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Trinder, Jonathan James (2012) *Mobile learning evaluation: the development of tools and techniques for the evaluation of learning exploiting mobile devices through the analysis of automatically collected usage logs - an iterative approach*. PhD thesis.

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**Mobile Learning Evaluation: The Development of
Tools and Techniques for the Evaluation of
Learning Exploiting Mobile Devices Through the
Analysis of Automatically Collected Usage Logs -
An Iterative Approach**

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MSc Computing for Commerce and Industry (Open)

Submitted in fulfillment of the requirements for the Degree of

Doctor of Philosophy

April 2012

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Abstract

There have been many claims as to the benefits of personal digital assistants (PDA) as tools in education, but little objective data concerning device usage patterns. The aim of this project was to overcome this deficiency by objectively investigating the use of mobile devices in teaching and learning, specifically in the process of formative assessment.

A bespoke PDA application was written, which recorded in detail when PDA applications were being used and overcame a number of technical barriers in securing this information for later analysis. This data, along with information on student access to the University Virtual Learning Environment (VLE) and final student examination results, formed the main objective datasets recovered in the project. Novel data analysis tools and methodologies were developed to mine the extensive, heterogeneous datasets obtained, and efficiently characterise how students used PDA applications. Finally, data analysis was performed on four cohorts of students: i) fourteen joint honours students in electronics and software engineering, where researchers learned that even for technologically adept students, simple issues (such as failure to replace batteries and resultant data loss) could significantly restrict useful research outputs; ii) five summer school students using quiz applications and question sets, where the first significant evidence of the educational benefits of using mobile devices was obtained; iii) students who failed to interact in any way with what they saw as obsolete devices, emphasising the importance of keeping student PDAs current with modern technology; iv) a full scale trial involving a 1st year cohort of BTechEd students, where the lessons learned in phases 1-3 were applied.

In the trials, technical and human-computer interface barriers to securing useful data were encountered and overcome, and guidelines for future good practice, of significant use to practitioners in the research area, determined. Patterns and modes of their PDA use - considering a range of factors including overall duration of use, use as a function of time of day or time of week, and the complexity of use (e.g. frequency of application switching within a usage session) - were obtained and correlated with exam results and access to the University VLE. A number of usage characteristics of successful and unsuccessful learners were extracted from this data. In addition to these results, novel student behaviour was observed, with volunteer students actively avoiding returning data despite stated interest in the project, lowered technical barriers, significant inducements, and guarantees of data anonymity. We suggest a number of

social factors, including on the nature of peer group formation in student cohorts and the socially disruptive nature of new technology, as contributing to this effect and identify the area as worthy of future investigation.

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Acknowledgements

Thanks are due to many people for their support, guidance, and encouragement during the work described in this thesis.

This work would never have started or reached an end without my supervisors Dr Jane Magill and Dr Scott Roy and I owe the completion of this endeavour to their guidance and patience.

The practical work could not have been conducted without students and so my thanks to all the staff and students who agreed to take part in the project and gave their time for discussions and interviews.

To provide PDAs for the students required funding and for this I am very grateful to Higher Education Academy for funding Phase 1 and the University of Glasgow Chancellors Fund for funding phase 4.

I would like to thank Howard Thomlinson and Alison Barclay of Astraware.com for their generous donation of the games applications used in phase 4. My thanks to John Walker at Palm UK for assisting with the supply of equipment.

I would like thank legendary Palm developer Bozidar Benc (1957-2004), who gave his invaluable advice about implementing the 'system traps' for the monitoring and recording of PDA activity.

Undertaking this research has meant some disruption to my 'day job' and so I would like to thank Professors Asen Asenov, John Arnold and John Cooper for their support to start the project and to Dr David Muir for giving me time to do the work. Thankyou to my colleagues; Billy Allan, Paolo Benassi, Nick Scott, Bridget Sweeney, Mike Cugley, Iain Gardner, Ken McColl and Walter Robinson for dealing with things when I was away at conferences. Paolo also provided invaluable support by modifying machines in computing labs to enable hotsyncing of the PDAs and Billy provided much appreciated advice on programming. Some of the work took place at the Robert Clark Centre for Technological Education and special credit is due to Hector Towers for allowing me to make changes to his carefully maintained labs.

For encouragement, useful discussions, organising meetings, locating people and never being afraid to ask “hows the thesis?”, thankyou Shona Ballantyne, Fiona Baxter, Susan Foote, Kay Wray and Dr Karen Mcilvaney.

I appreciated discussions with others who had been through the process of thesis writing, and for this I am very especially grateful to Dr Gareth Roy and Dr Tim Drysdale.

I would also like to thank all the people I have met through this work at conferences, seminars and workshops and to everyone who contributed to discussions on the pda-edu@jiscmail.ac.uk list.

My thanks to my parents Jack and Rhoda for instilling in me a sense of curiosity and to my wife Kathryn for putting up with how long I took to get this research completed and for her support and encouragement throughout.

Jonathan James Trinder

University of Glasgow

April 2012

Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Jonathan James Trinder

Dated: 5th April 2012

Publications

Portions of the work described in this thesis have also appeared in:

Book Chapters

- Trinder, J. J., Magill, J. V. & Roy, S. (2009) Using automatic logging to collect information on mobile device usage for learning In Pachler, Kukulska-Hulme & Vavoula (eds.), *Research Methods in Mobile and Informal Learning*. Peter Lang Publishing Group.
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- Trinder, J. J. (2008) "An Introduction to Mobile Learning" Invited presentation of pre-conference workshop for mLearn 2008 on behalf of the Learning Lab (Telford). October 7th 2008.
- Trinder, J. J. (2008) "The Future Now" Invited presentation at JISC workshop "JISC Emerge Workshop: "Adding a mobile dimension to teaching and learning"" . University of Bristol October 1st 2008.
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- Trinder, J., Roy, S. and Magill, J. (2008) Seeing and Hearing Log Data. Proceedings of Mlearn 2008 Conference (Ed, Traxler, Riordan, Dennet) University of Wolverhampton
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Chapter 1

Introduction

Pocket sized devices now have the computing and storage capacity that only a few years ago would have required a desktop computer system.

One of the first tangible and useful examples of a pocket sized mobile computing device was the Portable Digital Assistant, better known as a PDA. A basic PDA is shown in 1.1.



Figure 1.1: A Palm PDA

A PDA is a hand-held computer equipped with diary and personal organiser tools that normally has the ability to synchronise data with a desktop system. The early PDAs were intended to be the electronic equivalents of diaries and personal organisers and are the ancestors of the current generation of 'smartphones' .

The pocket size format of a PDA means it has a big advantage over other portable computing devices such as laptops; a PDA can be carried unobtrusively all the time. Also unlike a laptop, a PDA when switched on is immediately ready for use with no long boot-up time.

Portable devices, such as PDAs have become increasingly important within education and “their potential for learning and teaching is widely recognised” (Roibas and Sanchez, 2002). PDAs can enable students to become mobile learners; a student is able to learn in the location that they find most suitable (Olsen, 2000). The use of mobile devices has been found to be particularly helpful to part time students who

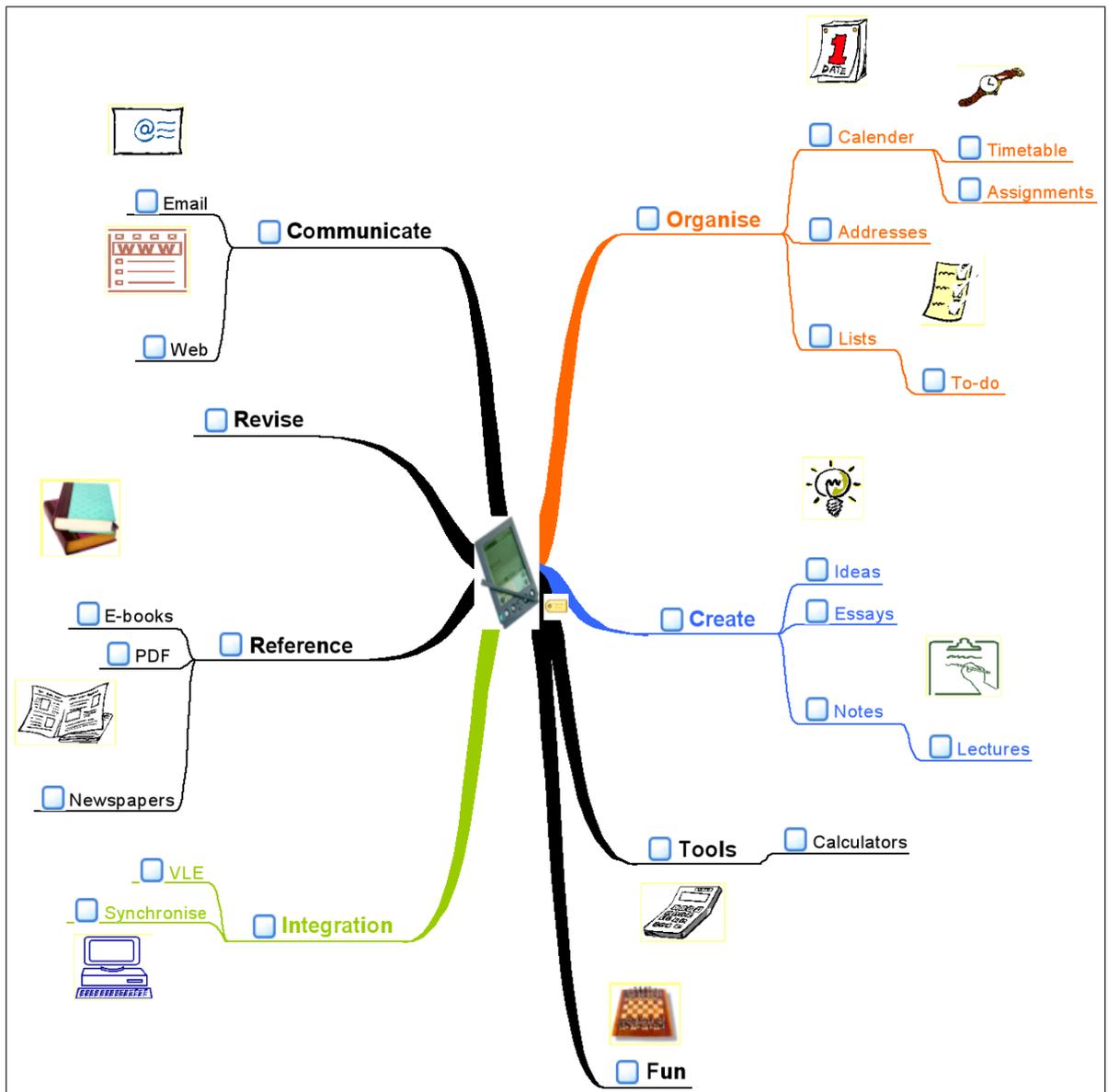


Figure 1.2: Mindmap of Potential Student PDA Uses

have to fit their study in between other tasks (Kukulska-Hulme, 2005). Many full time students also have part time jobs and so the differentiation between full-time and part-time students has become blurred (Evans, 2005). For current students, time spent in employment is time that has been lost to study or relaxation. Combined with suitable application software a PDA or similar mobile device can provide valuable educational assistance to students by making productive use of rare periods of spare time in their busy lifestyle, for example while travelling or waiting for a bus.

“Our team carried out a detailed study of how radiology is taught and practised. One clear finding was that trainees have very little spare time. They can’t take the time to sit in libraries or computer labs, and so any computer-based learning must fit into the gaps in their busy schedule - in the hospital, at home, when travelling - which means a personal and portable system.” (Sharples, 2000b)

Assessment

An important component of the education process is that of assessment. “The role of assessment in the learning experience is crucial” (Brown, 1999). Assessment can be delineated into two categories, summative where the assessment is marked and the scores contribute to the students’ final grade, or formative where the main purpose is helping students to improve their knowledge and understanding by enabling the student to evaluate what knowledge they have gained, and to identify those areas in which their knowledge is weaker.

The use of computers to provide an assessment system can enable a student to undertake formative assessment exercises at times that suit them but with a restriction on the location that this can occur. Traditionally Computer Aided Assessment (CAA) had only been available in computer labs using desktop computers. But it is now possible for a PDA or similar device “to provide all the processing power and communication applications that students need” (Cochrane, 2005). So to provide CAA no longer requires a desktop or laptop PC and a PDA or smartphone is an ideal platform.

For the purposes of studying the use and evaluation of PDAs mobile CAA was chosen as the educational task to use the PDA for, but before measuring the effect of the introduction of a mobile CAA a reliable mechanism was needed to prove, objectively and accurately, *if* the PDA and the assessment application were actually being used by the students before attempting to measure any educational impact.

According to the literature in previous research on PDA use has relied on observations of how the devices are used within the classroom and of feedback, via questionnaires, which have ask participants which software applications they had used (Sharples, 2008, p17).

The reliance on questionnaires makes the usage data potentially unreliable as it relies on the participants’ memory. This drawback suggested that an key requirement for the work described in this thesis was to develop a reliable means of proving if the PDAs were being used.

To move the burden of recording use from the user it was intended to use the PDA to automatically record a log of when it was used. Using a logging system also allowed the project meant that more general aspect of PDA use could also be investigated during the mobile CAA research. For example which applications the students used and if they installed other applications.

As well as the built in organisational application extra software applications could be added to the device enabling the students to enhance the PDA by adding subject specific tools to aid their study. The potential uses of a PDA in an educational context are summarised in 1.2 on the previous page

An aspect of PDA use mentioned in the literature, for example Robertson *et al.* (1997); Sharples *et al.* (2005) was that when PDAs are loaned to students, the amount of use made of the devices decreases throughout the duration of the project. The use of automated logging would also provide insight into how the use of the PDA changed

throughout a project.

1.0.1 Aims and Objectives

The overall aim of this project was to investigate the use of mobile devices in teaching and learning. Specifically we will investigate the use of PDAs in the process of formative assessment.

In order to fulfil these aim we have the following objectives.

1. To successfully record when PDA applications, including formative assessment applications, are used. In order to do this successfully we will have to understand the technical and social barriers to successfully recording this information and overcome these barriers.
2. To successfully build tools and methodologies to analyse this recorded data. In order to do this it will be shown below that we will have to create bespoke data analysis software and analyse complex data sets to discover the key measures required to characterise student use.
3. To perform this analysis on real examples of students using PDAs for formative assessment. We must investigate patterns of use , modes of use, measure benefits of PDA based formative assessment on students and ascertain bottlenecks to such benefits.

1.0.2 Context

There is a historical dimension to this work as the physical form and functionality of the technology that is described, PDAs, are now integrated into other devices, for example smartphones. Even though the physical device has changed, the majority of the conclusions arising from this work are largely device independent and will apply to current and future mobile technology.

The initial research in the field of mobile learning was largely concerned with the *technology* but has now moved towards the pedagogical and social dimensions.

The research was conducted in the Department of Electrical and Electronic Engineering and the Robert Clark Centre for Technological Education at the University of Glasgow.

At the time the work described in this thesis was conducted the use of mobile devices within education in the UK was in its infancy. According to Smith (2003).

“There are very limited examples of PDA use in further and higher education sectors. Projects have begun at five FE colleges and three universities” Smith (2003) .

Of the 3 universities mentioned 2 were in Scotland - the University of Glasgow (the projects described in this thesis) and the University of Paisley (Smith, 2003).

The field of research into the use of mobile devices is now known as mLearning (Mobile Learning). The first conference specifically dedicated to what is now perceived as mLearning was held in 2002 in Birmingham UK with under 100 delegates. When the conference returned to the UK in 2008 there were over 200 delegates.

Throughout the duration of this project the terminology of mobile devices has changed and the definition of a PDA is less clearly defined. Many of the features of current smartphone and media players overlap with traditional PDA features and so the findings in this thesis are applicable to newer devices. Also the additional feature and educational affordances provided by such devices should increase the devices richness of functionality and make them appealing devices for students to own.

Sharples *et al.* (2007) noted that there were two definitions of mobile learning which are now converging, one device centric and one user centric. The device centric (also known as the techno-centric view) considers the technology that facilitated mobile learning opportunities such as PDAs, smartphones, media players, USB memory sticks, (Winters, 2007; Traxler, 2007). The user centric view is that it is the learner who is mobile and using whatever technology is available at their present location. Thus facilitators of mobile learning are not always mobile themselves, for example an Internet café or Wi-Fi hotspot can be an enabler of mobile learning (Naismith *et al.*, 2004).

An influence on the direction of the project was that the author, as a part-time student, had found a PDA a very useful educational tool and believed that other students would also find the device and the facilities it provided useful. The authors existing skills and experience as a programmer of mobile devices made it practical to implement the software tools needed both to support the work conducted in this study.

The model of centralised control of IT in many institutions has been seen as a barrier to the introduction of mlearning (Bird and Stubbs, 2008). The problems may be lack of expertise to support mobile learning or the effect of institutional policies limiting user privileges to install software (Traxler, 2008). During the projects described in this thesis the author was a member of the departments computing support team it made it possible to arrange permission for making the modifications needed to computing labs and associated equipment.

1.1 Outline of Thesis

Chapter 2. Reviews the research literature on mobile Learning. There is an overview of technology, history and usage patterns of PDAs and similar mobile technologies, and theories of mobile learning are introduced. The literature encompasses the challenges of evaluating mobile devices, and the strategies that can be used to perform such evaluations. Evaluating mobile device use involves unique challenges due to the mobile nature of the devices and the breadth of uses, both formal and informal for which a mobile device can be used.

Chapter 3 describes the research methods used, the planned means of data collection,

data analysis strategies, special software applications written to support the project, technical issues, and the choice of PDAs that were used.

Chapter 4. The practical aspects of the project were conducted as a series of sub-projects. The common characteristics of the sub-projects are explained with an summary of each project and how the results informed subsequent phases.

Chapter 5. Presents the main results of the project and discusses how the data was explored and visualised, and the iterative process that took take place in order to analyse the complex set of automatically collected raw results, student questionnaires and interviews. The main results obtained are detailed.

Chapter 6. The motivations to use the PDAs and the problems encountered with student co-operation are discussed.

Chapter 7. Contains the conclusions and suggestions for further work.

Chapter 2

Literature Review of mLearning Technology and Theory

“Every era of technology has, to some extent, formed education in its own image” (Sharples *et al.* 2007)

This chapter provides an overview of mobile learning technology, related research theories and a critical review of work that has taken place in the field.

There will first be a description of the technical aspects of PDAs to give the reader an understanding of overarching benefits and limitations of the technology, followed in Section 2.2 by the specific advantages and disadvantages of PDAs in education. Then sections 2.5 and 2.6 discuss the emerging theories of mobile learning and practical examples from the literature of PDA use in education. Section 2.5 summarises the themes emerging from this previous research and in Section 2.6 the challenges of introducing technology in an educational environment are discussed. Section 2.7 specifically focusses on Computer Aided Assessment. The chapter concludes with discussion of the most recent issues related to mLearning and summary of key facts raised during the chapter.

