked to the file operation as a request for help, allowing for peer anonymous help requests to teachers in regard to current work, with the file providing a reference for the request. This would give testers a defined reason to communicate with the teacher's device. To this end an additional File operation was added for the student application to request help on a specific file.

6 5.2. Non file focused functions

- Viewing file folders
- Peer to peer communication
- Creating groups
- Viewing group details
- Teacher notation
- Creating files
- Multimedia
- Student teacher communication

While these are not all possible actions for a management application they represent the core functions that most additional functionality would extend. For example, while ClaMApp does not include a direct submission box, functionally this operates in the same way as a general shared folder, as a directory that users as a group can copy information too. Thus, functionally it is the same as a group, simply with some additional rules on folder visibility and access control.

When looking at how best to represent these domains there were some key factors of concern. It is important that when users are selecting a non-file or file operation it is clear what that association is, and how to initiate the view; for example, it clearly does not make sense that activating a file action is done from a disassociated menu, that then requires you to then select the file. It was also important for actions to have a direct consequence, and in situations where additional qualifiers are required that they be clear to their purpose. Part of this was achieved by keeping branches in selection as linear as possible. Users should also be able to abandon the action at any time and this is a realm where mobile interface structure can be used effectively through dialog menus. There is invariably a compromise made between the amount of information that can be presented to the user in a single screen before they are required to step to the next. In many desktop and most web spaces this involves a shift along the interface hierarchy that will require an additional action to return to the default starting state, whereas in web interfaces, a link or button selection to abandon the current form. As mobile dialogs are intended to be short lived overlays, when abandoned they allow the user to immediately return to the start state without requiring additional steps. It is important to remember that the skill levels of users will show a large discrepancy and as such some standard mobile presentation techniques may not be appropriate and navigation of the interface should be explicit where possible. Yet traditional UI design guidelines should still hold true, while it is important that information be clear and understood this should not mean an acceptance of excessive prompts, explanations or confirmations.

6 5.3. Default view presentation

When considering how to provide the default view for ClaMApp two points were considered:

- Starting from a menu
- Starting from a default file screen

However, after initial flow testing the idea of starting from a menu was quickly abandoned. In an ad hoc on paper environment most users would look to navigate almost immediately to file views, and this is somewhat expected given most users familiarity with windows style environments. While for experienced mobile savvy users, navigating to these folder locations would not be an issue. The application must cater to the novice mobile practitioner simply so they do not get left behind; the point is to provide confidence. Additionally, the introduction of new display widgets at the time of development provided new approaches to menu display, outside of the originally envisioned spinners and drop down menu widgets. There was also a decision between using a windows style file system display verses a structure that is simpler to implement and uses less space; file lists. However, when conducting drawn ad-hoc UI tests with peers it was found that when presented with a list and asked how it would work most followed up the request with a comment similar to “Are these the files in the list?” whereas when using the familiar pictorial representation all evaluators immediately identified the nature of the objects. It also allows for a larger icon display to provide a more graphically meaningful representation of the file type. This provided a “normal” start screen and a simple option for addressing file function operations, the user selects the file they are wanting to action. Due to the discussed interface concepts on tablets and the lack of a double click most files and apps will open on touch, however by grabbing that command and instead opening an intermediary dialog, with open being the next step that is displayed over the file, the file action menu can be displayed without unduly delaying the “normal” action of opening the file.

When looking at how best to present the non-file focused features it was necessary to use an interface that would provide sufficient detail while not hijacking the initial screen. It was key that the user experience should not change in the course of selection only when a selection had been finalized. Had a new screen been used for menu selection, users would be locked into that screen and need to navigate manually back to the file view environment. Presenting the default view of a folder, exhibited its own problem set. With the limited space available to tablets, having a permanent menu displayed would take up significant space, especially when screen space concerns had been somewhat abandoned in the default view implementation. The initial consideration was a spinner style drop down menu but early prototyping showed it to be a poor element for displaying lists longer than three or four items. This was abandoned for the newer Navigation Drawer component that had been added to the Google interface library. This provided established support for “slide in” menus from the side of the screen, overlaying the current display with a list of menu options and sliding back off the screen when it lost focus. This had the benefit of allowing for more space and clearer interactions than a spinner menu, with the ability to provide clearer delineation between non file function sub sets. One additional benefit of the Navigation Drawer object was the ability to easily include non-interactive headings allowing for sub classification of non-file functions to users as an additional tool in differentiation. This had the benefit of breaking down the non-file functions into sub groups without increasing or modifying the overall set, for example:

- My Folders, the user’s own folder and their camera folder
- Group Folders, containing all the folders associated with the groups students belonged to
- Group, made up of all group management actions. For students this would be Group chats that they were part of while for teachers this would include actions for creating, viewing and deleting groups
- Tools, consisting of all other functions such as viewing notes, taking pictures, creating documents, viewing student help requests, creating files and making notes

By default, Navigation Drawers are accessed by swiping in from the side of the screen however in keeping with the goal of explicit instruction it was decided to also add a direct action button to bring the menu up, and this replaced the original spinner location.

6 5.4. Environment definitions

Working within the Android user interface environment requires some background knowledge of how the operating system looks to construct interface components. Unlike a standard windows style environment where executing a program will allow the program to “take over” the environment, mobile applications often operate within the confines of the provided user interface elements, similar to how a web page is presented within a browser; the browser is the program running and the pages are a delivery for functionality.

6.5.4.i. Fragments

Working in the Android environment involves using modular components to build hierarchal interfaces. Interface elements are generally constructed from what Android refers to as Fragments. These can be full screen or partial screen panels that in turn contain element components such as lists, images, buttons or text; widgets. In this application it was important to only replace the primary screen fragment when it was necessary either due to the function having no clear end of life or because there was too much information to cleanly display using a dialog menu. ClaMApp uses a straight forward two fragment structure:

- Title fragment, containing non changing data, including menu / logout buttons and an information stub providing the current user, located across the top of the application
- Content fragment, containing the details of the current function content, for example a list of available notes to view or the default file view

This allows for easy replacing of one aspect of the user interface without affecting the other, allowing the non-file function actions available through the menu button as needed. The use of fragments allows the seamless switching out of content during run time, however in doing so the current fragment will be replaced, making it important that a static element remain in play to allow users to navigate back to their desired view.

6.5.4.ii. Dialogs

For short-form user information, the dialog component of the Android user interface was used. This provides a small box that pops up on the screen, providing interface widgets the user can select or manipulate. These boxes will overlay the current application and provide explicit instruction that should be familiar in operation to most users. They can also be constructed in a wide variety of configurations, employing most of the standard interaction components that a fragment can use. This provides the benefit of being easy to cancel without interrupting the rest of the program flow, often by simply removing focus, and ClaMApp makes extensive use of them for selection environments.

6.6. Feature Implementation

When designing the features, as has been noted, it was important to keep the number of selection steps to a minimum while still providing complex functionality. Each of the function implementation descriptions below provide a screenshot of the action flow from the user interface as well as a function flow diagram showing the functions internal operation. For all application screen shots, the teacher version was used, as the student version is the same as the teacher version minus some functions.

6 6.1. Logging in

As ClaMApp can be employed in a shared device scenario it is essential to have a user identification structure and uses a standard login implementation of username and password. When registering, users provide a username and password, since the target population is students and there is an expectation that teachers will wish to both refer to and see who a user is as a student name, users also provide their first and last name at registration. The login and registration screens are shown below in Figure 6.55.

With the username and password provided a call is made to the server, compared to the database entry and either authorized or denied. This state flow is shown in Figure 6.66. In this prototype software, as it is not going to be deployed in an insecure instance, credentials are stored in plain text, but it is recognized that in a proper implementation this is insufficient security.

Assuming the valid authorization of the user, the server will also register the current device to the user who just logged in with it. This ensures that in a shared device classroom, communication intended for a student is targeted toward the correct device. Once registered the tablet is notified and provided with the current status of the user, including the groups they belong to, chat messages they have waiting, and details of files located in their accessible folders.

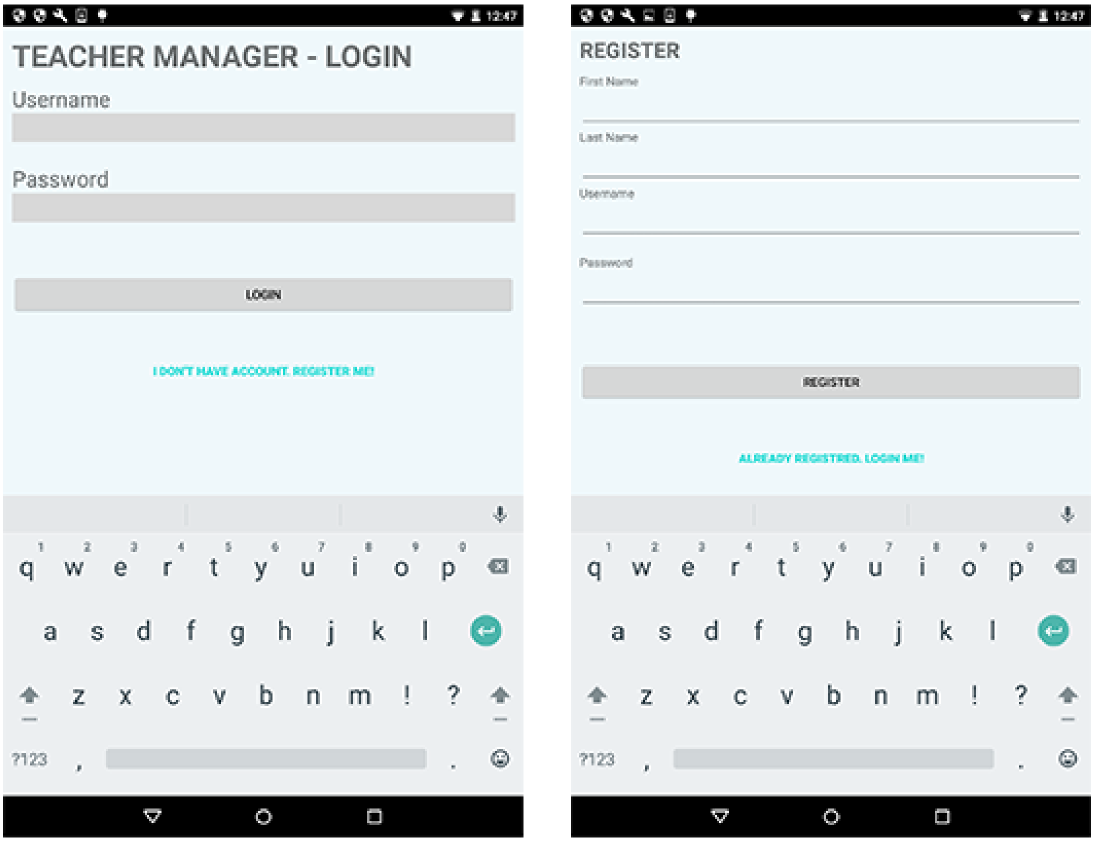


Figure 6.5: ClaMApp Login and Register fragments as seen on the tablet device.

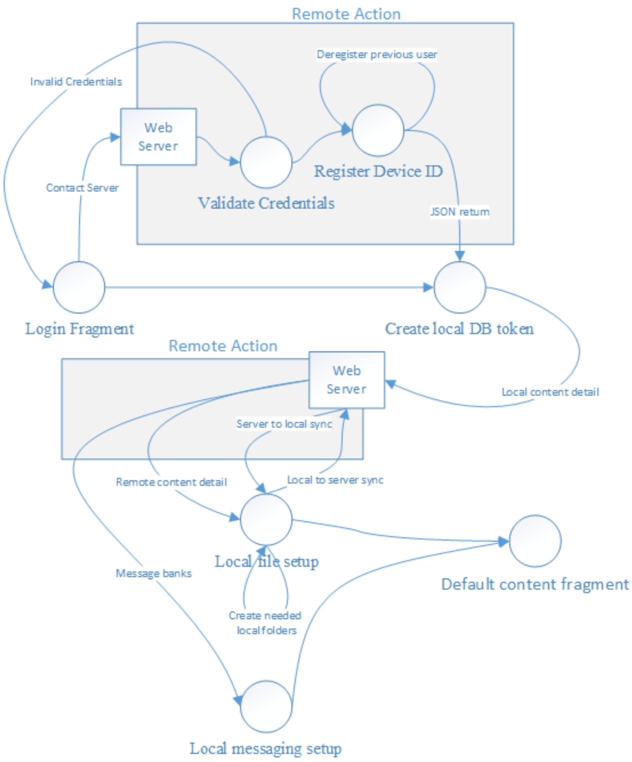


Figure 6.6: Login state flow. Users contact the server and provide details. If accepted the server responds with user details stored on the server including any messages and groups they belong to. If the client requires updated files from the server, they are handled through a GET command. On the user's device a database token is created to persist the currently logged in user during periods of application shutdown.

Once received the device checks for valid local directories, if not found these are created and a client side database entry is created for the user, acting as a login token. This database entry provides validation when returning from activity suspension that the user is still the same. In a production version additional constraints would be added to this structure to control session timeouts.

With the server data bundle provided, the application compares the server state to the local device state, creates a sync list of changed file states, and using the latest modification time for files, either downloads updated versions or uploads newer versions of files that exist on the tablet. During this process users are presented with the default fragment screen, but operations are paused while the sync is in progress. From the initial bundle the local device also compares chat messages, teacher's help messages and notes, to ensure the device being used has the latest updates. If users are not currently registered they are given this opportunity from the login screen.

Registration works by providing detail to the server and having these details entered in the `users` table of the database, shown in Figure 6.77. One issue that was observed is when large files are present in multiple groups amongst students that are frequently switching devices. There would be the bloat of user folders, and in a full application this would need to be addressed. At its heart it is a trade-off between downloading data and keeping it locally. By using the internal database that is holding the user token ClaMApp could also track the frequency of when users last logged onto the device and either purge data from users who have not logged on in a designated time, or as the device fills, purge data from the oldest user sources. As this data is not lost, as it is stored on the server there would be no content loss in this design. The user would simply have to wait on the download of new data the next time they used that device.

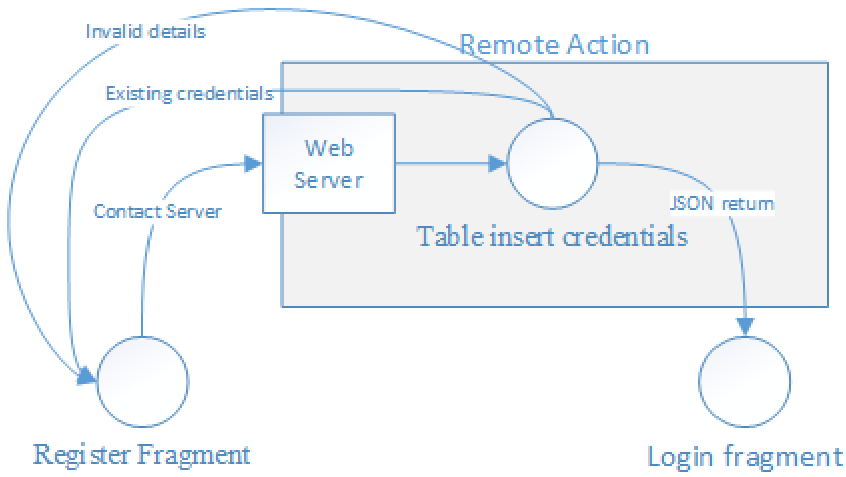


Figure 6.7: Registration state flow. The web server is contacted and database checked for existing credentials, with username acting as a unique identifier. If not present, the user is created and the return JSON informs the user and reverts to the Login fragment. If a user exists, the application is notified.

6 6.2. Default Interface and navigation

Figure 6.88 shows the default personal folder, an individual location unique to the current user, if another student uses the device, they will be provided with their own location. The camera folder while appearing visually to be a separate location is included as a sub folder of the user directory for server cohesion. When images are taken from within the application they are saved automatically to this folder instead of the standard gallery folders provided by Android. This ensures that images for classwork are contained in their own location away from those managed by the operating system.

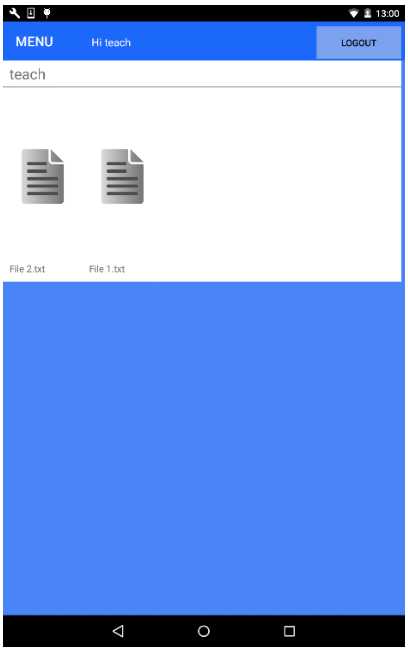


Figure 6.8: The default view when logging in to ClaMApp, showing the users personal folder space. The menu bar along the top provides access to the Navigation Drawer menu, details of the logged in user and logout option.

A string in the title fragment provides simple detail about the currently logged user along with a menu and logout button. When clicked, the logout button deregisters the user with the server and wipes the local database token. When next started without a valid token the application will load to the login fragment instead of the last actioned fragment. The menu button allows access to non-file function actions by opening the Navigation Drawer component. While this can be accessed with “swipe in” functionality from the side of the screen, it was important given the target audience to have an explicit method of accessing the menu as well. Both swiping from the side of the screen and selecting the “Menu” button perform functionally the same. When open the Navigation Drawer menu provides the initial jumping off point to access all non-file functions, seen in Figure 6.99. While the intention is for both versions of ClaMApp to be as close to identical as possible the menu display provided the largest difference, with the teacher having more options, as their role befits. However, the teacher should have no problem interpreting the interface of the student as all of the options present to a student are also available to the teacher.

Students are provided with the same basic menu structure as teachers but lack some of the management tools. From the default view file actions can be accessed by touching any of the file icons present (Figure 6.1010). This will open the file action dialog which provides a similar visual experience to both students and teachers. The key differences are the ability for students to submit a help request for a file, and the teacher's ability to batch Send To… students and groups.

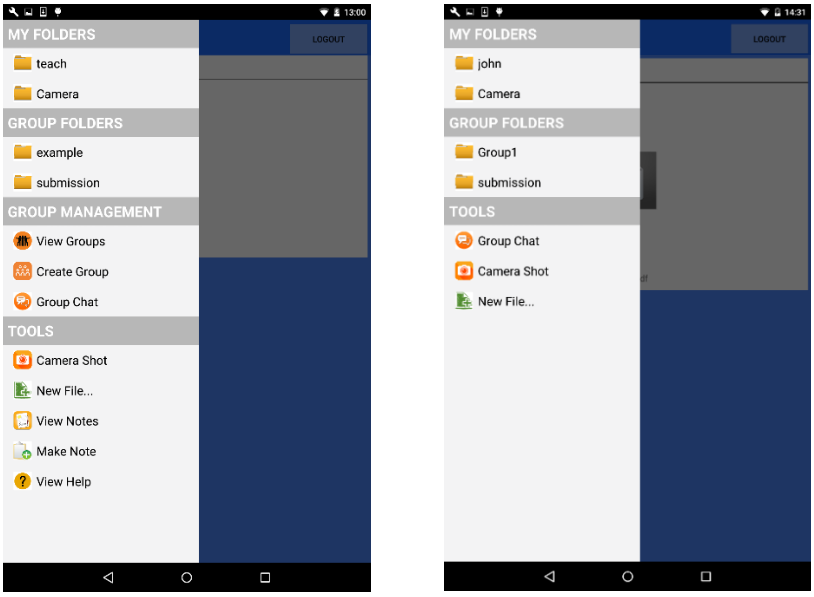


Figure 6.9: The non-file function menus for the teacher (left) and student (right) versions of ClaMApp. Both are controlled by a Navigation Drawer widget. As discussed the teacher version contains all of the same non file functions as the student to ensure expectancy of student operation for teachers.

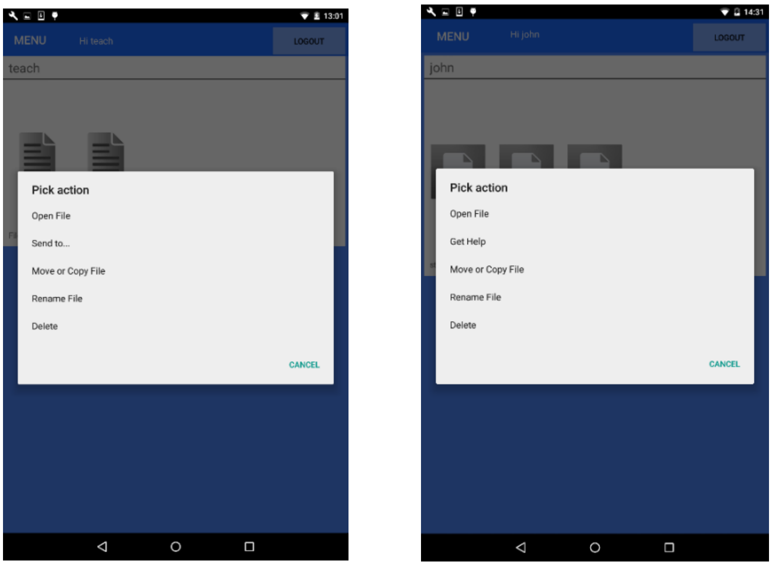


Figure 6.10: The file function menus for the teacher (left) and student (right) versions of ClaMApp. Both are controlled by dialog interfaces and can be cancelled either explicitly or through a loss of focus. The teacher version includes options to batch distribute files, while the student version includes the “Get Help” file function activator.

6.7. File Action operation

All file action operations apply a direct action to the selected file. They do not involve navigating away from the current content fragment and are all accessed through dialog menus. During any file action removing focus from the dialog, or clicking the cancel button, will return the user to the file view fragment they initiated the action from. No state changes are made to a file during the dialog process and in instances of state change to the folder, all state actions must be complete before the action is finalized on the local device.

6 7.1. Open File

Opening files in the application is similar to opening files on a standard desktop environment, the user selects the file and from the menu selects open file (Figure 6.111). As the application is type agnostic this will prompt the device to find a viable MIME type if available and open the file. Any commonly used mobile file types will perform as expected. If the user installs a second program to open the same file the application will prompt the user which program to use, or they can set a default.

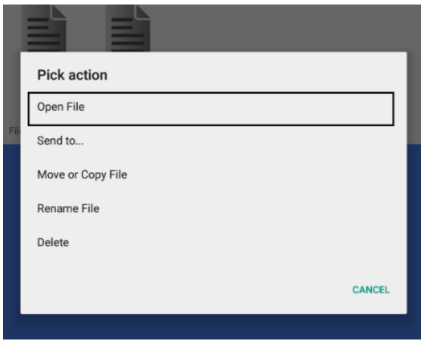


Figure 6.11: The open file option in the file function dialog. Selecting this executes the procedure for attempting to open a MIME type.

It is important to recognize that the app itself does not handle opening and if a file is not recognized as having a valid opening application the user will need to have a recognized app to handle that. An example of this was evident in classroom tests discussed in Chapter 9 where a third party mind mapping application was used during the lesson. In this situation the teacher could distribute the default save file to the students and they could open it because the devices had been pre-loaded with the relevant application, but without it the file would not have opened and there is no defined way of telling what MIME type an application is registered to.

Some special considerations are needed since files are synchronised to a server (Figure 6.122). Due to how Android applications work, when a second app takes priority in the operating system the current app is sent to the background, for example clicking a hyperlink in a pdf document would open a browser suspending the pdf reader application. This means it is difficult to dynamically update an application in the background, as it is not being provided resources. Additionally, if the user is simply reading a document without modification then there is no need to be uploading or downloading files before and after reading. To address this ClaMApp stores the details of a file when opened, tracking the file size and current state. When a user has finished with task actions and returns to the application, the state of the file before suspension and after suspension are compared. If the file details are the same then no further action is taken. If the two states do not match, then the new version is sent to server and the remote version is replaced.

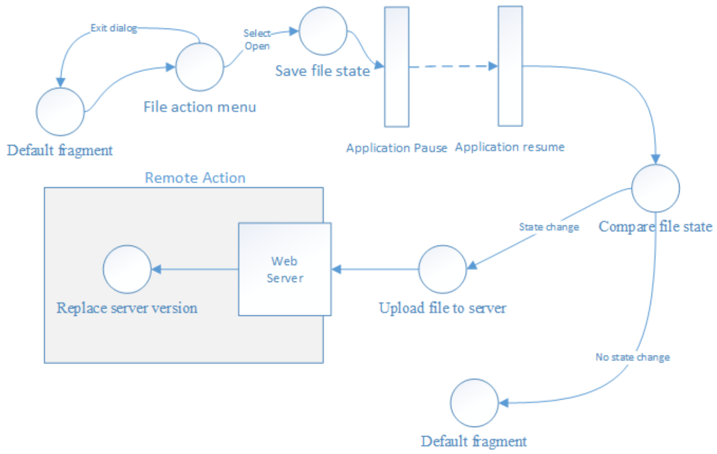


Figure 6.12: Open file state flow. The file is actioned locally and if the MIME type is known, opened. At opening file details are stored before ClaMApp goes into the Android paused state. Upon returning to active operation the current details of the file are compared with the previous version. If there is a difference, the sever is contacted and the new file is uploaded to replace the current server version.

6 7.2. Move or Copy file

Moving and copying files share nearly all similarities between actions and can be functionally grouped. The only primary difference is that a move command deletes the current file after the operation while copy leaves the original intact. This is a purely dialog driven event involving a two-step process for the user (Figure 6.13):

- Pick action
- Pick destination

There are no additional steps for the user if dealing with a group, however the application protects group files from deletion and move by not providing these options when a file in a group location is selected.

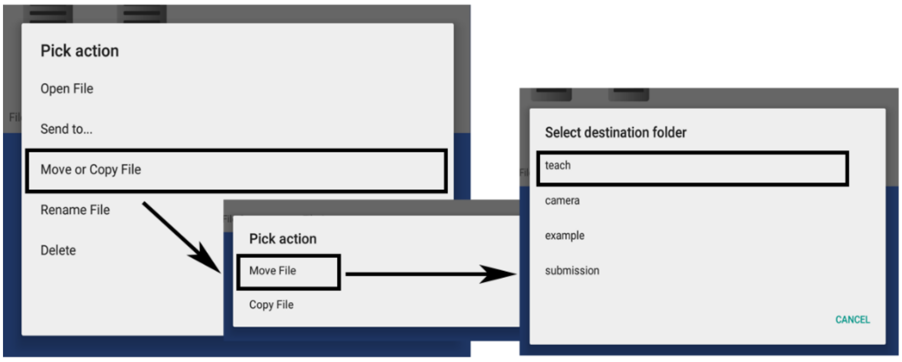


Figure 6.13: The Move or Copy File file function execution. At each selection the previous dialog is replaced. At any stage users can exit explicitly or through loss of focus. No action takes place until a destination folder is selection at the end of the sequence.

Should the user abandon the dialog mid choice there is no change to the file. Upon the selection of a destination an attempt is made to contact the server and notify it of the movement order. The server contact contains the details of the file and a flag for the operation as a move or copy. In the case of move, the server will replicate the file in the new location, and then delete the old version.

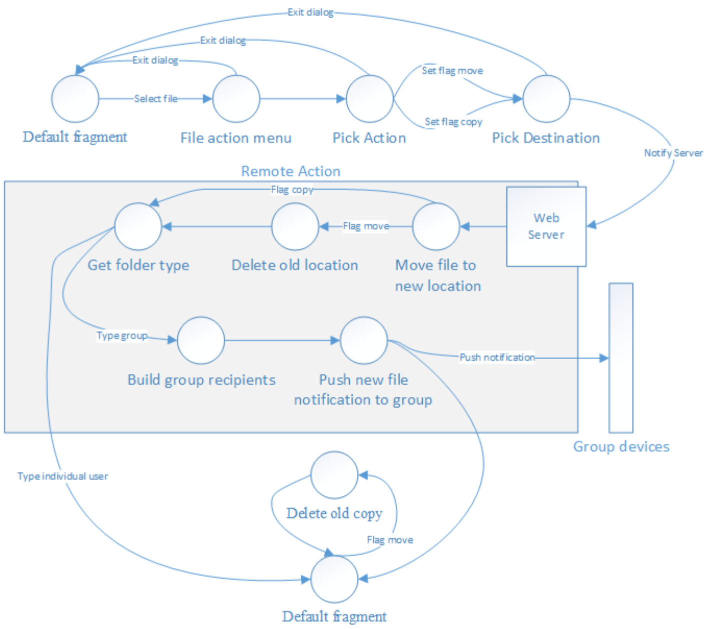


Figure 6.14: Move or Copy File state flow. Move and Copy actions are functionally similar, with Move having an additional deletion stage at completion. If the copy is legal (no version of the file already exists in the location) the local copy is prepared for moving, and the server is contacted. The remote version is copied to the new location and ClaMApp notified. The application then completes its own copy action and, in the case of Move, deletes the old version. In the case of group actions other group members are notified of a new file to download.

If this action is successful, the client is notified and the file is moved to the new location and the initial version deleted. In a situation where the server cannot be contacted the device will note a lack of reply and perform the action anyway. In the case of files being copied into a group folder by a user the process remains mostly the same except where the target directory is a group space a further action is taken by the server. An additional message is pushed out to all other members who are in the group and currently have a registered device, informing them that a file is available for the group folder. Group devices will then download the new file, preserving sync. This process is shown in Figure 6.14.

6 7.3. Teacher Send To

Teachers also have an additional copy mechanic to allow them to batch send files to students, represented by the Send To… option. From here teachers can quickly send files to either a student, a group, all students or all groups (Figure 6.15). The distinction between all students and all groups is the destination folder that students will receive the material, i.e. individual or collaborative folders.

Figure 6.15: The Send To... file function. This function works similarly to a Copy command, with four explicit pre group options. As with Move or Copy File each new dialog selection replaces the previous and can be exited explicitly before the final stage with no device state change.

This operates with the same visual presentation and steps as a move copy and behaves functionally in the same way as a copy command, with the same state flow as shown in Figure 6.14. When a Send to… request is made, the server JSON contains a bundle of the intended usernames. As a teacher is always a member of any created group they will always have a local directory of all groups. Files are then copied to server locations for intended students and the server then uses the device allocation table to look up the devices in use by students currently and to inform them that a new file is waiting for download. For offline students the material will appear as un-synced files in groups they belong to the next time they log on and will download as part of the initial synchronise bundle.

6 7.4. Rename file

Renaming a file acts as expected, changing the file name on the local and remote version. When selected users are presented with a dialog option to enter the new filename, shown in

Figure 6.16. They can then enter the new filename, the server is then informed of the change and adjusts remote file version.

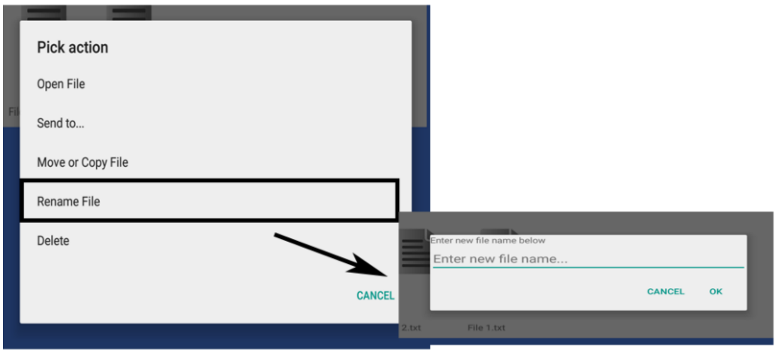


Figure 6.16: The Rename file function. Activation produces a dialog box where the user can provide a new file name.

The rename function requires that in order to successfully complete the server must be accessible (Figure 6.17). This is to avoid disassociation with the server version especially when dealing with group files, and if it is unable to do so will prevent the local version from renaming. If the rename is successful on the server side the local version will be renamed.

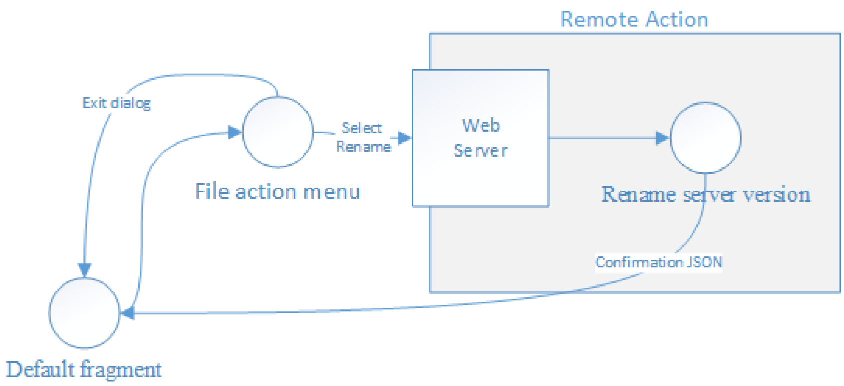


Figure 6.17: Rename file state flow. To avoid desynchronization, the server must contactable before ClaMApp will allow a file name change. If it is the server will change the remote file name and notify ClaMApp that it is allowed to change the local name.

6 7.5. Delete file

Deleting a file is a simple single action with a confirmation prompt, shown in Figure 6.18. As with most delete actions users will encounter in other environments they are warned and prompted that a deletion is permanent.