It is difficult to separate mobile learning from the technology that is used to facilitate it and “Many of the virtues of m-learning are the virtues of the power of its technology” (Traxler, 2007). To an extent the devices used in past mobile learning projects have shaped the perceptions of what is feasible in the present and set expectations for the future.

Research in mobile learning was stimulated by the availability of suitable technology and for many this was the Palm Pilot series of personal organisers introduced in 1996, however the technology of mobile learning and portable computers can be traced back to the 1980s and the concept of the Dynabook proposed by Alan Kay at the Learning Research Group at Xerox Palo Alto Research Center [PARC]. The Dynabook was proposed in the early 1970s as a book sized computer with educational uses, its link to learning was influenced by the work of Seymour Papert (Kay, 2000).

It should be noted that in the years covered by the literature referred to in this

section the technology, terminology and concepts used in the areas of mLearning and e-Learning have evolved.

Technology: The original PDAs were stand alone devices with limited network connectivity. Some of the appeal of the early PDAs was their ease of use, simplicity and suitability for the tasks they were able to perform. The original PDAs have all but disappeared, and many current devices now incorporate the functionality that PDAs used to provide. Today the term PDA would include smart-phones and media players such as the i-Pod. A problem faced by a new technology is that if it resembles an existing one then it is likely to be compared to the existing technology even if intended to be used for a different purpose. “Even if the new technology is intended for a new domain, if it looks like the old one it will be judged by the same criteria, and invariably it will be found lacking” (Norman, 1998, pp237). This may have been the problem for PDAs and similar devices. The initial devices performed their intended function very well but when their performance was compared with that of the laptop computer - the nearest comparable technology - the PDA appeared to lack functionality.

Terminology: In earlier research publications the terms mLearning and e-Learning are not used though the content of the material clearly encompasses work that would now be described by such terms. Online Learning Environments(OLE) have been variously known as Virtual Learning Environments(VLE), Managed Learning Environments and Online Learning Environments. Whilst slight and often subtle differences have existed in systems capabilities, for example the integration with other institutional systems such as students records systems, their core functionality is similar.

Concepts: In earlier research the mobile component of mLearning was the technology, now it is focussed more on the student being mobile and utilising whatever technology is available where they are located (Winters, 2007) delineates mobile learning as *technocentric* where the focus is on the device used for example PDAs and notes that this perspective dominates the literature.

2.1 PDA Technology

A PDA is a hand-held mobile computer that typically comes equipped with diary and personal organiser tools and has the ability to synchronise data with a desktop system. Most are also capable of exchanging data with other PDAs, and other devices. The early PDAs were intended to be the electronic equivalents of diaries and personal organisers. It is important to appreciate that PDA were not intended to replace desktop systems or laptops.

PDAs were a significant departure from previous mainstream mobile computing, previous mobile computing had not been handheld. The earliest computers that resemble current laptops appeared in the late 1980s with the arrival of such machines as the NEC Ultralite and the first Apple Laptop. Between the 1980s and mid 1990s various attempts were made to market hand-held computers. The first handheld device that

bears close resemblance to what we now consider a PDA was the Apple Newton Messagepad. The first successful mass market PDA type of device was the Palm Pilot. Launched in 1996, “by the end of the year Palm had 70% of the USA market share for hand-held computers” (Butter and Pogue, 2002; Shipman and Morton, 2001)

1996 was a pivotal year for mobile computing with the introduction of the both the Palm Pilot PDA and Microsoft’s PDA operating system. Palm and Microsoft took different approaches to the design of the PDA operating system. The Microsoft strategy was to produce a cut-down version of its Windows desktop operating system. They reasoned that by maintaining the same interface “look and feel” users would be familiar with how to use it. Microsoft did not manufacture the hardware upon which the operating would run.

The approach taken by Palm was first to specify what tasks a PDA should be capable of performing and the maximum physical size of the device necessary to perform these tasks and to then design adequate hardware to realise the device. Palm designed an operating system specifically for a device with limited processing power and with a user interface suited for use with a small screen and limited input facilities. As Palm were in control of both the hardware and software design of their PDA, unlike Microsoft, they could readily make design trade-offs to optimise the system. Palm were not relying on a user’s familiarity with another interface, instead they made the device simple to use so that the operation of the device was closely matched to the task being performed (Norman, 1998, pp57).

The differences in implementation also had significant influence on the performance, hardware requirements, battery life and the cost of the devices. The difference in design philosophy between Palm and Microsoft may have had an influence of how mobile learning has since been interpreted and implemented “.it may in fact transpire that different hardware and software platforms support rather different interpretations of mobile learning” (Traxler, 2007).

2.1.1 Why PDAs are Different to Other Types of Portable Computing

As explained above the philosophy behind the design of PDAs is different to that of a PC, and a PDA occupies a different domain to a laptop computer, it is a different type of device for use in different ways. "They should not be viewed as replacements for laptops or desktops, rather as useful, lightweight portable adjuncts to these systems" (Smith, 2003).

The requirement that a PDA can be held in one hand limits the form factor and size of the device and these constraints dictate the maximum screen size that can be accommodated. These limits implicitly make a PDA different from a laptop computer. Unlike a laptop, which can act as a substitute for a desktop system, a PDA is intended as an additional tool. PDAs are used in conjunction with laptops or desktops



Figure 2.1: Graffiti

(Cochrane, 2005). Some of the generic features of PDAs now described.

Interface and screen size

Although the screen of PDA is bigger than those used on mobile devices such as those of basic mobile phones it is much smaller than the screen of a laptop ,netbook or ebook reader.

When compared to a desktop system, the screen "real estate" of a PDA is very limited. The display of a typical desktop system is 19 inches across with a resolution 1024x768 pixels, a PDA screen may be less than 2 inches across with a resolution of 160x120 pixels

What works well on a large screen does not necessarily work well on a small screen(Malliou, Savvas and Sotirou, 2002). The User Interface(UI) has to fit in a screen small enough to be carried in a hand without fatigue - but bigger than the screens or UI of a single function device like a basic phone. Thus the interface needs to be different, not just an existing desktop interface squeezed onto a small screen.

Microsoft did try to fit a desktop interface onto a small screen but this was later seen as a mistake and the interface was later adapted to be more suitable for a small screen device. A representative of Microsoft at a developer conference said that "it had been a mistake to take a user interface designed for a big screen and shoehorn it onto a small screen" (Nielsen, 2000). Subsequent versions have been more compatible with a smaller screen.

The size of the screen can limit what material can be viewed and may necessitate bite sized selections of data to be presented though for the display of some types of information this may be adequate, "Mobile devices are suited for chunking due to their smaller screen size and storage capacity" (Mellow, 2005). It is also noted by Mellow (2005) that the current generation of students are used to selecting the materials that are of most interest to them, and cite the example of buying individual music tracks rather than entire albums worth of material.

Data Input

Some PDAs have miniature keyboards, others rely on handwriting recognition and some have both options, but in all cases entering a large amount of text is very time consuming. These are limitations that should be taken into consideration when designing an application for use on a PDA. For example in order to reduce the amount of text a user has to input it can be better to provide choices for a user to select from, using such interface devices such as lists and check boxes (Palm, 2001).

Unlike a desk based computer or even a laptop, when using a PDA the technology is ready for immediate use by the student, wherever they are located. There is no need to wait for the device to 'boot-up' The importance of the application being immediately available is very important, there is a subtle difference between items that are ready for immediate use and those that are nearby. These states equate to something that, to use the terminology of the German philosopher Martin Heidegger is "present at hand" or "ready at hand" (Soloway *et al.*, 2001). A PDA can be considered to be ready at hand, whereas a laptop is often only present at hand (the immediate readiness with no boot up time is now a feature of tablet devices such as the iPad).

Being nearby, in a pocket, and almost instantly on with no boot up time makes it possible to use a PDA even when there are only a few minutes or less available . The importance of PDAs being at hand, in the context of student use recurs throughout the literature such as (Waycott *et al.*, 2002; Soloway *et al.*, 2001). A comment made by a student during a study conducted by the Open University in the UK, was that a PDA is something that is "unobtrusive and neat and that could always be ready at hand" (Waycott *et al.*, 2002).

Usage Pattern

The usage pattern of a PDA is different to that of a PC or laptop computer. The typical use for a PDA is to use it to quickly look up or jot down some information; it therefore needs to respond quickly and reliably. "People generally use handhelds in frequent, short bursts-more like a watch than a PC. They take a handheld out of their pocket or briefcase to review and update small chunks of information."(Palm, 2001)

Any delays, however small will detract from how useful a device is and whilst on initial use small delays may seem to be acceptable, if it is a task that is performed frequently the delay will become annoying and may even become a barrier to the use. The designer of the Palm OS interface uses the analogy of how annoying a wristwatch would be, if to check the time you had to "boot up" your watch and wait for two seconds for the time to appear (Bergman, 2000).

The PDA shares characteristics with the concept of an "Information Appliance". The psychologist Donald Norman defines an Information Appliance as: "An appliance specialising in information: knowledge, facts, graphics, images, video or sound. An information appliance is designed to perform a specific activity, such as music, photog-

raphy, or writing. A distinguishing feature of information appliances is their ability to share information among themselves" (Norman, 1998).

The PDA differs from an information appliance in that it is a general- purpose device that can be adapted, through the installation of different software, to do other jobs as well. There are a large number of inexpensive software applications available for the PDA.

Amongst the features that make PDAs useful to a students are: The device is small and easily portable, relatively inexpensive in comparison with a laptop, extremely short start up time, large choice of cheap or free applications.

2.2 Why Mobile Learning?

2.2.1 Working students

Many 'full time' students also have to work part time so the distinction between full and part-time students is now less distinct (Evans, 2005). Mobile computing that can be used anywhere and at anytime can be a valuable asset to them. The following comment, mentioned earlier in Chapter 1, was made during a project studying medical students and highlights the importance of providing an instantly ready learning resource.

"Our team carried out a detailed study of how radiology is taught and practised. One clear finding was that trainees have very little spare time. They cant take the time to sit in libraries or computer labs, and so any computer-based learning must fit into the gaps in their busy schedule - in the hospital, at home, when travelling - which means a personal and portable system." (Sharples, 2000a)

2.2.2 Mobile Learners

One of the benefits claimed for mobile learning is that learning can occur anywhere as PDAs enable students to become mobile learners (Olsen, 2000). Mobile learning was possible before the era of mobile computing, in the past distance education students took books or other written materials with them so they could study during lunch-breaks, while waiting to collect children from school, while travelling and many other locations (Messing, 1995).

If such times and locations were practical places for the use of books then they should suit mobile devices enabling the use of materials which have richer content. The suggested locations of train and bus occurs frequently in the literature but it is noted by Vavoula *et al.* (2004) that in a survey conducted as part of the mobilearn project only 1% of learning activities took place on transport. In another study it was also reported that none of the students used public transport (Riordan *et al.*, 2005).

But as noted above there are other periods of “dead-time” that can become useful opportunities for learning.

2.2.3 Accessibility

An important consideration in the introduction of new teaching methods is how accessible it makes the materials to students.

There are two aspects to accessibility of mobile learning, making the device and materials usable for someone with a disability and also using mobile devices as an enabling technology to overcome a condition.

The screen of mobile devices is by the nature of the device small and so not particularly easy to use for someone with visual impairment. Mobile devices can have accessibility issues for users with poor motor skills the size of the device its controls and interface can be a problem (Rainger, 2005). The extent to which systems can be customised, for instance to allow different interface colours varies between platforms (Rainger, 2005).

Mobile devices can be used both directly and indirectly as enabling technologies. A directly assistive use could be using a PDA or smartphone as memory aids for people with learning or organisational difficulties (Trinder, 2003; Rainger, 2005).

A specific example of mobile devices providing an indirect benefit is a project that enabled a mobility impaired student to take part in geology field trips. In the project the student was able to remotely direct and interact with field geologist. To facilitate this an ad-hoc battery powered wireless network was installed at the site on a Scottish hillside. The wireless link provided two way voice communication, live video images and allowed high resolution still images to be sent back to the student (?).

2.3 Theories of Mobile Learning

Mobile Learning is a relatively new field of research and the theoretical and philosophical foundations have not yet been established (Muyinda, 2007) and so the formation of underlying theories is still developing. It has been suggested that in order to formulate a theory of mobile learning four criteria need to be satisfied (Sharples *et al.*, 2007, p221). The criteria are: to identify what is different about mobile and other types of learning, to account for learning that occurs outside of the classroom, to be based on currently identified learning practices such as being learner; knowledge assessment and community centred; and finally to account for the widespread use of mobile devices.

Activity Theory, Conversation theory

Other researchers have proposed models to form the basis of a theory of learning that incorporates a mobile component. One theory that is frequently cited is based on a variation of Engestrom’s expansive activity model (Engestrom *et al.*, 1999).

Activity Theory provides a model of the activities of people and systems. The concept is that an activity occurs as the result of the interactions of various actors. The activity comprises of a subject, an object and the actions between which are mediated by a tool. The action takes place not in isolation but within a social context. The main actors are the *Subject* which is the activity being examined, or the person whose motives are being examined, the *Object* is the problem or item that the activity is directed at, and the *tools* through which the activity is mediated. The remaining components are the *Rules* which may be formal or social conventions, the *Community* which consists of other actors related to the activity and *division of labour* is of both the community and those of hierarchical power and status.

Another model of mobile learning suggested by Sharples (2000b) applies the conversational theories of Pask (1976). Pask's theories describe learning as being facilitated by conversations between systems. The systems' engaged in the conversation may be people or machines. The systems differences in their understanding, perceptions and disagreements about the concept under discussion are refined and altered by the further iterations of the conversation towards a point where there is an agreement between their understanding.

The conversational framework has also been explored by Laurillard (2007) where it is related to construction of academic knowledge and how technology can aid the conversational process. Technology can facilitate communication between students and becomes an enabler of conversational learning, described by Sharples (2000a) as a pervasive conversation learning space. In other situations the conversation may be between the student and the technology such as simple computer based tutoring systems or self assessment quizzes where the level of conversation is limited.

2.3.1 Educational Affordances of mobile technologies

So what can mobile devices bring to education that other methods or tools cannot? What are the unique affordances of a PDA? Before exploring these the term affordance should be explained as it will recur throughout the thesis. An affordance is the property of something that makes it suitable for a purpose of use. As terminology in user interface design it was used by Donald Norman in his book "The Psychology of Everyday Things" (Norman, 1988). It is the type of action that an item appears to be able to perform, for example a handle on a door suggests the door can be pulled toward you, whereas a plate implies the door should be pushed (Norman, 1988). Norman has stated that the term is perhaps better thought of as *perceived affordance*. (see Donald Norman http://www.jnd.org/dn.mss/affordances_and_design.html)

Returning to educational affordances, it has been suggested by Klopfer *et al.* (2002) that the affordances of mobile devices that make them suitable for education are :

- Portability
- Social Interactivity

Theme	Key Theorists	Activities
Behaviourist Learning	Skinner, Pavlov	Drill and Feedback, Classroom response systems
Constructivist	Piaget, Bruner, Papert	Participatory simulations
Situated Learning	Lave, Brown	problem and case based learning, context awareness
Collaborative Learning	Vygotsky	Mobile computer-supported collaborative learning (MCSCL)
Informal and Lifelong Learning	Eraut	Supporting intentional and accidental learning episodes
Learning and teaching support	n/a	Personal Organisation Support for administrative duties (eg attendance)

Table 2.1: An activity based categorisation of mobile technologies and learning (from Nesta Futurelab (Naismith *et al.*, 2004, p18))

- Context Sensitivity
- Connectivity
- Individuality

Mobile devices can be used for a variety of tasks and the delineation of these is complicated by the wide variety of devices now included in the field of mobile learning. A report by Futurelab (Naismith *et al.*, 2004) classified the activities that may be supported by mobile devices as Behaviourism. Constructivist, Situated, Collaborative, Informal and Lifelong, Learning and support (Naismith *et al.*, 2004), these are shown in table 2.1. The Futurelab report takes a different approach from previous literature and rather than focussing on the technology or subject areas identifies the types of activity that mobile learning can support.

An explanation of the main categories can aid understanding of how mobile devices can support the learning process.

The constructivist paradigm suggests that a learner constructs knowledge from their perceptions and interpretations of their environment (Phillips, 1997). Participatory simulations are where users take part in an activity that simulates an environment (like a technology enhanced role-playing situation).

Behaviourist learning is a stimulus-response model. In the context of Computer Aided Assessment the stimulus is the the question being asked and the response the actions and decisions taken by the student to answer the question. Behaviourist learning would include formative assessment tools such as quiz applications.

Situated learning was introduced as a concept of how learning occurs within a community of practice (Wenger, 1998). The community of practice concept is a model of how learning may take place in a social context, with the participants who have some common aim and are working together towards those aims. The community of practice concept arose from Lave and Wengers work to understand how newcomers to a field improve their knowledge and understanding, for example the training of apprentices. The viewpoint is that learning occurs in the same context in which the knowledge will be applied. A mobile device's suitability in this context is that its portability can enable it to provide materials in almost any location the user is in. Examples of the application of situated learning are the use of mobile technologies on field trips, providing information about the surrounding environment (Johnson, 2007), or within museums to provide information about the exhibits. The devices can also be aware of the location in which they reside, either due to some local identifier such as an RFID tag, ultrasonic beacon, QR Code or based on location via GPS.

A view of situated learning is also relevant to the project in that users showing each other how to use the device are working within the locations where the device will be used and are also forming a community of practice.

Formal and informal learning As the PDA is a a device that can be carried it is an ideal device to support lifelong learning (Clough *et al.*, 2008).

Informal and lifelong learning describes the learning that occurs out-with the boundaries of formal education. Such learning may be intentional , such as learning a new language or spontaneous and triggered by events such as finding an unusual flower, or hearing a unknown word and looking it up in a dictionary. (Scanlon *et al.*, 2005) makes comment that there is no easy way of defining the boundaries between formal and informal learning.

A framework to categorise mobile learning applications was proposed by Patten *et al.* (2006) and is shown in 2.2 on the following pageThe diagram is useful as it also shows example applications in each of the categories. The mobility of devices used in education may also facilitate taking learning back into the community “Mobile learning can take education back out into the home, the workplace and the community” (Kukulska-Hulme and Traxler, 2005, pp42). In Schools projects such as Wylie and Perry (2008) the PDA allowed parents to understand the work the pupils were doing.

2.4 Specific Projects and Reports

There now follows a short overview of various mobile learning projects that have been undertaken worldwide with a specific focus on UK projects. The UK focus is taken as that is the environment in which the practical work described in this thesis will be situated. A mixture of both recent related and historical projects are highlighted to show the current state of the art and earlier ones to show the rate of progress of

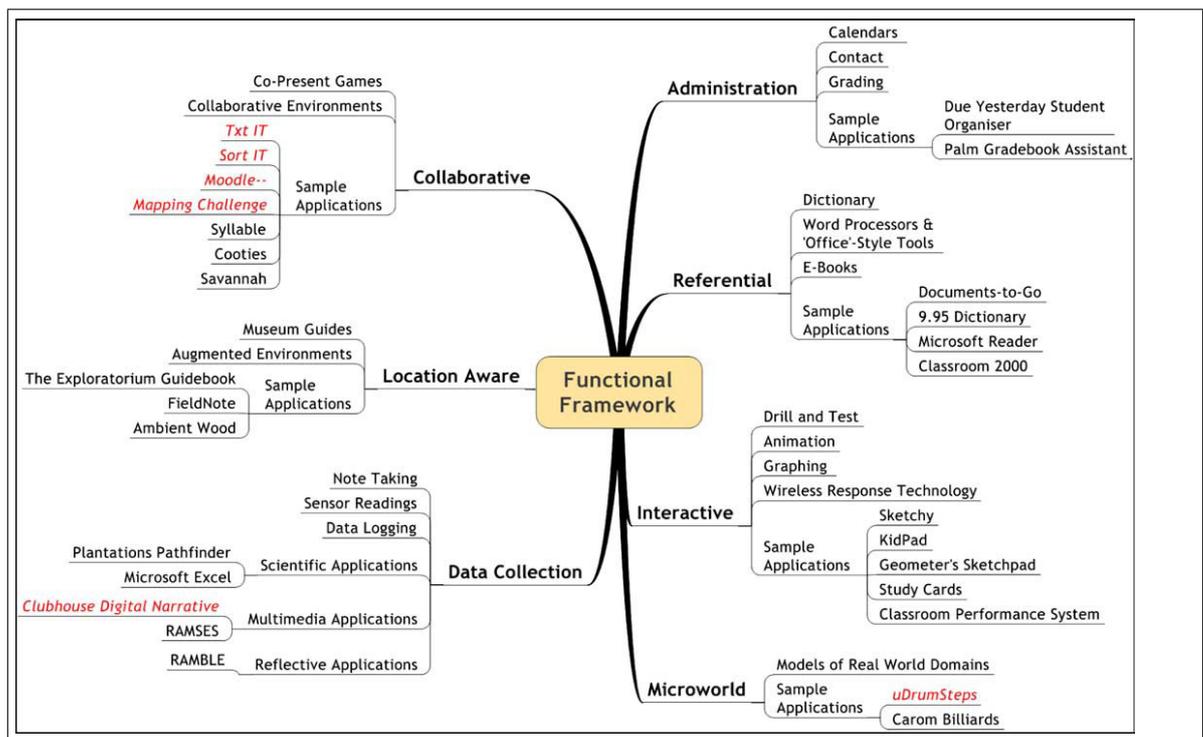


Figure 2.2: Functional Framework of Mobile Device Uses (from(Patten *et al.*, 2006, pp296))

mobile learning. Projects of particular relevance to this thesis have been selected for more detailed description due to their overall significance in the mobile learning field or their similarity to the context or methods used in this thesis.

2.4.1 Background

Use of PDAs in academia has been influenced by the use of the devices in industry where the largest initial uptake was by medical, business, law and technology companies (Fox and Schwartz, 2002).

As the use of PDAs became established in many professions it made sense for students to gain familiarity with them during their education prior to joining these professions. The medical profession were rapid adopters of PDAs mainly as a means of accessing reference material such as drug databases and clinical procedures (Shipman and Morton, 2001). The popularity of drug databases is reported as being one of the main motivations for members of the medical profession to acquire a PDA (Shipman and Morton, 2001; Brilla and Warteborg, 2004). Some medical schools have provided or required PDAs to be used (Brilla and Warteborg, 2004). It is not just the medical applications that are useful to students and medical practitioners but also the organisational tools. One medical student commented “I cant live without this thing now. Its a great way to keep all the information in my life organised” (Shipman and Morton, 2001). The ability to easily transfer materials between PDAs has been of great use to medical staff as a means of transferring work notes over to colleagues between shifts (Al-Ubaydli, 2003).

Schools

Much of the early research into the educational use of PDAs occurred in schools in the USA, notably through the work of Soloway *et al.* (2001). An important early finding was that PDAs can help facilitate both collaboration and provide an opportunity for pupils to reflect on the work they have done (Soloway *et al.*, 2001).

In the UK many of the early larger projects have been within schools, with much work centred on the West Midlands. In 2004 a pilot project in Dudley utilised Palm PDAs in schools and a reported benefit of the project was that it moved education back into the community and enabled parents to gain a better understanding of the children's homework (Kenny, 2005). It was projected that up to 40,000 PDA would be distributed around schools in the areas. This did not happen because of reliability problems with the model of PDA that was used in the pilot. The pupils involved in the project commented that PDAs provided the benefit of allowing individual access to computing equipment compared to multiple students sitting around a computer in a lab.

When pupils who have had the benefit of using mobile devices in schools reach Further and Higher Education it is likely that they will have expectations that mobile learning will be supported in those institutions (Evans, 2005).

The reported benefits from schools projects have been improved results and increased pupil motivation (McFarlane *et al.*, 2007). It is not clear if the increased motivation is as a result of the use of PDA or due to some incidental factor such as the pupils feeling that staff are taking a greater interest in the pupils and their work. Similar motivational effects have also been noted in adult learners and also in informal settings (Jones *et al.*, 2007).

The motivational quality of mobile learning is a recurrent theme in the literature and it has been suggested that perhaps this is due to its novelty value (Savill-Smith and Kent, 2003, p10) Reports such as Perry (2003) have indicated that the PDAs have provided an improvement in the performance of the pupils, but doubt has been cast over the amount of improvement by more recent reports such as McFarlane *et al.* (2007) which suggest the use of mobile devices bring little improvement, but recognise that this may be due to limitations of the current assessment system.

Further Education

In the UK the MoLeNET (Mobile Learning Network) series of projects in England have probably been the largest deployment of mobile learning in the UK (Attewell, 2005). The MoLeNET project is on a very large scale compared to the majority of small scale projects that have been undertaken the UK so far. The project is in collaboration with with the Learning and Skills Council (LSC) and Learning and Skills Network (LSN). The amount of investment in the project to date is £12 million. Currently approximately 32 MoLeNET projects are ongoing in a variety of areas of mLearning.

MoLeNET projects have involved over 40,000 learners and 7000 staff. (figures quoted are from <http://www.molenet.org.uk/>)

2.4.2 Mobile Learning Projects in USA

Amongst the early projects utilising PDAs in education in the USA were:

Avazanto (Avanzato, 2001)

This project involved electronics and computing science students, a group with similar technical interests to some of the students involved in the investigations of the work described in this thesis, although later in their educational careers.

Class notes, course reference material and quizzes were distributed to the students, the transfer was achieved by infra-red beaming. An important feature of the project was that the students evaluated the materials and applications for the PDAs and also authored some of the materials and applications for use on the device, thus integrating the students actively in the research.

In addition to the use of the PDA as an educational tool the PDAs were also used as the controller in robotics projects which were part of the students curriculum. To write bespoke PDA applications requires a good understanding of how the device works and indicates that the students had a greater familiarity and technical competence with the device than the students who took part in the practical work described in this thesis. Both the students and tutor reported that the PDA was useful as an instructional tool and also facilitated collaborative learning.

Palm Education Pioneers Program (2002)(Crawford and Vahey, 2002a)

In 2001-2 a large scale study into the use of PDAs in schools was conducted in the USA. The Palm Education Pioneer Program comprised over 100 schools in projects that utilised Palm PDAs. The project was conducted on behalf of Palm by SRI international and is by far the largest study of the use of PDAs in education that has been made to date and its reports are frequently cited.

Feedback from all the participating schools was obtained by questionnaires issued to teachers and students at the end of each semester along with a small number of site visits. Members of SRI evaluated some of the projects in more detail. The reports summarise the benefits and drawbacks of PDA use and many of their points reappear in later studies from other PDA projects.

Key benefits for students included; Increased time using technology, increased student motivation, increased collaboration and communication.

The study did, however, flag a number of drawbacks, which included; Inappropriate use, support issues, usability problems, equipment damage. One finding of the SRI project of particular relevance to this thesis is how to deal with situations where there

are a limited number of PDAs available relative to the number of students. The schools tried various strategies for deploying the PDAs, including;

- PDA loaned to student for duration of project, but PDA not to be taken off-site
- PDA loaned to student for duration of project and allowed to take the PDA off-site
- PDA issued for the duration of a class

The conclusion of the SRI research was that students are only able to fully utilise the benefits of a mobile device if it is available for them to take with them whenever they want. Only by having full time use of a PDA is a student able to exploit both the additional benefits of the organisational tools, such as diaries, that the PDA provides and the opportunity for taking notes or for looking up information or reference materials. The importance of ownership of the PDA is another common factor in many other studies. McFarlane *et al.* (2007); Kukulska-Hulme (2007); Sharples *et al.* (2005).

A problem when evaluating new technology in education is securing funding to purchase the equipment. In the USA, Palm provided grants and donated equipment to a number of projects, whereas in the UK they showed almost no interest in assisting the education market. They did finance a proof of concept project to illustrate the feasibility of a mobile learning tool (Phillion, 2002).

Greenberg 2004

This project is of particular relevance as an automated logging mechanism was used to record the duration of device use to provide a source of objective data.

This project was conducted at Louisville School of Medicine USA in July 2001. PDAs were distributed to 137 3rd year medical students. The devices had 5 clinical applications installed along with an automatic logging application that recorded cumulative application use. Use of the PDAs was recorded over a 3 month period with additional data collected by using surveys and focus groups.

Results from the log data suggested that the number of uses per week increased from 29 to 37 occasions but the cumulative usage times per week reduced from 37 to 29 minutes. The reduction in the amount of time for which the device was used was attributed to the students improved familiarity with the use of of the device and applications. The students also stated that the device made them more efficient dealing with both patients and information.

The research team noted that their project experiences confirmed their initial belief that large scale technology based projects need large amounts of time, funding and expertise (Greenberg, 2004).

2.4.3 Mobile Learning Projects in UK

UK PocketBook (Project conducted in 1996 Sector UK School)

One of the earliest UK projects investigating the use of mobile technology in education took place in the UK in 1994 where a study was made of PDA use in a secondary school in England. The project is described in Robertson *et al.* (1997) and utilised a device called the Acorn Pocket Book (also known as the Psion Series 3). A Pocket Book was issued to all teaching and administrative staff in June 1994 and four months later an entire first year class of pupils aged 12-13 were also given Pocket Books. The four months delay before introduction of the PDAs to students gave staff the opportunity to become familiar with the technology. The study concentrated on the use of applications such as spreadsheets and word processors.

The areas of interest were: the users perceived familiarity with the applications, how much the device was used, what purpose the device was used for. The project data was collected using questionnaires.

After a period of 5 months the students own estimates of their familiarity with the applications had fallen. “With more experience the students may have begun to realise that their knowledge of the applications was not as comprehensive as they had thought” (Robertson *et al.*, 1997). An example being ‘consciously incompetent’, as discussed later in this chapter in section 2.6.2.

This project is useful as a reference point for comparison with other investigations as it was one of the earliest schools mobile learning projects from which a number of themes, such as the fall off in use, emerge that recur in later projects. The results of the analysis of how much the PDAs were used was reliant on users filling in feedback questionnaires and only 50% of the participants did so. The fact that the device was “always available” was highlighted as a benefit of the technology. This is a benefit that is reported in most PDA studies and indicates just how important “instant readiness” is. It could also reflect how dissatisfied everyone is with the performance of applications and operating systems on desktop systems.

In the reports’ conclusions it is noted that “The results show that providing palm-top computers to both teachers and students has led to a considerable increase in the knowledge and use of various content-free applications by both groups” (Robertson *et al.*, 1997).

Open University (Waycott 2001 Sector UK Higher Education)

The Open University conducted a study in 2001 of 65 distance education MA students on the course “Applications of Information Technology in Open and Distance Education”. Students of the Open University are distance education students, many of whom are used to studying in their spare time. The project evaluated the PDA as an eBook reader to read course materials. The PDA was supplied in addition to the printed course materials which are normally divided into sections to make them

convenient to carry.

Students found the small screen a problem for reading and text input difficult, but in spite of these difficulties the students found the project useful as it enabled them to easily carry course materials, and they liked the PDAs organisational tools(Waycott *et al.*, 2002).

Some points that later recur in literature were highlighted during this project. For example, although the PDA made it easier for students to carry the course materials with them it made it more difficult to read and annotate them. Despite these limitations students found ways to adapt (Kukulka-Hulme, 2005) and (Waycott, 2005b) and developed mechanisms for using the PDA in conjunction with the printed materials.

Linking mobile devices to Virtual Learning Environment (VLE) (Project conducted 2003-2005 Sector UK Higher Education)

The introduction of VLEs (Virtual Learning Environments) was happening around the same time that many of the early mobile learning projects were in progress. An early project to explore the use of mobile devices to access institutional systems such as VLEs was undertaken (Ramsden, 2005, 2003) The PDA used was Palm M105 which had no WiFi capability, and so the connection to the network was achieved via an infra-red link to a mobile phone. This is a far less convenient means of connection than utilising a built in wireless facility to a locally available wireless network. Materials had to be converted to a suitable format for PDA viewing and web-pages adjusted to make up for the lack of javascript capability of the browser. Materials were transferred to the PDAs by access to web pages and using FTP (File Transfer Protocol) applications. (I wrote one of the FTP applications used by the project).

An observation made during the project was that for many tasks if PCs were easily available the motivation to use the PDA was low, even if it meant waiting to perform the task. This phenomenon was also observed by Wishart (2006), with trainee teachers, where some participants stopped using the PDA once other PCs were readily available in their school. This is a theme that recurs in other projects.

The project did show that a relatively simple PDA could be used to access materials on a VLE and participate on the discussion boards. Even though connecting to the VLE required significant effort it was none the less used, and this suggested that in the future with many of the connection barriers lowered such use of mobiles and VLEs would become routine. The project researchers note that educational materials will still need to be designed with consideration of the device upon which those materials will be used.

Birmingham student organiser - (Project Conducted 2002-2003 Sector UK Higher Education)

This project centred on the design and support of a 'student organiser' utilising wireless enabled Hewlett Packard iPaq PocketPCs. A suite of applications were installed on the device along with a custom designed Learning Organiser, comprising a Time Manager, Course Manager, Concept Manager and the Communication manager, which acted as a launcher for tools such as email and a web browser. The students found the organisation tools useful and it appeared that the device was just seen as another means of accessing materials.

In some application areas, such as entertainment and communications the students found the loaned device was inferior to other technology they already owned (Sharples *et al.*, 2005, pp148). Over the duration of the project the device use decreased and the differentiation between frequent and infrequent users of the PDA widened.

The Birmingham and Bristol projects illustrate the difference in capabilities of the two main platforms used in mobile learning projects at this time, the simpler monochrome Palm PDA and the media and wireless ready Windows mobile based devices. The two projects also show the difference in available wireless infrastructure capabilities at different institutions Sharples *et al.* (2005).

Wolverhampton (Project conducted in 2003 Sector UK Higher Education)

This project involved a cohort of 20 HND Computing students, and was conducted at a similar time as phase 1 and 2 of the investigations described in this thesis. The project utilised a Sony Clie SJ22 PDAs which were loaned to the university by Sony UK (at the time to buy 20 devices would have cost approximately £3000).

The PDAs were to be used to assess the efficacy of tools to access the course materials and timetables.

The students were positive about the battery life and found the device useful for taking notes and for its diary and organisation applications. The students did have criticisms: they wanted wireless connectivity, web and email support, the ability to edit word documents, found the cost of memory sticks prohibitive and did not like a non Microsoft environment. The students' confidence in the devices was undermined by the syncing set-up which overwrote data on the PDAs (Riordan *et al.*, 2005).

In the second semester of the project it was found that many of the students had acquired other devices of their own that could provide much of the functionality of the PDAs and which the students believed to superior (Riordan *et al.*, 2005). A frequently claimed benefit of mobile learning is that students can use the device while travelling on the bus or train, but in this project it was found most students did not use public transport. Training was offered to the participants but only 5 out of the 20 participants in the project took up the training provided.

Themes arising from this study that recur in other projects are: syncing, infrastruc-

ture and technology ageing.

MyArtSpace - University of Nottingham In this project mobile devices were used to access network based shared resources and content that is shared via a common web space. It is primarily designed to support school field trips, and the pilot project incorporates 3 museums. Prior to each museum visit the teacher sets a question for the class to answer during the trip. The students are issued with multi-media smartphones to use throughout the trip. During the visits students are free to investigate the museum and to collect visual representations of the exhibits. This is achieved by entering a code into the smartphone which triggers a multimedia presentation about the exhibit on the smartphone and also uploads an image of the item to their personal web-space. The student may then make notes about the exhibit and why it interests them, and the note is also uploaded to their web space. The students can also see a list of all the others who have collected the item in their web space and encouraged to have discussion with those students. The smartphones also enabled students to collect their own photos and sounds which can be uploaded to their web space. The web space allows the students to reflect on their experiences after the visit and to share and discuss their selections with other students (Vavoula, 2007).

This project is a good example of using a mobile device as a component of a bigger project and as a means of stimulating communication between project participants,

2.4.4 Reviews of the Field

The first report into the potential of mobile devices for use within UK Further and Higher Education was by Professor Ted Smith (Smith, 2003) The purpose of the study was to report on the potential and anticipated uses of PDAs in education for 3 years leading up to 2006. The main focus was on PDAs and gave a snapshot view of early projects in the UK. There are 8 UK projects identified in the report. It is likely that there were others that are not mentioned but it gives an indicator of the level of activity and types of use at that time.

Various predictions were made in the report, amongst these were: that the incorporation of MP3 playing capability in PDAs would create student demand for them, tablet PCs would remain a niche market, PDAs and smartphone would only be used on specialist courses. Smith stated that PDA could be useful educational tools but that by 2005 most students would not own a PDA but would own a smartphone where synchronising calendars and course details would be possible. Smith also thought that student use of mobile devices would push institutions towards using and supporting mobile learning.

In 2004 a report was produced on behalf of JISC to evaluate mobile devices in education. Amongst the report's findings were: that training would be a requirement for staff who may not have an adequate understanding of the capabilities of mobile

devices (Anderson and Blackwood, 2004) and that portable media player devices would play an important role in education.

2.4.5 Themes Emerging From The Projects

The projects described above encompass all sectors of education and there are number of themes and features worthy of note the most important are:

Device Provision: Own or Loan

A fundamental area for consideration in a mobile learning project is how the devices are provided to the participants. The strategies employed were to loan devices for specific tasks or to loan devices for the duration of the project. Where devices are loaned to participants different limitations were placed on when and where the devices could be taken for example if they were only used on campus or if they were allowed to take them home or use them out of term time. Limitations on where the device can be taken are an important factor on how the device is subsequently used. Other research in mobile learning has indicated that users are more engaged with devices they can use off campus (Crawford and Vahey, 2002b) and users with access to their own data had sense of control and ownership of learning Scanlon *et al.* (2005). It has also been reported that users value data on personally owned devices (McFarlane *et al.*, 2007).