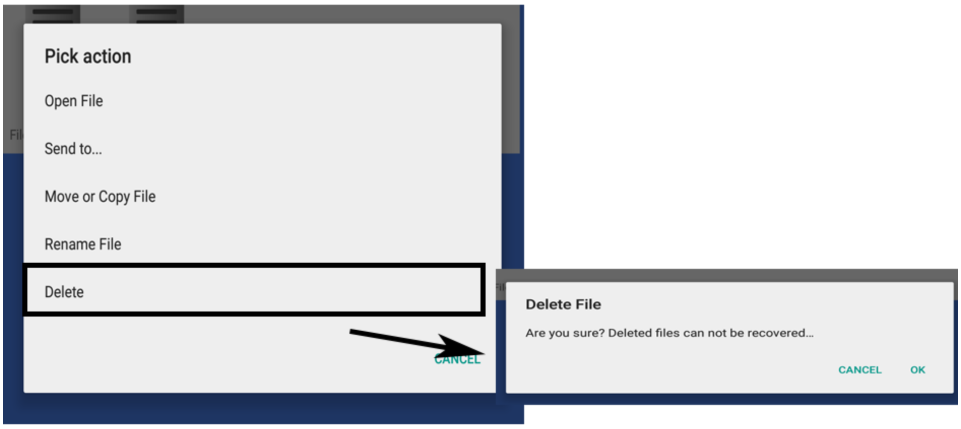


Figure 6.18: The Delete File file function. Users are provided a secondary prompt for confirmation to protect against accidental deletion.

As with renaming, there is the possibility of desynchronization between server and local device so in the case of deleting a check is made to attempt to delete the server version (Figure 6.19). If this action is successful, the server returns a confirmation to delete and the device will delete the local version. While students and teachers are both free to delete any files from their own local spaces, by default only teachers are able to delete from shared group spaces. Students would be advised to copy over working documents they may wish to edit or delete to personal folder spaces

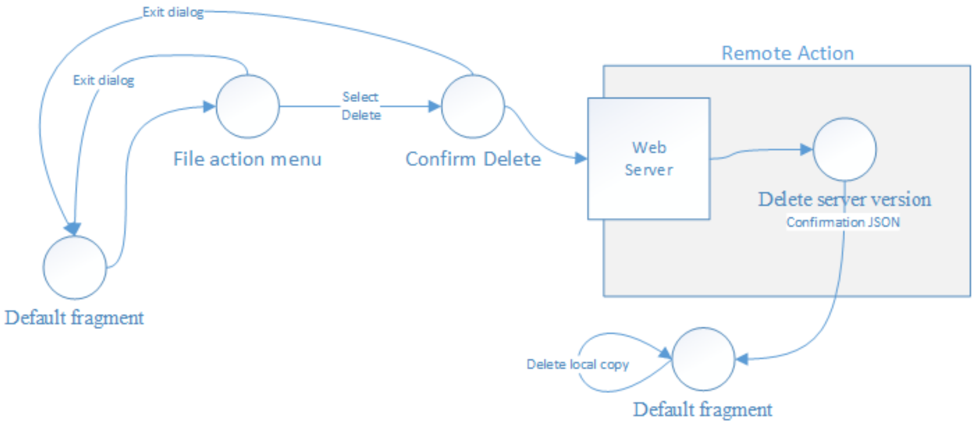


Figure 6.19: The Delete File state flow. Deletion can only occur when the server is accessible to prevent desynchronization. The server is contacted to remove remote copies of the file. On the success of this operation ClaMApp is notified to remove the device copy.

Functionally when called and confirmed, delete will contact the server and check the folder status of the file. While the device checks before contacting the server if a file is allowed to be deleted by the user, the server contains a second check to establish that if the file is stored in a group location the user asking for the deletion is a teacher. If the conditions are met the file is deleted remotely and the local device is informed, allowing it to delete the local copy. In the case of a teacher deleting a group file the server sends a message to group devices and initiates a delete, while a message will display to users that the file has been deleted.

6 7.6. Student Help Request

The request help function is an implementation to provide student to teacher communication channels and is only present on the student platform. When selected, students are provided a dialog comprised of two components, allowing them to provide some additional detail for their help request (Figure 6.20):

- One of these is a small text box where students can give a simple message
- The other is a sliding scale to represent the level of difficulty they are having with the file.

When submitted, users are acknowledged with a short pop up prompt that their message was successful, and the message is registered to the teacher's device. Help requests are tied to the file that they are actioned from, providing direction as to what is causing the issue.

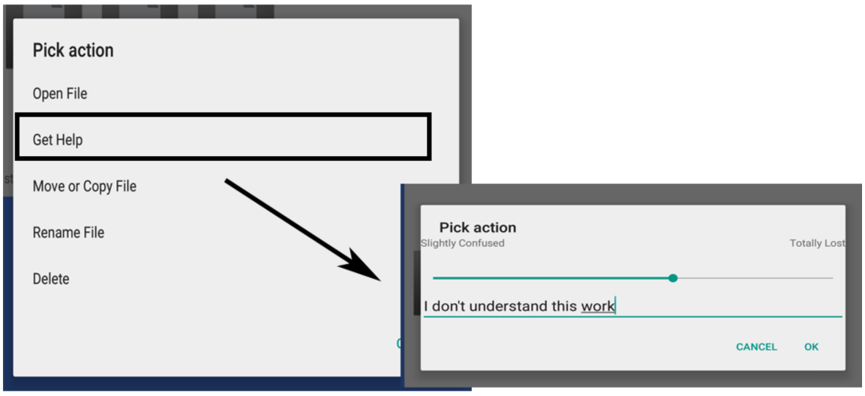


Figure 6.20: The Get Help file function. Users are provided with a dialog where they can choose the level of distress from a slider and include a textual explanation of any issues.

When submitted, the server is contacted and a database entry is added to the relevant table, logging the issue, shown in Figure 6.21. If currently registered, the teacher device is then contacted with the details of the help message which is added to the local message banks.

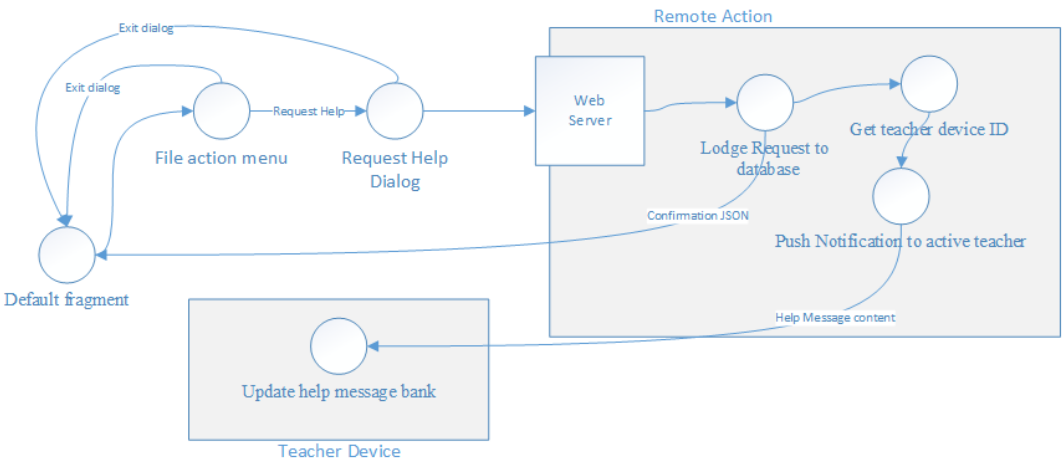


Figure 6.21: The Get Help state flow. The remote server is contacted and the details of the message are entered into the help_requests table. The server checks if the teacher is active and if they are the new

help message is pushed to their registered device. If no teacher is registered the new message will be downloaded when the teacher next logs in as part of the standard login synchronisation.

6.8. Non File actions

6 8.1. Folder Views (Default view)

Users have two personal folders at their disposal, their own personal location and a folder where pictures and media from the camera are stored. The personal folder is named after the user's username while the camera folder is titled Camera. Additional folders also exist for all groups a user belongs to. Visually all of these folders are the same and present their files in the same manner as noted in the default view. A visual reference for this is found in Figure 6.8.

6 8.2. Group Chats

For every group that is created a server side chat record is created as well. When a user logs in to a device they are provided with all past messages associated with a group, however it is necessary that messages also be updated in real time to provide synchronous chat. When selecting the group chat option from the menu a dialog selection is used to allow users to view the chat group for their desired group, with each group having its own distinct chat. Once selected users are taken to the chat fragment, shown in Figure 6.22. In order to return from these replacement fragments, users reselect their desired folder from the menu. The fragment itself contains a simple running display of text messages. While the device uses a username as a login identifier, within a student chat group it is not appropriate that they be referred to by usernames. Rather when chat bundles are updated group members' real names are pulled from the message and stored in the bundle. This ensures that when a user comments others will see their actual name rather than a username.

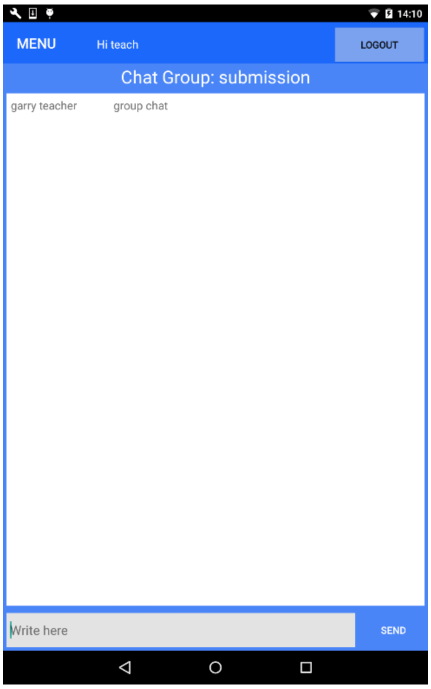


Figure 6.22: The Group Chat non-file function. Messages from group members are displayed in the fragment window. Users can type messages into the grey message box and send them to the group by clicking SEND.

Students can text chat in any of the groups they belong to by simply typing in the box at the bottom and pressing send. Messages are then forwarded to the server which relays them to all currently active devices in the group.

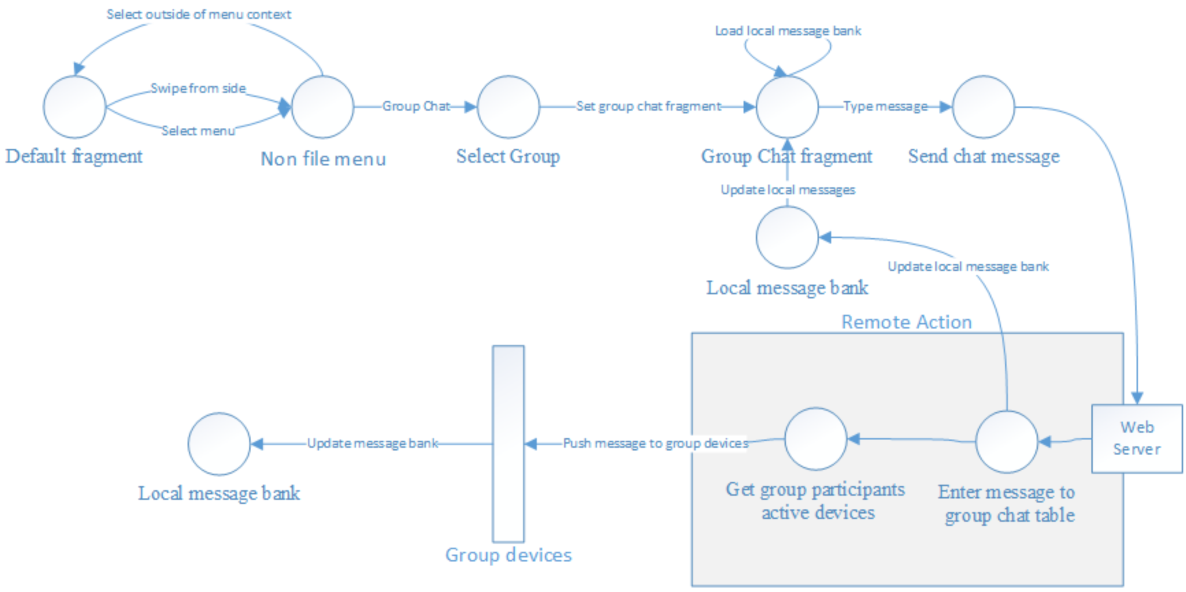


Figure 6.23: The Group Chat state flow. When messages are sent from the Group Chat fragment the message is sent to the server and entered into the relevant group chat table. The server then checks for currently connected group member devices. A notification containing the new message is then pushed to the devices and the relevant local message banks are updated. If the user is currently in the chat fragment upon notification, the fragment is refreshed.

When a device is first synced to a server part of the authorization bundle contains a package of objects, each containing the details of a group's message bank. If a user is added to a group during a session, thereby not having an existing message bank, one is created at that time. When a message is sent to a group the server is contacted and the content transmitted. On the server the appropriate group chat table is updated with the message and they are sent out to currently connected group members. In this situation if the device is not connected to the network when the message is sent it will be propagated the next time the application performs a full synchronisation, this process is shown in Figure 6.23.

6 8.3. Teacher Create Group

Figure 6.24 shows that teachers are able to create groups easily and quickly by selecting the Create Group option. Initial implementations of the function attempted to use the dialog system but this had a number of limitations. Chief amongst these was the amount of information required for display, especially when dealing with a larger list of students. While a small list of under 5 users worked acceptably this was not realistic of students in a classroom and the dialog quickly became unmanageable. It was also found that this task required a significant time investment from the user that an accidental cancellation by touching outside the dialog menu, could cause unacceptable frustration. When coupled with the mentioned size issues and the fact users would almost definitely have to scroll around the dialog, this system was abandoned for a fragment screen. This provided the maximum screen space for viewing students as well as preventing accidental exit from the function. To address being stuck in the function menu after the action and to preserve the app design of returning from functions to the original state, the previous fragment is stored. At the conclusion of the group creation, or at cancellation, the user is returned to the previous saved state.

From within the fragment teachers can supply a group name and are provided a real name list of all students. A group can then be created by tapping student names and copying them to the right-hand list. Similarly, they can be removed from a group during creation by tapping them out of the Group Members list. Once satisfied with their group structure the user can press the create group button to create the group, returning to the starting fragment state. At any stage they can abandon the process with the Cancel button and return to the starting fragment.

When a group is created the server is notified with a bundle containing a list of all members, the teacher and the group name. When this bundle is received a table is created listing the associated users. A table is also created to manage chat messages within the group with a naming association to the group table; a group called "experiment group" would result in a user table titled `experiment_group` and an associated chat table of `experiment_group_chat`.

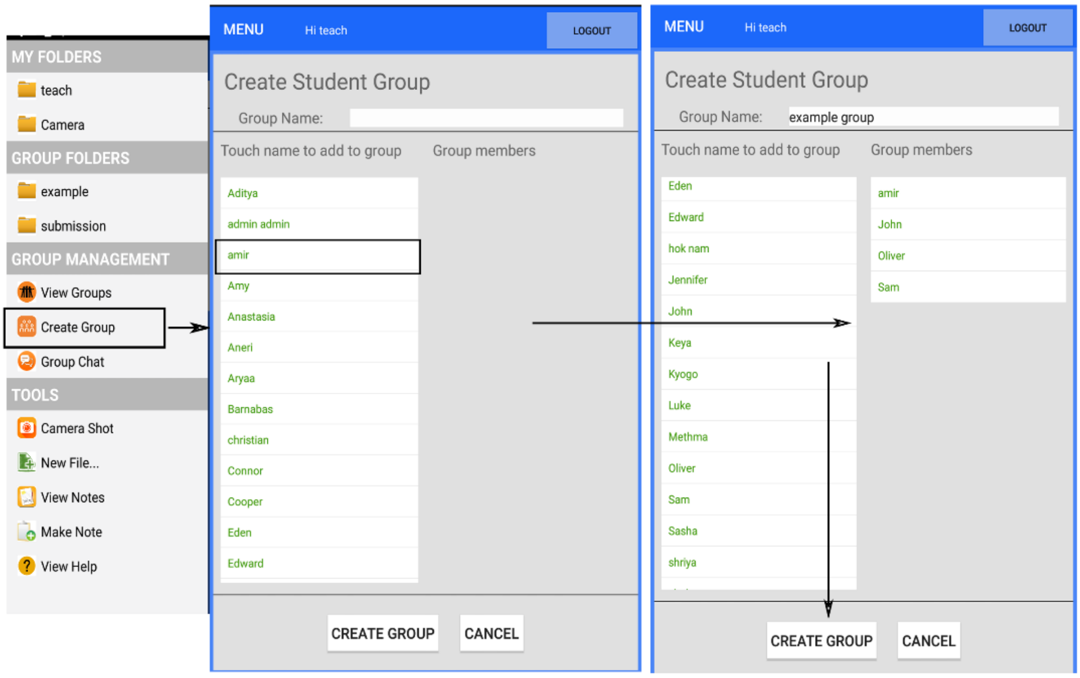


Figure 6.24: The Create Group non-file function. Upon selection users are taken to a new fragment. Here teachers are provided a list of all students (left list) and can select them to move them to the right list as group members. They must also provide a name for the group. They can cancel at any time by clicking cancel or navigating away from the fragment via the menu. Upon creation they are returned to their previous fragment.

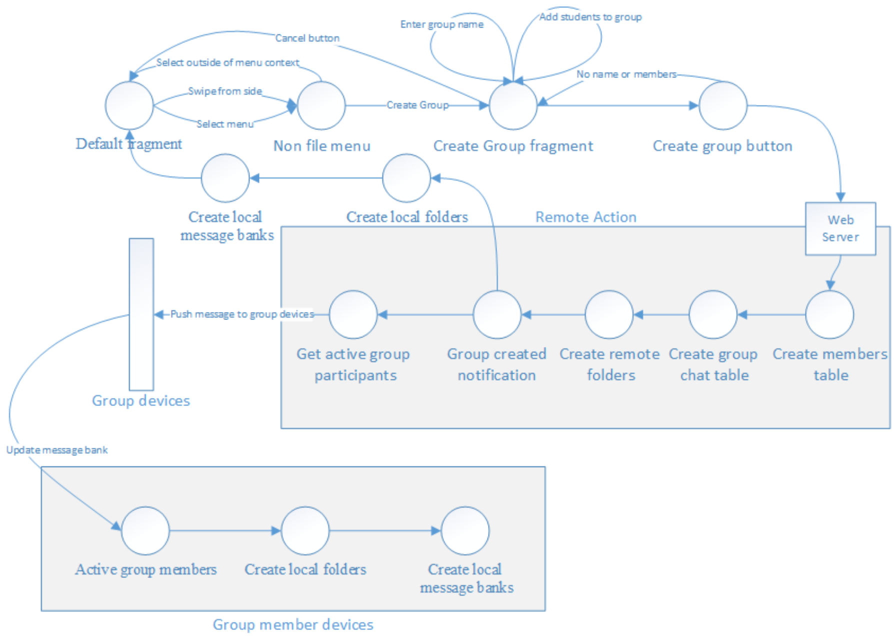


Figure 6.25: The Create Group state flow. Once the teacher has performed the group naming and student selection the information is bundled and passed to the server. The server creates tables for the group users and an associated table for storing chat messages. A local directory is also created for any group files. Once this is done the server notifies any registered group members. At a device level ClaMApp creates a local folder for group work and an associated chat bundle for future messages.

Once the tables have been created the file handler creates an associated directory within the folder structure. Lastly a message is sent to all users who are contained within the group and currently registered to a device to inform them of their addition to a group. On receiving this message, the local device creates the necessary local directories and updates the user interface to allow access to chat group and folder areas (Figure 6.25).

6 8.4.Teacher View Group

View group allows teachers to review members and remove groups. When the function is selected the user is presented with a list of current groups and can select the group to review, shown in Figure 6.26. In review, they are provided with a dialog overview listing the group name and the members of the group with the option to cancel or delete a group. If deleted the group is removed from the group features and users are notified of the groups dissolution. When a group is deleted the server is notified and the tables associated with the group are dropped. The next time a user in the group logs on to the application they will be unable to access group files through the application. Additionally, their group files will no longer attempt to synchronise with the server, this is detailed in Figure 6.27.

However, as noted, as there are cases where students may still need group files the local folders are left intact temporarily. This provides a buffer for students to get the documents. Should a teacher wish to ensure all group work is gone from the group they can delete the files before removing the group.

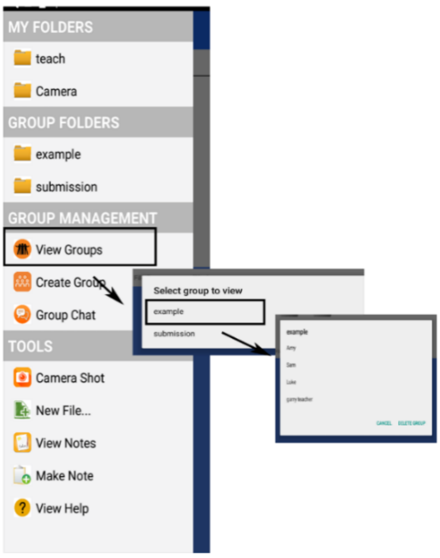


Figure 6.26: The View Groups non-file function. Upon selection teachers are provided a dialog of all existing groups. Selecting a group provides a new dialog containing that groups information and the ability to delete the group.

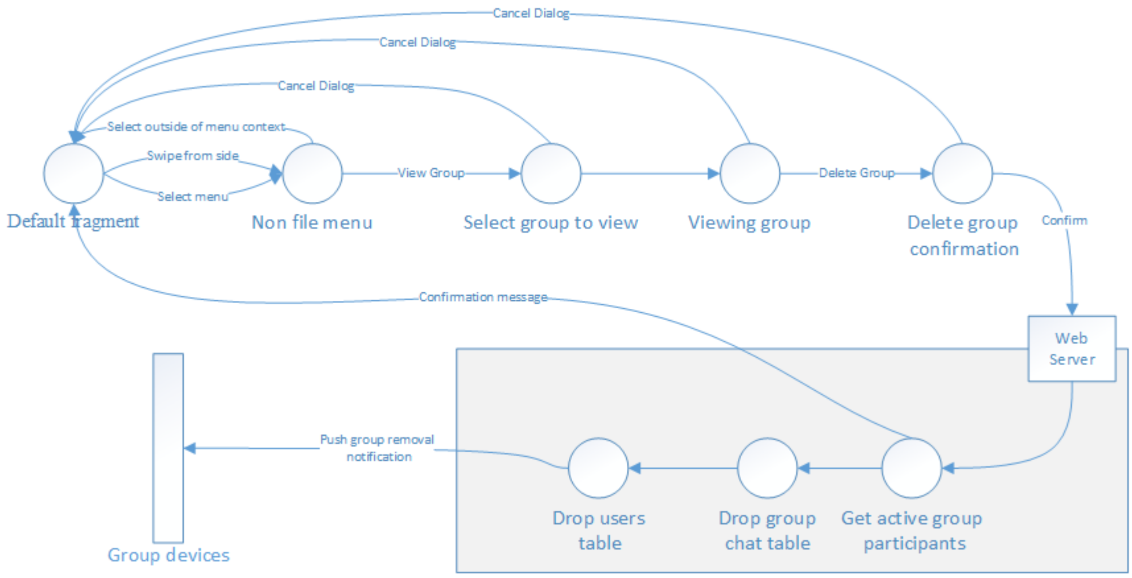


Figure 6.27: The Delete Group state flow. A simple view causes no server interaction. Selecting to delete a group cause a notification to the server. The server will delete database entries for the user list and chat. Remote files will then be deleted from the server. Registered devices of group members are then notified of the group deletion and folder access from within ClaMApp is removed.

6 8.5. Camera Shot

While students are still able to use the standard camera features of the device how they wished ClaMApp employs a method for allowing them to quickly and easily add to the application internally. This allows users to easily associate media files with the app without needing to go through copying from gallery locations and ensures that class work photos taken by students are directly related to that student. This prevents a multi user device situation where the images of all students registered on the device would be stored in the same gallery location. When actioned the application suspends to launch the camera operation (Figure 6.28). This is the standard camera interface used by the majority of apps that utilise the camera in some way. From here students can take a photo and upon acceptance of the shot they are immediately returned to the starting fragment. This behaves in a similar manner to opening a file. Taken images are then available in the camera directory, this flow is detailed in Figure 6.29. By default, the images are provided a system generated file name however the user can define a meaningful name if they wish using the Rename function. Once a picture is taken and the user is returned to the application the camera file is subject to the same functionality as a changed file and uploaded to the server to store the remote copy.

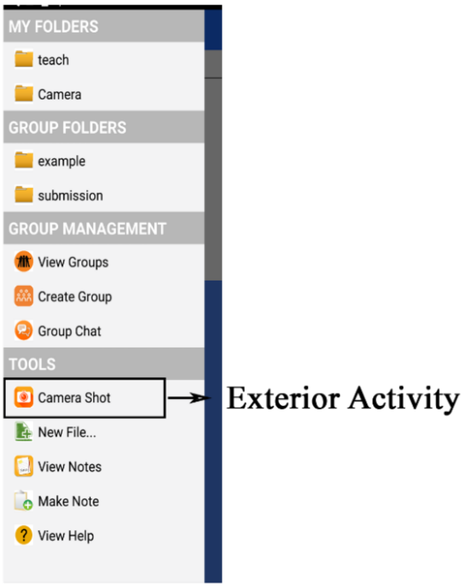


Figure 6.28: The Camera Shot non-file function. Selecting this initiates the devices camera functionality.

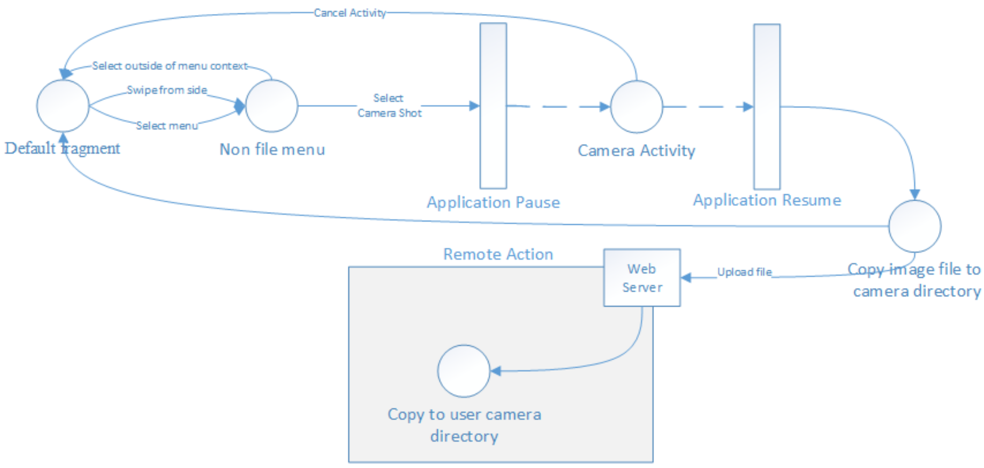


Figure 6.29: The Camera Shot state flow. Upon selection ClaMApp is suspended and the devices own camera functionality takes over, until the user exits. Upon exit ClaMApp resumes and copies the current buffered image or video to the user's camera directory. The file then behaves as a normal file and synchronises to the server, storying a remote version.

6 8.6. Create file

Users require the ability to create files as needed. They can do this using the create file option. As this is prototype software, supported and MIME types are creation specific, limited to text and doc format (Figure 6.30). This does not mean that these are the only types of files the application can open, but additional structures would need to be added to scrape available MIME types, parsing if they can be used in a creation context. For example, there is limited benefit to creating a pdf file as it would contain no data and is not generally edited. Also as testing devices would be stock there would be minimal editing programs available. Users are prompted to select a location for the file from a dialog providing a list of available directories, including any groups the user belongs to. Once selected the user can provide a filename and select the type of file. This creates an empty file of the type in the specified location.

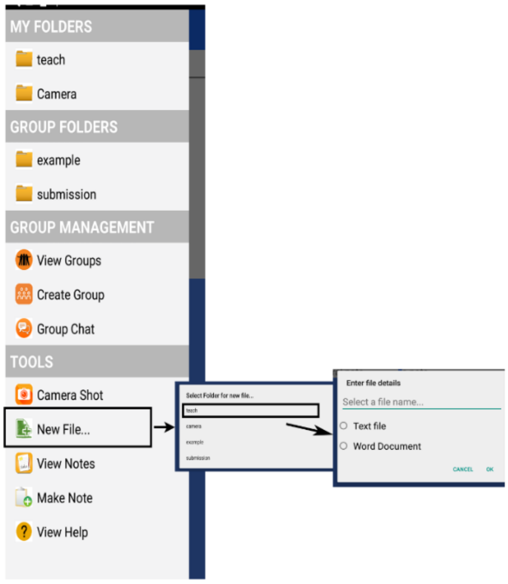


Figure 6.30: The Create File non-file function. Selecting this action creates a dialog requesting the intended storage location. Upon providing a location a third dialog requests a file name and type. In this version of ClaMApp creating is explicitly defined for word and text documents.

When created a local version of the file is instantiated and then defaults to the standard sync pattern employed on a file change or picture addition, uploading the file to the relevant remote folder, as shown in Figure 6.31.

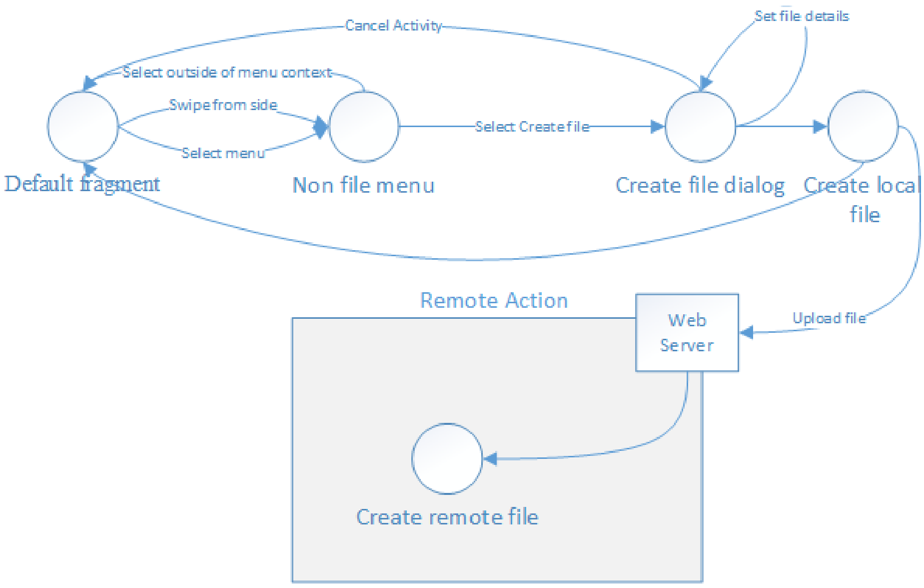


Figure 6.31: The Create File state flow. Upon naming, selecting type and creating the file a local version of an empty file of type is created on the device. The server is then notified and a remote version of the same file name and type is created, effectively acting as a placeholder.

6 8.7. Teacher Create Note

Teachers can, if they wish, create short notes that are stored in the application. Due to the prototype nature of the app rather than include a host of self-assessment metrics a generally applicable option was selected.

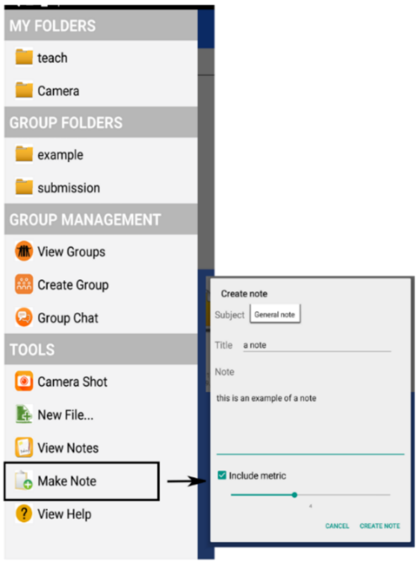


Figure 6.32: The Create Note non-file function. Upon selection the teacher is provided a dialog interface where they can specify a subject, title and content for a note. If they wish they can include an arbitrary metric, provided by a slider.

When selected the user is provided a dialog containing detail fields for Subject, Title and the content text (Figure 6.32). The subject drop down provides the options for a General note or a note relating to a specific student. While it is not necessary for a general note to show the additional features that could be implemented, the dialog style notation system included a metric slider that could be toggled by the user.

Created notes behave similarly to chat messages and are added to the local device note bundle, and uploaded to the server where they are stored in the database notes table, shown in Figure 6.33. However, as this is a one-way communication, if the server cannot be contacted there is no impact on device operation or sync. In this case the application simply waits until it can contact the server to upload the note. The only instance this may cause an issue is when a teacher's device cannot connect to the server before they log onto another device, in which case their notes may not be synced, however this could be remedied by simply logging into the previous device.