Engaging Participants

In some projects PDAs were also supplied to the teaching, lecturing, support or administrative staff. This has the advantage of providing a first level of support for the students/pupils and creating greater awareness of the capabilities of the devices and as will be seen later in this chapter in the section (2.5), knowledge and awareness of the capabilities of an innovation are important factors in its uptake. A potential advantage of supplying devices to local support staff is to help overcome some of suspicion of such devices harboured by institution support staff as reported in Bird and Stubbs (2008).

In projects described by Avanzato (2001) and Sharples *et al.* (2005) the participants in the projects were also involved in choosing, evaluating and in some cases developing the materials used on the PDAs. This can help to reduce technical barriers and the extra engagement could encourage users to develop a deeper understanding of the affordances of the PDA.

Evaluating Mobile Learning

Many of the projects investigating mobile learning have utilised interviews, questionnaires, diaries and focus groups to collect information (Sharples, 2008). The drawbacks with such techniques are the reliance on the memory and honesty of the participants (Traxler, 2007; Nestel *et al.*, 2005; Waycott *et al.*, 2002; Wali *et al.*, 2008). A further

drawback of instruments such as learning logs and diaries is that it may take far longer to record the use of the device than the task being documented. (Traxler, 2007; Nestel *et al.*, 2005; Waycott *et al.*, 2002).

In reviewing the projects discussed above it has become clear that evaluation of mobile learning is challenging due to the nature of the technologies that may be involved. This is also recognised in the wider literature, for instance Kukulska-Hulme *et al.* (2005) state “there is no agreed method and there are no widely used novel tools for collecting evaluation data”. This problem continues to engage researchers and in 2007 a seminar was held in the UK specifically to address the problems of evaluating mobile learning. As this theme of evaluating mLearning will be central to the rest of this thesis, the remaining discussion of above projects in relation to such evaluation will be more detailed, and include additional commentary from the present literature in the field, to draw out some of the subtleties of this theme.

So what are the difficulties? In a technology centric mLearning project the mobile device may be used in different locations and for both formal and informal educational purposes, so even when the use of the device can be successfully recorded there is the problem of determining when and what learning activity has taken place. Also it is increasingly likely that a user may employ a number of different devices and so the use of one of those devices may only show a fragment of a learning episode.

A complication that may occur in evaluating mobile learning is that participation in many projects is voluntary and it is thus necessary to provide alternative means of the delivery of materials for those not wishing to take part, this dilutes the intervention and described as a hobbled horse race by (van 'T Hooft, 2007). An additional problem with relying on users to articulate how they have used a device is they may not possess the necessary skills to report their experiences (Vavoula, 2007).

Rather than rely on the user to record information about how they use a device there are technical solutions such as eye tracking (Mayr *et al.*, 2008) or video recording. A drawback of such techniques is they need additional equipment and may also require that the user is in a specific location where they can be observed. Whilst constraints on location may make it easier to collect the data they may also limit how the device is actually used.

An alternative recording strategy is to use the mobile devices under study to record how they are used (van 'T Hooft, 2007). Automatic logging can collect reliable objective data about various aspects of device use and has been utilised in various projects investigating the use of PDAs, early examples of this were Greenberg (2004) and more recently Wali *et al.* (2008) .

Automatic logging does have the drawback of normally requiring special software to be installed on the device under study and depending upon system architecture it may not be possible to record great detail about a users actions within an application. One technique to work around such limitations can, where possible, be to periodically record screen captures of the device such as in Wali *et al.* (2008).

A problem of recording device use is that the participants may modify their use of the system because they know they are being watched (Wali *et al.*, 2008). The limitations upon what information is collected are not only technical, there are important ethical aspects that need to be considered regarding what information it is appropriate or acceptable to collect about a user.

A particular problem at this stage in the development of mobile learning is that it may not be possible at the outset of a project to clearly define what the learning experience will be, which in turn makes it difficult to advise the user about what data will need to be collected (Vavoula and Sharples, 2008).

Looking to the future as the functionality of the mobile devices used by students increases so will the richness of information that may be collected about the use of the device. For example if a device has GPS features then it is potentially possible to record where the device is used.

Evaluating mobile learning may become more difficult in the future as the students will own the devices being used, which in turn raises additional ethical problems and data protection issues (Traxler, 2008).

2.5 Adoption and Integration of mLearning

In the previous section we reviewed a number of international and UK projects in the field of mLearning, flagging the achievements of these projects, the benefits resulting to students from the use of PDAs, and noting a significant opportunity for continued novel research in the area along the theme of mobile learning evaluation, a theme which will form the core of this work. However, proper investigation of this theme can only come about through practical experimental work, where the non-trivial hurdles of introducing such new technologies to both students and staff in a real educational setting must be overcome. This section discusses, from both a theoretical and practical point of view, with reference to current literature, how this may be accomplished.

The current state of mLearning in the UK is characterised by many small scale trials and pilot evaluations (Traxler and Sugden, 2007). Although mLearning is making inroads into mainstream education only some aspects, such as podcasting and SMS, have gained widespread acceptance.

A key difficulty in introducing a new technology is that the special attributes and affordances of the technology may not be fully understood and new learning opportunities made available through its use not appreciated (Patten *et al.*, 2006). A problem that has occurred when introducing technology into education has been in trying to use or adapt applications that have been developed primarily or solely for business purposes (O'Hagan, 1999). Providing the relevant tools but without accompanying these with suitable materials or integration with the courses resulted in failure of some early attempts of introducing laptops in universities (Csete *et al.*, 2004).

Moving mobile to the mainstream may also be a case of recognising that mobile is

just one tool amongst many (Stead, 2005). For mobile devices to be integrated into mainstream education it will require institutions to support suitable devices and for students to be willing to adopt the use of mobile devices in educational contexts. These ideas are now considered in more detail below.

2.5.1 Introducing New Technology in Education

Introducing a new technology or system into any environment may be met with resistance for a variety of reasons. The reasons may be technical, usability, psychological or political and those barriers may be real or perceived. There are a number of theoretical frameworks that can help to model and predict whether a person will utilise an item of technology.

Technology introduction

In a survey of students conducted by Jacob and Isaac (2007) regarding the potential of using mobile devices for learning the majority rejected the idea of using mobile devices in favour of using desktop alternatives. A difference in attitude was noticed between engineering and business students; the engineers were more negative in their views on the technology than the the business students. Jacob and Isaac suggest this could be due to engineers having greater technical knowledge, the negativity may have been due to a better understanding of the limitations of the mobile devices. The majority of the students in the survey indicated that they wanted to use a variety of mobile devices and it has been suggested that moving mobile to the mainstream may involve recognising that mobile is just one learning component (Stead, 2005)

Diffusion of Innovation

According to Roger's concept of the Diffusion of Innovation Rogers (2003) innovations spread through society in the following way: they are first taken up by early adopters, ultimately the technology is taken up by the majority of the population and then becomes a mainstream technology. An important factor in each person's uptake of a technology is their attitude towards it. Within the diffusion of innovation concept there are 5 steps in the innovation decision process. These are reproduced from (Rogers, 2003, p169).

1) *Knowledge* occurs when an individual (or other decision making unit) is exposed to the innovations existence and gains an understanding of how it functions.

2) *Persuasion* occurs when an individual (or other decision making unit) forms a favourable or unfavourable attitude towards the innovation.

3) *Decision* takes place when an individual (or other decision making unit) engages in activities that lead to a choice to adopt or reject the innovation

4) *Implementation* occurs when an individual (or other decision making unit) puts a new idea into use.

5) *Confirmation* occurs when an individual seeks to reinforce an innovation decision already made, but he or she may reverse this previous decision if exposed to conflicting messages about the innovations. (Rogers, 2003, p169)

These stages will be returned to later in this thesis as a means of categorising some of the barriers to use that were encountered during the practical work.

Diffusion theory was used by Bird and Stubbs (2008) as a mechanism for interpreting the barriers to the adoption of mobile learning. One particular point of interest from their paper is: “it seems clear that a temporal dimension will be important for understanding m-learning adoption” (Bird and Stubbs, 2008). This suggests that the effect of the introduction of mobile learning may not be immediately apparent and that time must be allowed to understand what impact the introduction of the technology has had.

Technology Acceptance

The Technology Acceptance Model (TAM) (Venkatesh and Davis, 2000) was designed to model the likelihood that someone will utilise an item of information technology. TAM builds upon the Theory of Reasoned Action.

TAM provides a simple theoretical basis to explain the behaviour of users in a wide range of computer use situations. The primary influences in TAM are the user’s perceptions of both the ease of use and usefulness of a system. The initial TAM model was later extended into TAM2 to account for social influences that are defined as subjective norm, voluntariness and image (Venkatesh and Davis, 2000, pp187). Subjective norm is defined as “a person’s perception that most people who are important to him think he should or should not perform the behaviour in question” (Venkatesh and Davis, 2000, pp187). It is noted by Davis that the influence for students is “the pressure they feel to use the system from instructors, other students, or key others in the learning context” (Demei *et al.*, 2006).

The image aspect is of the effect using the technology will have on the users group status, does it make them more or less a part of the group. Image could thus be considered to be a coolness factor. Voluntariness and compliance with social influence is where the requirement to use the system is either voluntary or mandatory. Davis notes that the influence of a mandatory requirement may operate “whenever an individual perceives that a social actor wants him or her to perform a specific behaviour and the social actor has the ability to reward the behaviour or punish non-behaviour” (Venkatesh and Davis, 2000). Davis also notes that even when the requirement to use an item of technology is mandatory some users will be unwilling to comply with such requirements.

The 4e Model

A model of technology acceptance specific to education was proposed by Collis and Moonen (2001) and is known as the 4e Model. The 4es are defined as Educational effectiveness(perceived), Ease of use, Engagement (personal), Environmental factors(institutional). The values are treated as vector sums which are added to determine the height of a line that determines the likelihood of use of an item or system of education technology. The 4e's and the most relevant sub-categories are now described:

Effectiveness The educational effectiveness is considered as long and short term benefits for both the student and the institution and how the technology can support a course as-is and what new aspects may be integrated due to the new technology. Collis and Moonen also note that learning may also be improved through enhanced communication and personalisation. (In earlier parts of this chapter it was noted that mobile devices can greatly improve communication and personalisation)

Ease of Use Ease of use is relative, not absolute, and may vary depending upon context (Kukulka-Hulme, 2007). For example if the only way of accessing a particular item of information is via an awkward to use mobile device then the user may determine that it is better and easier to wait until a later time when it is possible to use a desktop or laptop device. An example of this is where desktop PCs are easily accessible and so students may wait to use them in preference to the mobile device, such a scenario is reported in Ramsden (2005, pp189). If an alternative to the mobile device is not readily available and the inconvenience and difficulty of using the small screen is far outweighed by a benefit that may be gained then the device will be used. An example of this would be a sales representative visiting customer sites. If the only way of obtaining information that would increase the chance of landing of a sale is by using the web browser on the tiny screen of a phone, the effort is worthwhile.

Engagement Is the extent to which a person engages with the idea of using new technology for learning. An important sub-factor of this being the users self-confidence in the use of technology.

Environment This includes the support infrastructure of the organisation technical, managerial and of the attitudes of the staff to adopt and adapt to learning technology.

Personalisation, Ownership and Appropriation of mobile devices

The personalisation of a mobile device can take many forms such as the configuration of the interface colours, the installation of specific applications or applying “stickers” to its case.

Users appear to form a greater emotional attachment to personal devices such as phones and PDAs than they do to desktop systems (Waycott, 2005b; Creanor *et al.*, 2006). To install applications on a PDA requires effort from the user and it appears that people are willing to invest time learning how to do this (Quinn, 2000). It may be that having installed applications is a useful indicator of how engaged with a device someone has become. It may not now be as apparent how much motivation was needed to purchase and install applications when the projects described in this thesis were conducted. Whereas today the cost of applications to install on devices such as the iPhone or Android based devices may be less than £1, when the practical work described in this thesis was in progress applications typically cost around £10-£15. Also today it is simple to download an application “over the air” whereas previously more steps were involved, often requiring the use of a PC and a separate syncing operation to install the application.

It appears that it is not just the physical ownership of a mobile device that is important but a more subtle sense of ownership known as appropriation. Appropriation is an iterative process by which a user evaluates what a technology can do and adapts it to fit into their life (Waycott, 2005b). It is often the case that appropriation of tools may also change the processes or activities for which those devices are used.

Many of the studies of mobile learning have been based around a model of loaning devices to students and in such situations usage of the device appears to decrease as the time to hand back the device approaches such as Sharples *et al.* (2005). It is possible that the reason for fall off in use is the user reducing their use of the device as they know they will be handing it back. Having a loaned rather than owned device is also likely to discourage a user from purchasing applications or add-ons such as memory cards for the device (Sharples *et al.*, 2005). This in turn reduces the likelihood of a user personalising the device. In a loan situation a Personal Digital Assistant becomes merely a *Portable* rather than *Personal* Digital Assistant (Trinder, 2005)

2.5.2 Institutional Aspects of Mobile Learning

The progress of mobile learning may be influenced by an institution’s capabilities for supporting the associated technology (Traxler, 2005, pp184). Attewell(2005) suggests 5 main areas that need to be considered to support mLearning: delivery options(for example sms,email,wap), transport options(for example 3g,infra-red,Bluetooth), platform options(for example Palm,PocketPC), media options(for example video,audio) , development languages (C, JAVA).

It is argued by Cobcroft (Cobcroft *et al.*, 2006) that institutions need to manage the support of mobile learning in a platform independent fashion. Enabling students to use a device of their own is a better solution than prescribing the use of particular devices which would remove the personal choice which we have noted above to be of considerable importance in device appropriation and acceptance (Jacob and Isaac,

2007).

The computing support departments of many institutions are reluctant to allow the connection of student's own devices to their network, often citing security concerns (Attewell, 2008). Computing support departments have been highlighted as a barrier to the introduction of mobile learning (Bird and Stubbs, 2008).

Sustainability

In many pilot projects the institution has financed devices which have been loaned to participants. There have been instances of universities requiring students to possess specific models of device in order to attend an institution (Kennedy, 2001). The requirement for all users to own a particular model of device can make support easier for the institution but may remove some of the personal attachment the users have to the device. As noted previously there are many subtle factors that lead to the appropriation of a device. Also forcing users to use a particular device can cause them to resist - as was noted in the Technology Acceptance Model mentioned earlier.

The lack of large scale or long term deployment of mobile learning in Higher Education may be due to "resource implications" (Traxler, 2008). It seems highly probable that the most sustainable model for mobile learning is to make use of the devices the student already owns. If there is a move towards students using their own devices, this of course has many implications. For example an institution will no longer be able to precisely control what materials the student has access to as neither the network nor the device belongs to the institution. This model of operation could be an especially sensitive issue in the context of primary and secondary education (Traxler, 2008).

2.5.3 Training and Technology Literacy

There is a perception that current students are more technology savvy than previous generations (Tapscott, 2008) and some writers have suggested that the current generation of students are different because they have never known a world without computers and other digital technologies.

A concept introduced by Prensky (2001) suggests that such students are *digital natives* whereas earlier generations are *digital immigrants*. A similar view was taken by Tapscott (1997) that there is "Network Generation" or N-Generation. An alternative viewpoint is that the divide is *not* generational, for example many people of the wrong age to be Prensky's digital natives or of the Tapscott N-Generation use technology in more effective ways than those considered part of these groups.

Others now argue that the difference between users is not generational. It has been observed by Traxler (2008) that the Digital native view is an over simplification as the rate at which technology is used and adopted varies by communities, cultures and individuals. In a detailed study Kennedy *et al.* (2009) states that few differences in the use of digital technologies can be explained by age, "dispelling the digital natives

versus digital immigrants argument” Kennedy *et al.* (2009, p 5).

An alternative view defines people as *digital visitors* or *digital residents* (White, 2008), those that use computers all the time are residents, those that use such tools when they need to are visitors. However independent of the precise terminology used it is true that, many current students are used to working in a different way to their predecessors, due to the availability of digital technologies and communication tools (Tapscott, 2008).

Perversely, considering themselves to be 'digital adept' some students may not be aware that they lack the required knowledge to utilise a device (unconscious incompetence) and may therefore not take up offers of training. When training was offered to a group of students in a PDA project in Wolverhampton only 5 out of 20 actually accepted (Riordan *et al.*, 2005). As users get more experience of using a range of mobile devices it is suggested that the need for training will become less of a problem (Kneebone *et al.*, 2003). However this is presently not the case even when the vast majority of students are adept, there will be those that are not, and partially this depends on the quality of the user interface of the particular devices being used for the task that is being carried out.

It has been suggested that just providing new educational technology to students is not enough and that to get students to utilise that technology they need to be taught the required skills (Messing, 1995). There are indications that there are more reports of usability problems in mobile learning projects that utilise PDAs than those using mobile phones. A possible explanation for this is that as students already own a mobile phone they are thus significantly more familiar with its use (Kukulka-Hulme, 2007).

Student Adoption of Mobile Learning

Amongst the factors that may slow the introduction of portable devices suggests the lack of suitable functionality, and lack of 'killer' applications. Whilst earlier devices may have lacked functionality by 2005 it was observed that the then current PDAs possessed all the processing capability required by a student (Cochrane, 2005). Given the nature of personal devices the 'killer' application may be different for each user. It has become apparent that 'coolness' is an important factor for device adoption. For example in a project described by Cochrane (2008) Windows Mobile based PDAs were not used due to their "instability and inherent un-coolness".

As highlighted in the earlier section on technology acceptance, technical problems can easily undermine confidence in technology. Until the use of a particular device or system is embedded within an institution the amount of available local expertise may be limited. Kneebone *et al.* (2003) reported that it was essential to have a member of the team specifically to assist with technical issues.

Although many technical problems are often trivial, the user's perceptions of the seriousness of a problem or unreliability of the technology are often exaggerated (this is confirmed in my own work supporting computing technology and as a software de-

veloper). Technical problems have been indicated as an important issue in a number of projects (Riordan *et al.*, 2005) . The type of technical problems that have been highlighted included failure of devices, failure of syncing mechanisms (Trinder *et al.*, 2005; Riordan *et al.*, 2005), battery failure, accidental device damage, (e.g. broken screens), data loss. Syncing (also known as HotSyncing) is the process of transferring applications and data to and from the PDA. The implications of its failure are that materials, content and applications do not get transferred to the device and any documents, such as student assignments, that have been created on the PDA cannot be handed in.

An individual's lack of use of a technology may be due to their failure to understand the affordances of a device an example of this is reported in the work by McFarlane *et al.* (2007). In appropriating a device as a new tool Waycott (2005b) noted that the user will evaluate both the tools potential and it shortcoming. In some case however it is possible that having found a particular use (perhaps the most obvious use of the mobile device) that less obvious affordances will not be explored. A users familiarity with a device may also be affected by how often they change the device (Kukulaska-Hulme, 2007). The speed at which new devices, with greater functionality become available, brings more temptation for upgrading a mobile device.

Speed of Technology Change

The speed of technology change is a frequently occurring theme throughout the literature. The speed at which the technology used in mLearning changes makes the building of an understanding of mobile learning difficult (Traxler, 2007). For example, following the completion of a pilot study the technology may already be obsolete or superseded and system, infrastructure or operating system issues that may have been fixed during the pilot phase may no longer work with the updated technology. These changes make it difficult to repeat projects for comparative purposes. It appears that as fast as we understand how to use a particular variation of mobile device it has evolved into a different device. The rate of technology change also creates difficulties for conducting comprehensive literature reviews (Savill-Smith and Kent, 2003; Nestel *et al.*, 2005). But the speed of change is not entirely negative and ensures the field continues to evolve and makes the technology interesting for its users (and researchers).

Even though the speed of change does create some difficulties, there are underlying principles that remain the same, as they are dependent on human physiology and psychology. For instance, as noted in section 2.1, PDA screen size, resolution and data entry techniques are ultimately limited by the ability to comfortably hold a device, the precision of the human eye, and the accuracy of controlling a finger or stylus. Also the potential for encouraging collaborative work increases as the communication capabilities of the technology improves. Many of the themes raised in this chapter are of such general applicability and when discussing our results, we shall particularly note those results of general applicability.

2.6 Role of Assessment in Education

As one of the intended uses of the PDAs used within this project is to provide a CAA(Computer Aided Assessment) delivery mechanism this section provides an overview of the purpose of assessment and the use of CAA in education.

2.6.1 Assessment and CAA

The main categories of Assessment are *summative*, where the assessment is marked and the scores contribute to the students' final grade, and *formative*, for which the main purpose is helping students to improve their knowledge and understanding.

Assessment is an important component of learning as it provides feedback to the student and enables them to evaluate the knowledge they have gained and to identify areas in which their knowledge is weaker. "The role of assessment in the learning experience is crucial." (Brown, 1999). The main reasons for which assessment are needed are outlined by Brown (1999). These are to:

- Provide feedback to students so they can learn from mistakes and build on achievements
- Classify or grade student achievement
- Enable students to correct errors and remedy deficiencies
- Motivate students and focus their sense of achievement
- Consolidate student learning
- Help students to apply abstract principles to practical contexts
- Guide selection or option choice
- Give feedback on the effectiveness of learning
- Provide statistics for internal and external agencies

Within the context of this project the focus is on formative self-assessment using computer aided assessment. Familiarity with self assessment can help students become more effective learners as they improve their personal evaluation skills (Brown, 1999)

2.6.2 JOHARI Window

A model that illustrates how formative assessment assists the process of learning is the JOHARI window as shown in Figure 2.3 on page 36. Originally a tool which described the formation of interpersonal relationships, it has been adapted into a model of learning.

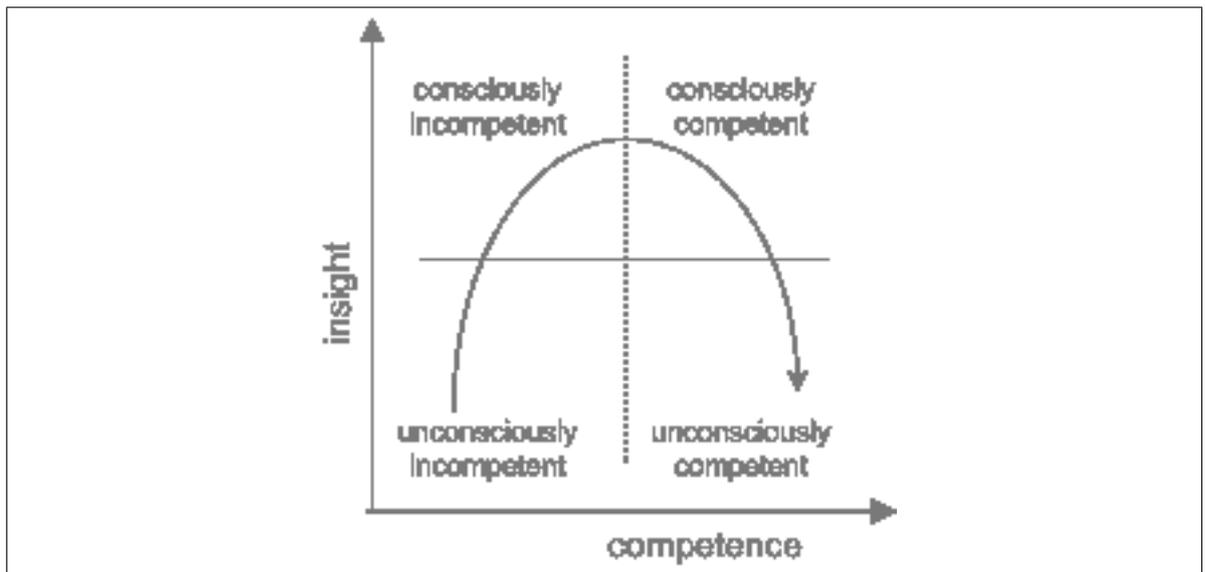


Figure 2.3: The JOHARI Window (©Luft and Ingham 1955 reproduced from (Perkin, 1999))

The adapted JOHARI window splits knowledge into four categories

- Unconsciously incompetent. At this stage we don't realise we lack some specific knowledge.
- Consciously incompetent. We are aware there is some knowledge we lack so can take steps to find out and learn.
- Consciously competent. Having gained the new knowledge, we are aware of it and notice we are putting that knowledge into use. (Maybe having just learnt to drive).
- Unconsciously competent (also known as Tacit knowledge). We have the knowledge and use it so unconsciously we don't even notice that we have that knowledge.

Most people learn when there is reason and opportunity to do so. However we may not always realise when we need to learn or what gaps there are in our knowledge (i.e. 'unknown unknowns' a phrase famously used by Secretary of Defence Donald H. Rumsfeld)¹, this is the unconsciously incompetent stage in the diagram above. Assessment helps us to determine the areas in which we are unconsciously incompetent or indeed to reinforce our feeling of being consciously incompetent or competent.

The JOHARI window model is used throughout this thesis as it can also help to illustrate a persons understanding of and ability with a given technology.

2.6.3 Computer Aided Assessment

In the past Computer Aided Assessment was only available in computer labs using desktop computers. More recently the availability of network based solutions has

¹<http://www.defense.gov/transcripts/transcript.aspx?transcriptid=2636>

enabled students to utilise these tests from remote locations. Web based assessment systems only require that the participant have access to a machine with a suitable web browser and network connection, which may be located away from the main campus, even at the students' home. This is especially useful for "distance education" students who are unable to visit campus facilities. CAA also adds to the flexibility and personalisation of education, allowing the student to utilise the system at a time that is convenient to them.

There are increasing demands being made upon universities to provide an adequate number of desktop systems. This is a great pressure on finances and space. To provide a practical CAA application does not always need the power of a desktop system and the alternative proposed in this thesis is the use of a mobile devices such as PDAs (Portable Digital Assistant)

2.6.4 Comparison of PDA and Paper Quizzes

The usability of quizzes delivered on a PDA compared with those using traditional paper and pencil methods was undertaken by Segall *et al.* (2005). Usability parameters were the effectiveness, efficiency and satisfaction of the PDA administered quiz compared with the paper based versions. Feedback was collected by questionnaires.

The device used in this comparison was a PocketPC based PDA which was loaned to students for a term. In addition to quizzes, course materials were also installed on the PDAs. Conclusions from the project were that the PDA quizzes were equal in overall effectiveness and efficiency to traditional methods, and students were found to take equal effort in preparing for both types of quiz.

The advantages of the PDA based system included the ability to perform automated real-time marking and so provide rapid feedback to students. In addition, the collection and collating of grades for summative assessment was automated. However, it was noted that to utilise PDAs that relied on wireless connectivity required a reliable and robust network infrastructure and that open ended questions were not suitable as text entry on the devices was not easy, and the automated marking of open ended questions is significantly more difficult.

2.7 Wider Applications of mLearning

The majority of this section has been concentrated on PDA type devices. mLearning now employs a wide variety of technologies and numerous different combinations of functionality are integrated into single devices. Examples of the use of different types and levels of sophistication are:

PodCasting. Initially an audio only medium the term now also includes video recordings (strictly speaking Vodcasting). At the simplest a Podcast maybe the recording of a lecture. Podcasting is also an important way for students to collect evidence of

practical work and to collaborate on projects by producing learning materials for their peers.

Games Consoles The use of games consoles may be to use educational games on the device. Consoles may also be expanded through the addition of extra hardware such as cameras and can thus be used to collect and author materials. Some games consoles such as the Sony PSP have wireless capability and a built-in web browser and can be used to access network based materials (Clay, 2008).

Lower cost and simpler devices than games consoles can also be utilised to deliver mLearning, for example the Des-Marches (Amyot, 2008) project utilises simple low cost mobile devices in the form of digital cameras and voice recorders as part of an arts activity. In the des-Marches project the student walks around a city and photographs sounds and records the sound of images, this apparent misuse of the technology is intended to assist the users to gain a new perspective on their environment.

Whilst these other devices are different to the PDAs used in the project described in this thesis there are general principles of mobile device use that are overarching, as they are to do with human nature, and whilst the details may be different in every case of mobile device use, this thesis will expose such general principles from the results obtained.

2.7.1 Summary

In this chapter important factors key in research and evaluation of mobile learning have been identified. The main themes are, the users, barriers to technology introduction and the potential problems of mobile learning evaluation.

For users to fully engage with a device and integrate it into their routine requires more than the physical possession of the device. To make real use of the device they have to fully embrace the device, a concept called appropriation. Appropriation of a device requires more than physical ownership (Waycott, 2005a). Users are reported to be more engaged with devices they can use off campus (Crawford and Vahey, 2002b) and value data on personally owned devices (McFarlane *et al.*, 2007), these points support allowing the students unrestricted use of the PDA and to be able to take it home.

The introduction of technology may be met with resistance from its intended users. The TAM (Technology Acceptance Model) warns that trying to force people to follow a course of action may increase their reluctance to do so. From the Diffusion of Innovation an important factor determining how well an innovation is adopted is peoples understanding of the capability of the technology. The affordances of devices may not be readily apparent (McFarlane *et al.*, 2007). Users may modify their routines to incorporate the use of mobile technology (Pettit and Kukulska-Hulme, 2007)

There are warnings from the literature of potential problems that could occur in a mobile learning project. Simple technical problems can undermine confidence in the technology and de-motivate participants.

In research where the PDA has been loaned to students for a short time it can be difficult to get students to engage (Riordan *et al.*, 2005). Also in short term projects a fall off in the amount of use has been observed, it was suggested that the reasons for this were the approach of the time to hand the device back or due to users becoming more expert in the use of the device. These are questions that can be answered by collecting usage logs.

The speed of change of technology as well as bringing increased capability for education makes developing understanding of mobile more difficult (Traxler, 2007). Many findings from mobile learning projects are context specific (Kukulska-Hulme, 2007), thus even methods that have been used unsuccessfully in other projects may be worth reevaluating. “There are no established specific methods to evaluate mobile learning” (Kukulska-Hulme *et al.*, 2005).

To account for the potential difficulties decried above informed these project objectives. First, the development of the technical means to record in detail when PDA applications are being used, and to overcome any technical or human-computer interface barriers to securing that recorded data. Second, to build appropriate tools and methodologies to analyse the resultant data, (recognising that the data-sets would be large and, because the type of data collected was completely novel to this field, liable to require considerable exploration), and the development of new measures to efficiently characterise how students used PDA applications. Finally, to perform data analysis on several cohorts of students, to investigate patterns and modes of their PDA use, ascertain bottlenecks to such use, and to measure where possible the benefits of PDA based formative assessment.

Chapter 3

Methodology and Materials

3.1 Introduction

The previous chapter reviewed in some detail previous projects in the area of mLearning. From this understanding of previous work in the field, we shall now present the experimental approach taken in this project. Firstly, an overview of the approach will be given. Then a discussion of the types of experimental data to be collected (via machine logging, interviews and questionnaires) and the means of measuring the effectiveness of mobile learning from this experimental data will take place. In the second half of the chapter we shall concentrate on the tools required to acquire this experimental data. These tools, are, by and large, machine dependent, and so we shall first review the physical platforms used for mobile learning, and the two specific bespoke applications written to collect and analyse data in this project

3.2 Researching Mobile Technology

Researching how a personal mobile device such as a PDA is used presents a number of challenges. The device is portable and so it can be carried and used almost anywhere, at any time, for a multiplicity of purposes. Even the device functionality is not fixed, as a PDA's functionality can be changed and customised through the installation of new software applications.

Unlike the desktop PC world where there are *de facto* standards to achieve specific tasks, (e.g. for business word-processing Microsoft Word or Open Applications which clone in detail much of its functionality form a *de facto* standard) in the PDA world there remain a wide choice of applications that can perform similar tasks. This large choice of software applications means that each student could have chosen a different application to achieve the same end.

In addition the device use cannot generally be observed, and separating formal and informal device use is difficult. In fact, evaluation of mobile learning is problematic precisely because "mLearning is voluntary, spontaneous, unstructured,informal" Traxler

(2002).

The location and time at which a PDA can be used, anytime and anywhere, prevents many traditional research methods being used without modification or some compromise. In other eLearning contexts, for example, in a case where focus group methodology was used with an online community researchers noted that “it is important to be aware that tried and tested approaches can give rise to problems in such novel situations” Oliver (2000).

For example techniques requiring direct observation of participants are of limited value as it is impractical to observe the users for all but a small fraction of the time during which they may be using the PDA. To confine the use of the PDA to class use only would restrict the richness of use and the opportunity for the students to buy-in to using the device by finding their own specific uses.

If the use of the device cannot be observed, then a possible source of data is to ask the user about how much they used the device. Research reports, such as Sharples (2008), Traxler and Riordan (2003); Traxler and Kukulska-Hulme (2005); Kukulska-Hulme *et al.* (2005) suggest that the majority of mobile learning projects rely on manual methods of data collection and evaluation such as interviews and surveys. Thus the recording of when and how the PDA was used relies on the user’s memory or necessitates the time consuming process of keeping a diary. These methods both have shortcomings. For example to look up an appointment in the calendar or to check a ToDo list may only need a few seconds on a PDA but the overhead of having to record that action in a diary may take much longer. Diary recording could be a disincentive to using the PDA. As noted in the research literature “any evaluation that is more ponderous, protracted, formal or compulsory than mLearning itself will not produce any valid conclusions” Traxler (2002).

To attempt to collect information about how and when the PDA is used after the event, for example through the use of questionnaires or interviews relies not just on the participant’s memory but subtle aspects including their own judgement of what is important and what they are willing to share.

"Students cannot or will not always be able to tell the evaluator about their abilities, knowledge, values, needs, preferences, goals or feelings, or any changes in them - they may not be able to put them in to words, they may be too embarrassed to disclose or reveal Traxler and Riordan (2003).

Overall Approach

When the practical work in this project was being planned, the best research methods for mobile learning had not been established (Kukulska-Hulme *et al.*, 2005), and this is still largely the case in what is a rapidly evolving field Vavoula (2008).

However, as there were no established methods for evaluating mobile learning research this did allow some flexibility and freedom in the choice of suitable research

methods. Although the practical work was approached with a set of research questions, there was also the knowledge that as this was a new field of research unanticipated additional questions could be generated as a consequence of pursuing those questions.

The research used an iterative and reflective approach that shares features with some aspects of grounded theory. Most notably to approach an area of research without pre-conceived ideas, though the researcher will have a viewpoint as evidenced by the research questions which prompted the endeavour (Bryman, 2004). The researchers viewpoint can help to suggest initial research themes. In using such an iterative approach the precise requirements for the analysis tools emerge as the data is collected.

The importance of this became apparent when initial results uncovered a usage pattern of PDAs that had not been accounted for in the design of the logging software.

In this work, the iterative and reflective approach proved to be very important, as initial results uncovered a usage pattern for the PDAs that was novel, unaccounted for in the literature then available, and which had not been accounted for in the initial design of the logging software. We note that in a grounded approach it is also suggested that literature searching may occur later in the research process Bryman (2004, pp 407). In our case, due to rapid advances in the field and the author's involvement in those advances, and the part time nature of the author's studies, the literature search spanned the whole of the research period.

Ethics

At all stages of the research ethical and data protection procedures were observed. Participation in the research was voluntary at all stages and individuals were assured of confidentiality and anonymity. A statement was made to the participants regarding how the data collected would be used and who would see it. To ensure anonymity the participants names in data files were replaced files with code numbers. Although anonymised it was important that it was possible to ensure that, for example sets of log files that were related to each user were associated with each other, and the software was written to make sure that this was the case.

Conducting the study in an ethical manner and ensuring that the participants had given informed consent had implications for the research. A problem of recording device use is that the participants may modify their use of the system because they know they are being watched (Wali *et al.*, 2008).

A further aspect of ethics was to ensure that no student was disadvantaged by their participation or non-participation in the project. Any educational materials that were issued in PDA format during the project were also made available in paper format. A drawback of doing this is that providing the materials in an alternative format can dilute and disadvantage the intervention being researched, described by van 'T Hooft (2007) as the 'hobbled horse' effect. If the materials are available in alternative formats it reduces the incentive for the student to explore the new and unfamiliar delivery mechanism.

Although students had the option of materials in paper form, none of the students opted out and used the paper based materials, so the direct 'hobbled horse' effect was not a problem in this exercise.

Sample Frame

The sampling strategy for picking which student groups to study was a combination of purposive and convenience. The type of student we wished to study were those familiar with technology and engineering. The reason was that for a project with limited resources that utilised new technology it was desirable that the students involved were located nearby in order to provide opportunity to to provide local technical support and it meant that some observation of their use of the PDA in educational settings would be possible. It was believed that students studying technology related subjects would be able to handle technical issues themselves.

Phase 1 ran between February 2003 and June 2003, and involved 14 undergraduate students from a Joint Honours computing and electronics course. This was intended to be a pilot project to test the logging software and to ensure that infrastructure and support were adequate.

Phase 2 ran between June 2003 and August 2003, and involved 5 "summer-school" students. These were school leavers in a university widening participation programme that targets schools from which low numbers of pupils progress to Higher Education.

Phase 3 began at the start of the next academic year in September 2003 and was intended to run for over a year. The students were first year students on electrical electronic engineering undergraduate courses. The PDAs and installed applications were the same as those used in Phase 1 and 2, with adjustments made to infrastructure as indicated by the findings from the earlier phases.

Phase 4 ran for 7 months, between October 2004 and mid April 2005. The student group chosen was a cohort of 36 first year foundation level technology students in the Faculty of Education. This course is taken by students who are likely to become technology teachers in secondary schools. Phase 4 took place at a time when there was growing interest in the use of mobile devices in schools, and the project team believed that future teachers would be intrinsically motivated to explore and engage in related developments.