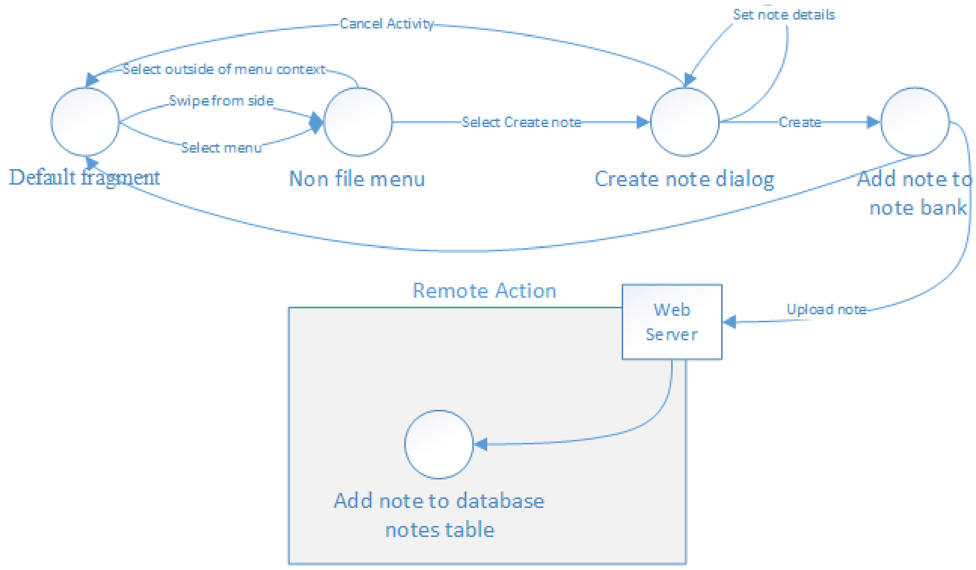


Figure 6.33: The Create Note state flow. Upon creation notes are added to the local note bundle. ClaMApp will attempt to then send the new note to the server where it is stored in the teacher `notes` table.

6 8.8. View Note

Teachers can view any notes made through the View Notes menu, shown in Figure 6.34. Rather than use a dialog this function uses a fragment display. This is primarily because the function has no defined end point and the teacher may want to view one or many notes. This content fragment presents all notes in a list that the user can tap on. When selected, notes are opened in a simple dialog view providing the note details. From here users can review the information, cancel the dialog or delete the note.

Deletion of notes is a straightforward process of removing it from the local bundle and notifying the server to drop the note from the relevant database table, this is detailed in Figure 6.35. Much like note creation, this is a one-way notification when the server is not available the app simply waits until it is available to update.

Figure 6.34: The View Notes non-file function. When selected the teacher is taken to a fragment containing a list of all notes in the current local bundle. From here selected notes are displayed in a dialog where the teacher can peruse the content or delete.

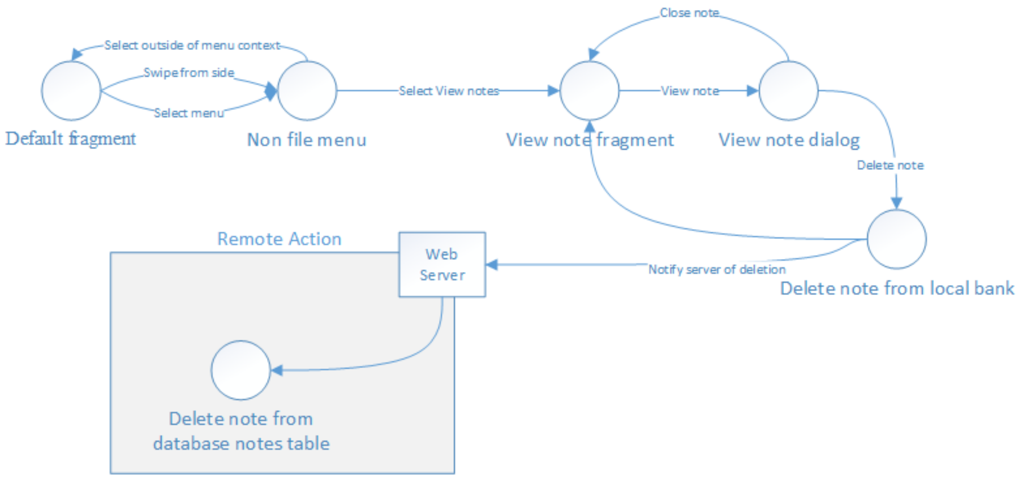


Figure 6.35: The View Note state flow. Selected notes can be viewed from within their fragment and deleted is desired. Upon deletion the note is removed from the local bundle and the server is contacted with instructions to remove it from the `notes` table.

6 8.9. Teacher View Help

When a student submits a file help request they are updated to a server table. A notification is then passed to any logged in teacher devices. Teachers can select the View Help to activate a new content fragment similar to the View Notes fragment. For the same reasons as View Note, the view help uses a fragment instead of a dialog display. Similarly, all help messages are presented as a list containing the originating student, and the file they have had issue with. The teacher can select the message they wish to view, opening a dialog containing the help message detail. This is shown in Figure 6.36. From here the teacher can again choose to cancel or delete the message, and also to mark the note as read. This simply changes the hue of the note to provide a visual cue to the user when looking at the view fragment that a note has already been addressed.

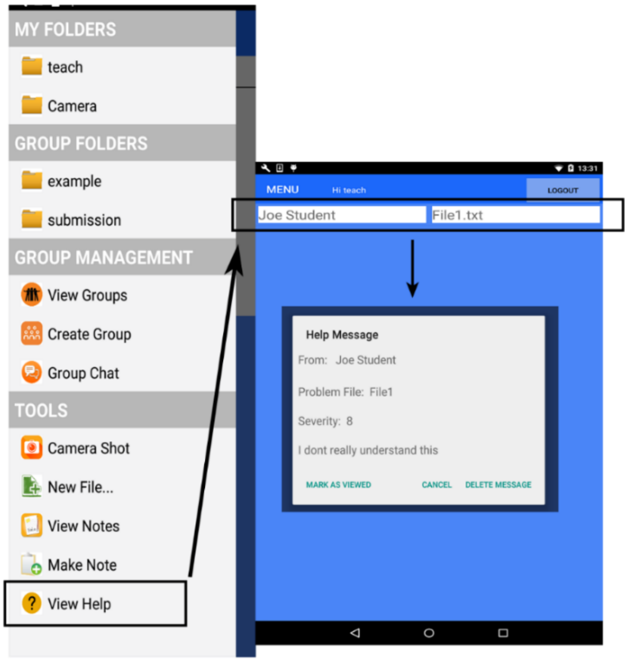


Figure 6.36: The View Help non-file function. When selected the teacher is taken to a fragment containing all student help request in a list. They can then select items from the list to display a dialog with the request contents. From here they can mark a request as read, cancel or delete the request.

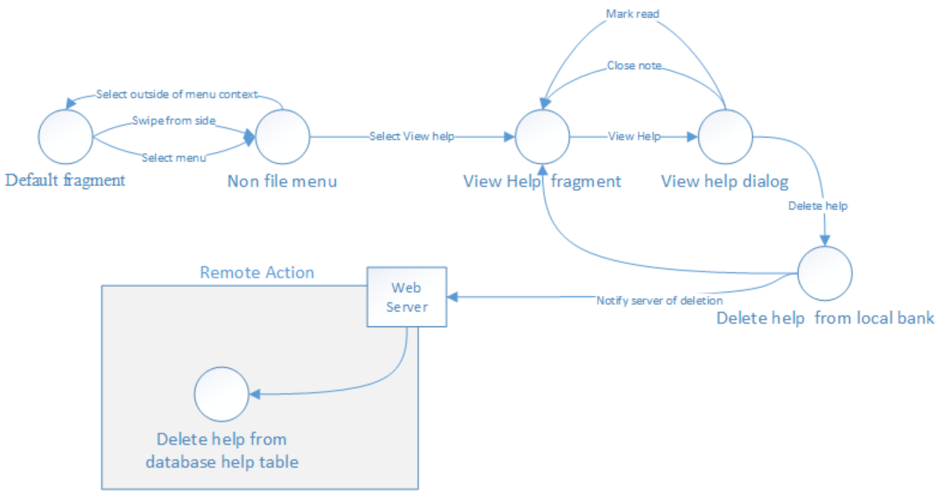


Figure 6.37: The View Help state flow. Help messages are loaded from the local bundle. If marked as read the local bundle is updated and the server is contacted to modify the entry in the help_requests table. If delete is selected the local version of the request is removed and the server is instructed to delete the request from help_requests.

As noted in student request help, when they submit a request the server populates the teacher's device with the help request. When viewing the fragment these requests are displayed and if marked read or deleted the server is notified of the status change of the note, thereby editing or removing it from the database (Figure 6.37).

6.9. Summary

When considering the factors that define ICT adoption by teachers, perception and expectancy of outcome are primary factors. These can be overcome with sufficient professional development but many teachers are reticent to spend large amounts of time on technical literacy. This resistance is amplified based on purely technical software applications. To counter these concerns, this chapter proposed the ClaMApp software to provide the most common LMS functions in an easy to use and learn tablet application. ClaMApp utilises the advantages of the native mobile interface to create a streamlined approach to functions that should allow for high confidence of use with little to no training.

Teacher and student versions were constructed with similar functionality, with ClaMApp providing file and non-file functions in a server synchronised environment. The software allowed for easy and robust file manipulation without impinging on the functionality of the tablet devices as a pedagogical tool. Non-file functions provide collaborative and communication channels for teacher-to-student and student-to-student communication, while providing collaborative spaces to share work among groups. The tablets natural multimedia functionality was also leveraged to allow personalised image storage on a per student basis.

This Chapter looks to target the core Research Question 5 (R.Q.5) through the design of software targeted to address these teacher driven elements, a further investigation of the usability and learnability of the ClaMApp software, and a deeper discussion of this question, along with the testing, refinement and in class testing of the software is presented and discussed in Chapter 7, Chapter 8 and Chapter 9.

Chapter 7

Usability Study 1

USABILITY STUDY 1

7.1. Overview

This chapter presents the initial testing for the ClaMApp software. It establishes the testing framework that will be the baseline for this and future testing, including the metrics that will be used to assess the application. This testing suite focuses on per function testing as well as overall usability and learnability of the software.
Following these testing parameters, a usability study was performed to judge the performance of the first iteration of the ClaMApp software with a focus on navigation and task execution in a controlled environment with simple function operation.

7.2.Background

In order to ascertain the usability of a piece of software it is essential that some level of user testing be conducted. While this chapter does not directly address the Research Questions, it provides the initial assessment of the software and useability feedback essential to ensure that when tested with the target audience simple usability concerns will not be at the forefront of any experienced issues. These formative and summative tests are essential to ensure that software is effective in achieving its goals and while these goals themselves may shift from application to application a definition for the idea of usability at least is something that can be specified. In this case as "*the extent to which a product can achieved specified goals with regard to effectiveness, efficiency and satisfaction within a context of use (International Standards Organisation 1998)*".

While there is limited direction as to how these goals are met, the history of usability experimentation can provide some context on generally measurable factors (Sauro and Lewis 2009):

- Completion rates
- Task times
- Task level satisfaction
- Help access
- Usability problems

As well as these elements it is important to ensure some common flaws in usability testing are accounted for. These include that the outcome of operation is assessed, that there is a clear delineation between the times and results of the material, and that results surveys are standardised using current to task options (Hornbæk 2006).

As with any application development it is always beneficial to test incrementally rather than do full scope user testing immediately and as this application is intended for complex, long term use a staged usability examination is beneficial. This begins with testing to ensure that the intended goals of easy learnability and hierarchal ease of navigation are preserved. This follows with the ideals of usability testing being primarily formative and conducted, at least initially, on improving design and function actions. Having a solid quantification to these tests is essential. While the designer has a solid understanding of software operation this position of knowledge makes it difficult to perceive how users will approach the app in a real world environment. Additionally, as noted one key aspect is ease of learnability and this cannot be deduced without outside input.

The goal of this initial test was small scale, isolated, formative task-based testing with a solid framework of qualitative measurements. Focusing largely on interface and operation metrics this study ignored the practical application of the software within the classroom. It was decided to not conduct in situ testing until the application was at a point where there was confidence operational bugs would not overly impact pedagogical functionality.

These iterative usability studies would occur until, based on metrics, there was sufficient general usability of the software and encountered no performance altering bugs at the task level, especially with regard to the inability of the user to complete the tasks. Before deciding on the specific test apparatus it was important to classify and understand the domains of the application for this test.

7.3. Testing Structure

For this test there were had three key domains to assess:

- basic interface navigation,
- logical core function state flow, and
- identify any serious operational bugs

While there is merit in gauging the perceived usability from participants for the app overall, serious flaws in any of these three areas could be a significant impactor and until they were addressed any overall usability metric could not be supported nor believed.

7 3.1.Basic Interface Navigation

At the heart of the software usability experience, accessing functions and features should be a straightforward experience requiring limited to no direction or learning. These functions should involve actions like file copying, creating groups, navigating to file folders and using the device’s multimedia features. However, excessively repeating a task that may be tied to a poorly implemented or bugged action provides little relevant feedback.

Simple task design ensures that actions are as self-contained as possible and rely on single function input, providing more directed formative assessment; when a user copies a file, only that function should be performed, avoiding compound function execution. Throughout this work when speaking of compound tasks this assumes the need for multiple application operations as defined in the application function set; copy a file and make a note would be two separate tasks. This ensures that confusion or erroneous behaviour detected are solely function specific.

7 3.2. Logical State Flow

The second area identified as important is that the features themselves follow a logical path of execution; it is unavoidable that some actions require multiple steps to achieve their goal. An example of this is file copying which by its nature can only be reduced to three possible steps:

- Select file to action
- Select operation to copy
- Select destination

Yet while for an operation like file copy the flow is generally defined by previous software implementations, it is less obvious in the mobile space where actual file action is generally avoided and alternate interface operations are more difficult (for example drag dropping). From the tablet interface perspective, screen real estate can have a significant impact on the best way to achieve a goal; a traditional desktop multiple windows can make dragging from one window to another straight forward but not on a tablet.

These issues while present for traditional operations are exacerbated when addressing the app specific functions. Actions like creating groups and making use of multimedia operations require non-traditional flow of control design, as laid out in 6.4, yet the implementation of these functions could have a significant impact on the usability of ClaMApp by unfamiliar users.

7 3.3. Bug detection

The last domain this study examines is general bug detection. When examining ClaMApp this is important due to the non-traditional designs employed; outside of the general app design philosophy of bite size, one function operation and its use of a remote server.

This is also essential due to the operational environment of tablet use. Unlike traditional desktop software that operates as a fully functional background application, in that the process is generally running in the same state regardless of its current system priority, tablet and mobile devices are different. When looking at tablet process management, applications that are heavily impacted in their resource and services allowance by being moved to background operation need to account for this. It is an important area to address as the resumption of operation with a very high likelihood of a changed state may require resource updating. A key example of this occurs when making file modification. Here a file opening will supersede the application priority and force a suspension. When control is returned to the application the state change made to the file must be addressed for not only the current user but any collaborative partners involved. Ensuring that this occurs in the right order and without error is essential.

7 3.4. First usability study

As noted the initial study looked at three important areas with an attempt to minimize cross functional operation when possible; it is unavoidable in some instances. Additionally, the study was designed to avoid any significant repetition of functionality. As this study was an opportunity to examine function operation on an unknowledgeable user and as high learning is a design goal, repeated action of the same function may obfuscate the experience of first time use. Rather the focus is on single function "basic" operations and navigation. These included feature set navigation in the form of:

- Creating a group
- Creating a note
- Accessing help messages
- Using the camera for a single picture

For file functions the focus was primarily on assessing the user's ability to open and use file features focusing on:

- File Copying
- Requesting file help

When considering measurement criteria for these actions it was important to consider the user groups that would be tested. While for general formative bug testing general users are acceptable, as the goal was simply the usability of the interface outside of a school setting, it was still important to consider the relative impact that user directed testing itself can have on users. The goal was to provide users with a streamlined and responsive experience, therefore complex testing frameworks can detract from that experience, especially at a task level. It is also worth considering how future tests could be compared and what the end target population may find onerous. In this case as the end goal is testing within a classroom a testing solution that provides a low impact to users while still providing necessary feedback metrics, comparable across tests, is necessary.

Testing should also not rely on a single metric when looking for a robust view of software problems. Usability testing should involve multiple tests of differing data types to provide a varied overview of issues. When considering user tests they usually take the form of discrete tests, scales that will provide a range of possible responses. But there is also benefit in using some discrete binary analysis as well.

As additional usability tests were intended to be run it was important to be able to provide solid comparison between the two studies. This meant ensuring that all aspects of the study should be comparable. This included both the monitoring of tasks during the test and the ability to make direct comparisons between features and function execution.

To begin with the study was broken into three main sections:

- Pre-test background
- Task assessment
- Overall usability assessment

As the initial studies did not target schools directly the participant groups' relative knowledge and personal belief in tablet aptitude were important markers. Matching task assessments would ensure that related task actions would, where possible, provide a clear change of perceived ease for each function and feature across studies. Usability comparison would provide the broadest comparison of the test; should improvements or changes be required following the initial testing round and do these changes impact the usability of the software to any appreciable degree?

Additionally, metrics needed to be robust enough to allow relevant feedback for any unplanned testing. Rather than looking at tests that would provide feedback specifically for a controlled environment, metrics should be broad enough to provide relatable feedback in all usable environments. Lastly the study uses a within subjects design. Participants will use both the student and teacher versions. As the study is primarily concerned with basic navigation and functionality access, the specific role the user plays in the test does not need to be specific. This test framework provided a secondary assessment of the general application operation, through a second run for users that was familiar but not a direct replication.

7.4. Selected Tests

With a mind to the tenets of usability noted at the start of this chapter and how they would map to desired function testing the test selection criteria were:

- Per function ease of use
- Application Learnability
- Overall Usability

In addition to user provided feedback there is a desire for non-user based metrics for:

- Pass or fail ratings
- Completion times

It is important here that any effective assessment of the software look at a number of different metrics to provide a clearer overall view of the software performance, rather than relying on a singular test (Nielsen 1994). This data provides a solid assessment of usability from a number of comparable metrics assessing both user and non-user factors.

7 4.1. Single function assessment

The overall test structure employed a task based approach, with each task representing a single function action. This would allow the gathering of relevant data on a function by function, task by task basis through user direct assessment as well as monitored data in the form of pass / fail rates, and timing. Upon the completion of all function tasks, users would provide overall usability feedback, giving both a task specific and overall usability comparison.

While per task assessment was necessary it was important that task testing was not a drawn-out process, reducing the impact that pauses for task assessment would have on overall usability assessment. While a task ideally should take 5 – 10 seconds, to then pull the user out of the experience to answer a barrage of test metrics would be detrimental. To combat this the primary metric for judging user impressions on a task was the Single Ease Question (SEQ), shown in Figure 7.1. Based around a simple Likert scale the SEQ provides a very straightforward way to gain assessment of a task (Tedesco and Tullis 2006, Sauro 2010). The SEQ follows the same structure for any given task using a scale of 5 to 7, with 7 being the preferred metric for a finer grained response.

Overall this task was?

1	2	3	4	5	6	7

Very Difficult Very Easy

Figure 7.1: The Single Ease Question scale. Presented as a question immediately following a given task.

While there are other tests that can be used like the After Scenario Questionnaire (Lewis 1995) or the Task Load Index (Hart and Staveland 1988) these are often multi question responses that require greater time away from task. Additionally single metric measurements like the Subjective Mental Effort Question and Usability Magnitude Estimation require more effort on the part of both the participant and study conductor to achieve results and do not provide a noticeable benefit to overall task assessment (Sauro and Dumas 2009). They may also confuse the core assessment, obfuscating the difficulty of the task they are measuring. The ambiguous nature of the SEQ questioning also avoids leading participants towards an expectation and broad enough to be applied in a task agnostic way.

There is also have an expectation of timely task completion. As learnability is a key measure, the time a user takes per task is a relevant factor. This also provides an appropriate comparison metric between users in combination with the SEQ. Additionally it is important that time recording take into account "thought time", how long a user takes before actually managing the task, as understanding a function is a core facet of learnability. There is also a point where a task has gone past the stage where it could conceivably be considered a success of fast navigation. Beyond this, a task is defined as failed if the user gets lost in the interface or fails to reach the correct application end state.

To this end there is also a need to measure the end states of a given task. While the intention of the study design was that tasks should be able to be completed by all users, there are scenarios where completion may be impossible, and thus counted as a failure, including:

- An incorrect end state for the task. This would be any state where the end point of the task has been incorrectly reached, for example the user task was to copy a file and the file has been placed in the wrong location.
- Taking too long. Beyond a set time the task could no longer count as being completed in a timely or usable manner
- The user may believe that they have completed a task satisfactorily but did not do so according to the study conductor.

To address these situations, it was important to maintain a pass / fail matrix for each task as well as the binary pass / fail data. This also served to provide a clear indicator in cases where the fail portion of the matrix had been clearly apparent for multiple users for a given function task. In these situations, even if a user maintains the task was easy, fails across multiple participants proves this was not the case.

While these provide good metrics for function task assessment, due to the nature of the prototype software it was also important to be able to collect direct user feedback about specific issues or confusions they encountered during testing. To this end, users were encouraged to provide direct feedback about each task. The problem matrix allowed for multiple users to pinpoint specific issues in usability in a continuous manner. At the end of testing it should be feasible to have a comparison of specific issues participants found within given tasks, and in collaboration with other data, be able to more accurately pinpoint aspects of the software that worked well, did not work without users realising it, or resulted in an unacceptable amount of user confusion. This assessment per function design maintained a limited burden on the study participant as after each task the necessary engagement was limited to a single Likert scale and any comments they wished to make, reducing overall usability bias.

The accumulation of these four metrics provided a robust examination of each functional task users were asked to perform and allowed for strong identification of areas of the interface and state flow that proved ineffective or poorly designed.

7 4.2. Overall usability assessment

Apart from task specific monitoring there needs to be application wide assessment of usability. This provides a picture of the software's ease of use on an overall scale, as function operation does not occur within a vacuum. To address this System Usability Scale (SUS), first developed by John Brooke in 1989 (Brooke 1996) was used. While Brooke described it as a "quick and dirty" usability scale, research has shown that, while quick, the dirty moniker is not deserved. It has shown a distinct sensitivity to changes in interface design of a product (Bangor, Kortum et al. 2008), making it ideal for interface heavy testing. While initial tests had suggested it was perhaps slightly unreliable as a single score metric, subsequent testing has shown SUS to be highly reliable (Lewis, Brown et al. 2015, Lewis, Utesch et al. 2015) and has become one of the premier scales for software usability testing. While the original scale was aimed at systems it has shown an equal robustness as a valid scale for most software.

Comprised of 10 Likert style questions the SUS is split into two domains, with 5 of the questions presented in a positive tone while the other 5 present a negative one. Each question is represented on a 5 point Likert scale with participants generally directed to provide a "gut" response rather than giving the questionnaire significant thought. Once users have provided a full response questions are factored on their slant. For positive values the score is factored $1(x_i - 1)$ while for negatively geared responses $(5 - x_i)$ is used.

Another significant bonus of the SUS scale is its potential as a two factor scale (along with its single factor value) to describe the domains of usability and learnability separately (Lewis and Sauro 2009). Studies have shown that the SUS scale can be separated into a two factor scale by splitting items 4 and 10 from the rest of the scale. From here the 8 scale can be factored as "Usable" while the 2 factor elements represent "Learnable".

When collating SUS results it is important to note that the values returned are not a representation of any percentage style metric of usability directly, but must be interpreted and compared to other SUS results. This has in turn suggested interpreting SUS as a relative grading scale than an absolute value, with Table 7.1 providing a grading scale based on large scale SUS reporting. For the SUS this can see a median grade of a C relating to a score of around 68 in the SUS results. Here software that scores lower than 68 can be considered below average, while above would mean an above average rating (Sauro 2011).

While the SUS does have a clear negative skew to its results, and tends to have distributed peaks at 50 75, 90 and 100 values, this can be addressed mainly through a focus on the mean score for results, with median proving of limited value. It is key to note however that this stresses the importance of addressing SUS scores as a set, and there is limited to no value in considering individual scores.

Table 7.1: The curved grading scale for interpreting SUS Scores (Sauro and Lewis 2016) .

SUS Score Range	**Grade**	**Percentile Range**
84.1–100	A+	96–100
80.8–84.0	A	90–95
78.9–80.7	A−	85–89
77.2–78.8	B+	80–84
74.1–77.1	B	70–79
72.6–74.0	B−	65–69
71.1–72.5	C+	60–64
65.0 –71.0	C	41–59

62.7–64.9	C−	35–40
51.7–62.6	D	15–34
0.0–51.6	F	0–14

With most usability assessments a key factor is established knowledge, both for environment and the software itself and a key aspect of ClaMApp is to provide high learnability. As required training time is a significant impactor on teachers' willingness to take up and employ software this should be kept to a minimum. To this end one of the most important factors is the applications usability when employed blind. Therefore, when provided with the application for the first time, users would not be given any kind of instruction about the operation of the environment. This is also a key factor in returning true SUS values, as familiarity with a product shows a correlation to increased SUS results; as a user becomes more familiar with the interface they like it more, though this often requires reasonable familiarization time. The only caveat to this was basic instruction on device operation for those who were unfamiliar with the navigation buttons of the Android device.

While there is a high chance that task failure rates and times would be reduced with the addition of limited documentation, this would also result in an obfuscation of the intuitiveness of the software. As this test focused on interface flow and ease of use, exacerbating these interface issues when possible, though a lack of guidance helped to highlight these flaws.

This results in the following tests to address ClaMApp usability:

- SEQ
- SUS
- Pass / Fail
- Task completion time
- Problem matrix

The results from these assessments should deliver the necessary results to provide a solid grounding for application usability as it is defined (International Standards Organisation 1998).

7.5. Methodology

This test focused on menu action, application navigation, ensuring interface flow performs as intended and that users can utilise these aspects of the application without having it crash or perform in an erroneous manner. The initial round of testing focused on the basic functions of the software:

- Moving files
- Collaborative use
- Accessing menu items

These concepts were mapped to related functions present in both versions of ClaMApp and accessible as single task actions through both file and non-file focused functions:

- Copy files
- Get help
- View help
- Create group
- Use chat
- Create a note

While tasks were designed to target a single function with features tested across both teacher and student versions each version of the app had a slight bias towards task sets. This was partly due to the design nature of the application. As discussed in Chapter 6, one goal was to have the teacher version of ClaMApp able to replicate where possible the function actions of the student one in an identical manner to assist in teacher confidence. The end result was that the teacher version of the application had more functions to test. While it was believed this should not impact user perception, as use was alternated and any change in familiarity would be averaged out, it is still worth noting that there was a level of asymmetry between the two test sets.

7 5.1. Testing Devices

For all testing in this work using the teacher and student applications ASUS Nexus 7 devices were used with all software designed to a minimum API deployment standard of 4.0. Before the second usability study was conducted devices had been upgraded to 5.01 but no changes were made to the deployment target of the application.

7 5.2. Pre-test questionnaire

Before the test participants answered a pre-test questionnaire obtaining a general background view of the participant's level of understanding of their own technology proficiency. Participants were asked to provide some general feedback on devices they owned, how often they used them, including if they owned their own tablet devices. As the testing pool was drawn from tertiary students this included a section addressing the user's views of technology and their own personal experiences with its importance in the education domain. Once the pre-test questionnaire was complete participants were provided with a device.

7 5.3. Task breakdown

Participants were provided a short intermission to familiarise themselves with the device itself, specifically the home button and general design of the Back and Apps soft buttons. Participants were also provided a numbered task list detailing the task instructions, presented as short natural language statements rather than as step by step guides. The goal was to provide the task request in a manner that would provide participants with the detail but no additional guidance:

- Use the camera shot button to take a photo of the provided note sheet. Select the camera directory and send the photo to your group. (Student task 3)
- Create a note about students of your choosing, for at least one student include a note. (Teacher task 6)

Once device familiarization had been performed participants were instructed to "perform task X" by the study conductor. Participants were then asked to complete sequential tasks with each device, designed to correspond to a function as detailed in Table 7.2.

After each task participants were asked to provide SEQ feedback. The task was then registered as a pass or fail depending on both the end state of the action and the user's belief in its completion. Participants were given up to three minutes of time to complete a task after which they were asked to show the researcher where they currently were so deviations from the task goal could be noted. At 3 minutes a task was considered a fail. At this stage users were also given the opportunity to make any comments they wanted and these were tracked in the problem matrix.

Table 7.2: Task function testing. Each taks corresponds to the active testing of a given function.

Teacher task function	**Student task function**
Copy files	Get help
View help	Use multimedia
Create a group	Copy files
Use chat	Use chat
Create a note	

At the conclusion of each application test (teacher and student) participants were then asked to fill out the SUS form for that version of the application. Once the SUS had been completed participants repeated the same process, excluding the pre-test survey, with the alternate version of the application.

7 5.4. Participant Pool

Participants for the test were drawn from a general university student pool. Participants had no required ICT skill sets nor specific knowledge of the application. As the application design is primarily focused on creating a usable and learnable application the exact user base is not required to provide assessment on the navigability of the interface or to highlight areas where functionality breaks down. One of the key elements of the ClaMApp software is to be usable with little to no exposure and across a wide range of user skill levels.

Participants were invited to participate by email sent university wide with approval from the Flinders University Social and Behavioural Research Ethics Committee (SBREC) (Appendix A.3). Upon expressions of interest potential participants were provided with an information pack detailing the intention of the study and expected time commitments. If they followed up with a willingness to assist with the study a time was arranged for testing. Tests were conducted in a one on one environment in a closed, quiet laboratory. Participants were provided with all materials necessary to perform the tests including devices, cheat sheets and task instructions.

7.6. Results

7 6.1. Pre Test Questionnaire

For this usability study there were 13 participants all under the age of 40 with varying degrees of mobile familiarity. All participants owned a smartphone which they said were used multiple times a day and 46% owned their own tablet device (Figure 7.2). When asked to select the response that most closely matched their usage all respondents stated that they used their phones at least “Occasionally daily” with no participants indicating sub daily usage, shown in Figure 7.3.

The participant’s views on the use of technology in the class showed that for nearly all of them technology and internet access are integral parts of the learning experience while opinion was more divided when assessing if technology was being overused (Figure 7.4).

These responses show that all participant’s view technology and access to the internet as a critical part of their education toolbox and have an expectation of ICT being used in their classes are managed. This is supported when asked for their views on the importance of ICT management in their classes, with the majority stating it is either essential (n=9) or as a supplement (n=2), demonstrated in Figure 7.5.

While these users are university students and not the teachers and students that are the final target audience of the application, these familiarity metrics help to provide additional context regarding the opinions of the participant group, which may impact results. If the study participants are all unfamiliar with tablet devices, or if none had owned their own smartphones, this would indicate a significant factor when assessing the results. Similarly, if participants are all familiar with the operations of an LMS there is room for the users to seek an expected behaviour with ClaMApp that they would already be familiar with, or expecting to have access to, from their own LMS familiarity.

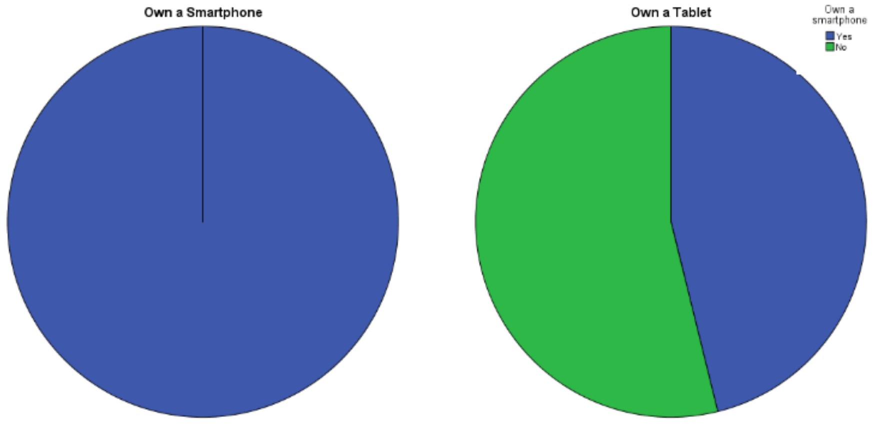


Figure 7.2: Comparison of participants who owned a smartphone and those who owned a tablet. All participants responded to both question.

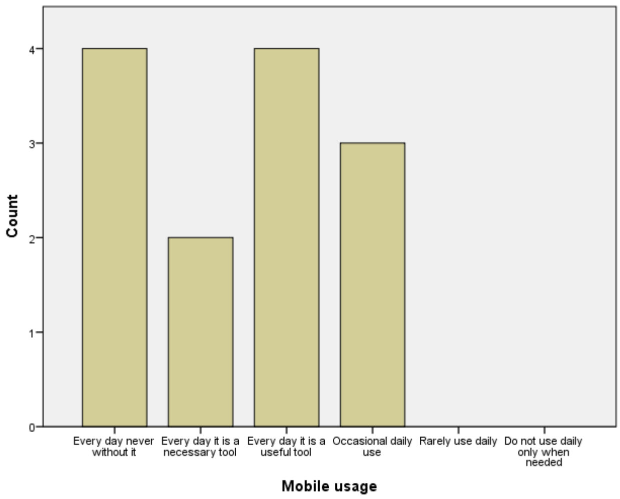


Figure 7.3: Count of participants who feel that statement best describes their mobile usage.

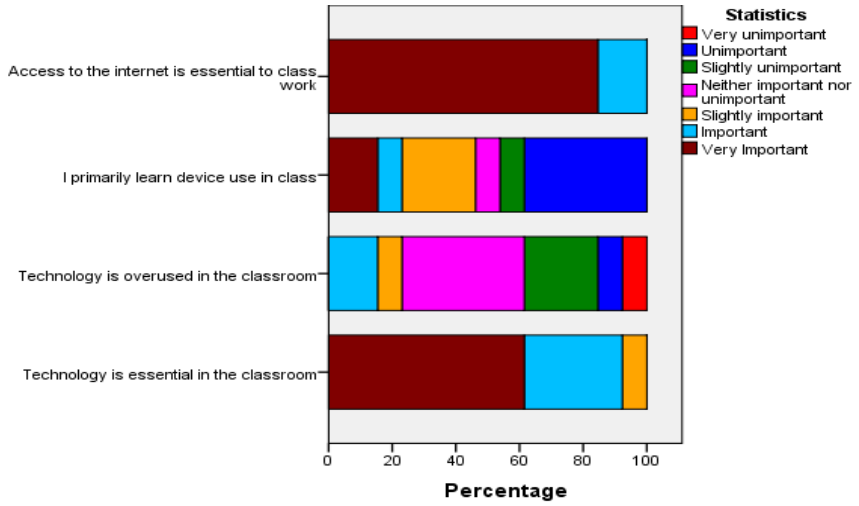


Figure 7.4: Participants views of how they use technology in their learning, and how important they see its role in their education. A 7-point scale was used from 1 (strongly disagree) to 7 (strongly agree)

USABILITY STUDY 1

After performing the required tasks with the relevant app participants were asked to perform a SUS survey. From this survey overall usability as well as the split factors of learnability and usability were obtained.

7 6.2. Task Specific metrics

When looking at SEQ results (Figure 7.6) it was found that while the overall usability of ClaMApp may have been above the average of 68 on the SUS (section 7 4.1), however there may be little confidence that the task results back that up, with only 3 tasks having a mean over 6 on the scale; Get File Help (M = 6.7, SD = 0.44), Group Communication (M = 6.38, SD = 0.90) and Create Notes (M = 6.08, SD = 0.95).

This suggests that while users viewed the overall usability of the app well the individual tasks still generated a level of confusion that is too high

When viewed as a whole usability and learnability are not reflected in a task by task assessment

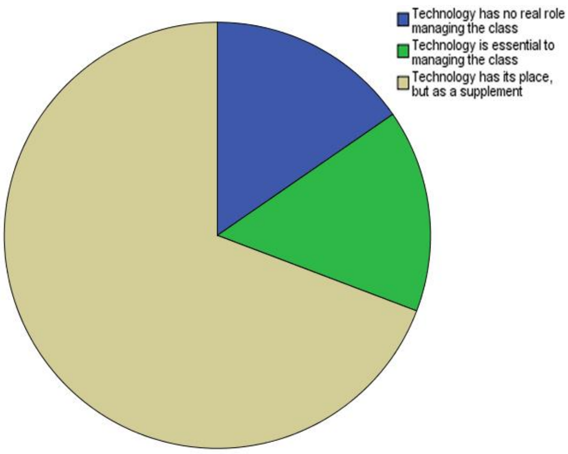


Figure 7.5: Participants views on the role that technology plays as a management aide in their education.

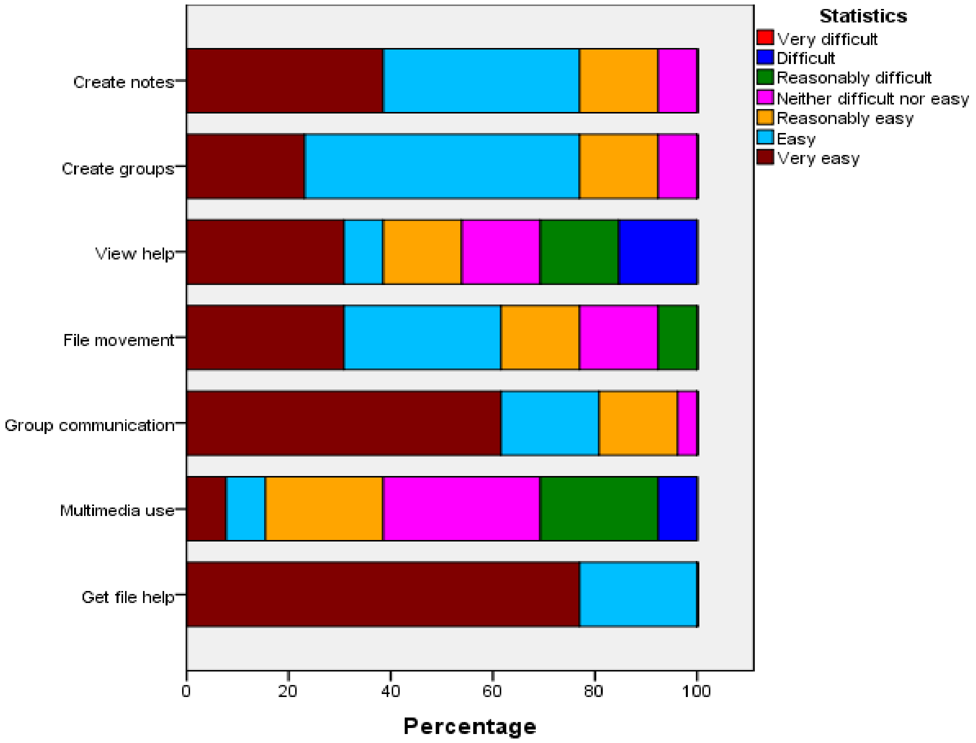


Figure 7.6: SEQ spectrum for each function action. A 7-point scale was used from 1 (strongly disagree) to 7 (strongly agree).

From these results, a much higher level of confidence with file than non-file functions were observed. View Help and Multimedia, especially, showed high levels of confusion and frustration with these functions.

When adding in task pass fail rates these (Table 7.3) issues were highlighted Here the results coincide with Multimedia and View Help functions showing a 38% failure rate. While no other task had more than one failure to complete, concerns were backed up in the feedback provided in the problem matrix. Key amongst these were Multimedia and Collaborative Spaces where users felt that ambiguity and a lack of feedback complicated the task.

Table 7.3: Task function pass / fail rates.

Function	**Pass %(n)**	**Fail %(n)**
Get file help	92(12)	8(1)
Use camera	62(8)	38(5)
Use chat	92(12)	8(1)
Copy files	92(12)	8(1)
View help	70(9)	30(4)
Create group	85(11)	15(2)
Create note	100(13)	0(0)

Looking at times taken, displayed as median in Figure 7.7, shows a similar result but demonstrates the wide swings in ability especially with the tasks that had shown failure rates and confusion in other metrics. Of note, in all the attempts only one user ran out of time while attempting to do the task, which was the create a group. For other failures it was a combination of the user either choosing to abandon the task or completing the task and ending in the wrong state. This happened twice with the multimedia task, where users simply exited the application and used the Android devices own camera, saving the image to the device gallery. Similarly, two of the failures for viewing student help requests accessed the notes and wrote that a student needed help.

7.7. Overall Usability and Learnability

Yet despite the voiced frustrations and failures during the tasks, it did not appear to heavily impact the overall SUS scored. While it had been expected that the lengthy periods taken to complete many of the tasks and the participants own verbal dissatisfaction would present itself firmly in the SUS survey this negative view did not materialise.

Instead the data showed the SUS score for the teacher version of ClaMApp (M = 77.88, SD = 12.07) was above the expected usable mean as described in previous work (Sauro 2011) providing a rating of B+, or the 80-04 percentile range (Figure 7.8). It also found the usability factor (M = 78.61, SD = 12.49) was slightly higher than the learnability factor (M = 75.00, SD = 25), which does indicate some impact from user frustration; they found the learning of the functions harder than the using. However a one way ANOVA ($F(2,36) = 0.153$, $p = 0.859$) shows no statistical significance across the scores, suggesting no significant gap between the usability and learnability, demonstrated in Figure 7.9.

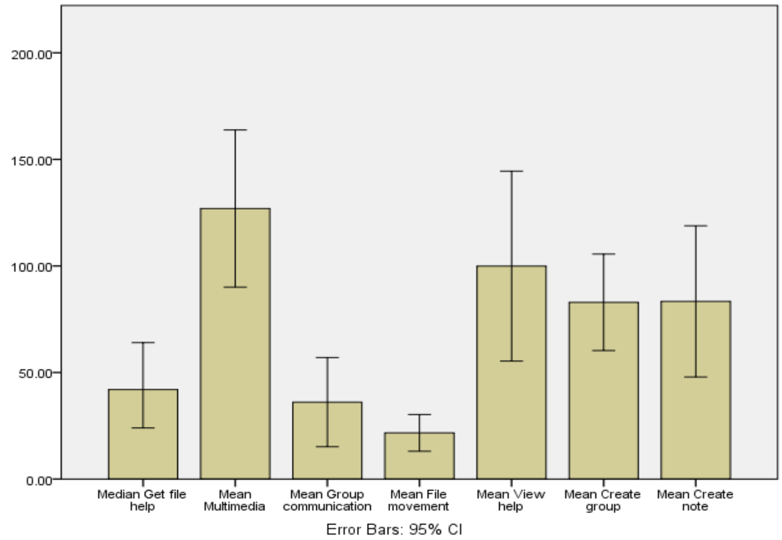


Figure 7.7: Median time for task completion. Here median time is used to account for the inherent skew in timed data.

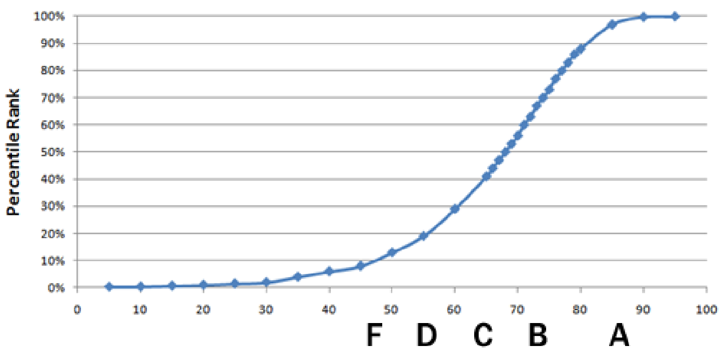


Figure 7.8: This chart provides a visual representation of the SUS comparative scale, demonstrating the skewness of results.

Figure 7.10 shows the SUS performed after the student tasks saw a rating of (M = 78.2, SD = 15.53) almost identical to the teacher version. Here the learnability (M = 78.85, SD = 29.92) was slightly higher than the usability (M = 78.13, SD = 14.93) however again a one way ANOVA (F(2,36) = 0.004, p = 0.996) shows there is no statistical significance to the difference. One area of concern however was the large standard deviation across the usability results, suggesting that while overall usability may have been acceptable for many users the learnability of the app was a real issue. This reinforces the large spread seen in the task performance times.

Lastly on an application vs. application level a paired samples t-test (t(12) = -0.91, p = 0.929) showed no statistical significance between the usability of either version of the application. As a goal was to have common functionality across both versions this result is positive, a teacher oriented participant with their version of ClaMApp has a similar usability experience to students. Furthermore, as both versions represent the same usability there is comfort in grouping both teacher and student user functions into a single result pool.

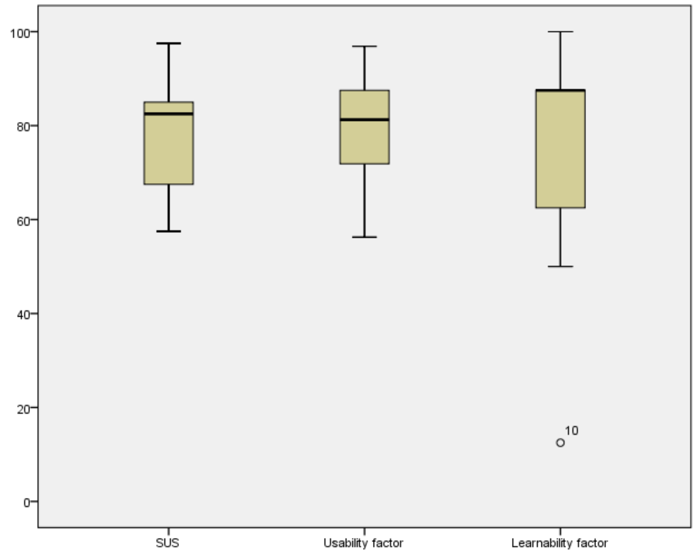


Figure 7.9: Teacher version of ClaMApp SUS scores

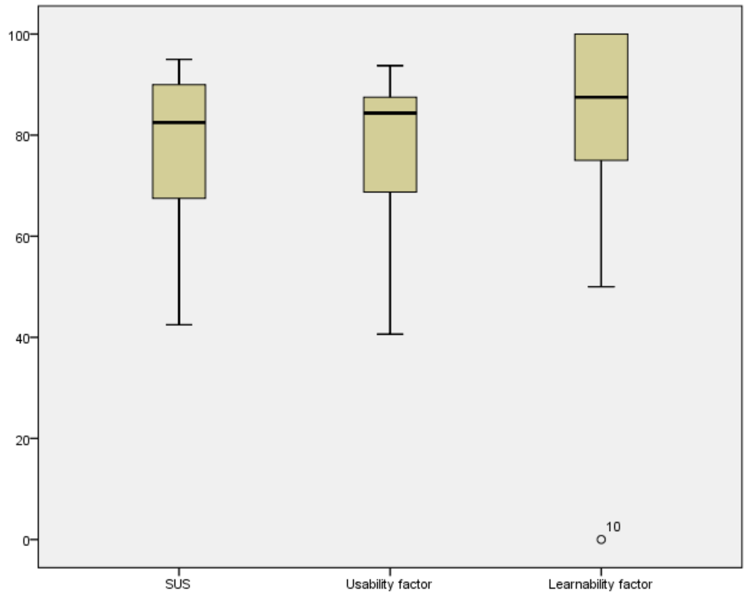


Figure 7.10: Student version of ClaMApp SUS scores.

Looking at user feedback across both tests showed a reflection of the metrics. For the most part, participants found the application easy to use, with a number stating that once they knew how to perform a function repeating it was trivial. One user noted when moving files "oh yes, now I know how it is easy" while for another participant they stated that the task description was confusing. However, worryingly, many participants who failed tasks were perfectly convinced that they had achieved the correct outcome. This suggests that while the application may be providing a sense of correctness for task, this is in fact a false sense of completion. Unsurprisingly, many noted confusion around navigating groups and taking pictures, as these were the highest fail rates, however the number of participants frustrated with group navigation aligned much more closely with the number that failed in the task, suggesting that in this case they knew they were not completing the task correctly. Meanwhile with multimedia while some expressed a level of frustration they often felt they had achieved the task goal.

7.8. Discussion

Overall the results from this study provided some strong indicators of areas ClaMApp did and didn't work, however much of the feedback seemed almost contradictory, especially when examining the task based results with the overall usability. Based on these results and comments made by participants it suggests that the application as a whole was easy to use, and once users knew what to do they find it easy to navigate, and this is supported by SUS results. With a higher learnability and usability this should lead to a reduction in the professional development time required by teachers and students to learn the application. A more usable system by nature results in a reduced time investment to effectively use the system with expectable outcomes. Similarly a high learnability leads to less time required by the teacher to become familiar with the functionality of the application and how that can best be implemented. SUS results however should be taken with a measure of doubt when such disparity exists within the application as a whole. While the initial positive SUS ratings are welcome, they are of not only limited benefit in this test but of lessened importance. The tasks for this test were by design simple and should not have proven an onerous burden to navigate.

For this study, those task based issues are of increased importance and present a clear issue in software that is intended to be highly learnable. Additional work is required to ensure that these initial executions of the function are clear and simple to initiate. Similarly, clearer pathways to function end states are required, with collaborative spaces specifically, additional thought will need to be given to how to more effectively breadcrumb users to the correct locations. When fail rates are examined on a function by function basis one thing that stood out was that these occurred heavily in tasks where the end state may have been ambiguous. In the case of images there was no clear feedback about the picture's location, just that it had saved. For operating between groups, users often seemed confused at the position in the task of the program state they found themselves in; i.e. when copying a file, they would go to the incorrect folders, or progress to the chat fragment looking for files. These early iteration confusions were identified to be addressed in subsequent development.

With Multimedia the decision to auto allocate a space for pictures proved a significant hurdle as even with a prompt on save, users showed significant trouble finding the stored image folder. With Collaborative Spaces there may have been too much of a technical approach in separating them into separate file and collaborative spaces with many users stating they found it confusing and unintuitive. There was also a lot of feedback regarding perceived ambiguity in the systems naming. Again, this may be an overly technical approach in labelling the functions rather than an intuitive one. One example was the file copy labelling where while labelling the choice as "File Move or Copy" was assumed to be clear when asking users to copy a file to a location this was not the case.

It is also important to discuss some of the limitations of this study. While the study is primarily interested in the qualitative results of the testing, it is still the case that this is not performed directly on teachers or school age students. However, as has been stated, the goal of ClaMApp is to provide a robust agnostic user experience, regardless of the skill level of the teacher or students. As a user base there is little to distinguish them as general users, indeed this perception of expected competence can act as one of the barriers to effective use (section 2.2), it is just their work environment that differentiates them. To this end testing the functional operation of the application is not tied explicitly to the "teacher" job title of a prospective user. Rather, the more crucial element of the participants is that they do not represent highly skilled or technical mobile users.

When addressing population, participant numbers also warrant discussion. While the testing pool was low, it is still above the generally stated "5 user limit" (Nielsen and Landauer 1993). While the five user limit is primarily concerned with qualitative assessment when discussing functionality, it has been shown to be deficient in detecting operational problems, sometimes failing to detect over 50% of functional errors (Faulkner 2003). However, newer studies suggest a 10 user population to detect over 80% of functional errors.(Hwang and Salvendy 2010). Overall, while the application's usability was acceptable, there were a number of areas that needed improvement before it would be ready for real world deployment. These modifications are discussed in Chapter 8.

While the usability and learnability were both observed to be above average, according the SUS results, there are clearly portions of the application that require additional refinement. While SUS results provided limited guidance on issues, thankfully the SEQ and pass / fail matrix both provided clear indicators of areas that were in need of attention.

First amongst the changes was overhauling how the Multimedia and Collaborative spaces operate. With multimedia, the overwhelming feedback received was not knowing where the images had been saved. Here perhaps is a mistake made in not being explicit enough with the definitions, or clear enough with the domain spacing. A redesign of how images were being handled by the application was required to provide a greater level of feedback to the user, taking into account that users will try to short cut the camera directory entirely.

A redesign of the approach to collaborative spaces was identified. Users clearly found it confusing to navigate between the chat and the folder domains and did not understand the action flow when dealing with chat-to-folder and folder-to-chat actions. Significant feedback was received that this separation was an ineffective implementation and needed to be addressed to make moving between groups more effective. While this goes against the original design philosophy of contained spaces, in this instance it was too big an issue to not remedy, with the same errors repeated by multiple participants. Lastly, issues with ambiguity in naming was to be addressed.

There were also a number of cosmetic issues to address. While little attention was paid to the visual aesthetics of the design, and on the whole participants did not find the layout difficult to address, there were a number of instances of ambiguity in naming. Rather than require function redesign these aspects should be able to be addressed through simple renaming of the menu action items.

7.9. Summary

This chapter detailed initial analysis and testing of the ClaMApp environment. When examining usability, it is important to have a variety of metrics to compare to provide a full review. A mix of open ended qualitative and metric data was discussed with the testing using the SUS, SEQ, task time and pass fail as metrics, as well as gathering user feedback on each task. During the study users performed a number of tasks, grading both the task and application overall.

The results of the study suggest that in its current form the application is not up to task, having an unaccbackgreptably high fail rate at tasks, a lack of confidence in users expected outcomes and with too much navigational confusion. While ClaMApp performed functionally correct there were a number of areas that needed to be improved, specifically around the multimedia and collaborative spaces. While the study provided strong overall usability through SUS results, the number of fails and situations where the user state was not consistent with user belief were too high to be acceptable. Revisions needed to be made to the software to address these issues and Chapter 8 details these adjustments and further usability testing.

Chapter 8

Usability Study 2

8.1. Overview

Chapter 7 discusses the refinement of the ClaMApp software and target the deficiencies shown in the user testing of Chapter 6. Following the fail rates and state inconsistencies highlighted in Chapter 6, changes were made to the ClaMApp software to correct, clarify and in some cases redesign functional operation. These are detailed below including how these issues were addressed and any changes that resulted to the action flow.

8.2. ClaMApp State

Observations and results from the initial user testing demonstrated there were a number of places where ClaMApp's design needed to be modified. The areas with the biggest issues were both related to too heavy a reliance on a traditional folder / file structure. While initially looking to keep the interface simple and segregated there were significant issues when trying to find folder locations. Many users did not see a conceptual difference in collaborative spaces for communication and collaborative file spaces. A similar confusion presented in the implicit handling of user created media. While few participants had significant issues in accessing the camera functionality many were at a loss once the picture was taken as to how to access and copy it, often overlooking the presented camera directory entirely and in 2 cases giving up. These issues resulted in an unacceptable number of failed task actions that, apart from introducing program ending bugs, resulted in a product that was not usable or effectively learnable without instruction. Before the application was ready for any kind of real world testing revisions needed to address these ambiguities in functions to ensure collaborative spaces were clearer and media handling was more explicit.

There were also a number of "quality of life" issues that needed to be addressed before additional testing. These mainly focused on renaming portions of the interface and making locations increasingly explicit to lessen the confusion of navigating the interface and increase learnability, especially in first time scenarios.

8 2.1. Application revisions

Observations from the previous study presented two clear design improvements:

- Using the camera feature
- Collaborative spaces

In addition to the above changes a number of minor amendments were required focusing on:

- Menu item naming
- UI flow tweaking

8.2.1.i. Camera use

One of the primary failures for the application was in the use of the camera feature. This task demonstrated the highest fail rate, as well as the highest rate of end state error; users believed they had succeeded or ended up in the wrong location when trying to find their pictures. With a 38% fail rate and by far the highest average time in seconds to execute out of all tasks (M=126 seconds) it warranted an overall redesign. Participants for the most part had little problem accessing and starting the camera function, i.e. taking the picture. Rather, the major issues occurred during validation of the task. Function execution itself worked as intended with images being saved to the correct location and syncing to the server, but users were often unable to locate the images within the application. For three of the participants when looking for their image exited the application to look at the devices internal gallery. Two other participants were unable to locate the file in the application folders, abandoning the task. To address this, the function needed to provide significantly more direct feedback when addressing the location of the file, as an implicit save did not provide sufficient information on where the file had been stored.

There are a number of possible solutions to provide that explicit feedback, with the simplest being additional information in the “picture saved” pop up. Another option is to allow the user to select their save location themselves. This had been considered in the applications initial design but was abandoned in favour of the implicit design to remove the need for another menu interaction. It was also important to consider the pass and fail of other similar actions, namely how users interacted with the move and copy actions. While only one user failed using the move copy feature some participants noted that the extra steps to get from the camera directory to the group directory seemed unintuitive, and copying files to collaborative spaces was the second highest fail rate task. This suggested that there were improvements that could be made to the collaborative space interaction, but also that not allowing explicit action for the camera to copy straight to collaborative spaces may be saving an interaction in one space only to cost it in another; users that wanted to save a picture to a collaborative space would require new steps to copy the new file to a group space than the single interaction to send it when it was taken.

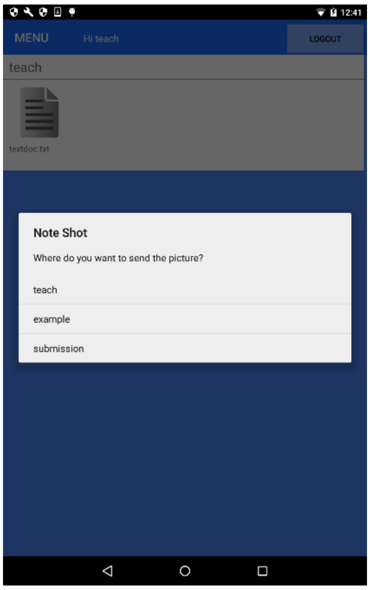


Figure 8.1: The Camera Shot prompt. Upon returning to the application the user is prompted to select a save location for the captured media.

To this end rather than utilizing a Camera folder to store images users would instead be prompted after an image was taken for where they wanted to image to be saved, as shown in Figure 8.1. The camera folder would be removed in this change. This results in a change to the user flow experience becoming:

- Access camera
- Take photo
- Choose save location

As an interaction medium for the save menu, the dialog system was again used; users would be presented on returning to the application with a dialog menu asking them where they wanted to save the picture with a list of available locations. While this results in a limited change from the user perspective, it did require a reasonable change to the backend. As users could now save to collaborative folders directly from the camera this needed to hook into the existing control flow for collaborative documents, syncing group work to other users as well as the local device.

This fix addressed the confusion users demonstrated when trying to find images as a two-step process. The user is directly selecting the save location and can be assured of where the photo will end up. Secondly the save prompt serves as an explicit feedback notification of where the user can find their image.

The final issue to be addressed concerned the dismissal of the save dialog without selecting a save location. As the loss of focus in the Android environment cancels a dialog it is important to have a distinction between a user cancelling their save through the cancel button on the dialog, and exiting the dialog through loss of focus. When dealing with the user explicitly selecting cancel on a save location an assumption can be made that this is an indication of dismissal of the image and can discard the image before it is saved or synced, shown in Figure

8.2. When dealing with a loss of focus however it cannot be assumed that this represents a desire to cancel the image save; it may derive from an accidental click. In this case, the cancel signal is caught and instead of removing the image, it is saved to the user's local directory. From here the user will be able to decide for themselves if they wish to keep the image. While this is almost counter to the initial desire to provide explicit action, it was seen as a safer option than accidently discarding an image the user wished to keep.

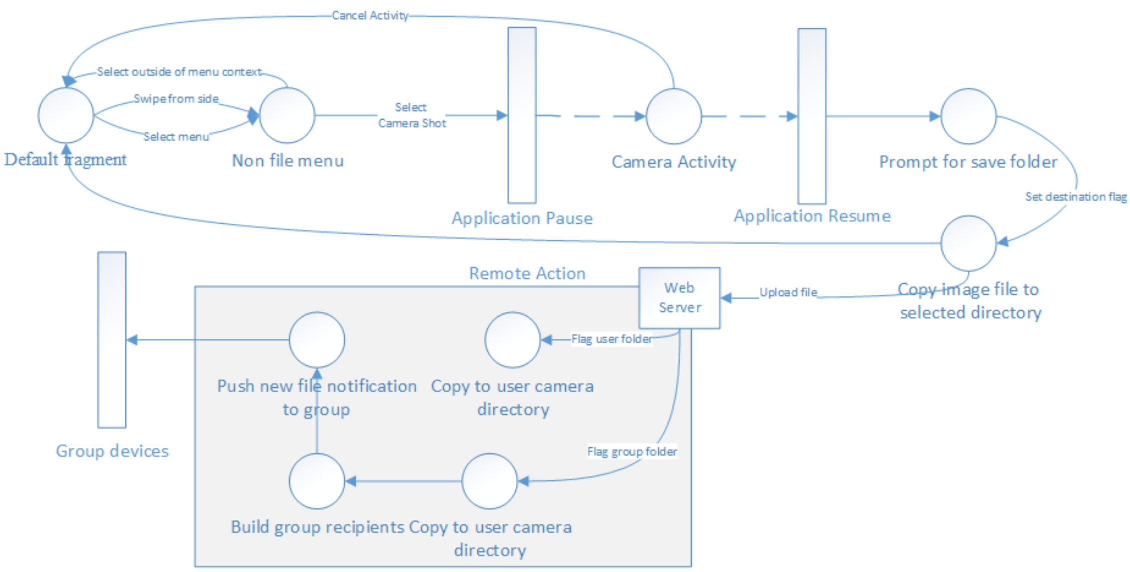


Figure 8.2:The Camera Shot version2 state flow. The revised function structure captures the user returning to ClaMApp and before saving initiates a dialog prompt to request the save location. Upon selection the application saves the file to that location and synchronises the file to the server. In the case of a save to a collaborative space, other registered group members are notified of a new file for download.

These changes addressed the issues users faced, primarily around the save location and accessing their images, when using the camera feature.

8.2.1.ii. Collaborative Spaces

The other domain that saw significant issues was in the participants' use of the shared spaces, particularly in the separated nature of the two areas. During the design phase it was felt that separating the areas would provide two primary benefits

- Creating an explicit area for each task
- Maximizing the screen space for each task

However, in practice the separation caused significant confusion for users. Collaborative tasks encountered the second highest fail rates, but generated the most vociferous feedback about the user's insecurity that they had achieved the task correctly or where they felt they should be within the application state.

As indicated in Chapter 7 the primary issues relating to failure of operation were sending messages and finding files, usually mutually exclusive; a user could find the files but couldn't chat, or they could chat but couldn't find the files. This seemed to be further exacerbated by the Home and Camera directories, the idea that separate spaces for each conceptual space would provide explicit indication was not born out in testing. Lastly there is also the matter of scale. During initial testing users were faced with a minimal amount of folder spaces; one folder was user created, one was created prior to the study and the home folder. In practical use additional specialized group folders may exist and this would undoubtedly amplify the confusion that participants had already expressed.

Perhaps the biggest implementation mistake made in the initial design was that a folder structure would prove a familiar friend to mobile users. While all of the participants were old enough and in a position to be extremely familiar with a standard Windows environment, and asserted they made extensive use of computers in their own student work, this familiarity did not seem to cross over to the mobile space. Rather there was a distinct separation in their minds about how a folder space on a desktop and a folder space on a mobile should appear. For a number of users this confusion seemed to stem from naming conventions, they simply failed to equate a folder named after their username with their own local files, and this was addressed with changes to wording. However, while understanding the lack of connection between a group folder and a group chat space is beyond this works remit, they had been envisioned as separate spaces. The fact is that for most users they saw only one effective group space when using the application and again this was generally mutually exclusive; either the group folder or the group chat, but significant confusion in the interaction between the two. This demonstrated a clear failure in the design idea that needed to be addressed.

While this could be addressed, as with a possible camera solution, through pointers and branding it seems clear that this was the inverse problem encountered with the camera. Rather than not being explicit enough the implemented solution was too explicit and subdivided a task that users saw as a single thing to multiple sub domains. This highlights the delicate balance that exists when developing software for a unique environment. The clearest solution was to generate a function that incorporates both spaces into a single area. From a design standpoint this meant a reduction in screen space available for each case. However, the introduction of scrollable elements allowed for a more adaptive space. The primary benefit of this solution was that users would only need to have a single group space, and this could be actioned from a single non file function. It was assumed that this would reduce the confusion about which area the user was access simply because a single action can only lead to one location.

As with the camera function there were no issues found with the operation side of the collaborative spaces, all files were copied to where the user defined and all chat messages worked and were transmitted. Rather the changes were at the interface level and this meant the practical menu changes of:

- Removing the Group Chat menu item

- Rebranding the icon for Folders to the Group icon
- Putting group menu items in their own sub heading; Groups

When selecting a group menu, users now get a single screen, split in two to provide the content that was previously contained in two separate fragments. Behind the scenes both functions continue to work in the same manner, the changes made are almost purely cosmetic; the one operational change made was the removal of the dialog selection for a group as it was rendered redundant. The new visual representation of the collaborative space is shown below in Figure 8.3.

For users accessing the space the new action flow becomes :

- Open menu
- Select desired group displayed under a "Groups" heading
- User presented with group screen containing files and chat
- Select files / Chat as previous

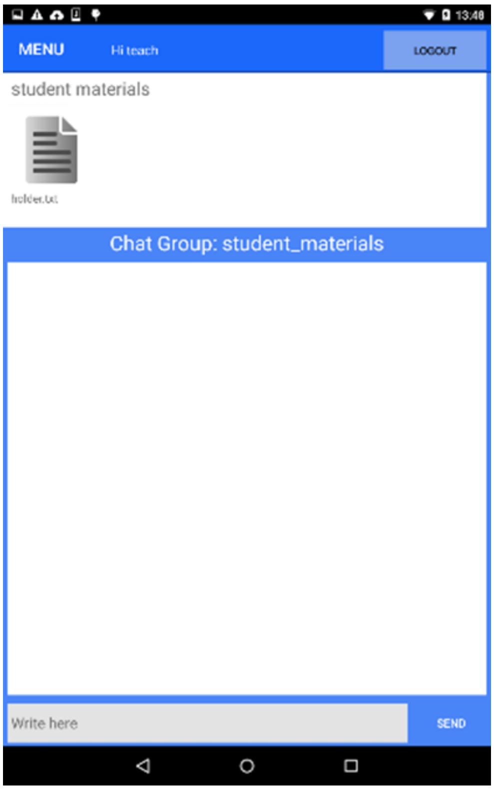


Figure 8.3: The combined file and chat space presented when the user selects a group from the Navigation Drawer.

One final change needed to the new collaborative space became apparent quickly and concerned the use of the chat space. The fragment was designed to dynamically resize the two portions of the screen based on content, with the file space minimizing to the grid display of available files. The file fragment would expand until it had taken up 50% of the screen size before changing to a scrollable display. The issue encountered in redesign occurred when the chat portion of the display had been decreased. When the user wishes to engage in the chat function the OSK will activate, pushing the chat fragment up to the top point of the keyboard. This is an issue when the file half of the fragment could be taking up too much room for the user to have enough room to type their message, see the recent text messages and have the keyboard all present on the screen at the same time.

To address this there was a limitation on the number of chat messages the user could see, that is four (4). If the compression of the chat window would result in less than this number of messages, then the file window is reduced in size to ensure the minimum amount of visible chat. This ensures that when using the chat function the user can always see the recent context of chat messages when replying. These changes remove ambiguity in accessing collaborative features, address user confusion concerning where they are in the app and streamline their access between group files and group chat. A visual representation showing the file and chat fragments, with the keyboard up, is demonstrated in Figure 8.4.