The number and type of participants are summarised in table 3.1

Phase	Students	Number of Students
1	Undergraduates of Electrical Engineering (3rd Years)	14
2	School Leavers attending Summer School	5
3	Undergraduates of Electrical Engineering (1st Year)	7
4	Undergraduates of Bachelor of Technical Education Course (BTechEd)	36

Table 3.1: Summary of Projects

3.2.1 Data Collection

In broad terms the measurements needed to answer the main aims of the previous chapter are: when is the PDA used, what PDA applications were used, is there was any educational benefit resulting from PDA use.

Measuring PDA Use

As noted in the introduction, most mobile learning evaluation has relied on questionnaires and user satisfaction surveys (Sharples, 2008). For the projects described in this thesis a more objective way of recording usage was proposed.

Rather than rely on the users recording their use of the PDA it was proposed to use the PDA to automatically log its own use. It was anticipated that such log information would provide reliable timing information regarding PDA use. Automatic logging was considered to be preferable to asking the participants to keep a diary of how and when they used the PDA. A manual diary method adds extra user overhead and unless the event is recorded contemporaneously it may be forgotten. Automatic logging also allowed the collection of additional information such as when the PDA was been hotsynced to a desktop machine, or when the student used the "beam" facility to exchange items with another PDA.

After the start of this project another project utilising logging was reported by (Greenberg, 2004) which used cumulative logs of application use but without the detailed information of usage sessions or application timing that will be described in this thesis.

Measuring VLE Use

As noted in the introduction the concept of mobile learning has moved from the technology being mobile, to the student being mobile, and with this in mind usage

information was also collected of students' access to the institutional VLE.

Whereas the use of the PDA was voluntary the VLE was something the students had to use. Data collected from VLE access logs can also provide other insights into the student's use and ownership of technology, for example at what times of day they accessed the VLE and whether the access was from on-or-off campus. The VLE usage logs also provided some insight into how accurately students reported their use of technology.

The VLE logs indicate which resources were accessed, the time the access took place and the IP (Internet Protocol) number of the device accessing the VLE. From the IP number it is possible to identify physically from where the access of the VLE occurred. There are limitations to the information that may be derived as depending upon how an Internet Service Provider (ISP) handles web requests all that may be indicated is the location of the web cache, not the physical location of the end user accessing the VLE. However, even basic information such as knowing if the access was from off-site can provide an indication that the student has the facility to use the VLE from off campus (and therefore owns or has access to a machine and network connection), dependent on the ISP it can be possible to determine if the access was via dial-up or broadband. On campus access can also usually indicate from where on campus the activity occurred.

Additional Data Collected

To evaluate the reaction of students it was planned to use questionnaires and interviews in addition to data logging. Feedback was also to be collected from tutors as it was thought that they were the people who would contact the students regularly and any queries about the content of the quiz was most likely to be directed at them. The tutors were also in the best position to be able to gain an impression of the level of student motivation.

Questionnaire

The purpose of the pre-questionnaire in the initial phases of the project was to identify the level of technical knowledge that the students already had, to help to assess the level of technical support resources that would be required in later phases of the project.

In phase IV additional questions to determine which model of mobile phone the participants used and their awareness of its capabilities. These questions were prompted by a technology ageing problem that was revealed during phase 3 that is discussed later, along with the other project phases in Chapter 4.

Interviews

Interviews were used in Phase 3 and 4 to gather additional information from the students. It was decided to use semi structured interviews as these impose less rigidity

and facilitate the discovery of areas that the participants consider important that we may have otherwise missed. A further reason of using semi-structured was that to make holding interviews practical required two people and using this form of interview provided a core of questions but allowed each interviewer the flexibility to adapt questions as necessary. The interviews were conducted by the author and the course tutor, as these interviewers were already known to the students. On reflection, it may have provided an interesting contrast for them to also have been interviewed by people they didn't know, however given the reluctance of students to engage, as described later, this would actually not have been fruitful or feasible.

Web based surveys and online discussions were considered as an alternative means of conducting a dialog with the students but as the students were local, face to face interviews were preferable. Face to face interviews can provide far richer interaction, for example being able to see the other person means that subtle clues to attitude may be gained from observing the interviewee's body language.

Observations

As an electronic engineer the author was able to assist students during practical laboratory sessions related to their electronics course work and this allowed occasional observations of PDA use. Such observations provided triangulation with information obtained from the logging system.

3.2.2 Evaluation Methods

Many factors needed to be evaluated throughout the project to assess the educational benefit of PDA use, based on the raw data collected from PDA logging, questionnaires and interviews. The factors which are most important include: the potential of the PDA to act as a CAA platform, how the PDA was used, what benefits the PDA could bring.

As well as evaluating the potential of a PDA as a CAA platform, the other benefits that the PDA may bring are also of relevance. For example better organisation and time management skills.

Measuring Educational Benefit

To measure the benefit that using a PDA can bring requires a more specific definition of what constitutes an educational benefit (Oliver, 2000). Such benefits may be direct (such as improved pass rates) or indirect (e.g. effects due to improved student motivation) (Whittington, 2000), a benefit may be perceived or real. If a student believes that a method is helping their education, even though it may not be doing so directly, then it is still of value. For a student to be willing to pursue a particular course of action they must perceive that it is important to *them*.

Measures of benefit should be considered in both long and short term. This is suggested by the 4e model (Collis and Moonen, 2001) and the Bird & Stubbs paper which suggests a time dimension is needed in mobile learning research (Bird and Stubbs, 2008).

The primary source of data in this project is from the PDA usage logs, so a key question is how those can direct us towards, and allow the analysis of areas of educational benefits of PDA use. Use of an application such as the quiz and its associated revision materials provides a direct benefit to a student by highlighting their knowledge (or lack of) in a subject area. That the quiz was used can be directly measured from the logs, but the benefit of the use of the quiz provided to the student may not be as easily determined. However it may, to a greater or lesser extent, be inferred by a correlation between the quiz use and exam performance.

Using a diary program on the PDA, and specifically its reminder functions, can ensure students remember lectures and work submission deadlines. Reducing the number of things the student has to remember may make the education process less stressful. Other aspects of using the organisation tools such as having a routine of checking the calendar and to-do lists helps keep ideas and priorities more structured. These may not be subject specific but are none the less valuable to the education process.

Recognising which applications have been useful to a student, one of the main research questions, asks whether it is possible to determine if an application is *useful* based on information from a usage log. Possible indicators of a useful application may be an application that is used:-

- Frequently, for long or short sessions.
- Infrequently, for long sessions of use, for example a document editor.
- Regularly, for long or short periods, for example checking a to-do list at the start of each week.

Other possible indications of applications providing a useful service to someone may be the interleaving of applications, for example using the quiz and calculator together strongly suggests some sort of learning episode is taking place. It is clear from the argument above that any measure of implied usefulness of an application or group of applications will result not only from measured data on the usage patterns of the applications, but also on objective knowledge of the functionality and affordances of those applications.

While some of the measures of use indicate use that *could* have brought educational benefit it is not possible to say that they have *definitely* done so, even for those few cases where there is statistical evidence of a correlation. However, this also applies equally to more traditional measurements such as student attendance at lectures.

Evaluation of CAA effectiveness

This project sets out to investigate how a PDA can be used as a useful educational tool, with particular focus on how a PDA may be used as a means of delivering formative CAA. To evaluate the performance and impact of CAA a number of areas for evaluation, as suggested by (Bull and McKenna, 2003), will be considered :

- Comparison of scores between CAA and paper based tests
- Correlation between CAA tests and other assessments within modules
- Student's measured attitudes towards CAA (ease of use, relevance of content, accessibility, perceived equity of system)
- Quality and speed of feedback to students
- Quality of questions
- Effects of CAA on student study behaviour
- Staff attitudes towards CAA (educational efficacy, ease of use, anxiety, use in different educational levels.

To determine if an improvement to learning had been made revision materials were provided to support those areas of the syllabus in which students had experienced difficulty with in previous years and then results from exams and class tests compared with those from previous years.

As each phase of the project progressed it became apparent that evaluating the use of the PDA based CAA incontrovertibly with statistically significant confidence would be of limited value as there was insufficient PDA usage data collected to show the CAA application had been used. However, despite this inability to resolve CAA usage in a statistically significant way, it will be shown below that anecdotal evidence of CAA usage, and statistical information on the general use of PDAs in an educational setting produced a number of very interesting and novel results.

3.2.3 Developing a Research Community

The speed at which research findings reach a wider audience is relatively slow. A journal article may take six to twelve months to appear, conferences may occur annually but it is inevitable that other useful research findings are occurring in between these events and the output of much research may not reach the public domain.

Today it may not be so obvious how difficult it was in 2002, at the start of this project, for disparate groups and individuals interested in mobile learning to become aware of each other.

At the time this research began the study of mobile learning in the UK was relatively new and there was no obvious community of practice and this made it difficult to

contact other researchers. It was apparent that what was required was a means of enabling communication between other researchers so that knowledge and expertise could be shared.

An opportunity to create a central point for connecting researchers arose with the first international conference for mobile learning which was held in the UK in 2002. Prior to attending the event I set up an email list on the UK JISC email list service. The mailing list, called `pda-edu@jiscmail.ac.uk`, went live the week before the conference and the list was announced at the event. This provided a number of contacts with those working in the area with whom to exchange ideas and findings. Once the list was set-up it became easier to gather information from other mobile learning projects utilised by "snowballing" the process of making contacts with key people then communicating with their contacts. It was through this community that I was invited to speak at 4 national workshops on handheld learning in the UK between 2002 and 2005. These events provided opportunity to discuss mobile learning with a wide range of end users and researchers.

In addition to these events I also arranged for leading researchers in mobile learning to be guest speakers in online discussion events.

In 2005 the company HandheldLearning launched an online discussion forum which attracted users and researchers from all sectors of education and this provided further contacts and larger community of those interested in mobile learning.

Finding projects that have been less successful or perceived by their researchers as failures was more difficult as many institutions do not wish to make their failure public. However direct contact with individuals provided many useful candid discussions.

3.3 Choice of PDA Platform and Applications

3.3.1 Platforms, Devices, Applications

A key component of this research was the PDA used in the projects and its choice was determined by many factors. At the time the decision was made there were a number of different PDAs available, which varied in : cost, size, weight, processing power and operating system.

A PDA utilising the Palm operating system was chosen as the main platform for a number of reasons. At the time the choice was made there were a number of companies who manufactured compatible machines that could run Palm applications. Other factors which influenced the choice of Palm OS were: Palm OS based PDAs were less expensive than competing products, the author's expertise of writing applications for the platform and, Palm OS based PDAs had biggest market share at that point.

[Event-Time]	[ID]	Human-readable-date	Components-of-date-time
1046472439	INE3	Fri Feb 28 22:47:19	2003 22 47 519
1046472958	lnch	Fri Feb 28 22:55:58	2003 22 55 34
1046472992	CRbl	Fri Feb 28 22:56:32	2003 22 56 8
1046473000	lnch	Fri Feb 28 22:56:40	2003 22 56 10
1046473010	PPlx	Fri Feb 28 22:56:50	2003 22 56 157
1046473167	CRbl	Fri Feb 28 22:59:27	2003 22 59 22
1046473189	lnch	Fri Feb 28 22:59:49	2003 22 59 75
1046473264	lnch	Fri Feb 28 23:01:04	2003 23 01 13

Figure 3.1: Example of AppLog Data Showing the Data Format

3.3.2 Applications Written For the Project

Throughout the project both "off-the-shelf" and customised applications were used. The custom applications included a logging application and a simple quiz application for the PDA, and PC hosted log analysis tools. These are described in more detail below.

AppLog

Central to the project was the requirement to monitor and log the use of applications on the PDA. There were some applications available to collect usage statistics for Palm based PDAs but none had the level of detail required for the project as they only produced a summary of application usage. The most noteworthy of these applications was called AppUsage, written by the late Bozidar Benc. Information about this application is no longer longer online. (Bozidar Benc was a very well known developer of PalmOS applications who died in 2004. He was very highly regarded by the developer community. I corresponded with Bozidar during the development of AppLog)

I also considered it to be very important to know exactly what the logging application was doing. Due to my familiarity with programming for PalmOS PDAs it was practical to design and implement a customised system. AppLog is an application-logging tool for use on Palm OS PDAs, written specifically for this project, and also as a more general tool. AppLog records the time, date and application identifier whenever an application is used on the PDA.

AppLog consists of a PDA application to perform the actual logging and a desktop "conduit" to facilitate the transfer and conversion of the logging data to a desktop machine. When the PDA is synchronised with the desktop application the log file on the PDA is processed to produce a text file on the desktop system containing: a creator ID (the application identifier) , the date and time the application was started , and for how long the application was used. The file produced is in tab-separated format suitable for use with spreadsheet and database programs. This is shown in Figure 3.1

The creator ID that is used as the application identifier is critical to the analysis of the logged data. By convention all Palm applications are supposed to have a unique creator ID. The ID is used by the operating system to associate data files with their companion application. The creator ID is embedded in a special part of the application

program code and used as an identifier in data files. It is important that creator IDs are unique. If more than one application with the same creator ID are installed on a Palm only one of them appears in the program launcher. To ensure uniqueness, developers are supposed to register their applications with Palm, thus given a creator ID it should be possible to identify the application. There are a number of games developers who have chosen not to register the creator ID they have used. This became a problem during the project as the students installed games (as they were allowed to) that had unregistered creator IDs.

Resolving an unregistered creator ID is possible if the device upon which it is installed can be accessed or if the device has been hotsynced to a PC. The application may be identified by examining the hotsync backup directory where applications are installed. By using low-level editing tools it is then possible to examine the program files to identify their creator code.

What can be derived from the Logs.

From the log data many measures of device use can be derived, these include:-

- How long a session lasted
- How many applications were used during an arbitrary time period
- The time interval between uses of the device
- The most frequently used applications
- The applications used for greatest or least cumulative time

Design of AppLog

The logging application was designed to have minimal memory and processing requirements, and the underlying mechanism was very similar to that of the AppUsage application used in the (Greenberg, 2004) project.

AppLog intercepts system functions that occur due to events such as applications being launched or the system power state changes. Two versions of AppLog were used during the project, with a version for PalmOS 4.x devices and one for PalmOS 5.x devices.

PalmOS 4.x devices were based on the Motorola Dragonball micro-controller. The CPU component is based upon the Motorola 68000 microprocessor. A feature of the operation of these devices is the trap mechanism. A Trap is a special CPU instruction that raises a software interrupt also known as an exception. Each exception is handled by a special program routine.

The address of the handler routine is defined by the contents of a special register, of the CPU referred to as a trap exception vector. The contents of the vector determines which function is then called to handle the event. This system made it relatively easy

for system calls to be replaced or enhanced by altering the function address in the trap table to point to the new function. The new function could then in turn perform its function and then call or bypass the original trap function.

To make it easy for developers to utilise and modify trap handling behaviour a system known as HackMaster was developed by a programmer called Edward Keyes. HackMaster extensions were a widely used advanced programming technique for PalmOS. The PalmOS 4 version of AppLog consisted of a system hack to intercept the system calls and a recording section that saved the information in a suitable compressed format.

PalmOS 5.x devices were based on a different processor from ARM, which utilise a different instruction set and do not utilise the trap mechanism. To maintain compatibility with existing applications the 68000 processor instruction set is emulated by a software emulation mechanism *for applications* but the operating system runs in native ARM code. As the trap mechanism is not emulated, HackMaster extensions cannot be supported by PalmOS 5.x devices.

In PalmOS 5.x significant system level events can be intercepted through a notification mechanism. Some system events generate a notification of their invocation. An application can register that it supports and handles specific event and install program code that is then called when the event occurs. Unlike the trap mechanism of PalmOS4 the notification mechanism only allows access to a relatively small number of functions, but fortunately amongst these are application launch and power state change functions. Unfortunately in PalmOS 5.2 there is no way to detect when beaming occurs.

Transfer of logs from the device. The mechanism by which Palm PDAs exchange information with desktop systems is known as HotSyncing. The desktop hotsync application is composed of a number of "conduits", with each conduit handling the transfer of data for a specific application. On a Windows host each conduit is contained in a dynamic link library (dll).

To facilitate transfer of the data collected by AppLog a desktop conduit also had to be written for the project. The desktop conduit was responsible for converting the packed data format used on the device into a human readable format and also to perform the relevant calculations on the data to indicate event length.

In the latter stages of the Phase 4 of the project an alternative means of collecting the data logs was used which enabled users to beam the logs to a collector (the researcher or tutor) via infra-red or Bluetooth. The PDA system (known as TeksLogs) performed the same conversion as the desktop conduit. In addition the AppLog program was modified so that it would send the log files in conjunction with information about what applications were installed on the user's PDA to TeksLogs.

Following the collection of the logs, tools were needed to analyse the data.

Graaf

The original intention had been to produce summary logs and then to visualise the data using graphs produced by excel or analysis with SPSS. However, neither the Microsoft Excel spreadsheet program nor the IBM SPSS application (Statistical Package for the Social Sciences) could provide the interactive means needed to be able to analyse the logged datasets efficiently.

The events recorded by the logging system produce sparse data, the amount of time for which a device is not used is significantly greater than the time for which it is used. Graaf was designed to facilitate interactive exploration of the log data and to present graphical representations of the data. An essential feature of Graaf was the ability to identify the event log from which a particular data point was derived and to be able to quickly navigate to, and display the entry in the source log that the data was derived from. This was to allow cross referencing and validation to ensure the data being shown represented what it was believed to be showing.

How Graaf works The data files come from either the AppLog desktop conduit or TeksLogs and are then processed to produce a human readable file. The human readable format, called an .alp file, contains redundant data both to make it easier to read and also to parse the file into other formats. Each line of the .alp file is considered as an "Event". In addition, a file is produced to cross reference the application creator ID to the application name. Within Graaf the lowest component of data is the "Event", and each event is tagged with the source file it came from and the line number within the file. Graaf enables filters to be applied to the logs to select subsets of the data, and the results of such filtering are immediately displayed to allow interactive exploration of the data.

Design of Graaf

Early in the project a simpler graphing application (AppLog Desktop) provided rudimentary views of the data. The log files produced by the hotsync process were processed utilising PERL scripts to produce summary reports in textual format and data files suitable for use in both Excel and the AppLog Desktop package.

An important requirement in the design of Graaf was the ability click on an item in a displayed plot which brings up a display of the original source file in which that event occurred. This is valuable for two main reasons. It is a cross reference to ensure the Graaf is displaying the event correctly (for example time of day) and that it relates to the correct user. By displaying the original log file it is also possible to see the event in context amongst what other applications were being used around that time.

Where a graph indicator does not relate to one specific event (such as the bar on the distribution of run times chart in figure 3.3) then clicking on the chart object brings up a display of the individual events and the name and line number of the source file

in which those events are recorded. This cross referencing is an important confidence check of the data and is valuable to identify apparent anomalies or unusual values in the data.