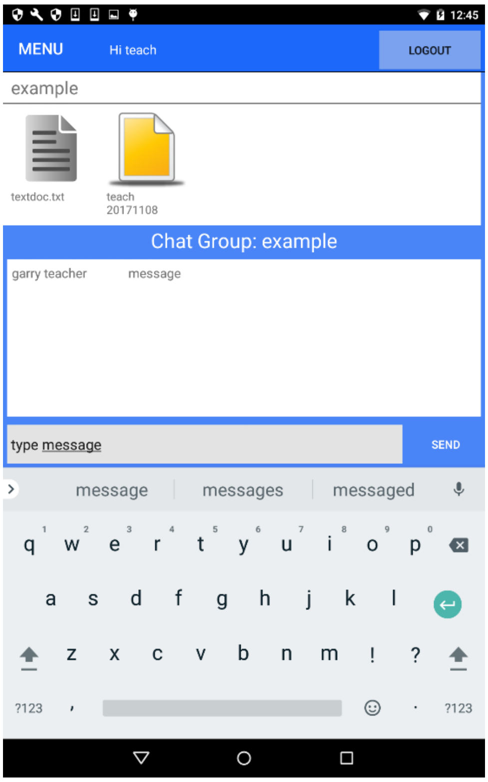


Figure 8.4: The collaborative space with all 3 possible screen factors present; files, chat and keyboard.

8.2.1.iii. Quality of Life improvements

Apart from the two major function changes, the back end functionality of the ClaMApp worked as intended for most actions and required no real modification, outside of accommodating the interaction changes in the interface. However, there were a number of what amount to quality of life issues, small changes that did not require significant functionality adjustments but were observed issues during the initial study. These were primarily focused around naming and selection flow from functions. These issues arose both on their own and in conjunction with camera / collaboration use.

The primary naming issue encountered was in the use of “View help” for accessing student help requests. Most users overlooked this response as providing some sort of application help. Despite there being no other help marked option even when asked to view student help requests participants took an inordinate amount of time before attempting to access “View help” and most of these said they accessed it by accident thinking it would provide additional direction. To address this, “View Help” was changed to “Help Requests”.

There was also considerable confusion over the Move or Copy function. Again, the expectation most users would be familiar with the function action when coming from a desktop environment was not correct. To address this the process was reordered to ensure that at execution of the file function the user was explicitly informed they were sending a document somewhere. This borrowed from the teacher distribution function and switched “Move or Copy” to “Send to…”. The function then performed the action as before, asking for the style of transfer and then requesting a destination. It was hoped this provided a clearer single step initiation of the file function, especially in first time use.

The last major naming issue concerned the user folder. For many participants there was confusion when asked to copy something to their folder. This tended to occur regardless of the language used in the task description. The logged in user’s username was used as it was assumed this was a clear indicator to differentiate between a group and personal locations, in conjunction with the Camera folder. However, with the removal of the camera directory and the confusion the named folder seemed to present, this was switched for a generic “My Files…” title. Again, this entailed no changes in the functionality of the program, the folders were still named after defined users and there was no additional burden; it was simply a cosmetic change to reinterpret the folder name in the menu display. The new Navigation Drawer element is demonstrated in Figure 8.5.

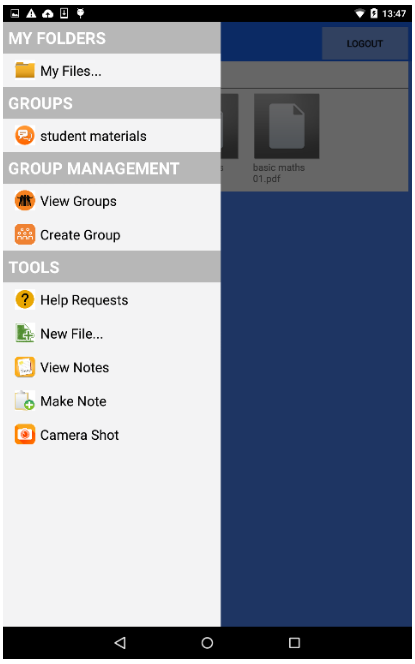


Figure 8.5: The revised Navigation Draw non-file function display showing new collaborative spaces and renamed headings.

The last issue encountered was not a naming but a design oversight. A number of participants missed sections of the menu items when they were covered up by the software keyboard. This tended to show itself when a user was creating a note for example, or looking to navigate away from a chat fragment. The fix for this was adding code to cancel the software keyboard whenever a menu was activated, either through the file or non-file actions. Lastly time was taken to address some formatting and resizing issues that were experienced during testing, primarily around icon padding and element alignment.

These changes addressed the feedback gained from the Chapter 7 and were significant enough to require additional testing.

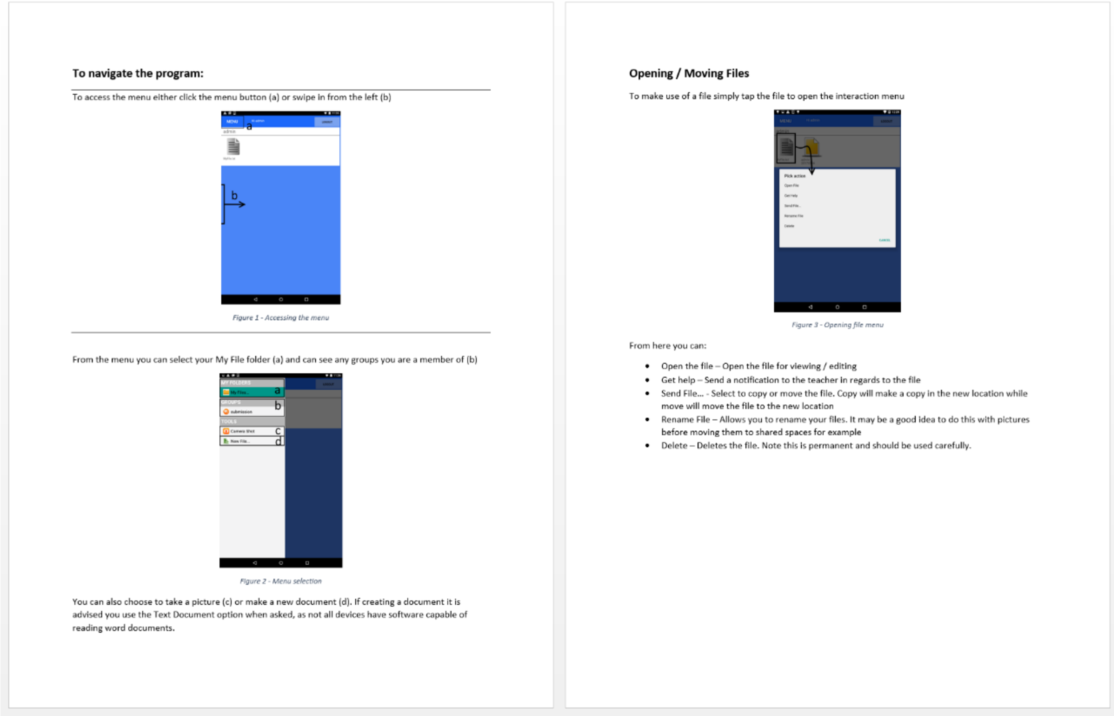
8.3. Study design

During the first usability study tasks and goals were kept simple to highlight function bugs and issues with the interface, there was limited benefit in additional assessment if the application was overly flawed. For the second test both improvements to the application and time constraints on the project time line meant it was important to gather additional in-depth data than just the basic interface flow. As such the second test moved away from task based step by step testing and looked to replicate a real world use with an additional focus on compound task execution; using more than one function in an operation. These tasks may involve repeated actions, or chained function tasks, for example copying a file and notifying a teacher a document is updated, or editing documents and notifying groups of changes made. As a key design goal was to facilitate management without impacting other application function on the device it was important that users could exit the app, utilise external app sources and then incorporate that information back into the management space; for example, getting information from the web and incorporating it into a document within the tablet app space. Therefore, tasks based on this use were also included along with similar task actions as were performed in Chapter 7. Significant crossover in task function use was also added. This provided feedback on two valuable metrics. Firstly, by increasing the number of times a user performs an action the hope was to amplify the impact incorrect design had while lessening the impact of erroneous user action. Secondly, by placing the repetition of tasks at the start, middle and end of the study it was expected that a comparison between a user's ability to navigate the interface at the start and at the end of the test would be gained.

As with the first test users would perform tasks with both the student and the teacher versions of the app were used. Initial testing indicated that usability was comparable between both applications, an important consideration when one of the goals was that teachers should be confident of student operation. To facilitate this comparison, the same metrics as those in Chapter 7 were used:

- Task based SEQ
- User feedback per task
- Task timing
- Pass / Fail matrix
- End of test SUS

The main significant change to the procedure of the study was in the amount of assistance material provided. During the first study where the flow from function start to end was the primary focus, the lack of familiarization helped to identify aspects of the software that needed to be addressed. However, in this second test the decision was made to allow a short familiarization period for users. While this is partly due to the real world limitations on running multiple usability tests it was also seen as appropriate as the function tasks themselves are more ambitious. A "cheat sheet" was also provided to users. A snap shot of this is provided in Figure 8.6 and the full version can be viewed in C.6. This was limited to a screenshot of the ClaMApp default screen and a basic bullet point explanation of menu items.



To navigate the program:

To access the menu either click the menu button (a) or swipe in from the left (b)

Figure 1 - Accessing the menu

From the menu you can select your My File folder (a) and can see any groups you are a member of (b)

Figure 2 - Menu selection

You can also choose to take a picture (c) or make a new document (d). If creating a document it is advised you use the Text Document option when asked, as not all devices have software capable of reading word documents.

Opening / Moving Files

To make use of a file simply tap the file to open the interaction menu

Figure 3 - Opening file menu

From here you can:

- Open the file – Open the file for viewing / editing
- Get help – Send a notification to the teacher in regards to the file
- Send File... - Select to copy or move the file. Copy will make a copy in the new location while move will move the file to the new location
- Rename File – Allows you to rename your files. It may be a good idea to do this with pictures before moving them to shared spaces for example
- Delete – Deletes the file. Note this is permanent and should be used carefully.

Figure 8.6: The cheat sheet provided to participants, detailing the basic actions of the ClaMApp interface.

8.4. Methodology

As noted a within subjects' design was used. This was run as two separate tests, conducted one after the other. During each test the companion actions required to provide information or feedback were conducted by the researcher; for example when a help request was submitted or a chat exchange took place the researcher would feed the necessary components back to the participant as though they were another member using the app. As with the first test participants were alternated between starting roles, student then teacher for one then teacher followed by student for the next. Before testing, the participants filled out the same questionnaire on their perception of their own mobile usage and how they as students viewed the position of technology in a teaching environment as that shown in Chapter 7. To ensure fresh perspectives on the application none of the users in the second test had participated in the first study.

8 4.1. Familiarization

Before each test was performed users were given the chance to familiarize themselves with the application through a free use period of 5 minutes. They were provided with the short cheat sheet (Figure 8.6: The cheat sheet provided to participants, detailing the basic actions of the ClaMApp interface.) for that version of the application. During this familiarization time participants were allowed to ask the researcher questions but would only be shown the relevant cheat sheet image or told to experiment to determine the function.

8 4.2. Task structure

The task structure for the study mimicked those used in the first study, targeted at a specific function concept. However, each test contained repetitions of certain single action tasks to provide a reference over time to a user's growing familiarity with the interface. The final task for both teacher and student required stepping outside of ClaMApp to perform various actions before returning to the application.

For each test, users were asked to perform a singular task with the application. These descriptions were again kept to a natural language sentence format:

- Students have had trouble with the tasks provided. Go to Help Requests and view their messages. Mark them as read when finished. (Teacher Task 3)
- Check the submitted files "stu1" and "stu2". Make two notes, one about each student. The category should be the students name and the content should be the item they returned with. (Teacher Task 8)
- The teacher has sent you a file called "basic maths01" to the "Student Materials" group. Open the file and examine it. Using chat check if the other students in the group understand the material. (Student Task 9)
- Monitor the chat for group "Experiment group". When the students have indicated they are finished copy the file to "My Files…". Open the document and edit in a sentence noting if the students were correct or not. The correct answers are:
    - Timecube: Otis Eugene "Gene" Ray, Wisest man on earth
    - Zombo: Flash animation, 1999
    - Go to notes and make a general note that "Students have completed all tasks".
    - Go to help requests and delete all help requests. (Teacher Task 12)

As tasks progressed additional functionality was incorporated into each task to require two or more functional actions with a focus on a combination of file and feature targeted operations. For example, a participant would open a file, modify the contents and inform of the changes through group chats. Each task was then categorized based on the functions it made use of:

- File action
- File movement
- Group management
- Group interaction
- File help requests (assessing and submitting)
- Creating notes
- Multimedia

With a second set of categories for later tasks divided into:

- Compound task
- Long compound task

It was important that when judging functionality that it be done in a manner that would be considered natural to real world use. As such, while tasks that utilised only a single function at a time may have provided clearer opinions on that specific function, requiring multiple functions was more in line with real world operation and would provide a clearer overall rating on a sequence's difficulty and the applications overall usability. It would also assist in highlighting areas where cross function communication may have been an issue.

Table 8.1: Task function test in order for both teacher and student tasks. Compound tasks involve multiple singular task functions, while the long compound task requires multiple functions and operation outside of the ClaMApp software.

Teacher application	Student application
Group management	File action
File movement	File help request (submit)
File help requests (assess)	File action
File movement	Multimedia
Creating notes	Group Interaction
Group management	File movement
Multimedia	File action
Compound task	File movement
File movement	Compound task
Help request (assess)	Compound task
File movement	Long compound task
Long compound task	

In order to accurately mimic how the applications would tend to be used in a real world environment the student tasks were given a heavy weighting towards communication and collaboration while the teacher's tasks focused on management and reaction to student actions.

The final tasks for both tests involved targeted activities that required repeated access of functions outside of ClaMApp. In the case of teachers, this was through multiple file access in cooperation with student file editing. For the student tests there was a component of external web searching that would require a specific intent to navigate out of the application to another application on the device. Each tasks function goal is shown in Table 8.1. There was also value in determining the speed increases during the test for given interactions, it was assumed that user speed would increase with familiarity. For this file movement was chosen and four of these were placed in the teacher tasks. This task required multiple menu input and had no ambiguity in its performance, making it a good candidate for this measurement (Figure 8.7).

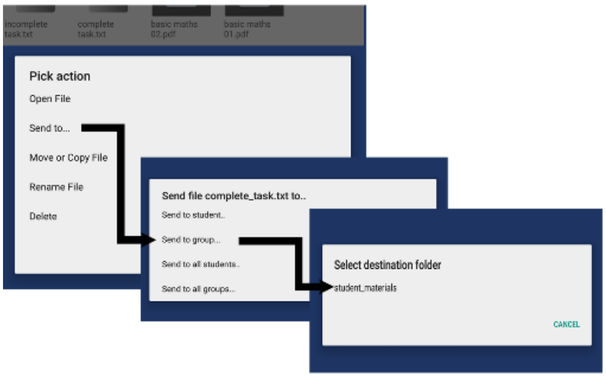


Figure 8.7: The copy file function process, showing the 3 steps taken to perform the action.

As with the first study in order to assess feedback on the functions three post task metrics were employed, the SEQ, a pass / fail task matrix and task timing. After each task users were also provided the option to provide open ended feedback. It is important to note that while timing for tasks that used a single function is a relevant metric, however timing across multiple functions merely provided a general mean time for a task that had less relevance to the execution of each function. This was due to the nature of multi-function tasks being difficult to separate into their individual function components. To this end some single function tasks were added later in each test to provide a reference and comparison point to early attempts when the user was less familiar with the application.

A time limit of 5 minutes for any given task was included and after this time a task would be considered to have failed. However, this did not apply to the final task due to the significant increase in required feature use. After each test with the respective application participants again would fill out a SUS to provide a measure of overall usability in a format that could be compared to the initial round of testing.

8 4.3. Participant pool

As with the study in Chapter 6, participants for the test were drawn from a general university student pool. As with the previous study the primary function was to assess functionality, task completion and satisfaction on “general” users, as teachers are themselves general users. As noted in section 7.8 the population pool is not required to have specific experience in the teaching field, as teachers encompass a “general populace” breadth of ICT skill. However as with the previous study it was important that participants not be highly skilled technical professionals.

Recruitment for this study was conducted in the same manner as the study presented in Chapter 7. Participants were again invited to participate by email sent university wide with approval from the SBREC ethics board (Appendix A.3). Upon expressions of interest potential participants were provided with an information pack detailing the intention of the study and expected time commitments. If they followed up with a willingness to assist, a time was arranged for testing. Tests were conducted in a one on one environment in a closed quiet laboratory, using the same space and environment as the first study. Again, participants were provided with all materials necessary to perform the tests including devices, cheat sheets and task instructions.

8.5. Results

8 5.1. Pre Test Questionnaire

This study had 20 participants and came from a pool of students in varying stages of tertiary education. All were under the age of 40 with varying levels of perceived ICT experience. All of the students owned their own mobile device of some sort but only 45% owned a tablet (Figure 8.8).

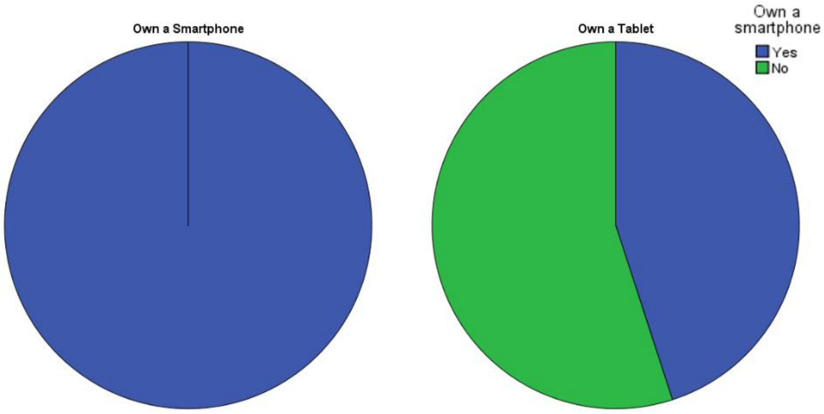


Figure 8.8: Comparison of participants who owned a smartphone and those who owned a tablet. All participants responded to both question.

All of the participants used a mobile phone daily and considered it a useful tool in their daily lives. 40% of participants said a mobile phone was an essential part of their day and they were never without it. 20% said they used mobile devices frequently during the day as needed. The remaining 20% felt that while their use was daily, it was not an essential tool for their daily lives (Figure 8.9: Count of participants who feel that statement best describes their mobile usage.).

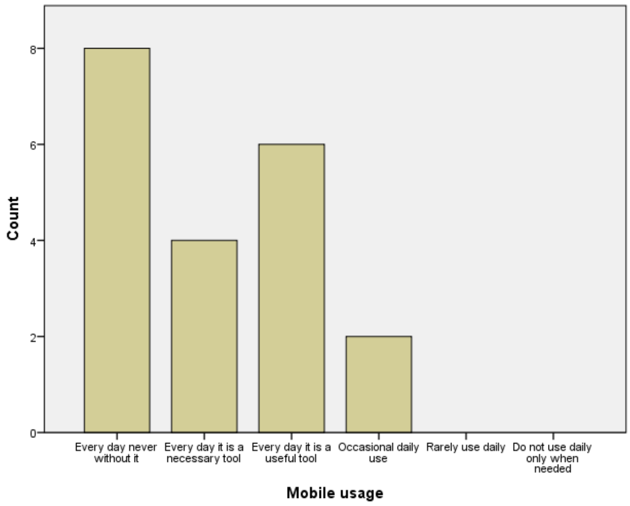


Figure 8.9: Count of participants who feel that statement best describes their mobile usage.

Participants were asked how they viewed the use of technology in the classroom through 4 statements with responses graded on a scale of 1 to 7, with 1 being strongly disagree with the statement and 7 strongly agree. Here participants were again strong in their support of technology and supporting role internet access plays in their education. However, opinion was divided in two domains; where they were primarily learning to use devices, and the level of use required for their classes.

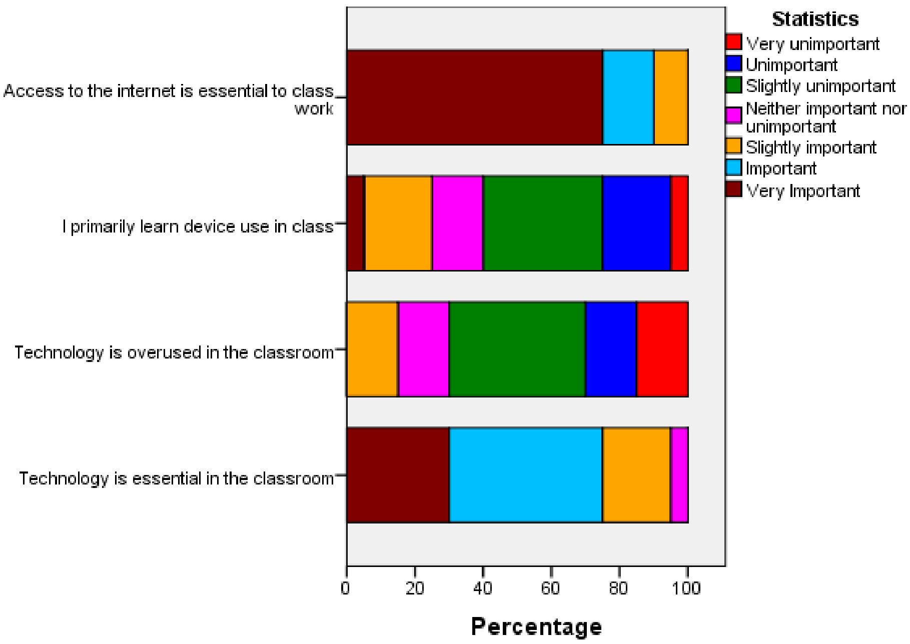


Figure 8.10: Participants views of how they use technology in their learning, and how important they see its role in their education. A 7-point scale was used from 1 (strongly disagree) to 7 (strongly agree).

When asked how they viewed the role of technology as a tool to aid in managing classroom tasks; such as file transfer, teacher to student communication and notifications all of the participants felt that the use of technology was a part of managing classroom tasks. However, respondents were split down the middle as to if it should be an essential requirement that digital management be an option or that traditional management materials should be complimented by technology, shown in Figure 8.11.

8 5.2. Overall Usability and Learnability

After the preliminary survey participants were given up to 5 minutes to familiarize themselves with the applications, though they were told they were welcome to begin the tasks when they felt they were comfortable. No participant with either iteration of the application made use of the full 5 minutes available. As stated in section 8 4.2, the participants used each application first in an alternating pattern, with the end result being 10 participants began with the teacher version while 10 began with the student. The teacher application involved 12 tasks while the student application required 11 tasks to be complete.

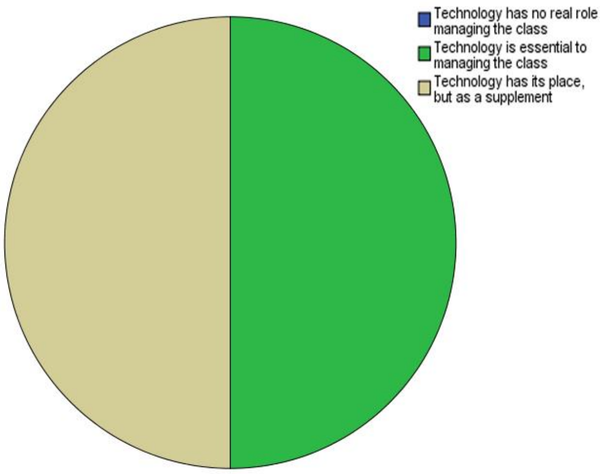


Figure 8.11: Participants views on the role that technology plays as a management aide in their education.

At the end of the required tasks participants were given a SUS survey to provide an impression of the overall usability of the application and establish if the two ClaMApp versions provide statistically comparable usability. The SUS results were again separated to provide additional factors in Learnability and Usability. From this data the overall SUS score (M = 80.5, SD = 12), was above the expected mean for usable software, when looking at the teacher version shown in Figure 8.12.

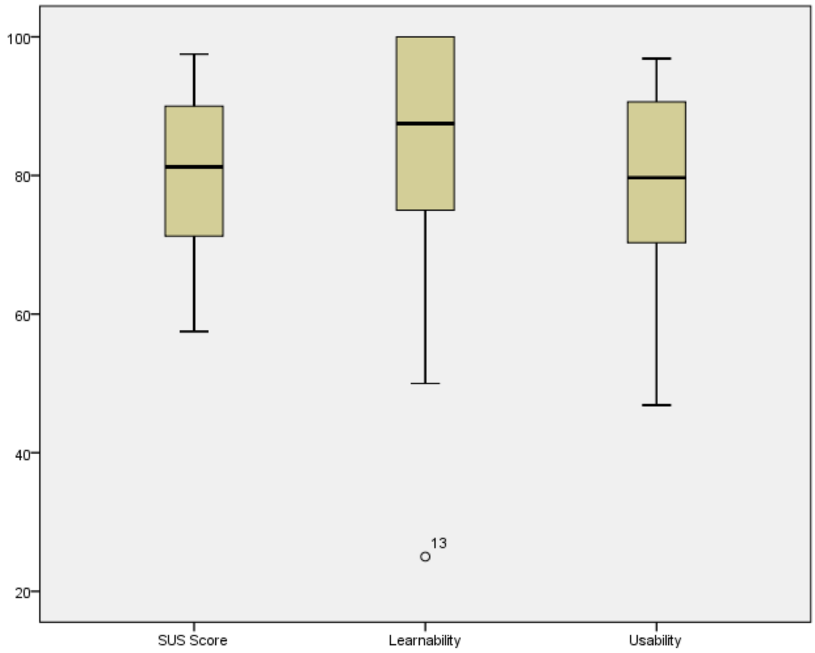


Figure 8.12: Teacher version of ClaMApp SUS scores.

This places the ClaMApp software again in the B+, 80-84 percentile range. Examining scores for deeper Usability (M = 79.84, SD = 12.6) and Learnability (M = 83.13, SD = 20.1) showed Learnability rated higher than Usability suggesting that while the overall SUS score indicates the software is usable, it factors higher in the speed at which users can learn its functionality. However, a one-way ANOVA run on the three scores showed no statistical difference between these sets ($F(2,57) = 0.254$, $p = 0.777$).

The same SUS surveys were performed by participants after their tasks with the Student targeted application providing similar results to the teacher application with an overall SUS score (M = 78.75, SD = 16.1) that placed the application at a B+ rating (Figure 8.13). Again, Learnability rated higher (M = 83.13, SD = 24.8) than Usability (M = 77.66, SD = 15.6) when approaching SUS scores as a two factor answer. A one-way ANOVA on these results showed that while there was a visual difference it was not statistically relevant ($F(2,57) = 0.446$, $p = 0.641$).

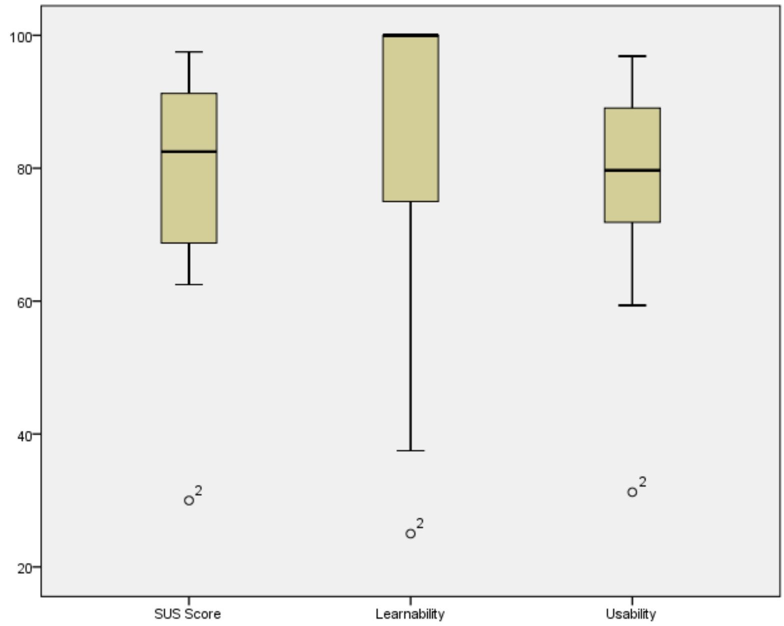


Figure 8.13: Student version of ClaMApp SUS scores

As SUS scores for both versions of the application appeared to align closely, expected due to their similarities, a paired samples t-test was conducted on both overall SUS scores. This confirmed that there was no difference is statistical significance in the usability of the teacher ($M = 80.5$, $SD = 12.05$) and the student ($M = 78.75$, $SD = 16.19$) applications; $t(19) = 0.725$, $p = 0.477$. As there was no significant difference in usability there was confidence to group function and feature use assessment across both applications. As the teacher application is capable of every file and feature function that the student version can perform this provided a deeper result pool on like determinants; for example, file copy tasks existed in both task sets. This also allowed a comprehensive single ease result for compound tasks (tasks that used more than one function to complete). It is important to note that this provided varying n values for a task as some were repeated more often than not; for example, File Movement ($n = 120$) made up a greater portion of the tasks than a Compound Task ($n = 60$).

This showed the participants found the tasks to be easy to execute ($M = 6.195$, $SD = .423$). With File Movement having the highest reported ease of use ($M = 6.67$, $SD = 0.726$) with the lowest being the compound long task ($M = 5.58$, $SD = 1.13$). This accurately portrays expectations with the most common task request being the easiest, while the most complex was considered the hardest (Figure 8.14). However, all functions performed within the upper 25% (> 5.25) of the scale range.

When examining time, shown in Figure 8.15, it was assessed on the median in order to account for the inherent skewness of timed data. Here values were as expected, with long compound tasks taking the most amount of time ($M = 160$, $SD = 88.49$) followed by shorter compound tasks ($M = 48.93$, $SD = 37.94$). Of the single task functions, the slowest performance times were in two specific instances, for multimedia (M = 43.35, SD = 21.74) and creating notes (M = 45.00, SD = 21.74). This was also an expected result as while multimedia is a single function it does involve consecutive actions including the time participants took to line up and focus on the object they were instructed to photograph. In the case of creating notes, participants had been instructed to create their own notes, composition and typing of these varied between users as reflected in the mean time for note creation.

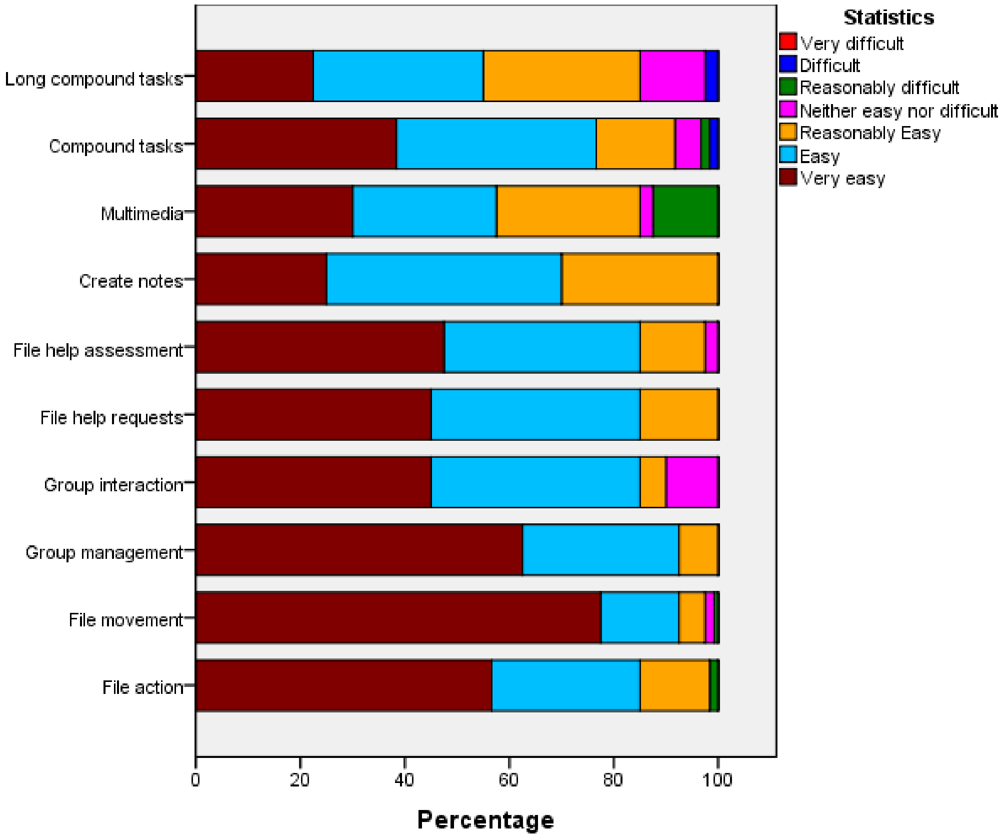


Figure 8.14: SEQ spectrum for each function action. A 7-point scale was used from 1 (strongly disagree) to 7 (strongly agree).

Lastly a repeated run of a file movement actions was used to attempt to track increases in learnability. This function required multiple factors including navigating to a folder to find a file and multiple selections on a file to copy it; resulting in the use of both file and non-file function interfaces and was represented in the teacher testing application as tasks 2, 4, 9 and 11.