When imported into Graaf each event is stored along with information relating to the source log file and line number within the file to allow further cross referencing during the debugging and testing of Graaf that occurred during its development.

Graaf also enables the collected events to be considered for the duration of the project or in block of discrete time slices such as daily or weekly.

To enable preliminary statistical examination of the data a library was added to Graaf to provide some basic statistical functionality which then enabled Graaf to display the distributions of collected data.

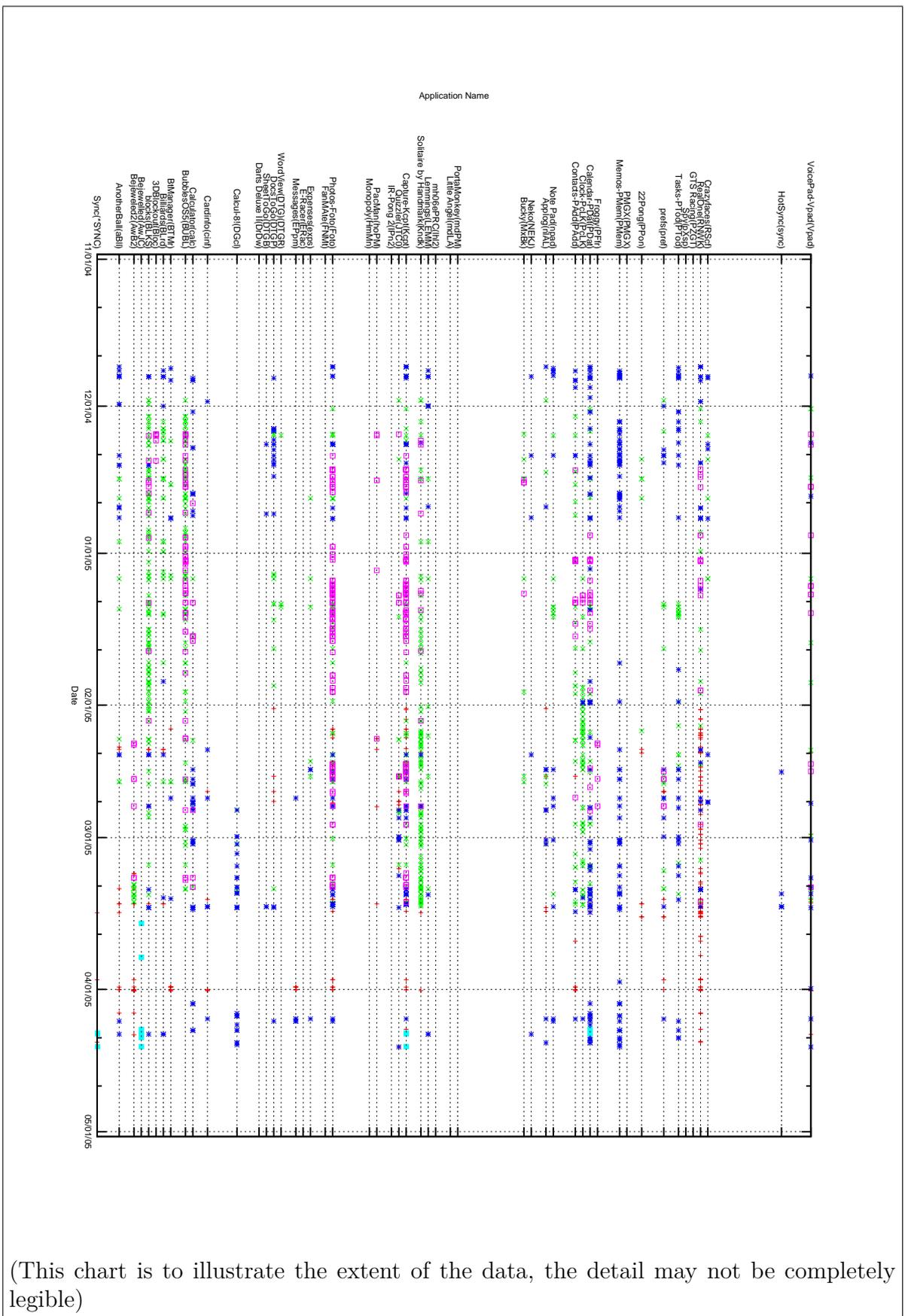
Examples of Charts produced by Graaf

Application Use Figure A.1 shows the overall pattern of application use. The value of this chart is showing a large amount of information in one view. The real benefit is only realised when viewing the chart as a 3D plot to separate the plots for each user more clearly.

This was important to help verify that the view of the data was consistent with the content of the log files. Within Graaf the events on the chart can be clicked on to show details of the event and the log file the data point is from.

Distribution Charts This family of charts shows distribution of the number of PDA uses by various parameters including; length of runtime, time of day, and the day of week. Graaf enables usage charts to be plotted against a Y axis that either show the actual number of instances of a particular value or the proportion of events relative to a user's total count for such events. The absolute allowed comparison of actual use and the proportional gives an impression of how a user's pattern of application use compares to that of the rest of the group. For example figure A.8 shows that the most used applications for all of the groups were organiser related.

Run Distribution (Number of Runs) Figure A.2 shows the distribution of uses of applications on the PDA. In the sample trace below it can be seen that the majority of uses are those of short duration. Some of the particularly long sessions have been labelled with the name of the application. In this type of chart, clicking on the one of the sessions produces a pop-up window that lists all events that lasted for the selected duration.



(This chart is to illustrate the extent of the data, the detail may not be completely legible)

Figure 3.2: Chart of Applications and The Time and Date Used.

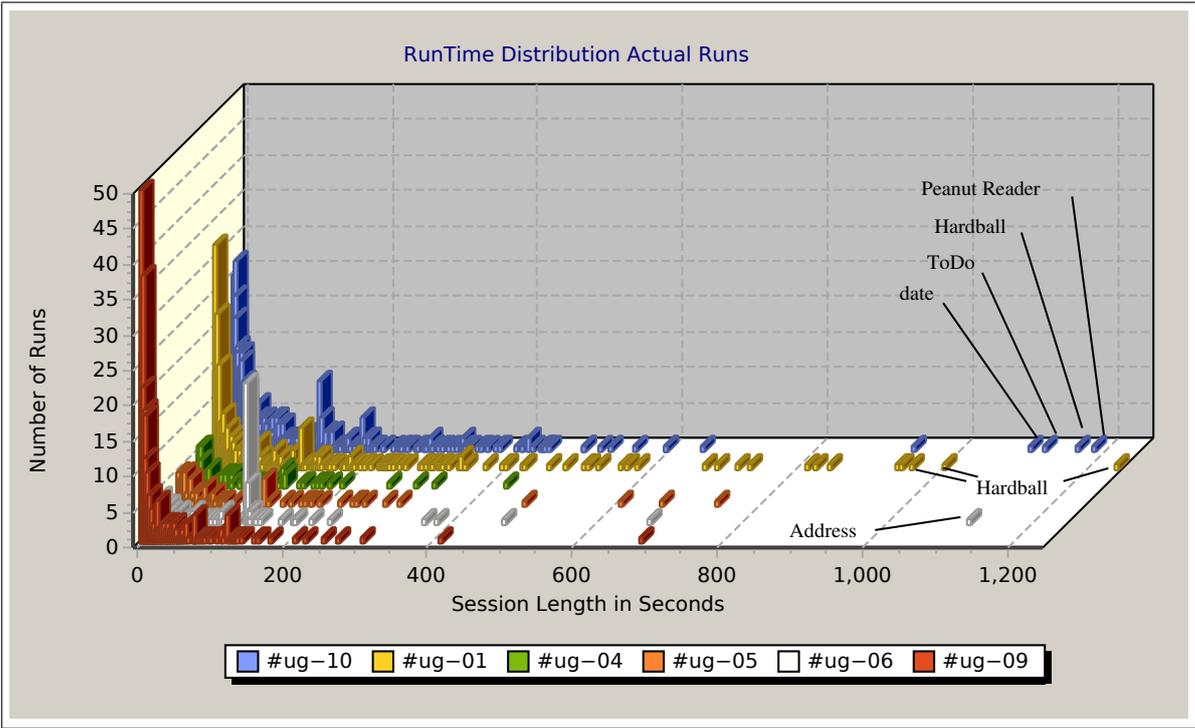


Figure 3.3: Runtime Distribution Phase 1

Time of Day (Number of Runs) Figure 3.4 shows the distribution of usage sessions by the time of day. In the example it can be seen that some use was made of the PDA in the early hours of the morning. Similar chart was also produced to show the distribution of uses by day of week.

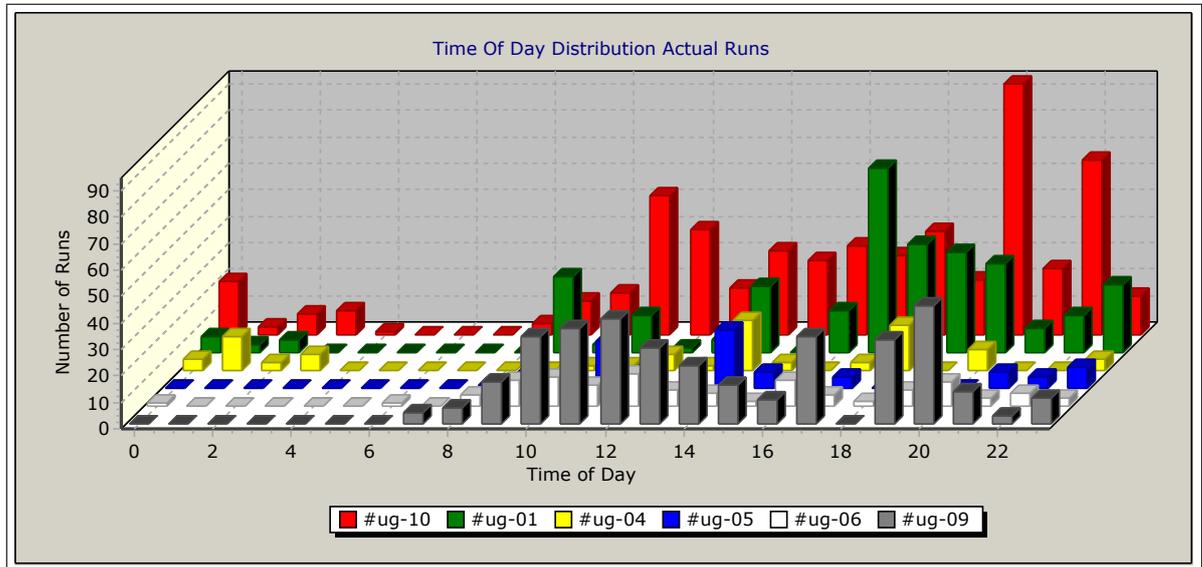


Figure 3.4: Session Distribution by Time of Day Phase 1

Application Family Usage Figure A.8 shows the device based on the number of times each of application was used. In the example the amount of usage is plotted as a percentage of an individuals total usage of the device.

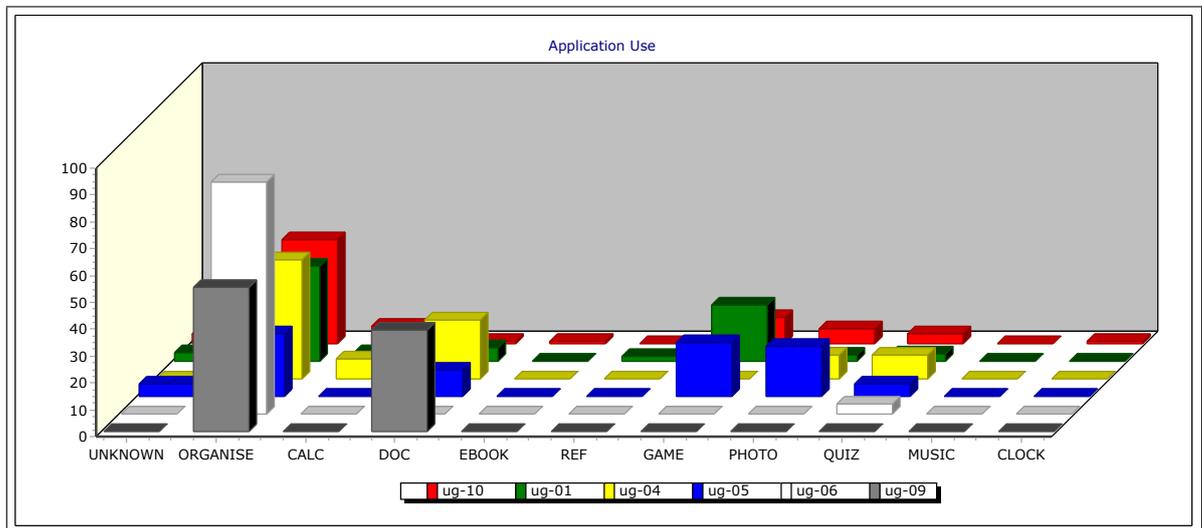


Figure 3.5: Application Family Use Phase 1

RADAR Charts These were used during the project to plot multiple parameters for multiple users on one chart to enable a quick means of getting an overall view of device use. Within Graaf it is possible to select arbitrary parameters for each spoke of the chart. The example here shows such a chart may be used to illustrate application family use.

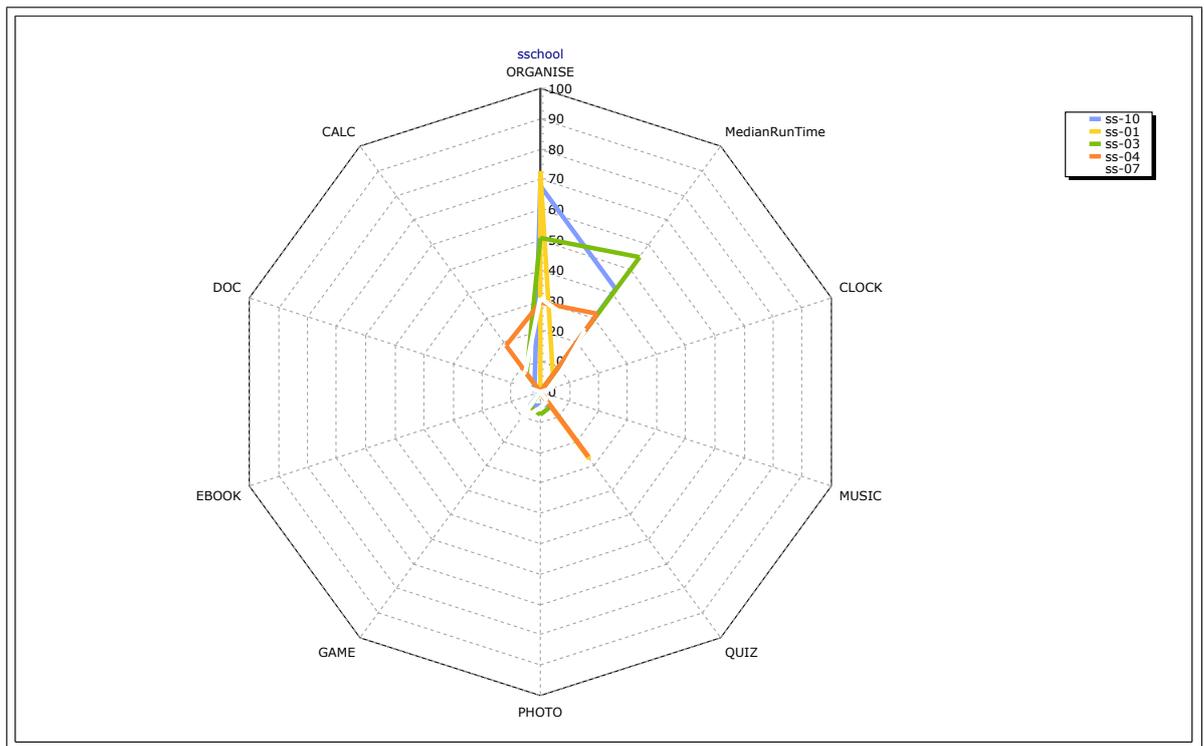


Figure 3.6: Radar Chart Phase 1 Device Use

Each spoke represents one parameter, and in this example nine of the axes represent the percentage proportion of use made by a user of a particular application family, the 10th shows the median of application runtime in seconds. So for the applications the axes represents percentage and for the medianRunTime the actual value.

The utility of these charts is discussed further in the results section.

Tag Clouds Tag-Clouds provided an easily accessible visual means of displaying proportional data. The example in 3.7 shows how much each application type was used in the phase 4 project. The most used application were (in descending order) Music, Photo, Organiser tools.

Outside of Graaf

Graaf can also produce tables of data to be used with external tools. The reason for visualising these outside of Graaf were due to problems with the graphing component's consistency in exporting images.

Graaf evolved and refined throughout the project. Due to the architecture of Graaf it was possible to enhance the functionality of the application without affecting existing capabilities. This was important for the testing and validation of program behaviour.

Per Week Charts The per week charts are used to plot the values of parameters over the course of each project phase. For example figure 3.8 shows how many applications the users of phase 1 used during each week of the project.