Examining geometric mean also showed a sizeable narrowing of the standard deviation as the task familiarity progressed (Figure 8.16). This suggests that participants both increased in speed for the function but also closed uniformly on what would be a baseline speed to perform the task after 4 repetitions, approximately 8 seconds for a task involving 6 lifts (Table 8.2).

The final assessed metric was task pass / fail rates. For all tasks in the study all participants finished within the allotted time, and finished in the correct end state. This meant that all participants completed all tasks successfully. This was reflected in open responses where the only critical responses concerned the aesthetics of the software with the majority leaving no comment for tasks or simply stating it was "easy" or "very easy".

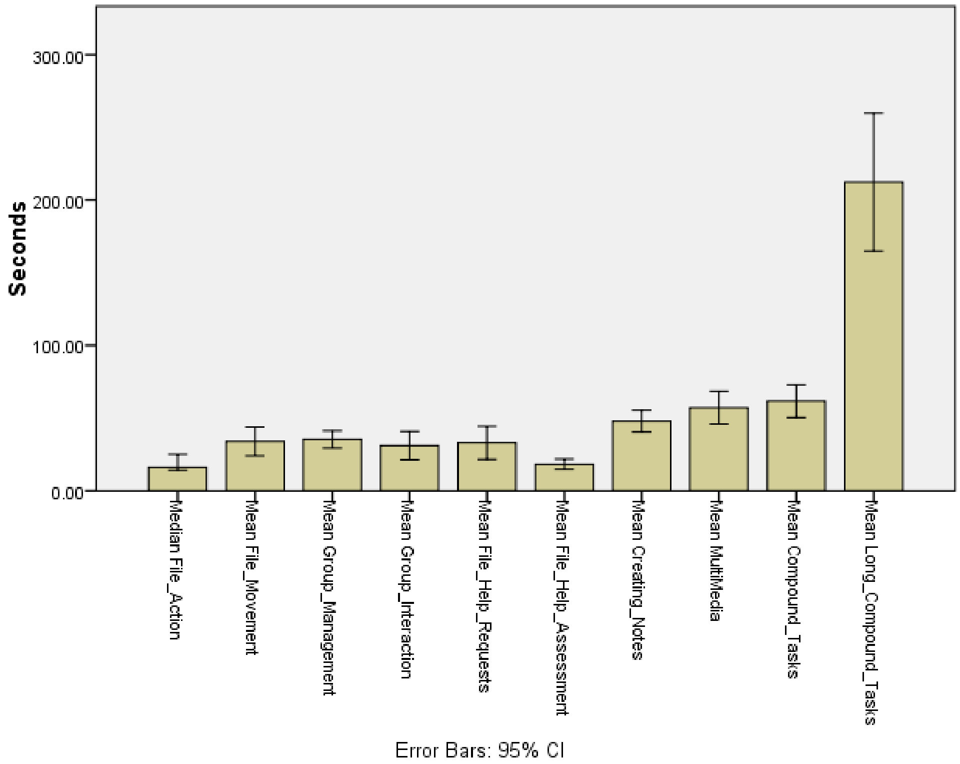


Figure 8.15: Median time for function completion across tasks.

Table 8.2: Geometric mean for repeated execution of the file copy function. This shows that with limited repetitions users familiarity and speed of execution quickly lowers, with users coalescing near 8 seconds for the action, with limited deviation.

Task	**Geometric Mean**	**Std Dev**
Task 2	19.39	19.81
Task 4	15.62	6.97
Task 9	13.5	6.99
Task 11	8.6	3.15

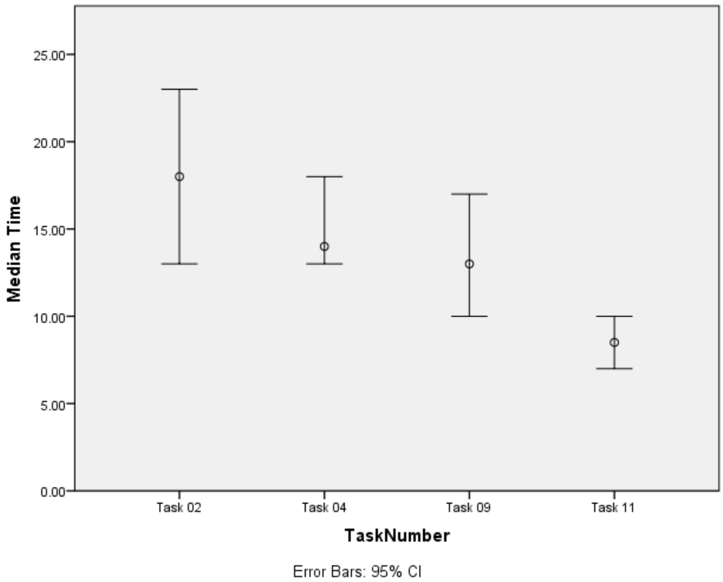


Figure 8.16: Median time for repeated execution of copy file function, showing the decrease in task time as users became more familiar with the interface, lessening their time to execution and reducing the deviation.

8 5.3. Study 1 and 2 comparison

With this information there was scope to also perform comparative analysis to the first usability study (Chapter 7). The most obvious distinction between the two is in the pass fail rates for each study, with the second study having a zero failure rate for tasks. While there is limited benefit in attempting to compare individual SEQ values out of context, the SUS results provided a clear point of comparison between the two studies, allowing an examination of any increase or decrease in usability. If the added complexity of the tasks and changes to the UI resulted in a significant loss of measured usability additional steps would need to be taken to address non obvious factors that missed the error reporting threshold.

Similar results were observed when considering a straight comparison in overall usability for the teacher application between both studies.

As the pools contained different participants an independent samples t-test was run confirming that there was no statistically significant difference between participants of the first study ($M = 77.9$, $SD = 12.1$) and the second ($M = 90.5$, $SD = 12$), $t(31) = 0.609$, $p = 0.897$ with the teacher application (Figure 8.17).

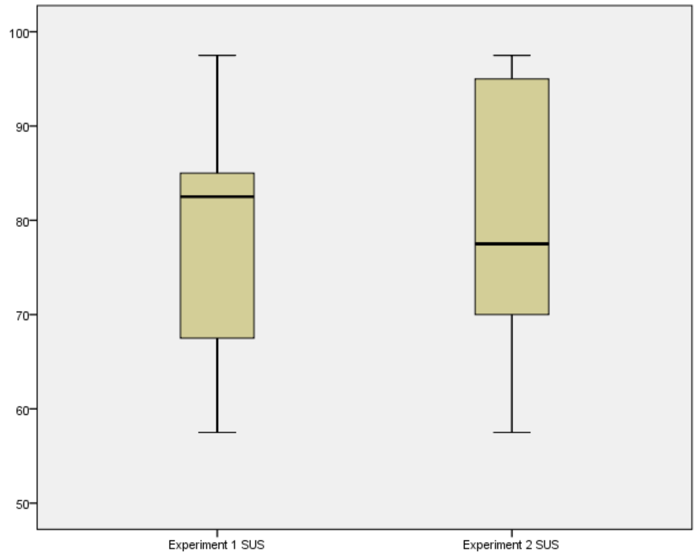


Figure 8.17: Comparison of Study 1 and Study 2 SUS results for the teacher version of ClaMApp.

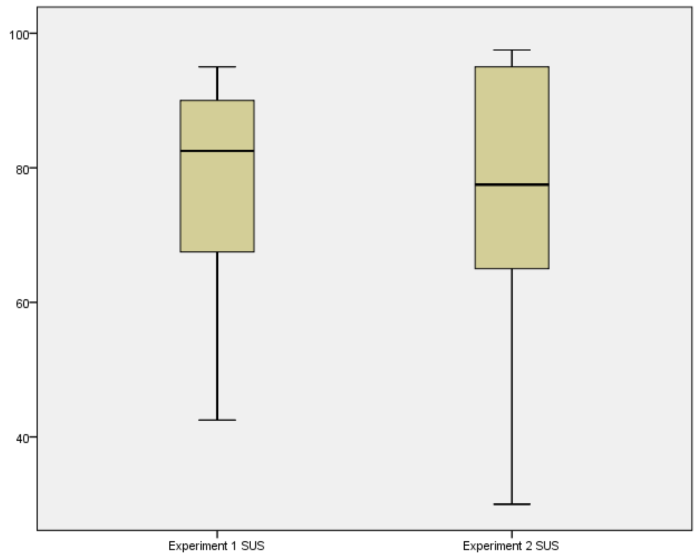


Figure 8.18: Comparison of Study 1 and Study 2 SUS results for the student version of ClaMApp.

When looking at the student application there was a comparable repetition with both SUS results appearing similar and another independent samples t-test showed that there was no significant difference between the scores for the student version in the first study ($M = 78.3$, $SD = 15.5$) and the second study ($M = 78.6$, $SD = 16.1$) , $t(31) = 0.085$, $p = 0.911$ (Figure 8.18). These results suggest that despite the additional complexity of the tasks the usability of the overall application for either version remained constant.

8.6. Discussion

The second revision of the ClaMApp software was designed to improve upon the original version and reduce the function specific errors the original usability testing revealed. While there was limited back end changes made there were significant interface changes especially in the domains of collaborative spaces and multimedia. The results from this second study showed that ClaMApp retained or improved on its overall usability when compared to the first version.

When looking at the time taken to complete tasks, all took under 50 seconds to complete (except the significantly longer compound task), with single target functions taking under 20 seconds for first time execution. Similarly, when looking at SEQ results for tasks all but multimedia received a rating of Easy to Very Easy. Meanwhile File Movement, File Actions and Group Management all achieved over 50% participant response of Very Easy, an important metric as these are the most used management system functions. For Group Management especially this shows the impact that the version 2 redesign had, as it went from one of the worst scoring functions in the first study to one of the highest in this one. There is however still some concern for the scattered response to the multimedia function. While the redesign seems to have solved the fail rates with the function, the SEQ scores remain the lowest of the functions by some margin with almost 15% of respondents stating the task was difficult. Had time allowed, multimedia was a function that would benefit from an investigation into the learnability of the action similar to that used with File Movement.

When looking at SUS results again ClaMApp version 2 performed on par with version 1. While the redesign saw no statistical increase in usability or in the usability and learnability factors this is less concerning when considering the difficulty of the tasks involved. Despite the increased task difficulty both versions of the application maintained their B+ rating.

One clear sign of improvement was in the pass fail rates of the tasks. Despite their increased difficulty none of the participants in this study failed a task or erroneously believed they had completed a task when they had not. This indicates that even when tasks were rated on a low SEQ score or users felt dissatisfied with the application as a whole, they were still able to achieve the function goals. This in turn supports the argument that the redesign of the software increased the learnability. This learnability factor is also demonstrated through the reduction in times of the repeated file copy task. Over the course of 4 repetitions the mean time to complete the function was cut in half suggesting that with a small number of repetitions, function action approaches a close to optimal time.

When the results from this study are compared to the first again the improvements seem clear. While SUS scores remain comparable the significantly longer testing time frame along with the increased complexity of the tasks would suggest that usability remained constant, or was over inflated in the first study, where tasks were simple. Similarly, when comping mean times there is a significant reduction in time to complete and again given the addition of compound tasks this indicates an increase in usability during the second study. Chiefly, the removal of task fails, despite the added complexity, indicates that the ClaMApp software is fit for purpose even if some concern exists around overall usability; all participants could complete all tasks, including tasks that resulted in fails in the first study.

As with the previous experiment, the sample size and population warrants discussion. As has been noted in previous chapters when assessing usability for qualitative feedback a sample of five users can provide significant value, however this population grows when seeking more statistically relevant results (section 7.8). For this second study it was considered important, in light of the task errors and fail rates in the first study, to achieve as high an error detection rate as possible. While a population of 10 can provide an 80% error detection, time and resource restrictions meant that detecting as many errors as possible in as few tests as possible was an important factor. With a sample size of 20 there is little benefit in error detection or statistical analysis in increasing the population size more. This allows for a high level of confidence that the lack of errors, correct state results and statistical analysis of usability and learnability are strong indicators.

However, while some usability questions may have remained, ClaMApp had reached the point where controlled lab testing had exhausted the majority of useful information to be gathered. Any additional revisions or work on the application would require the input of the target user group rather than general usability testing. As such, additional usability testing had to happen within the classroom and with teachers and students within the school environment.

Testing within the classroom helped to provide additional insight into the value of learnable and usable interfaces as a tool to reduce the professional development time needed to make a management system usable. In this study the ClaMApp software demonstrated a high usability and ease of learning, with all participants being able to effectively use the software with no formal training and a simple 10-minute familiarization session at the start of the class.

During the study session the application performed the necessary tasks as expected and allowed the teacher to easily disseminate the learning strategies materials. Overall, the software for the most part was a clear supportive element to the session, effectively performing the needed management tasks without requiring additional instruction in its use or confusing the teacher. The students similarly found the system easy to use and the mobile nature of the tablets allowed them to take the system around the classroom as groups were changed and supported the mobile learning environment with little learning time. The ClaMApp software supported this collaborative environment well, however it did suffer from some unforeseen user impacts, especially with the chat, again indicating the importance of multiple in-classroom tests to provide a true usability experience.

This chapter helps to establish the importance of learnability and usability as tools to effectively reduce the time investment of teachers, a key factor in software uptake as established in section 6 2.4. This study also supports that effective targeting of key factors that impact the uptake of software can be made through the minimization of learning time to provide a more positive personal experience for the teacher. Similarly, the usability factors of the software help to ease the element of personal comfort teachers experience with the software allowing them to be more confident that the intended outcomes of operation are the outcomes that occur.

When looking at the role this work plays in the domain of Research Question 5 (R.Q.5), it is felt that following this study, general testing on non-specific users had reached the limit of its effectiveness. The results from this study indicate that the ClaMApp software is learnable, usable and provides a strong confidence to users that they are achieving the correct outcomes when operating the application. This looks directly to address the time requirement and perception aspects raised in sections 2.2 and 4.5, in providing a solution that requires minimal amounts of time to learn and provides a strong usable environment. Additional studies with the software now need to be applied to the intended user group, in a classroom setting, to provide additional information. The next stage of study must look at the ability of the software to provide a similar experience when faced with the social and practical challenges of classroom use. It is important to recognise however that there are tertiary factors to the deployment of ICT in the classroom beyond the simple idea of "give teachers a device and software to use". These elements and a study examining preliminary classroom testing are presented in Chapter 8.

8.7. Summary

Based on the results from the first usability study a number of design changes needed to be addressed before ClaMApp could be considered usable. Firstly, the multimedia function was adjusted to provide a more explicit experience when saving media. This was done to address issues experienced by users that resulted in low confidence of operation, or a high confidence in an erroneous operation. The other significant adjustment concerned the collaborative spaces. To address confusion between file and social spaces the two were combined allowing chat and file storage to be present on the same fragment, although this required some additional structures to control visible screen space. Lastly, a number of quality of life improvements were made including renaming menu items, addressing some screen formatting issues and fixing some Android interface problems.

Following these changes, a second usability study was conducted. This demonstrated that despite the evaluation of complex tasks the software retained its overall usability, especially in the key area of failed tasks and expectant outcome with all participants successfully completing all objectives. This study also demonstrated the learnability aspect of ClaMApp through repeated function execution showing a rapid decrease in function execution over repeated attempts. With all 20 participants in the test successfully completing all tasks, ClaMApp had proven successful in controlled testing.

This success suggests that the ClaMApp software passes the need to be learnable and usable, a requirement for deeper investigation into Research Question 5 (R.Q.5). With no task fails and with general users able to complete tasks with no specific direction, the next stage of testing needs to be performed in a real world teaching environment. This further testing and the important mitigating factors of classroom software testing are discussed in Chapter 9.

Chapter 9

In school testing

9.1. Overview

Following controlled environment studies to achieve an acceptable usability and learnability status with the ClaMApp software it is necessary to take the application out of the lab and assess its ability to perform in a real-world scenario. However, testing in a real-world classroom with nascent technology presents a number of obstacles that need to be addressed. The following chapter looks at the testing environment to be used and discusses some of these important impactors when deploying software to a live environment.

A study is presented in this chapter that employs the ClaMApp software in a complimentary capacity to an existing classroom lesson. The software is employed over a two-hour teaching block and assessed for usability, learnability and user opinion.

9.2. Background

Following the second usability test presented in Chapter 8 ClaMApp was believed to be in a state that it was for all intents “usable” by people. It also demonstrated, albeit in a controlled environment, fast learnability with a low error rate. However, these short targeted tests do not represent the intended real world usage of the application. For that the application needed to be tested in a classroom, away from targeted tasks and for an extended period of time. However, it is still difficult to deploy the software to a classroom in any longitudinal study without a targeted usability study aimed at the intended cohort. Previous chapters looked at general usability, however a usability assessment from the intended user base was desirable. Nearly all persistent software can be susceptible to bugs during extended run times and as the nature of the software is group based it was essential that ClaMApp be tested in in the intended group environment.

With the aim to run a relatively contained usability study on a classroom there are a number of factors that needed to be considered. The first was that to achieve some kind of natural user environment it will be difficult to justify any set task achievements. In real world settings users are expected to use the application as they need, facilitating their other work and a targeted task list would inevitably take away from that usage ideal. Therefore, it was necessary to abandon the task structure of previous studies. There was also a desire for firm usability metrics and the SUS still provides that information for the overall use of the device.

Aside from the testing issues there are a number of other significant factors with bringing assistive technology into an active classroom. As ClaMApp serves primarily as a management solution, providing a number of teacher student facilitators as prototype functions, the impact of a class making use of just the application for a lesson could be onerous. It would require teachers to transfer and prepare their expected class material to the devices, and be prepared to utilise this information disconnected from their usual lesson structure in a new environment.

They would do this knowing that the information on the lesson is short term and any additional information or generated content will need to be reverted back to their original lesson structure after the study. This places a significant strain on accurate usability metrics. One added way to lessen the impact of the new environment is simply through acclimatization and having it be present for the full lesson period. This also lessens the “task” nature of ClaMApp usage, leaving the interaction with the application more open ended; if it is required at various locations during the lesson rather than one after the other in a short space of time. This assists in a natural usage environment.

There is also a need to lessen any sense of new technology impact. To properly discover usability, it is important that the application be used as much as possible in line with real world class activities. Much like the issues that would be faced by a teacher converting a lesson plan to a new device, asking students to perform their lesson solely within a new experience carries the weight of adding an artificial element to any results. A key goal then becomes creating an environment where the application can be utilised in a manner most aligned with real world expectation while minimizing the strain of a new environment.

This leaves some clear guidelines for classroom testing:

- Limited standard lesson impact
- Utilise the application within the lesson structure
- Non-task oriented
- Reasonable time investment of use

A collaboration with the Flinders University School of Education utilizing ClaMApp on a within class study offered a framework where these goals could be met. Their aim was to investigate mobile devices as a way of delivering lesson content as complimentary learning strategies to students within the classroom, initially as documents. The intent presented was to use tablets in conjunction with standard lesson plans to implement learnability strategies during the course of a standard lesson. During this 2-hour block students were presented with documents outlining the various learning strategies, advice on how to approach the learning outcomes and ways to utilise different techniques, primarily mind mapping, to achieve outcomes. This aligned with the goals set out for in-class testing. By using the tablet as a complimentary device it would lessen the impact of the new technology factor, and remove the need for the teacher to port their lesson content over to a new environment. The distribution of learnability materials during the course of the lesson would necessitate students interacting with ClaMApp in as close to a natural manner as could be managed. The staggered deployment of these materials to students ensured they would access them in a non-rigid time frame, aligning strongly with the study outline goals.

As an additional benefit the education experiment encouraged students to take pictures and utilise mind mapping software to solidify their learning outcomes then share them with their classmates. This allows us to test additional features of the application, namely the camera shot function, and the effectiveness of students to work with the tablet outside the application, save that work back to ClaMApp and sync it to group members or the teacher.

By delivering complementary material throughout the lesson via the tablet it allows for the application to be used without any additional setup or teardown by the teacher or students and with a minimal impact on the overall lesson plan, while still requiring a significant encouragement to engage with the app.

9 2.1. Learnability Study

It is worth addressing the pedagogical goals of the learning experiment, so as to inform the role the application plays in that context. The goal was to present self-learning strategies to students in conjunction with the classroom material. This content was presented as four different types of self-learning assistance:

- Mapping
- Self-explanation
- Visual imagery
- Checking self-understanding

These factors were laid out in a series of four documents to be distributed to the students over the course of the lesson, with each document having a bearing on a portion of the class material. The class itself was focused on introducing ionic, metallic and covalent bonds in introductory chemistry and the learning strategies provided were explicitly connected to the subject matter.

To start students were supplied with the first document as a starting point, containing an overview of the explanation and an introduction to mapping as a concept and the concept of mind mapping software to help establish mental links between ideas, shown in Figure 9.1.

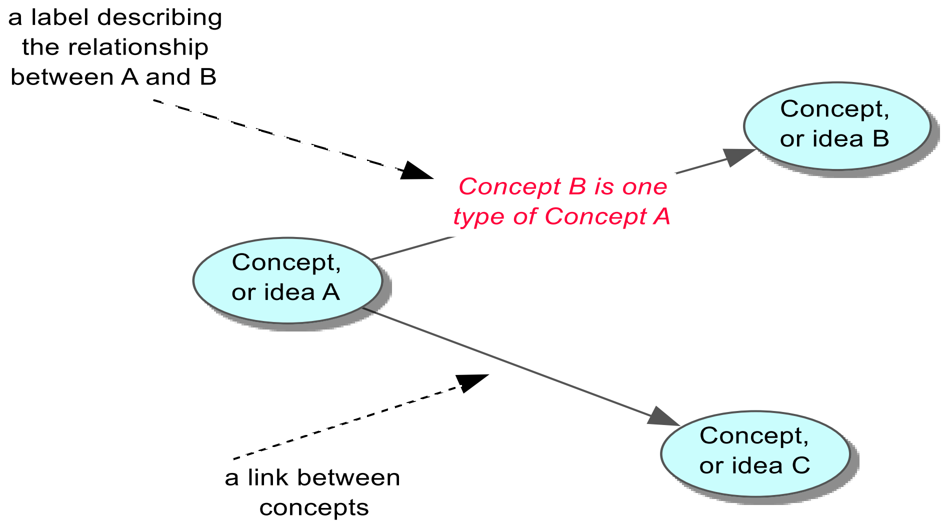


Figure 9.1: A diagram from the learning strategies documents presenting the idea of mind maps to students. These were utilised from within the tablet via the SharpMindMap application. The resulting mind maps were collected at the end of the experiment, provided through ClaMApp, by the teacher.

During the course of the lesson students were encouraged to engage with the learning strategies with a particular focus on mapping and collaborating.

Over the course of the lesson the teacher would release additional strategies to students. The second and third strategies were released to students when a critical mass had completed the previous work. The final strategy was released to students who had finished the standard work and were looking for additional challenge and information. A key aspect was to encourage student self and peer evaluation, with a lessened reliance on the teacher providing answers.

9.2.1.i. Strategy 1

This strategy would lay out a brief overview of the strategies and detailed how incorporating mapping concepts could assist in self-learning. Students were encouraged to utilise the mind mapping software of the tablet to create their own mind map with relevance to the course material.

9.2.1.ii. Strategy 2

Here students were encouraged to self-explain their mind maps and share them with partners and other members of their groups

9.2.1.iii. Strategy 3

Students would make use of visual mental imagery and actuate it as a real drawing, again comparing their work to other members of their groups or partners, and save copies of their images to refer back to later.

9.2.1.iv. Strategy 4

This strategy was primarily for students who finished work early and was part recap part checking their own understanding. This is done by self-assessing their own learning and requesting additional clarification when needed from the teacher.

9 2.2. Classroom ICT Environment

Within the class students had access to their standard laptops, supplied by the school to all students. The school itself had no LMS implementation to support the school as a whole but teachers, including the one in charge of the study group, had taken to utilizing Google Classroom to handle management tasks within their classroom, primarily for document distribution and the provided Google Drive space. Most ICT solutions implemented within the school were done ad hoc and as teachers needed, with no clear direction from administration about services to use beyond Office 365 and Google Classroom.

9 2.3. Application context

This thesis will not present the educational aims of the self-learning strategies as they focused largely on testing responses conducted outside the use of the ClaMApp software. What was important for this thesis was the ways students could be expected to utilise the app during the study. Foremost, the application was the primary interface for distribution and consumption of the learning strategies, distributed by the teacher. They were sent from the teacher as a mix of "all students" and targeted deployment depending on student progress. Collaborative features of the application would be utilised through group creation with students able to share their mind maps and visual images with other members of their groups, and collaborate through chat if they wished.

A key aspect that was present was the moving in and out of the application. Both the strategy documents and mind mapping software would involve exterior applications and students would need to navigate from within ClaMApp to outside it through the two primary ways of moving outside the app:

- Automatically through document opening, in the case of opening the strategy pdf documents
- Exiting to the home screen and opening a second app, in the case of initially starting the mind mapping software

Students could also be expected to utilise the camera functionality through the visualization tasks to share their images with other students and the teacher.

From the expected actions students' explicitly made use of the features:

- File open

- File move or copy
- Group spaces for small groups and “submission”
- Camera shot
- File distribution from teacher

There is also an implied encouragement to utilise:

- Student teacher help message
- Group chats

Each of these expected functions had in expected usage within the study, with the four primary functionalities being a requirement of the studies instructions. For file opening task these were conducted by bother teacher and student as need. For the teacher this would occur when confirming the files within the system were the correct ones to send, as well as after the study in review of the student data. For students file opening was through the examination of the distributed learning materials and mind map images. Group spaces were used by the teacher to allow varied distribution of the learning materials at their discretion. Students meanwhile used group spaces to chat with each other and if desired share files and media. Students also had access to the chat system within their designated groups allowing non-verbal communication. The camera shot functionality was provided to allow students to capture the images of their mind maps, and of their implementation of the learning strategies. Through the server based nature of the application all of these images were then collected by the teacher and researcher for later review. File distribution was used exclusively by the teacher to allow for delivery of the learning strategies to the students and is an extension of the file move / copy functionality.

The final two examined functionalities were discussed in the initial familiarisation, but there were no tasks that explicitly required the students to make use of these system. It was left up to the students to make use of these options or to ignore them.

It should be noted that very limited instruction was provided to students on how they should use the application and if they chose during the study time not to use a function this was not penalized in any way. The key goals of the study were to get a general usability metric, from the target user group when deployed in a real world class environment, ensure effective use of the functions to achieve the aims and assess the applications usability in a long form open use environment. It was also important to do this in a way with the lowest impact to the general running of the lesson.

9.3. Methodology

The test took place during a 2.5-hour lesson block at Glenunga High School in South Australia with Year 8 students (aged 12-14 years old). As the devices were to be used as a compliment to the student school laptops the researcher provided all the devices, and all devices were the same model, the Nexus 7 devices used in the previous usability studies, and running the same operating system (Android 5.01) as was used in the Chapter 8 study.

The teacher device was preloaded with the 4 learning strategy documents and all the devices also had a copy of the Sharp Mind Map (https://sharpmindmap.droidinformer.org/) mind mapping software installed. This software was chosen as it met the defined pedagogical needs of the education design. Students were provided with the same cheat sheet as was used by participants in the second usability study and as with that study given limited to no instruction. The only place where students were provided a step by step guide was in specifying the server address, due to the dynamic nature of the server IP assignment on the school Wi-Fi. As with the usability studies students did not need to register the devices, as this was done prior to the test. The teacher was provided with no additional training from the students. As the lesson was dependent on the distribution of learnability materials it was decided before beginning that if the teacher was unable to decipher how to deploy documents to student devices she would be shown the first time, but this was not needed.

As the user base was from a singule group and in a cohort the application targeted there was no need to collect the same general background information from the previous tests. There was some initial introductory and explanatory content before the test began, this served a similar function to the acclimatization period at the start of the previous study. The students were instructed when the first and second documents were sent, however after that they were sent to the students' devices in an ad hoc manner.

During the lesson the researcher was to avoid providing any assistance to the students or teacher in the use of the application and limit help to any technical issues that may arise. Usability issues that were encountered to a degree that they could not be solved without researcher intervention were noted on an issues matrix for later study. However, assistance was provided where needed with navigating the mind mapping software. This was because the software was not part of the usability test and had proven in the past to be, despite meeting the functional goals for the learnability study, somewhat difficult for novice users to navigate. This was both to assist in the smooth execution of the learnability factors of the first study and to prevent a negative opinion of the mind mapping software impacting ClaMApp's usability assessment.

While the application had performed functionally as expected in laboratory testing there is always the chance that in a prolonged testing environment technical issues could become apparent. To track these problems a technical problems matrix was maintained throughout the study to record any functional failures in the software. There were no restrictions placed upon the students in how and in what ways they used the tablet devices, though they were clearly aware that two studies were being conducted. However, they could choose to use any of the tablets features or functions however they wished.

In school testing

As with studies in Chapter 7 and Chapter 8 overall usability was primarily measured using a SUS questionnaire at the end of the lesson. As there was no task focus there was no way to arrange any SEQ measurement or measurements of function completion time, but the problem matrix was employed again to track any issues encountered during testing. A technical pass / fail matrix was also used for this test to track technical issues that arose during the test. While in a controlled environment technical issues could be quickly addressed there was a significant risk in a long-term test that technical bugs manifest in software and it was important to note these. Similarly, despite the second usability study showing no fail rates for targeted tasks the difference in user cohort, as well as the extended nature of the test, meant that there was a chance of a user's failing to understand how to perform an action and these would need to be noted. The key difference in this from previous tests was that they would not be recorded unless the student could not solve the problem themselves without researcher intervention. There was no time limit associated with waiting for tasks to be complete.

To complement the SUS metric and to capture the subjective views of the students, a number of Likert metrics were included at the end of the session. These were chosen to target some of the core features of the application, namely file usage, collaborative spaces, perceived learnability and ease of navigation. Therefore, at the end of the study along with SUS students were asked to provide ratings on a scale for four metrics:

- I could easily access what I wanted
- It was easy to communicate with other students through the app
- I could easily navigate the application
- I felt I quickly learnt to use the app

Additionally, participants were asked for three basic qualitative metrics related to the applications

- The easiest thing to do was…
- The most difficult thing to do was…
- I had issues with…

These would allow the drawing of some similarities between the classroom experience and the results seen on per function testing in the controlled task based studies. It would also allow for some interpretation of user feedback that is missing with the lack of SEQ function targeted testing.

9.4. Results

This study was performed in class with a group of Australian Year 8 students in a co-ed classroom. The primary lesson content was Year 8 Chemistry and the class was part of the school's high achievers program. There were 23 total participants (including the teacher), however 1 student failed to complete the Likert and short answer surveys, while a student left some short answer options blank.

During testing students had no problems operating the application and only 2 technical issues that required intervention. The first occurred outside the testing domain and concerned an issue with the provided school Wi-Fi. This resulted in needing the change the server address on the devices within a very limited time. Due to this, students were enlisted to make the changes themselves and a number needed to be guided through that process. However, the server detail entry screen was by design obfuscated and hidden from accidental access. As such this is not included as a legitimate ClaMApp error. The only other technical error encountered involved a synchronization issue between one student device and the server. This resulted in the first learning strategy appearing on the device but with no data content in the file and re-logging the user fixed the issue. As noted there were no operation issues with students for accessing any portions of the ClaMApp software, although as predicted a number of students required assistance with the mind mapping software.

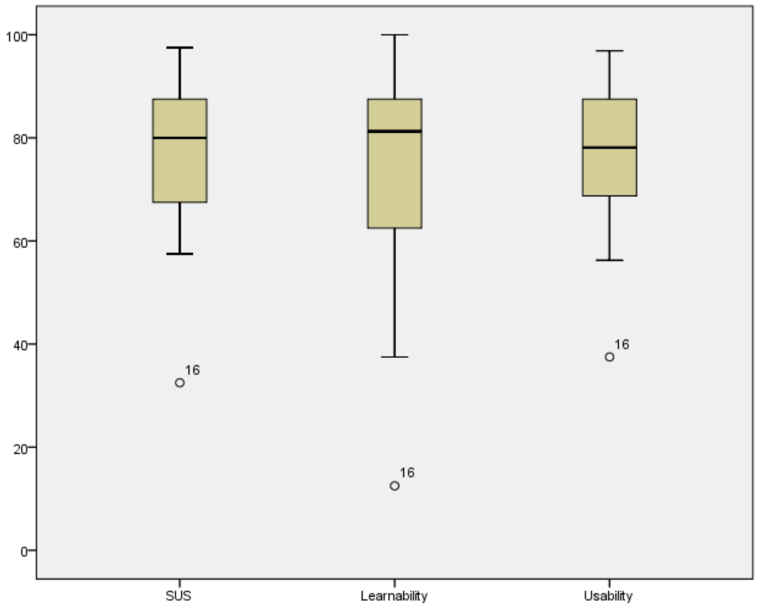


Figure 9.2: SUS results for classroom trial. This graph includes both students and teacher results combined

When examining the classroom SUS results (Figure 9.2) it was found that again the software performed above the referenced mean for usable work overall (M = 76.59, SD = 15.5), as well as above in the Learnability (M = 77.27, SD = 21.6) and Usability (M = 76.42, SD = 14.9) factors. Here again as with the lab test while the Learnability is nominally higher a one-way ANOVA run on the three scores showed no statistical difference between these three sets ($F(2,63) = 0.014$, $p = 0.986$). These results were slightly lower than previous tests providing a result in the 75-80 percentile range, or a B equivalent.

IN SCHOOL TESTING

When asked to provide an ease of use Likert responses all of the factors performed above average; ease of accessing files (M = 6.00, SD = 0.82), easy to learn (M = 6.27, SD = 0.93), easy to navigate (M = 5.84, SD = 1.44) and easy to communicate (M = 5.04, SD = 0.81).

This is shown in Figure 9.3 with students stating that file access was reasonably easy or above and that learning the app was reasonably easy or above (90%). The lowest score, ease of communication, was also the domain where there was a significant user impact during the test with two students realizing there was no spam filter in the chat feature and filled the channels with random off topic messages.

When asked what the easiest part of the application to use was over half (n=13) the students responded that material management was the easiest function to use, as shown in Figure 9.4. However, it should be noted that as this was the primary action they performed, and would have required repeated executions of the function, this may have bias. For three students each navigating ClaMApp and sending images to their group mates was listed as the easiest feature. One student stated that logging on was the easiest thing they did with the app, because there is always one.

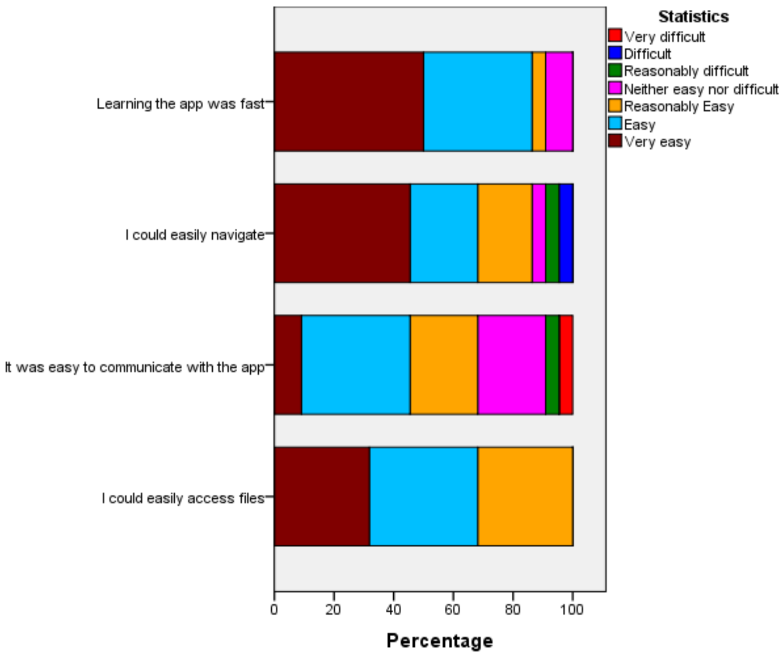


Figure 9.3: Respondent Likert scores for qualitative impressions of ClaMApp. A 7-point scale was used from 1 (strongly disagree) to 7 (strongly agree).

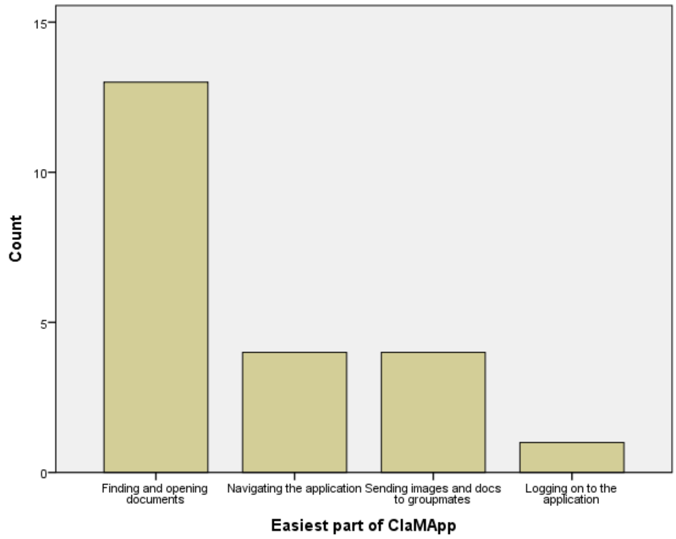


Figure 9.4: Responses as to the easiest part of the application to use. Responses were open format and grouped by response language.

When asked which function was the most difficult to use however opinions were far more diverse (Figure 9.5). For four students navigating was listed as the hardest while communicating, understanding groups and using the camera were the most difficult aspect for three students. It bears mention that of the students who noted communicating as the hardest, two of them made direct mention of the chat spam, when providing qualitative assessment. For 7 students however, the hardest function was nothing or actions unrelated to the ClaMApp software. The last two students stated that the hardest part of the software was in relation to the initial connectivity issues.

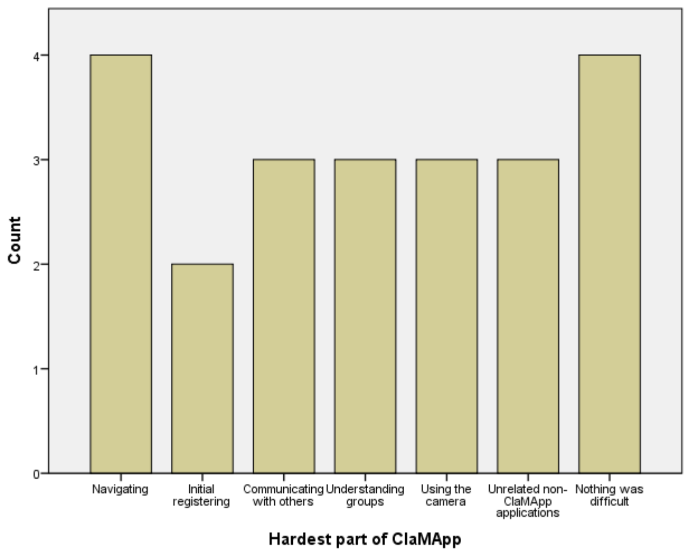


Figure 9.5: Responses as to the hardest part of the application to use. Responses were open format and grouped by response language.

Finally, students were asked if they encountered any other issues with the software during use that they wanted to mention, shown in Figure 9.6. Here the majority again listed “No issues” or some derivative of that message in their response. For four of the students the spam issues with chat were noted, with two of them stating it made communicating with their group difficult. Four other students noted the visual appearance of the software "*It could look better*" and "*It could be more aesthetically pleasing*".

Overall these results reinforced the usability and learnability of the application, this time with the intended user group. There were no significant technical or usability issues during the class period of 2.5 hours and at no stage did the ClaMApp software appear to interfere with the pedagogical aims of delivering the strategies, facilitating the use of mind mapping software and collaborating with group partners.

As a final comparison the SUS scores obtained from the second usability study were considered with those from the in-class study to determine if there was any significant difference in the downgrade to B from B+ recorded previously. For this an independent samples t-test was used as participant groups were not the same. As the primary user base for Study 2 was students only the Student results from that study were used. Here there was no statistical significance in the usability of the class room group (M = 76.59, SD = 3.31) and the student lab simulation (M = 78.75, SD = 16.19) applications; t (19) = -0.532, p = 0.601. From these results it can be assumed that the usability of the application has held in both studies; controlled task focused testing and free form dynamic classroom use.

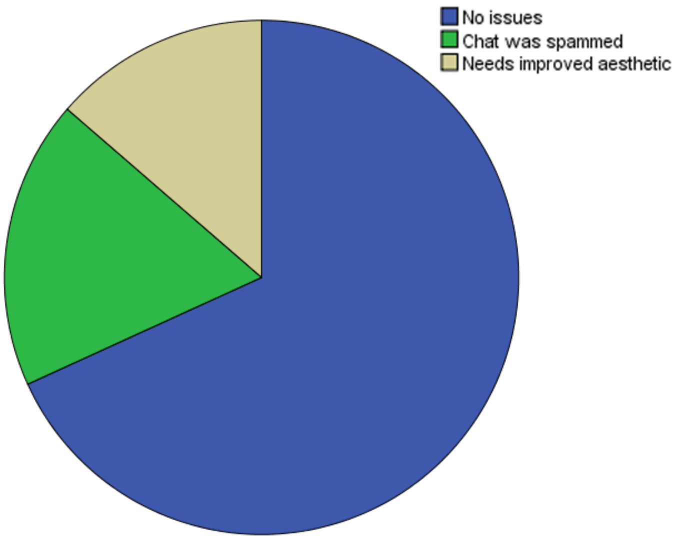


Figure 9.6: Responses as to any other issues or problems users experienced using the application. Responses were open format and grouped by response language.

9.5. Discussion

As noted in the introduction to this chapter one of the most telling proponents of the ClaMApp software was the prelude to this study and the collaboration with the Flinders

University School of Education. In this case the Education School study required software for the role that ClaMApp fulfilled and was sought out because no current software existed to provide the desired functionality; for example providing the materials and tablet software needed in a way that allowed them to be presented to students in order, allowed the students to use the multimedia features of a tablet and tablet based software (a mind mapping application). This also demonstrates the benefits of software that is disconnected from any pedagogical design, at least as far as the actions of an application goes. ClaMApp fulfils a role as a facilitator of the pedagogical choices teachers want to make rather than enforcing its own perception of how that should be interpreted. In turn this supports the already discovered need for autonomy among teachers for how they look to employ technology while also supporting ad-hoc implementations, where a single cohesive tool can provide linked collaboration among students and teachers without institution level implementations. In this particular circumstance the need to link together written materials, un-connected mind map software and the classroom into a shared space is handled seamlessly by ClaMApp with minimal impact on the lesson. Meanwhile the targeted desire to use tablets to deliver this complimentary material further reinforces the focus that schools, even in early 2017, are placing on these devices. Again this use of tablets displayed the dichotomy of the environment where teachers are looking to employ the devices but the school has no clear strategy, relying primarily on the single laptop device and again eschewing mobile phones as a distraction. While there was no provisioned familiarization period for students there was ample time for students to become accustomed to the interface during the first five minutes of the class and most used the time to study with the tablets.

As noted the ClaMApp software itself experienced only 1 technical issue; a student logged on with the device and synced their version of the initial strategy, however it downloaded a 0-byte size file instead of the server version. Upon logging in again the full version of the file downloaded. This tends to suggest an issue with the download from Android, probably a failure to copy the file from the temp download cache to the students file location. However, since this was the first time encountering this bug in 3 tests across over 50 participants there is confidence that it was not an internal problem with ClaMApp. Beyond this instance the only technical support that was needed by students related to the use of the mind mapping software, primarily as the application seemed to reset positions arbitrarily. While there was no time to investigate the cause, and it had not materialized in pre-test testing, there was little recourse during the test itself and it was hoped this would not reflect on the ClaMApp usability results. This appeared to be mostly the case though with three students they noting these third party app problems as their greatest issue.

Overall the ClaMApp software performed exactly as expected, facilitating the class action, providing access as needed and at the teacher’s discretion to class materials, enabling multimedia actions and collaborative sharing. This was achieved without obfuscating the core content of the lesson’s focus on chemistry and the supplied learning strategies. While the initial

5 – 10 minutes involved a significant amount of play with the tablet itself beyond that ClaMApp served as a silent facilitator to the learning strategies, allowing the focus to be on pedagogical directives rather than management operation as was its intention.

This same background performance was found with the teacher's interaction. Despite contingencies being in place in the case of confusion the teacher found and distributed the first set of learning materials on her own while the researcher was assisting with the previously mentioned technical issue. This was despite this being her first use of the application. The only episode of teacher confusion was when instructed that she had control over the dissemination of material; that it was up to her when and how to deliver the materials, the students did not have default access to them. However, this ability was met with enthusiasm as a means to control their access to the documents and prevent the students skipping ahead without first digesting the current strategy.

The final usability results from the SUS were statistically comparable to those achieved from the second usability study, although standard deviations still remained high. Promisingly when asked what functions of ClaMApp were the easiest to use Material and Collaborative spaces rated the highest. However as mentioned a significant portion of their interaction with the application will have been through opening learnability materials and it was expected that by the end of the study that would result in a strong sense of usability. When asked about the hardest part of the application the results were scattered, although a third of the students (including the teacher) report no issues or issues unrelated to the operation of ClaMApp. For four of the students, navigating the application was noted as the hardest part while for three students communicating was an issue. This may have been tempered somewhat by the users in the last set being in a group with a student who filled the chat with spam messages, making it difficult for the rest of the group to conduct any meaningful communication through the app.

Despite students responding to the hardest part of the app question, when provided a qualitative assessment of any issues the majority of students, almost two thirds said there were no issues, with another 4 stating that their only issue was aesthetic. This suggests that while there may be a response when asked directly what was the hardest, the idea of hardest may have been more subjective than actual, or aspects would have shown up in issues. Two students who had stated the hardest part was communicating again indicated the issues with chat spam while the remaining students made comment to the aesthetic of the application which, as ClaMApp is both prototype and has had no visual design consideration, are less important factors.

Overall during the free form classroom test ClaMApp performed as it should. There were no significant technical or usability issues. The learnability materials were delivered as needed successfully, relevant multimedia was archived for the teacher and the access and use of the third party mind map software was maintained. It allowed the use of pedagogically targeted software and materials without enforcing any strictures on the environment and operated primarily in the background as a manager. At the end of the study it allowed the teacher and education researcher to easily collect associated mind map save files, multimedia images and any documents the students created within ClaMApp.

As with any software testing in the real world there are inevitably important limitations both on what can be tested and the time frame that is allowed. In a perfect world, software could be employed longitudinally across multiple iterations however this is rarely the case. Within the classroom itself there are significant deployment factors, noted in section 9.2, but also social and professional limitations. In order to truly test the effectiveness in an environment, testing needs to extend beyond the point where "newness" is a factor in user perception. Similarly testing needs to be impactful enough to provide relevant results while not being so disruptive to the normal teaching pattern. This is one of the main reasons that a complimentary testing structure was chosen, but it is important to note that this does not come without a cost. The application is not tested at this stage in a longitudinal manner where ClaMApp provides all, or the majority of, the management functionality in a classroom.

Additionally, while this type of long form study could provide a more accurate representation of the way the software works in a "real world" environment it is not feasible to jump straight to a long term trial straight from controlled laboratory testing. There must be some middle ground testing to assess the practical implementation in the classroom and ensure that software failure is not immediate. Thus, while this study does not represent a sole use of the ClaMApp software in the exact environment for which it was designed, it still fills an important step in assessing its real world practicality. The use of the app in conjunction with current lesson structure and content, while not allowing ClaMApp to manage in full the lesson content, provides a middle ground where immediate failure is not a fatal blow to the professional environment to which it is being used. Similarly, the ease of use and learnability of the application can still be assessed in a case where significant functionality had failed. While in this study there were no functional issues it was still a consideration factor in the study design.

Another limitation in the study is the use of a single class. Again, while the preference would be for multiple class implementations the realities of the environment prohibit such a study. This is a mixture of available classes, the allowed testing bounds of the learnability study, the considerations placed on the study by DECD and willingness of teachers in the allowed schools to participate. However, while the number of students presents a suitable user group for usability and learnability assessment (sections 7.8, 8.6) the single teacher leaves some hesitation in teacher specific functionality assessment. Learning strategies were distributed correctly to groups with variation in time and action to a point that there can be confidence in correct operation in this environment. Similarly, while function operability is similar across app versions more teacher specific usability and learnability results would have been of benefit. Unfortunately, the only way to increase the teacher implementation is to increase the actual classes tested and this was not possible at the time.

In school testing

It is also worth discussing the merits of managerial support versus usability. As noted above, the realities of the available testing environment meant that for the most part functional actions were undefined; there was no task structure comparative to the initial controlled studies in Chapter 7 and Chapter 8. The study was conducted to allow students and teachers to make free form use of the application. This allowed the study to both test functional stability in an uncontrolled environment and to minimize impact on the professional elements of teaching a real world class and this latitude by nature clouds specific results. At the same time the ClaMApp software had not been tested in a real world environment and while there was confidence in function operability from the study presented in Chapter 8 there is a significant difference between in-lab testing and real world application. So while it is acknowledged that continued study is warranted, it was not feasible within the bounds of this work, and within the professional environment this testing would take place, for such longitudinal studies.

As discussed in Chapter 6 the key goal of ClaMApp is to provide these managerial functions easily through a usable and learnable application and thus usability and learnability trump functional operation, so long as functional operation is successful. This means that the most important initial test factor was the correct operation of functions in an uncontrolled format. Testing managerial task assistance when the software is not in a functionally usable and learnable state is not the goal of this work and would lead to additional issues if functionality was not acceptable. Indeed, key managerial support issues that need refining would need to be assessed on the failure of the software to function similarly to the in-lab implementation when used in the classroom. While in the case of this study there were no functional issues and the software did perform in a comparable manner to lab studies, outside of the initial log in issues, that does not exempt this usability focused testing from being a necessary step.

This leads to Research Question 5 (R.Q.5) and the question of introducing functionally complex software that, through usable and learnable design elements, can be introduced into the classroom and perform with little to no learning time.

One of the chief aims of the development of the application stems from the investigation of ease of use when used by teachers. Previous sections of this work have discussed the link between perception and learnability on the willingness to uptake technology (section 2 2.3). Perception is an important driver and this is heavily impacted by the perception of usability and expectation. Software needs to provide usable functionality in a way that confidence in outcome is assured and operation is in line with expectation. By nature, usability allows for easier access and outcome in software operation and provides a boost to this initial perception of the application. The operator can be confident in their ability to perform an action and end up with the expected result in an acceptably straight forward manner. At the same time teachers want software that they view as easily learnable. This helps to combat classroom perceptions, their own confidence in use and time restrictions required to learn more complex systems. All of this while allowing them to action pedagogical goals and computer assisted outcomes in a constructivist classroom where collaboration and peer interaction are important (section 2.3). So long as the software provides similar functionality while taking into account these domains then the learnable and usable implementation provides the feedback loop discussed earlier; comfort in device and software use leads to a higher uptake of software and devices, leading to a greater confidence with ICT solutions. This greater confidence in turn provides confidence to employ devices in other manners (sections 4.5, 6 2.1). From this position it becomes more likely that teachers will utilise Technology Mediated Learning and make use of the learning strategies and theories that are actuated by mobile leaning (section 2 3.2) and Web 2.0 (section 2 3.3) environments. The results of this study suggest that ClaMApp provides common LMS functionalities in this usable and learnable state, with the tablet device opening the door to further actualize these mobile centric ideals like flipped learning and personal learning environments (section 2 3.5). There were no issues amongst either the student or teacher in operating the application nor in understanding the layout. Outcomes were as users expected when looking at both the teacher to student interactions of forming groups and sending cohort specific information and student to student interactions. There was no notable learning curve for either student or teacher group while the functionality of the app itself performed as intended.

This study supports that at least in this situation it can provide these benefits. While the limitations of the complimentary interaction and limited longitudinal exposure are important, the commonly complex LMS environment operations were achieved with no particular professional training investment from either students or teachers. Casual operational competence was demonstrated by the teacher by the end of the lesson period. ClaMApp allowed a nuanced approach to groups and document handling that was intuitive in an environment that no participants had trouble using. Despite being used in a complimentary fashion to standard lesson tools there was little trouble from students utilising the environment to address the learnability strategies outlined. While longitudinal studies are still a necessary next step to ensure long term learnability and ease of use, this work shows that software can be employed in the classroom without the need to spend significant time learning the functional operation of the environment, when that software is designed to a specific task and user group; teachers.

9.6. Summary

Deploying new technology to a classroom entails a number of conflicts that need to be addressed in order to minimize the impact of the software on the lesson structure. This is especially true when that software should be as unobtrusive as possible and facilitate rather than dictate lesson action. For this study, ClaMApp was deployed to a Year 8 South Australian high school as part of a collaboration with Flinders University School of Education. Here ClaMApp served as a facilitation tool to enable the examination of the effective use of learning strategies by allowing easy distribution of material, functional use of multimedia and the use of third party software chosen for its pedagogical value.

During this testing period students and teacher had unfettered use of the software with little to no instruction in its use for a two-and-a-half-hour lesson. During this time the software performed without error, successfully facilitated the integration of learning materials into the lesson and collected the relevant student submissions for further analysis. ClaMApp had an impact free presence during the lesson and performed as intended, managing the digital tasks of the teacher and student without error. At the end of the test the software again received comparable usability and learnability scores to those achieved in the second usability study with most students stating they had no issues or concerns with using the software.

Despite the limitations this study suggests that learnable and usable software can be employed within a classroom environment to bypass time intensive professional development training and to activate the positive feedback loop that high usability provides in a teaching environment.

Chapter 10

Conclusion

10.1. Overview

The work presented in this thesis documented the design and development of a small scale learning management system that was targeted at primary and secondary schools with a focus on managerial functionality within the classroom. This system would be of benefit for teachers who need management tasks that are easy to control and direct, as well as teachers in lower economic environments who may be sharing in class devices and have limited access to institutional level LMS environments, or limited infrastructure support.

Teachers should be able to easily and quickly perform the standard digital management tasks they need without the requirement of excessively developed cumbersome systems that require extensive cost. These costs are not just limited to the financial licensing and purchasing aspect of such systems but also the cost in time and professional development for teachers. The notion of implementing mobile learning and Web 2.0 software is tightly bound to a teacher's perceptions and willingness to make use of the software. Many teachers, quite appropriately, are concerned with the pedagogical outcomes such software brings than the technical aspects of its operation; they want to know how the software benefits their teaching aims, not what buttons to press. This can be especially true of management style software and it is essential to ensure that software is usable and learnable, something that cannot necessarily be said about popular business driven implementations which can suffer from bloated cost, operation and functionality that is primarily focused towards the institution rather than the classroom. Tablet devices offer a compelling alternative to laptops as both creation and consumption devices. They take up less space, have superior portability, young users are generally more familiar with the interaction and they have a significantly lower cost. There is also a growing trend of tablet and smartphone devices as complimentary within the classroom and a simple system to disseminate information and create social mobile learning spaces quickly and easily for students is important.

Early in the development of this thesis, a survey of South Australian public schools was conducted to canvas their views on tablets and smartphone devices in the classroom. Results indicated that respondents mostly confirmed the work present in contemporary literature. Teachers wanted to be able to make use of tablet devices in the classroom and saw them as beneficial to student learning. Most respondents wished they could make better use of the devices and this was a confirmation of the idea that, the more skilled a user was the more inclined they were to employ the devices in the classroom. School administrators provided their views on mobile devices and wireless infrastructure in their school and it was found that most did not make use of an LMS environment and left these tasks up to the individual teachers. As there appeared to be limited institutional direction this further highlighted the need for an easily learnable, low cost option for teachers. Schools were also often unsure of how to handle the idea of BYOD ideology, with their policies on mobile devices varied and sometimes poorly defined.

As the use of tablet devices as a primary tool in the classroom would necessitate the need for these devices to be used in content creation, and given their perception as primarily for content consumption devices, an experiment was conducted to assess the truth of how effectively a Bluetooth plus tablet combination could compare to a laptop as a text entry paradigm. Perception data from users as to what input options they felt provided them the most accuracy and comfort of entry were taken to examine how the continued emergence of software keyboard interfaces was being received. This was important as users’ views and technical aptitudes shift over time and recent literature on these aspects of text entry were limited. The experiment conducted showed that a tablet provided commensurate performance to a laptop when entering text and is an acceptable substitute. There was also a growing acceptance of GSK style interfaces, with students showing that the mobile focused swipe text entry idea provides users with a high level of confidence and sense of textual accuracy. This sense of accuracy was also supported in their error rates, significantly higher than the standard OSKs. These results showed that the tablet device is as capable as the laptop of being a content creation tool on par with the laptop, albeit with a peripheral attached and a greater portability and software keyboard suite. However, this caveat is aided by the fact that due to the already lower cost of the tablet, a Bluetooth keyboard would still not price the tablet over a laptop. Additionally, the wireless nature of the Bluetooth device allows the user to easily walk away from the keyboard at any time with no infringement of mobility.

From the results gathered from the survey and the keyboard experiment, it was evident there was a place for tablets in the classroom where they could compete or work in tandem with traditional laptop and desktop environments. This notion of the tablet in the classroom demonstrates the potential to provide a portable, cost effective option for teachers to be able to manage their classroom tasks in an easy to learn and deploy way. This tool would allow them to support the pedagogical application choices without locking them into a larger software eco system or overloading them with functionality they were unlikely to use.

To this end a tablet based classroom management system was created, focused on providing management functionality to teachers in classrooms either independent or in conjunction with other learning systems. The design was straightforward and utilised the unique aspects of the mobile interface to provide management functions in a streamlined and easy to use format. The ClaMApp software provided the core function sets present in most major LMS systems including:

- Material distribution and access
- Simple collaborative group creation for teachers
- Peer communication channels to leverage the social benefits of mobile computing

- Student to teacher communication channels
- Document and targeted note creation
- Leveraging the multimedia aspects of the tablet's camera and video operation.

These features were presented in a local server storage format that allowed for classroom device storage as well as BYOD options. The environment was device agnostic and students who accessed the system from different devices were provided up to date versions of both personal and collaborative work. Collaborative work was dynamic and updated when changes were made to allow students to effectively share and cooperate on group work.

The key design consideration for the application was a usable and learnable interface that would ensure teachers could be confident in both their own and students operation of the environment. The system required little to no training for use by teachers, and would not interfere with the operation of any other pedagogically aimed applications the teacher wishes to make use of. Interacting with software was done through two upper level hierarchal menu structures termed file and non-file functions with a clear explicit stepping operation. It was important that users were able, when possible, to abandon the menu structure without suffering from a state change that would place them in unfamiliar or partial operation states.

The initial design focused on explicit locations and actions for the different function facets and to test these a simple function usability study was conducted. This study showed that while the backend functions operated as intended there were some significant issues to address in the interface interaction. These changes were primarily focused around the collaborative spaces and folder display structure. To address these issues changes were made to combine the collaborative file and group space as well as adding explicit storage options for multimedia files. A number of additional quality of life changes were made based on user feedback. The revised ClaMApp software was used in a second usability study and found that with extremely limited exposure, under 5 minutes, to the application users could successfully perform all basic and compound functions with the application. The application obtained usability and learnability ratings from SUS measures that placed it in the above average category and there were no user task fails or errors in operation.

Lastly the application was tested in a classroom setting with the intended target population, a Year 8 South Australian high school chemistry class. Here the device was used in conjunction with standard class laptops to provide a complimentary stream of learnability documents to students and to allow them to collaborate, communicate and share their own multimedia and work. Students were encouraged to make use of a pedagogically targeted application outside the ClaMApp software and to share these creations with the teacher through the group folders. As with the previous lab based studies, participants were given no verbal instruction or defined familiarization time, their only instruction was a simple 2 sheet function descriptor. During the study both students and teacher demonstrated no issues with making use of the application for distributing and consuming media or in using the group features to communicate. After the test, ClaMApp again received a SUS score of above average with the clear majority of students and teacher responding that the software was simple and easy to use and effectively provided the management tasks intended. At the end of the test the teacher had direct access to students; mind map and group contributions for assessment.

10.2. Using ClaMApp to address perception

One of the key themes throughout this thesis has been the importance of the teacher perception on ICT implementation. This intangible covers a wide scope of opinions and it is impossible for software to cover every possibility. However, this again stresses the importance of teacher autonomy to make selections for themselves within their own classrooms to utilise the software they want, and managerial options should always look to facilitate this activity rather than force teachers down a set path. Teachers are aware of the importance of embracing technology in their lessons, and so too are schools. Yet there is clear confusion on exactly how to approach this and the best options, both pedagogically and managerially. As noted in the survey section of this work many of the implementations were ad hoc and despite the similarly aligned respondents, how they chose to address these implementation issues varied wildly. So too did teachers' personal views of device use. While most looked to tablets as a useful and necessary tool, often external factors of training and availability were significant impactors. All of these facets are outside the ability for software to address directly and solutions must attempt to weigh these different aspects for a best case solution. With teachers seemingly being the primary drivers of their own adoption lessening the impact to them of software uptake is vital. This was demonstrated in Chapter 9 with the use of Google Classroom by teachers at Glenunga High School in an as needed manner. The school provided no LMS environment and Google Classroom had become the default partly because it was seen as the easiest to learn and most inclusive option. This again stresses the factor of learnability as important and when tested, as documented in Chapter 8 and Chapter 9 this was a focus. In the classroom test especially, the learnability of the software allowed ClaMApp to integrate into the lesson seamlessly and students who had no exposure to the environment picked it up quickly. The same applied to the teacher. While structures were in place to address the failure of learnability of the app there was no need. At the start of the class she picked it up and sent the documents without issues. Throughout the study ClaMApp did exactly what it was designed to do, allowing the teacher to provide the material and software they wanted to use with no training and minimal impact on the actual lesson. This was backed up by the results and while there was inevitably a period of "new tech" when they were first presented with the software this quickly subsided and the class focused on the learning strategies and chemistry work. Indeed, for most users, the primary technical interaction was with addressing mind mapping issues, ClaMApp was an afterthought for the users who were part of the study. However, regarding managerial software that is a good result. The software is intended as a facilitator environment and it should perform as an afterthought. Here ClaMApp acted as it should; a managerial option that has no impact on what the teacher actually wants to do but allows for the digital management without a requirement for training.

While it would be beneficial to get results in longitudinal studies as the sole content manager, in the 6 years since the software was conceived there has been continued shifts in environment, both in technology, software and teaching environments; especially around mobile and tablets as complimentary devices. The old discussions of "either or" has, for the most part, given way to both. Work on ClaMApp software had already begun when the explosion of larger format phones, devices with screen sizes closer to 7 inches. Similarly, this work had performed its initial usability testing in late 2014 before Google Classroom was released in 2015. As such it is strongly felt that while ClaMApp performed well and filled what was still a necessary position, especially in schools where classroom tablets are the primary available device, there is a significant need for ground up re-examination of its core goal; a shift from tablet only to a more mobile focused multi-device, single user domain.

When considering the framework established in section 2.6 there are a number of elements that deserve consideration and reflection. One of the key elements in the framework was the need to establish localised and current information when looking at ICT use within classrooms. The ICT domain is a shifting paradigm, constantly evolving, not just within its own environment but also within the environments where it is utilised. In schools especially, there is a constant shifting of position that is far from consistent across all communities. Schools are frequently looking at the best ways to adjust or incorporate ICT elements, and the need for consistent, up to date information about the environment in which the software or devices will be deployed, is vital. Even over the course of the work presented in this thesis, the shift in approach and perception was noticeable. Even within the school environment, in which the study presented in Chapter 9 was conducted, inter teacher opinions differed significantly on the role that ICT played. Therefore, when looking to conduct research within this domain, literature alone may not be enough to provide the environment conditions that are essential to correctly target software to a user base.

In a similar situation, the role of tablets is evolving. In the time between the initial literature and methodology work presented in this thesis, as well as the study presented in Chapter 9, the tablet space has evolved dramatically in the real world. The work presented in Chapter 5 has been reinforced, and built upon in unforeseen ways. Most notable the development of combination laptop/tablet devices like the Microsoft Surface, that look to provide the traditional input paradigms discussed here with a tablet style device.

The ClaMApp software showed that software designed for the classroom can overcome the need for significant professional development when designed with usable and learnable structures in mind. With these two factors it can be relatively straight forward to incorporate complex collaborative and classroom management tasks in a way that requires little to no training for the teacher or students. Here the benefits of supporting the learning environment in a way that takes little control away from the teacher is important and effective, allowing for additional classroom complexity with minimal educational impact, as shown in the classroom study presented in Chapter 9.

10.3. Contribution

The thesis contributes by expanding on the understanding of mobile interfaces and how important usability and expected outcomes are to the efficacy of application use. This is especially true in education where the target population has a very large spread of technology comfort and very specific implementation needs that are rarely met by general use apps. Additionally, this is in both the domains of ensuring the teachers can select applications based on pedagogical importance and that their professional training can focus on learning the pedagogical use of the application instead of technical proficiency.

This work also demonstrated the need for teachers to have a tighter control on their management tasks within the classroom, while also requiring simple and easy to learn software. There are some significant benefits in streamlining that are provided through a mobile interface that are not present in general Windows based systems. These can be leveraged to create a hierarchal interface that largely removes the ability for users to end up in an incorrect or unfamiliar application state. These interfaces can provide a highly learnable and usable interface alternative that requires little to no familiarization and removes the need for significant training in software operation (Armstrong and Wilkinson 2016a). These systems can and should break from the general mould of one app one function when dealing with a user base with specific needs. Here the grouping of function sets into a single application provides a cohesive theme and "look and feel" to the interface that can assist in increasing the expected outcomes of an operation, and thereby increasing the willingness for teachers to make use of it.

The research presented here also contributed by highlighting the need for direct solutions that focus primarily on the classroom as the centre for digital management (Armstrong and Wilkinson 2015). This is important not only in modern classrooms where teachers need to feel they have autonomy over the technology used, but also in developing and low economic environments where the costs of an institution wide, full LMS deployment is not feasible. In these environments where mobile devices are more readily available than laptops, the need for a simple management solution is amplified. This is doubly important when consideration is given to the lack of resources available for professional development courses in these areas. These contributions have been validated and reinforced in examples from the business world with a greater focus on emerging LMS environments that are targeted at the classroom rather than the institution level, including systems like Google Classroom that place the focus firmly on the classroom level.

There is also a contribution in the realm of tablets as creation devices, showing that they can be as effective as laptops as content creators (Armstrong and Wilkinson 2016b). Additionally, there is the growing acceptance and preference of software keyboards, especially GSK implementations. The thesis also contributes to the continued examination of typing speeds among users, especially in the field of software keyboards and presenting the importance of user perception to their preferred interface regardless of quantitative outcome.

The work also provides additional insight into the perceptions and opinions of school teachers and how they view mobile devices and tablets in the classroom, their opinions on social media as a factor in the classroom and their own personal experience with technology in the classroom, reinforcing current literature that use propagates comfort and use. It also provided similar additional insight for how the institutions themselves view the place of mobile devices in the classroom and how schools look to manage the student use of mobiles in the classroom. The culmination of this contribution can be found in the report published with the South Australian Department for Education and Child Development.

10 3.1. Professional discussion

Aside from the academic contribution made by this work it is worth noting that many of the ideas discussed in this work have seen significant uptake in recent years within the business domain. The rise of classroom focused management systems including Google Classroom and Daymap have shown the importance that business and schools are putting on the need for teachers to have direct digital control of their classrooms. Similarly, the interface ideas and concepts presented, such as low hierarchal structure, progressive selection and soft button selection, have become increasingly popular in consumer products, moving away from the traditional WIMP style designs. While this work does not claim sole authorship of many of the concepts, this increased focus on these aspects from business reinforces the importance that streamlined and simple usability has on users.

10.4. Future work

10 4.1. Education focused

This work provides significant options for future work, both directly related to the ClaMApp environment as well as additional research avenues. When this work was started in 2012, the discussion within schools and their administration networks was either a laptop or tablet framework. Since then the landscape has changed significantly and mobile and tablet devices are viewed in a far more complimentary light. As demonstrated in the final usability study, there is significant domain for further examining tablets as a complimentary device to the laptop in the classroom. Rather than treating the tablet like a digital textbook however, investigations should consider software similar to ClaMApp that provides students with a synchronised experience bringing together all their personal digital devices and classroom interaction into a singular space.

The positive responses received to the interface design also suggest additional research into the application of hierarchal streamlined menus outside of the mobile space. Especially as usable options in environments where professional development time is a factor and how users will make use of software is more important than learning technical intricacies.

Education is a changing and developing field perhaps only equalled in its rapid change by technology. As such over the six years of this thesis, the landscape has in some cases shifted greatly. For this reason, any future work should always look to provide additional feedback on the changing attitudes and impacts of both the technology teachers use and how they look to employ it. Background research and elements of this work have clearly shown the relationship between comfort and use among users and as such constant re-evaluation is essential.

There is no indication of any reduction to the deployment of technology in classrooms and as such the aspects raised in this work with regard to teacher acceptance, what is required for an interface to be learnable and the design of targeted applications for specialized fields where standard mobile design is not suitable, will continue to be necessary.

10 4.2. Tablet input

Beyond the education domain and looking to the thesis' keyboard study, there are also investigations into input devices that bear greater examination. This is especially true when focusing on the perception of users towards emerging OSK developments and the impact these can have on user's acceptance of the technology. One area that is especially interesting would be an examination of user's perceptions before and after longitudinal use of a GSK environment, and how effectively these predictive systems can lead to increased use amongst previously calcitrant user's.

Another avenue of further research highlighted by this work is the examination of what impacted user rejection of the Bluetooth keyboard as an acceptable alternative to the laptop. Physically these devices were as close to each other as possible yet there was significant pushback to its use. While it was posited that this may be due to latency or screen orientation there is value in understanding if this effect is repeatable and if so what the driving factors of the rejection are. As eluded to in this thesis, the potential of a "computer lab" populated by Bluetooth keyboards that a user brings the computing device into may be an attractive challenge to the conventional point of view.

Again, as with the changing realities of education and mobile technology, users typing speeds with various devices is evolving at a rapid pace and as such there is a constant need to re-evaluate what constitutes a baseline text entry, especially with regard to emerging OSK and GSK options.

10 4.3. The future of ClaMApp

The ClaMApp application itself is in a constant state of development and at the conclusion of this work will be undergoing some significant changes in its target and purpose. Feature sets are being provided to students and prototype channels, especially between student and teacher, are being expanded to provide more direct, non-file specific communication. There is also the expansion of the basic note metric into sub categories targeted towards students, to allow teachers to effectively record marks and additional quantifiers added to user groups to allow them to work as targeted folders, for example dated submission. Lastly a function set for targeted form testing is being investigated to provide in app short tests that can be deployed to students.

While initial usability and classroom testing has proven encouraging the application is still short of the desired outcome of a comprehensive system that allows teachers to pick their targeted learning apps without worrying about their fit within a cumbersome LMS or corporate locked in environment. Along with longitudinal testing this is the next evolution of the ClaMApp system

Lastly, based on the feedback and actions of students during the final usability test, ClaMApp is going to be implemented in mobile and desktop environments to provide a full classroom system to students and teachers, independent of corporate environments.

10.5. Final remarks

The culmination of this work has resulted in an easy to use, easy to learn tablet application that provides digital management to teachers in a way that requires limited to no formal training, using interface interactions mostly unique to mobile. This was a system that was embraced in real world testing and sought out for use by fellow academics, demonstrating a strong desire for the function set provided. Even as the landscape shifts the need for teachers to be able to actuate their own technological choices with confidence, and to employ the software they see as the best fit in their own classes, is an essential one and ClaMApp brings that reality closer. It removes the onerous training and slots seamlessly into lessons, facilitating the digital tasks so necessary in today’s schools. I look eagerly to embrace its future potential in the education landscape.

Appendix A

Ethics Approvals

A.1. School Survey

FINAL APPROVAL NOTICE

Project No.:	**6372**
Project Title:	Investigation of a framework for effective use of Tablet devices in Australian classrooms as a teaching and collaborative aid- (south Australian independent schools)

Principal Researcher:	Mr Patrick Armstrong
Email:	Patrick.armstrong@flinders.edu.au

Approval Date:	24 January 2014	Ethics Approval Expiry Date:	**30 June 2015**

The above proposed project has been **approved** on the basis of the information contained in the application, its attachments and the information subsequently provided.

A 1.1. DECD Approval

Government of South Australia
Department for Education and Child Development

Strategy and Performance

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DECD CS/13/190-3.8

26 November 2013

Mr Patrick Armstrong
School of Computer Science
Flinders University
GPO Box 2100
ADELAIDE S.A. 5001

Dear Patrick

Your project titled *"Investigation of a framework for effective use of Tablet devices in Australian classrooms as a teaching and collaborative aid"* has now been reviewed by a senior Department for Education and Child Development (DECD) consultant with respect to protection from harm, informed consent, confidentiality and suitability of arrangements. Accordingly, I am pleased to advise you that your project has been **approved.**

The reviewer has made a suggestion for your consideration and this is to make the links of your research to TfEL. Details can be accessed at TEfL

Please contact Ms Jenny Paterson, Project Officer - Research and Evaluation on (08) 8226 3825 or email: jenny.paterson3@sa.gov.au for any other matters you may wish to discuss regarding the general review/approval process.

Please supply the department with an electronic copy of the final report which will be circulated to interested staff and then made available to DECD educators for future reference.

I wish you well with your project.

Dr Mark Witham
DIRECTOR, RESEARCH AND EVALUATION

APPENDIX A – ETHICS APPROVALS

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25 November 2013

DECD CS/13/201-2.10

Dear Principal/Director/Site Manager

The research project titled *"Investigation of a framework for effective use of Tablet devices in Australian classrooms as a teaching and collaborative aid"* has been reviewed centrally and granted approval for access to Department for Education and Child Development (DECD) sites. However, the researcher will still need your agreement to proceed with this research at your site.

Once approval has been given at the local level, it is important to ensure that the researchers fulfil their responsibilities in obtaining informed consent as agreed, that individuals' confidentiality is preserved and that safety precautions are in place.

Researchers are encouraged to provide feedback to sites used in their research, and you may wish to make this one of the conditions for accessing your site. To ensure maximum benefit to DECD, researchers are also asked to supply the department with a copy of their final report which will be circulated to interested staff and educators for future reference.

Please contact Jenny Paterson, Project Officer – Research and Evaluation on (08) 8226 3825 or email: jenny.paterson3@sa.gov.au for further clarification if required, or to obtain a copy of the final report.

Yours sincerely

Dr Mark Witham
DIRECTOR, RESEARCH AND EVALUATION

A.2. Keyboard Experiment

FINAL APPROVAL NOTICE

Project No.:	**6715**
Project Title:	Investigation of a framework for effective use of Tablet devices in Australian classrooms as a teaching aid and collaborative aid (tablet keyboard input experiment)
Principal Researcher:	Mr Patrick Armstrong
Email:	Patrick.armstrong@flinders.edu.au

Approval Date:	30 March 2015	Ethics Approval Expiry Date:	**30 June 2017**

The above proposed project has been **approved** on the basis of the information contained in the application, its attachments and the information subsequently provided with the addition of the following comment:

A.3. Usability Studies

FINAL APPROVAL NOTICE

Project No.:	**6645**
Project Title:	Investigation of a framework for effective use of Tablet devices in Australian classrooms as a teaching and collaborative aid (questionnaire and experiment)
Principal Researcher:	Mr Patrick Armstrong
Email:	Patrick.armstrong@flinders.edu.au

Approval Date:	2 October 2014	Ethics Approval Expiry Date:	**30 June 2018**

The above proposed project has been **approved** on the basis of the information contained in the application, its attachments and the information subsequently provided with the addition of the following comment:

MODIFICATION (No.1) APPROVAL NOTICE

Project No.:	**6645**
Project Title:	Investigation of a framework for effective use of Tablet devices in Australian classrooms as a teaching and collaborative aid (questionnaire and experiment)
Principal Researcher:	Mr Patrick Armstrong
Email:	Patrick.armstrong@flinders.edu.au

Modification Approval Date:	10 August 2015	Ethics Approval Expiry Date:	**30 June 2018**

I am pleased to inform you that the modification request submitted for project 6645 on the 7 July 2015 has been reviewed and approved by the SBREC Chairperson. Please see below for a list of the approved modifications. Any additional information that may be required from you will be listed in the second table shown below called 'Additional Information Required'.

Approved Modifications	
Extension of ethics approval expiry date	
Project title change	
Personnel change	
Research objectives change	
Research method change	
Participants – addition +/- change	X
Consent process change	
Recruitment process change	
Research tools change	
Document / Information Changes	
Other (if yes, please specify)	

MODIFICATION (No.2) APPROVAL NOTICE

Project No.: **6645**

Project Title: Investigation of a framework for effective use of Tablet devices in Australian classrooms as a teaching and collaborative aid (questionnaire and experiment)

Principal Researcher: Mr Patrick Armstrong

Email: Patrick.armstrong@flinders.edu.au

Modification Approval Date: 14 October 2015

Ethics Approval Expiry Date: **30 June 2018**

I am pleased to inform you that the modification request submitted for project 6645 on the 22 September 2015 has been reviewed and approved by the SBREC Chairperson. Please see below for a list of the approved modifications. Any additional information that may be required from you will be listed in the second table shown below called ‘Additional Information Required’.

Approved Modifications	
Extension of ethics approval expiry date	
Project title change	
Personnel change	
Research objectives change	
Research method change	
Participants – addition +/- change	X
Consent process change	X
Recruitment process change	
Research tools change	X
Document / Information Changes	X
Other (if yes, please specify)	

Appendix B

Survey Questions

B.1. Teacher Questions

Classroom

1. **What year / years do you teach?**

2. **What study fields do you teach (check all appropriate)?**
   - ❑ Science \ Technology \ Mathematics
   - ❑ Social Sciences
   - ❑ Arts

3. **On a scale of 1 to 10, with 1 being very uncomfortable to 10 being very comfortable, how comfortable do you feel using tablets/mobile devices?**

1	2	3	4	5	6	7	8	9	10

4. **Do you personally own a tablet or mobile smart phone device?**
   - ❑ Mobile Smart Phone (e.g. iPhone, Galaxy)
     - ❑ Yes
     - ❑ No
   - ❑ Tablet
     - ❑ Yes
     - ❑ No

5. **On a scale of 1 to 10, with 1 being never and 10 being multiple times a day, how often do you use tablet or smart phone devices?**

1	2	3	4	5	6	7	8	9	10

Tablet Use in Classroom

6. **On a scale of 1 to 10, with 1 being very uncomfortable and 10 being very comfortable, how comfortable are you using mobile devices in the classroom?**

1	2	3	4	5	6	7	8	9	10

7. **On a scale of 1 to 10, with 1 being completely unnecessary and 10 being vital, how do you view the role of laptops in the classroom?**

1	2	3	4	5	6	7	8	9	10

8. **On a scale of 1 to 10, with 1 being completely unnecessary and 10 being vital, how do you view the role of tablets in the classroom?**

1	2	3	4	5	6	7	8	9	10

9. On a scale of 1 to 10, with 1 being completely unnecessary and 10 being vital, how do you view the role of smart phones in the classroom?

1	2	3	4	5	6	7	8	9	10

10. How do you personally view the role of these devices in your classroom?

11. Do you attempt to actively incorporate these devices in your curriculum?

- ❑ Yes, as much as possible
- ❑ Occasionally
- ❑ No

12. If yes what devices do you predominantly use?

- ❑ Tablet
  - ❑ Yes
  - ❑ No
- ❑ Mobile phones
  - ❑ Yes
  - ❑ No
- ❑ Laptops
  - ❑ Yes
  - ❑ No
- ❑ Desktop
  - ❑ Yes
  - ❑ No

13. What are your typical experiences with mobile / tablet devices in the classroom. On a scale of 1 to 10, with 1 being strongly disagree and 10 being strongly agree how do you view the following statements:

- I try to employ computing devices regularly in class work

1	2	3	4	5	6	7	8	9	10

- Technology has its place but not for regular use in the classroom

1	2	3	4	5	6	7	8	9	10

- Devices are typically a distraction from classwork and I try to prevent their use

1	2	3	4	5	6	7	8	9	10

- If possible I do or would ban these devices within the classroom

1	2	3	4	5	6	7	8	9	10

- I have no personal view on technology in the classroom the classroom

1	2	3	4	5	6	7	8	9	10

Social Media

14. On a scale of 1 to 10, with 1 being completely restricted and 10 being unrestricted, how heavily do you attempt to control social media access during class times?

1	2	3	4	5	6	7	8	9	10

15. On a scale of 1 to 10, with 1 being ineffective and 10 very effective, how effective do you feel social media controls are during class times?

1	2	3	4	5	6	7	8	9	10

Collaborative Work

1. Approximately what percentage of your classwork is collaborative?

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%+

2. Do you wish more collaborative work could be employed in class?

❑ Yes

If yes elaborate

❑ No

If no elaborate

3. When working with groups, what sizes have you found to typically be the most effective?

❑ Pairs
❑ 2 to 4
❑ Greater than 4

4. **On a scale of 1 to 10 with 1 being strongly disagree and 10 being strongly agree how would you rate the following statements about typically creating collaborative groups**

- ❑ The best way to assign groups is randomly

1	2	3	4	5	6	7	8	9	10

- ❑ Groups typically work better when all the students in the group are mostly from the same social circle

1	2	3	4	5	6	7	8	9	10

- ❑ Groups typically work better when they are mostly from separate social circles

1	2	3	4	5	6	7	8	9	10

- ❑ It is usually best to create groups on the spur of the moment as needed

1	2	3	4	5	6	7	8	9	10

- ❑ It is usually best to follow a structured plan for group assignment

1	2	3	4	5	6	7	8	9	10

5. **Do you typically attempted to integrate technology in to group work?**
   - ❑ Yes: Mostly as an online resource
   - ❑ Yes: We use collaborative software
   - ❑ No

IT

1. **To your knowledge, does your school make use of a Learning Management System?**
   - ❑ Yes
   - ❑ No
2. **What electronic systems do you make use of during class?** *(select all appropriate)*
   - ❑ Class roster lists
   - ❑ Course Calendar's (*assignment due dates, important events*)
   - ❑ Document Delivery (*e.g. providing course files/media to students*)
   - ❑ Document Control (*e.g. ensuring class documents are available and visible to the teacher*)
   - ❑ Minor assessment tasks (*quizzes, impromptu testing*)
   - ❑ Major assessment tasks (*major assignments, extended course work*)

3. **Are there class rules for connecting to the internet?**
   - ❑ Yes, strict school guidelines exist and are enforced
   - ❑ Yes, school policies dictate rules but there is latitude for teacher discretion
   - ❑ No, students have open access to the internet

B.2. Administrator Questions

1. **What Year ranges are taught at your school?**
   - ❑ Primary
   - ❑ Secondary
   - ❑ Both

2. **What education sector does your school operate under?**
   - ❑ Public
   - ❑ Independent)
   - ❑ Catholic
   - ❑ Other

   If Other please elaborate

3. **How is information technology viewed as part of your schools strategic goals?***

4. **Is information technology taught as its own subject within your school?**
   - ❑ Yes

   If Yes in what years do students start IT classes?
     - ❑ Before Year 5
     - ❑ Year 5
     - ❑ Year 6
     - ❑ Year 7
     - ❑ After Year 7

   - ❑ No

5. **Does your school employ a Learning Management System (LMS) of some sort (e.g. Moodle, Blackboard, Desire2Learn)?**
   - ❑ Yes
   - ❑ No

6. **If yes, on a scale of 1 to 10 with 1 being very resistant and 10 being completely accepting how have teachers, in general, been to the LMS?**

1	2	3	4	5	6	7	8	9	10

7. **Does the school have a policy on IT devices used by students within classrooms?**
   - ❑ Mobile Phones?
     - ❑ Yes

       If yes, what is it?
     - ❑ No
   - ❑ Tablet?
     - ❑ Yes

       If yes, what is it?
     - ❑ No
   - ❑ Laptops?
     - ❑ Yes

       If yes, what is it?
     - ❑ No

8. **Can students use their own devices in class?**
   - ❑ Mobile
     - ❑ Yes
     - ❑ No
     - ❑ Teachers discretion
   - ❑ Tablet
     - ❑ Yes
     - ❑ No
     - ❑ Teachers discretion
   - ❑ Laptop
     - ❑ Yes
     - ❑ No
     - ❑ Teachers discretion

9. How are portable devices like smart phones and tablets seen as a factor in the schools future information technology needs?

Circle answer on scale of 1 to 10 with 1 being not important and 10 being essential

1	2	3	4	5	6	7	8	9	10

10. Rate the importance of issues related to using devices from an Administration level on a scale 1 to 10

- ❑ Resources

Circle answer on scale of 1 to 10 with 1 being not important and 10 being essential

1	2	3	4	5	6	7	8	9	10

- ❑ Practicality

Circle answer on scale of 1 to 10 with 1 being not important and 10 being essential

1	2	3	4	5	6	7	8	9	10

- ❑ Training

Circle answer on scale of 1 to 10 with 1 being not important and 10 being essential

1	2	3	4	5	6	7	8	9	10

- ❑ Educator opinion

Circle answer on scale of 1 to 10 with 1 being not important and 10 being essential

1	2	3	4	5	6	7	8	9	10

- ❑ Usefulness

Circle answer on scale of 1 to 10 with 1 being not important and 10 being essential

1	2	3	4	5	6	7	8	9	10

- ❑ If other issues are important please mention them below

11. Does your school have its own dedicated Information Technology staff?

- ❑ Yes
- ❑ No

12. If yes how many?

- ❑ 1
- ❑ 2
- ❑ More than 3

If more than 3 please state how many:

Information Technology

1. **Does your school have wireless network access in classrooms?**
   - ❑ Yes
   - ❑ No

2. **If yes what percentage of classrooms able to access that network at will?**

10	20	30	40	50	60	70	80	90	100

3. **How do teachers and students store school related data?**
   - ❑ Within the school on central servers?
     - ❑ Yes
     - ❑ No
   - ❑ Within the school, on each machine?
     - ❑ Yes
     - ❑ No
   - ❑ Another company handles data management?
     - ❑ Yes
     - ❑ No
   - ❑ On their own personal devices under their own oversight?
     - ❑ Yes
     - ❑ No

4. **Does the school have a goal for education in ICT (for example use of laptops in classrooms)?***

Appendix C

Usability Study materials

C.1. SUS

Circle the matching answer. All answers are a scale of 1 to 5 with 1 being strongly disagree and 5 being strongly agree.

1. I think that I would like to use this system frequently:

1	2	3	4	5

Strongly disagree Strongly agree

2. I found the system unnecessarily complex.

1	2	3	4	5

Strongly disagree Strongly agree

3. I thought the system was easy to use.

1	2	3	4	5

Strongly disagree Strongly agree

4. I think that I would need the support of a technical person to be able to use this system.

1	2	3	4	5

Strongly disagree Strongly agree

5. I found the various functions in this system were well integrated.

1	2	3	4	5

Strongly disagree Strongly agree

6. I thought there was too much inconsistency in this system.

1	2	3	4	5

Strongly disagree Strongly agree

7. I would imagine that most people would learn to use this system very quickly.

1	2	3	4	5

Strongly disagree Strongly agree

8. I found the system very cumbersome to use.

1	2	3	4	5

Strongly disagree Strongly agree

9. I felt very confident using the system.

1	2	3	4	5

Strongly disagree Strongly agree

10. I needed to learn a lot of things before I could get going with this system

1	2	3	4	5

Strongly disagree Strongly agree

C.2. Study 1 and 2 user background

1. What degree are you currently studying

2. What year level are you at in the degree?
   - ❑ 1 ❑ 2 ❑ 3 ❑ 4

3. Do you own your own personal smart phone device (iPhone / Windows Phone / Android)?
   - ❑ iPhone
   - ❑ Android
   - ❑ Windows Phone
   - ❑ Other
   - ❑ Do not own a smartphone

4. Do you own a personal tablet device?
   - ❑ Yes ❑ No

5. How regularly do you feel you use your mobile device?
   - ❑ Multiple times daily
   - ❑ Sporadically daily
   - ❑ Every few days
   - ❑ Weekly

6. Please select the statement that most closely matches your mobile usage:
   - ❑ I use my mobile device heavily every day, I am never without it
   - ❑ I use my mobile device frequently every day, it is necessary to my day to day life
   - ❑ I use my mobile device frequently every day, it is a useful tool
   - ❑ I use my mobile device occasionally during the day, when I feel like it
   - ❑ I use my mobile device occasionally during the day, as necessary

- ❑ I use my mobile device rarely during the day, when I feel like it
- ❑ I use my mobile device rarely during the day, as necessary
- ❑ I do not use my mobile device daily, but use it when I have time / inclination
- ❑ I do not use my mobile device daily, but use it when necessary
- ❑ I rarely use my mobile device and only when I have time
- ❑ I rarely use my mobile device and only when necessary

7. On a scale of 1 to 7 with 1 being completely disagree and 7 being completely agree please answer the following questions
   1. Technology is an essential part of education

1	2	3	4	5	6	7

   2. Technology is over used in the classroom

1	2	3	4	5	6	7

   3. Students learn how to use technology primarily from use in school

1	2	3	4	5	6	7

   4. Access to the internet is essential for all students

1	2	3	4	5	6	7

8. How do you view technologies role in education:
   - ❑ Technology has no real role in managing the classroom
   - ❑ Technology is essential to managing the classroom
   - ❑ Technology has its place as a supplement

C.3. Study 1 task list

C 3.1. Student

When instructed with the phrase “Students please perform task “ and a number please attempt, to the best of your ability, to perform that task. If you find yourself unable to perform the task please request assistance before the next step of testing commences.

Task 1

Login using the username and password provided below:

Username______________________

Password_______________________

This will send you to the home screen for the application.

Task 2

Select one of the available documents and select help with it. Choose a level and note of your own devising.

Task 3

Use the camera shot button to take a photo of the provided note sheet. Select the camera directory and send the photo to your group.

Task 4

Send a chat message to other members of your group.

Task 5

Please log out of the application.

C 3.2. Teacher

When instructed with the phrase “Teachers please perform task “ and a number please attempt, to the best of your ability, to perform that task. If you find yourself unable to perform the task please request assistance before the next step of testing commences.

Task 1

Login using the username and password provided below:

Username______________________

Password_______________________

This will send you to the home screen for the application.

Task 2

Select a file and send “document1” and “document2” to all available students.

Task 3

One or more of your students has requested help. Determine which student requested help and the severity of the help required.

Task 4

Create a group consisting of two of the three students you have available. Once the group is created send “groupdocument” to members of the group.

Task 5

Monitor the chat conversation of the group you created and make the group members aware that you read the message.

Task 6

Create a note for about students of your choosing, for at least one student include a note.

Task 7

Please log out of the Application

C.4. Study 2 task list

C 4.1. Student Tasks

Before the experiment begins

Before testing the software you have up to 5 minutes to familiarize yourself with the user interface of the software. You have been provided a sort cheat sheet on the application menu and the file contextual menu. You are welcome to create any files or take any actions, however please do not delete or change documents currently in “My Files…”.

During this time please take a moment to create a new text file, open the file in the text editing (File View) application, and make changes to the file and save it. This is a non app specific task that will be necessary during the text. If you are unsure how to use file view please ask the experiment conductor.

If you are unfamiliar with android note that the central circular button will return you to the home screen. This does not close any currently running apps. You can return to an app that is running by pressing the right hand box button. This will open a menu of currently open apps you can select from.

Starting:

You should be a member of the group “Student Materials” though it should currently be empty.

You will be asked to complete these tasks in order. Please wait for the experimenter's verbal indication to commence before starting the tasks. After each task you have been given a single question response for the task difficulty. For all tasks a response of 1 indicates the task was very difficult while a response of 7 indicates the task was very easy. If you find yourself unable to finish a task notify the experimenter and it will be skipped. Note that this is an evaluation of usability not personal competence.

<u>To be completed after each task</u>

Pre task:

A teacher has added you to a group. You can now view files in this group and chat with other members of the group.

Task 1:

You have received a file from your teacher. Open it and examine the contents, then close the file. Verbally acknowledge when you have opened the file.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 2:

The file sent to you by the teacher is incomplete. Request help on the document and let the teacher know the file is not complete.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Pre-Task:

The teacher has copied a new set of instructions called "complete_tasks".

Task 3:

Open and read the document "complete_tasks" and take note of the instructions. If any instructions are unclear seek clarification from the experimenter. Verbally note when you have opened the document.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 4:

Take a camera shot of the colored paper at your station and save it to "My File….". Take a second shot of the three items and save that to "My Files…" as well. Rename them in "My Files…" to something relevant (for example "jill items and jill paper".

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 5:

One of the three items is listed on the colored paper. Communicate this item through group chat. You will be instructed through group chat which of the three items to return with.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Post Task:

Once you have your required item and a pictures return to the group.

Task 6:

Copy your pictures of the colored paper and items to the group "Submission"

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 7:

Create a new text file in "My Files…" named John, after your log in. Open the file and add in three lines:

Student name (the literal text, not your real name)

The item you returned with

The color of your paper

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 8:

Copy your text file to the group "Submission"

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 9:

The teacher has sent you a file called "basic maths01" to the "Student Materials" group. Open the file and examine it. Using chat check if the other group members understand the material.

Overall, this task was:

1	2	3		4	5	6	7
Very Hard							Very Easy

Task 10:

Send a help request (not a chat message) to the teacher that you need help with the file "basic maths01", include a rating and note about the difficulty

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 11:

You will need to find information on the web. Using chat ask the teacher which of these two you will search for:

A. Time Cube
B. Zombo

Go to the home screen of the device and open Chrome. In the browser search for the Wikipedia page on your topic.

For Time Cube, you should take notice of the name of the creator of the site and the title he gives himself.

For Zombo you should take notice of the Animation program used to create the site and the year it was created.

In the group "Experiment Group" create a text document called "answers". Edit it with a single sentence stating the answers to your question. When you have entered your answers inform the teacher via chat you have completed the task.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

C 4.2. Teacher tasks

<u>Before the experiment begins</u>

Before testing the software you have up to 5 minutes to familiarize yourself with the user interface of the software. You have been provided a sort cheat sheet on the application menu and the file contextual menu. You are welcome to create any files or take any actions, however please do not delete or change documents currently in "My Files…".

During this time please take a moment to create a new text file, open the file in the text editing (File View) application, and make changes to the file and save it. This is a non app specific task that will be necessary during the text. If you are unsure how to use file view please ask the experiment conductor.

If you are unfamiliar with android note that the central circular button will return you to the home screen. This does not close any currently running apps. You can return to an app that is running by pressing the right hand box button. This will open a menu of currently open apps you can select from.

Starting:
You have been provided with a number of documents, some that will need information added to them by you during the course of the experiment and some will be created by students and copied to your device.

You should currently have the documents:

- Incomplete tasks
- Complete tasks
- Basic maths01
- Basic maths02

You should also see the group “Student Materials” though it should currently be empty

You will be asked to complete these tasks in order. Please wait for the experimenter’s verbal indication to commence before starting the tasks. After each task you have been given a single question response for the task difficulty. For all tasks a response of 1 indicates the task was very difficult while a response of 7 indicates the task was very easy. If you find yourself unable to finish a task notify the experimenter and it will be skipped. Note that this is an evaluation of usability not personal competence.

To be completed after each task

Please give a verbal confirmation when you feel the task has been completed.

Task 1:

- Create a group named “Experiment Group” consisting of:
  John Student
- Jill Student

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 2:

Send the document incomplete_tasks.txt to the group “Experiment Group”.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 3:
Students have had trouble with the tasks provided. Go to help requests and view their messages. Mark them as read when finished.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 4:

Send the document complete_tasks.txt to the group "Experimental Group".

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 5:
Make a note with the category "General Note" with the content "incomplete tasks is not a finished document"

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

While the students are gone:

Task 6:

While the students collect their items and create their documents, create a group called "Submission" that includes all students.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

While the students create their documents:

Task 7:
Take a camera shot of the items the students returned and save the picture to "teach

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 8:

Check the submitted files "john" and "jill". Make two notes, one about each student. The category should be the students name and the content should be the item they returned with.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 9:

Send the file "basic maths01" to the group Student Materials.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 10:

Students have not understood the content and submitted a help request. Check these requests and note verbally any comments they left and mark them as read.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 11:

Send the file "basic maths02" to the group "Student Materials"

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

Task 12:

Monitor the chat for group “Experiment group”. When the students have indicated they are finished copy the file to “teach”. Open the document and edit in a sentence noting if the students information is correct or not. The correct answers are:

- Timecube: Otis Eugene “Gene” Ray, Wisest man on earth
- Zombo: Flash animation, 1999

Go to notes and make a general note that “Students have completed all tasks”.

Go to help requests and delete all help requests.

Overall, this task was:

1	2	3	4	5	6	7
Very Hard						Very Easy

C.5. Classroom test additional questions

On a scale of 1 to 7 (with 1 being strongly disagree and 7 being strongly agree) how do the following statement represent your opinions.

1. I could easily find and access the documents I wanted

1	2	3	4	5	6	7

Strongly disagree Strongly agree

2. It was easy to communicate using the app

1	2	3	4	5	6	7

Strongly disagree Strongly agree

3. I could easily navigate around the application

1	2	3	4	5	6	7

Strongly disagree Strongly agree

4. Learning to use the app was a fast process

1	2	3	4	5	6	7

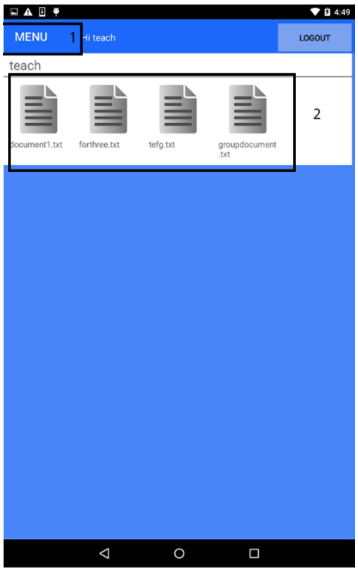
Strongly disagree Strongly agree

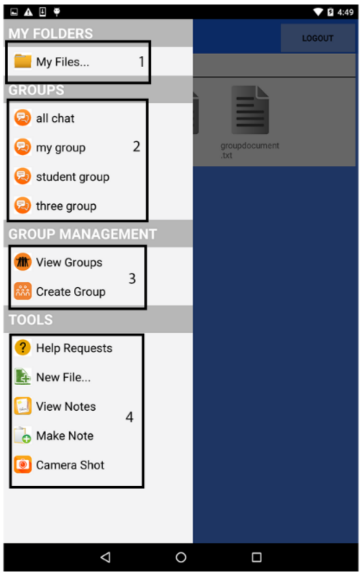
5. The easiest part of the app was…

6. The most difficult part of the app was…

7. Were there any other issues you had using the software

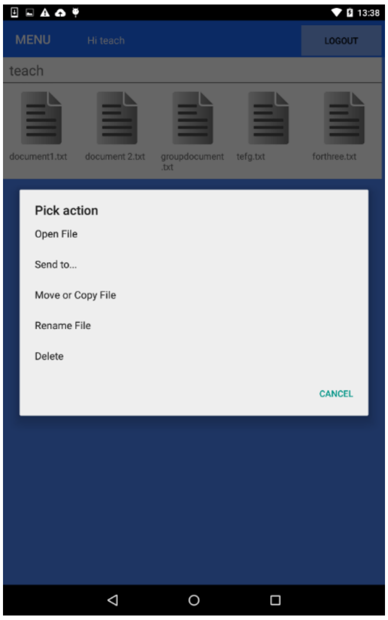
C.6. Provided ClaMApp cheat sheet





1 – Menu Selection. Opens the application options as a side menu.

2 – File window. Show files for a given folder.



1 – User folders
2 – Group views for any groups the user belongs to. View shared content and allow user to communicate and with other group members or the teacher.
3 – Group tools allowing the teacher to create, view and delete groups of students. The teacher is added to all groups as a member by default.
4 – Application tools.

- Help requests allow you to view any files students have reported having problems with and any messages they have included.
- Create a new file and select the folder to send it to.
- View and notes the user has made about a specific student or a general topic
- Make a note about a specific student or general topic
- Take a picture and send it to either your own or a groups shared folder

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