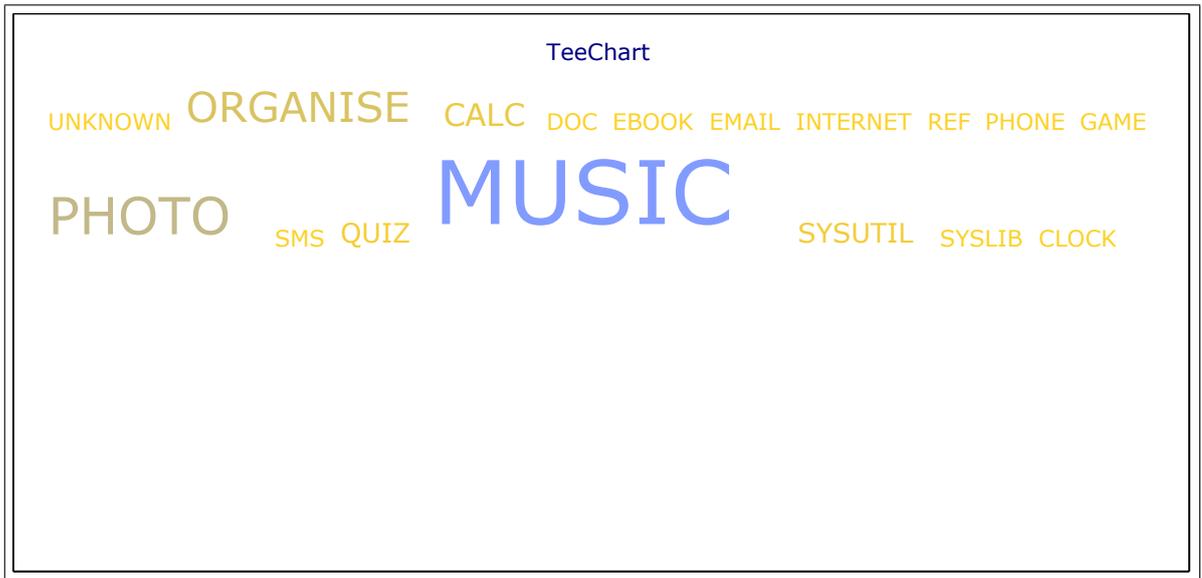


Figure 3.7: Tag Cloud of Phase 4

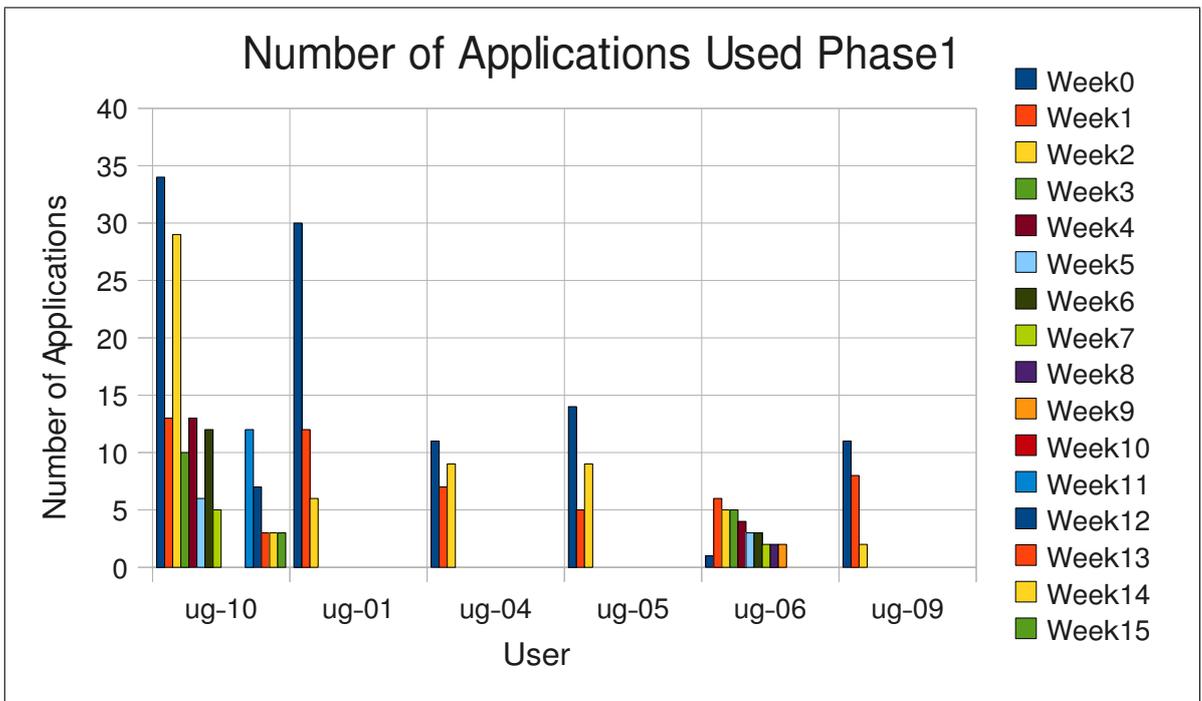


Figure 3.8: Applications Used Per Week during Phase 1

Quiz Applications

It was initially intended to develop a custom 'quiz' application as that would have allowed detailed logging of what happened within the application, such as how long a student spent on a question and the path they took through the quiz.

A prototype quiz application was written and implemented that could display text based multi-choice questions based on a simple tagged plain text file format.

For reasons that will be explained shortly, this custom written quiz application was not used but its development helped in understanding the requirements to pick a third party quiz application, and provided the basis of a desktop "conduit" for transferring data to and from the PDA that would be used by the logging application.

The features of the custom quiz application were:

- to log information such as how long a question has taken to be answered and how many times the question has been attempted,
- deliver multi-choice questions with single or multiple-answer,
- record time taken per question/test,
- display feedback after a question answered,
- Change question order dependent on answers given to previous question.
- Quizzes can be beamed to other users.
- Time/Date Quiz Started

The log information is transferred to the PC during synchronisation when new questions are downloaded. The questions are converted by the desktop conduit from the custom format into a form suitable for the PDA.

The route the user takes through the quiz can be sequential, random or directed where the next question asked is dependent on the answer chosen to a question. The latter option makes it possible to develop simple "tutor" systems as well as interactive tests.

The quiz application automatically lays out the questions so that they fit on the screen. The quiz could also show feedback to the user after a question has been incorrectly answered.

Math Symbols Although the authors quiz application was adequate for text based multi-choice questions many engineering related subjects require more complex text formatting, such as subscripting and the display of mathematical symbols. The workaround for this limitation would have been to display such questions as images but the additional time required to provide this functionality for the PDA quiz, the desktop conduit and to provide a suitable desktop authoring package for such questions was too great.

For the initial pilot of the projects a free application called "QuizApp" was used. The developers of QuizApp provided a web based conversion facility that took questions in excel spreadsheet format and produced a Palm ready data file. QuizApp was chosen as it could also display math symbols and handle sub-scripting.

In the latter stages of the project QuizApp was replaced by Quizzler (www.quizzlerpro.com) as support for 'QuizApp' ceased. There is no longer any information about QuizApp available online.

Interoperability of Content Ideally it would have been possible to develop platform independent applications that could have been used on any of the mobile devices that were available and would be easily adaptable to future devices. This idea was hampered by the fact that PDAs use different operating systems. At the time of the project, even for a single operating system, for Windows Pocket PC, different versions of an application were required depending on which make of PocketPC was used, as they had different microprocessor architectures.

One way of providing platform independence is through the use of "virtual machines". Rather than a program being written to run on a specific platform it is instead written for a virtual machine. To run the program on a physical machine requires a program that interprets the instructions for the virtual machine into instructions that are understood by the real machine. The virtual machine provides an abstraction layer between the different platforms. Thus a program written for the virtual machine may run on any platform for which there is a virtual machine interpreter program available.

This concept is the basis for the JAVA programming language, programs written in JAVA are compiled into virtual machine instructions. There are implementations of JAVA Virtual Machines for many types of system, from small, embedded devices to large mainframe systems. Obviously the capabilities in speed and storage vary widely between that of a small, embedded processor used in a consumer device such as a phone and the capabilities of a multiprocessor workstation or server. To support these variations of system capabilities there are a number of subsets of the full JAVA implementation, those that were of relevance to this project are the CLDC Connected Limited Device Configuration, and J2ME Java 2 Mobile Edition.

Support for JAVA has been less widespread for handheld systems. There are an increasing number of mobile phones that support limited functionality through JAVA. Manufacturers have attempted to create a generic portable device platform with the standardisation of the JAVA Connected Limited Device Configuration (CLDC) specification(Sun). At the time the only compatible devices were those from Palm, the "Blackberry" from RIM, and a few JAVA enabled mobile phones.

As part of this project the author wrote an application to deliver questions using CLDC devices. Further work on a single cross platform application using JAVA was abandoned, as the number of compatible devices was too limited. At the time of writing the situation has not improved.

Whilst it was not possible to create one quiz application that was compatible with all platforms, it was potentially possible to create a format for the questions that aided adaptation of quiz questions between applications. Some work was conducted to facilitate this in the future.

The work is co-ordinated by the IMS Global Learning consortium (IMS). A specification, known as the IMS Question & Test Interoperability Specification, has been defined by the consortium to enable the interoperability of questions between different assessment systems. The IMS QTI standard enables questions to be developed for use in any IMS QTI compliant application under the premise that as educational institutions adopt the use of different Managed or Virtual Learning Environments (MLE or VLE), interoperability is essential. If material developed in these applications is in proprietary format, the institutions are forced to stay tied into that system or potentially face being unable to reuse materials, or collaborate and exchange materials with other institutions, without re-development.

There were a number of Computer Aided Assessment question formats that were unsuitable for delivery on current PDAs, the limitation being due to the hardware facilities of the PDA, screen size and media capabilities. Software that supported a limited subset of QTI question types was partly developed to import questions from IMS QTI compliant applications into the authors application, permitting limited interoperability.

Summary

In this chapter the tools needed to measure PDA use and assist in their interpretation have been introduced. A bespoke PDA application was described that can log detailed PDA application use in real time and this will allow for research flexibility in a new and rapidly advancing area. To maximise the chances of collecting useful data, student cohorts already familiar with technology will be chosen in each research phase.

It was also flagged up here that the educational benefit to a student of a particular PDA application might be indicated by infrequent short sessions of use, or frequent short sessions, and that additional evidence from logs such as time of day/week of application use, or which applications were used in conjunction with the one of interest could all give additional evidence to an application's utility. This provides an initial focus for areas of interest to search for in the usage logs.

A means of communicating with the maturing UK mobile learning community through the formation of a mailing list was outlined. Finally, the quiz applications used to offer students formative assessment opportunities when using the PDA were described in detail.

The refinement of the applications and methods in this chapter was an iterative process that was informed by the work that will now be described in subsequent chapters.

Chapter 4

Practical Application of the Research Tools

This section provides an introduction to, and overview of the practical experiments conducted during this project and introduces the format of the project reports that appear in subsequent sections describing the project results. The purpose of the various project phases was to examine how student used the PDAs they were given to use. These experiments were conducted in two departments of Glasgow University: The department of Electrical and Electronic Engineering and the Robert Clark Centre for Technological Education. The departments are in separate buildings located approximately half a mile apart.

Within each phase of the research, the PDAs used were effectively stand-alone and did not have integrated 802.11 WiFi, although they could potentially be connected to Internet services via infra-red, or to Bluetooth devices such as phones.

Four phases of the project were conducted, the first phase was intended to act as a pilot study to help identify any technical problems with the logging system and data collection processes prior to conducting the main study of mobile CAA. In the first three phases the PDAs were loaned to the students for a term or less, in the fourth stage it was intended to give the students a PDA to use throughout their time at University, with the potential of being allowed to keep the PDAs.

It was anticipated that results from the pilot and indeed each stage of practical phase would raise new questions and present a number of potential areas for additional research topics: e.g. how best to design a user interface constrained by screen size for optimal learning.

It was planned that PDA use would be evaluated by system log files, questionnaires and interviews throughout each project phase. In addition automatically recorded device logs would be analysed to provide unique quantitative insight into the student learning process.

The first two phases of the project were encompassed within an LTSN (Learning and Teaching Support Network, now called the Higher Education Academy) mini-project from which funding of £3000 was gained to purchase equipment.

Phase 1 ran between February 2003 and June 2003, and involved 14 undergraduate students from a Joint Honours computing and electronics course. This was intended to be a pilot project to test the logging software and to ensure that infrastructure and support were adequate.

Phase 2 ran between June 2003 and August 2003, and involved 5 “summer-school” students. These were school leavers in a university widening participation programme that targets schools from which low numbers of pupils progress to Higher Education. The course was held at the University of Glasgow within the Department of Electronics and Electrical Engineering it was attended by 5 students and consisted of two 3 hour sessions per week.

Phase 3 began at the start of the next academic year in September 2003 and was intended to run for over a year. The students were first year students on electrical electronic engineering undergraduate courses. The PDAs and installed applications were the same as those used in Phase 1 and 2, with adjustments made to infrastructure as indicated by the findings from the earlier phases.

Phase 4 ran for 7 months, between October 2004 and mid April 2005. The student group chosen was a cohort of 36 first year foundation level technology students in the Faculty of Education. This course is taken by students who are likely to become technology teachers in secondary schools. Phase 4 took place at a time when there was growing interest in the use of mobile devices in schools, and the project team believed that future teachers would be intrinsically motivated to explore and engage in related developments. Additional funding of £10500 was obtained for this phase , from the University of Glasgow Chancellors fund, so that new PDAs with a richer feature set could be used.

For each phase of the project PDAs were issued to students on which were installed a quiz application to provide basic formative CAA and a logging application. An additional set of useful applications were identified in conjunction with course tutors for use on the PDAs. The applications were those that appeared to provide useful functionality for students, either in general terms such as scientific calculators or subject specific application such as resistor colour code helpers.

A summary of each phase of the project is provided in Table 4.1

Phase	Students	Device Used	Number of Students
1	Undergraduates of electrical Engineering (3rd Years)	Sony Clie	14
2	School Leavers attending Summer School	Sony Clie	5
3	Undergraduates of electrical Engineering (1st Year)	Sony Clie	7
4	Undergraduates of Bachelor of Technical Education (BTechEd)	Palm Zire 72	36

Table 4.1: Summary of projects

To facilitate easier comparison of the projects a common format has been adopted for the description of each project:

- An overview of Project
- The Technology infrastructure used
- Changes from Previous Phase
- Brief overview of how well this phase of the research progressed
- Lessons Learned.

4.1 Projects

4.1.1 Phase 1

It was both impractical and undesirable in the initial phases of the project to issue PDAs to an entire class. The first phase was to be a pilot study and it was more practical with a smaller group as it made support issues easier to handle and there was only enough funding to purchase 24 PDAs.

The PDAs were supplied to students without any initial content for the Quiz application, this was to allow students time to gain familiarity with the built in applications.

To ensure fairness, course related materials that were supplied for use on the PDAs was also made available in printed form for students that were not using the PDAs. The first quiz questions were beamed to students 2 weeks into the project at the time that the first log data was collected from them.

Overview of Phase 1

The student group chosen for phase 1 comprised of 14 joint honours computing science and electronic engineering students who had previously worked together and thus knew each other. The group was described by their tutors as having a good

electronic systems background and being well motivated. It was thought that these qualities would mean only the most critical technical problems would require assistance from support staff and was the primary reason for selecting this group of students for the pilot phase.

The group were issued with PDAs and the students were encouraged to contact members of the project team in person or by email to assist with any technical queries or for advice on applications or the use of the device. The students were intentionally not given any training in the use of the PDA or its applications in order to reveal how capable the students were of finding out how to use the PDA themselves. The reason for this was that if PDAs are to be deployed in larger numbers, training may become a significant overhead. The plan was to ask about training requirements and what training the students themselves felt was needed after they have been using the PDA for a few weeks.

The Technology

Sony Clie SL10 PDAs running PalmOS 4.1 with 8MB Memory and a 33Mhz Dragonball processor. Power was supplied by 2xAAA batteries that lasted approximately 4-6 weeks.

Each PDA was supplied with the AppLog logging application to record when the PDA was used, along with a quiz application to deliver formative self- assessment questions. Additional applications were installed on each PDA, including chemical tables, a scientific calculator and document readers.

The transfer of the data logs was planned to take place during scheduled laboratory sessions, ensuring that the process could be supervised and any problems directly observed and resolved. To transfer the logs the students were supposed to visit the researchers in the laboratory at agreed times in order to sync their PDA. Their tutor also planned to bring small groups of students together to have their PDAs synced.

Summary of Results

The first log data collected provided reassurance that the logging system appeared to be working correctly. The logs showed that the students were using the PDAs and that they had installed additional applications on the PDAs. Most of the students appeared to have connected their PDA to a desktop system and all had installed at least one game. It was not obvious if applications had been installed during hot-syncing or if they had been hot-synced by one student and then beamed by infra-red to the others.

Lessons Learned.

Syncing was highlighted as a problem in the first few weeks. To ease the burden on the research staff, students needed to sync their PDA at a fixed location and at certain times of the day. Students found this inconvenient perhaps especially as the

ethos of the use of the PDAs was portability and flexibility. An attempt was made to address this problem by making a suitable machine available throughout all of the day for hot-syncing, though the students made no use of the facility.

Batteries were the a cause of problems, if the batteries were allowed to become completely discharged then all of the data on the device was lost. The device did provide reasonable warning of when batteries were running low but special care was needed when replacing the batteries, if having removed the old batteries new ones were not installed within a minute or so then then all data was lost on the device. It was naively believed that electrical engineering students would understand and be able to work within this requirement.

Failing to replace batteries in adequate time or losing data whilst taking too long to change batteries appeared to be more of a problem during holiday breaks. Of the 7 students who had discussions with the research staff after a holiday break all of them claimed they had lost all of their data, including the log files. It was therefore seen as essential that in future the students should synchronise their PDAs to our systems more regularly.

There were some aspects of device use had that not been anticipated and these caused problems with the logging system. For example, it appears that many users stay within one application and allow the device to automatically switch off, they then periodically wake the device to resume their work. This mode of operation was not very well indicated in the logs and so AppLog was modified to handle this correctly. AppLog was also enhanced to record when beaming occurred, to help identify how applications were being distributed amongst students.

4.1.2 Phase 2

Due to the timing of the project funding, phase 1 had occurred at the end of the academic year and so it would be a few months before the next phase of the project could be conducted with undergraduates. This provided the opportunity to utilise the PDAs with a group of school leavers.

Overview of Project

The second group of students were 5 school leavers attending “summer school”. The summer school is for pupils who have applied for a university place but need some preliminary study, and/or have attended schools which rarely send students to University and are therefore participants in "widening participation" programmes. The Summer school ran for ten weeks and consisted of two 3-hour sessions per week. The course was held at the University of Glasgow University within the Department of Electronics and Electrical Engineering. The students used the PDAs during the lectures and practical laboratory sessions and were allowed to take the device home.

As the students attended lectures at regular times each week it was easier to ensure

that the devices were synchronised more frequently. Their devices were hot-synced during the laboratory sessions meaning that the collection of data was more successful than in phase1 of the project.

A questionnaire was issued to the students at their final summer school session. The final session was an exam session and the questionnaire was issued after the exam. Time had been scheduled for this at the end of the exam and resulted in an 100% return rate of the questionnaires.

The Technology

The same Sony Clie SL10 PDAs that were used in the previous phase.

Changes from Previous Phase

Researchers attended student lab sessions and hot-synced the students PDAs to a laptop. The project team attending the labs also enabled observation of how the device was being used and provided an opportunity to talk to the students about the device and also to assist them in finding and installing applications

Summary of Results

The course tutor reported that the quiz application generated queries from students which had resulted in useful learning episodes. For example, one student thought that one of the questions was incorrect until it was pointed out that they had failed to consider other important facts. The subsequent discussion with the tutor helped to improve the student's understanding of the subject. Some of the students commented that they liked the mixture of questions, from the easy ones that "could be done on the bus" to the more difficult ones that required additional time and calculation to answer.

The logs showed an instance of a student swapping between using the quiz application and the calculator , presumably to assist in determining the answer to the question.

The ability to "beam" items between PDAs encouraged collaboration and communication both between the students and between the students and their tutor. The items beamed were not limited to those directly related to the course. For example exchanging of eBooks became popular with the summer school students especially once they discovered that the tutor had a large collection of copyright free eBooks. The tutor was very positive about this aspect stating that: "We don't normally get to know the pupils beyond our own subject area, so this put a whole new slant on the summer school".

For these students the PDA appeared to possess a definite "wow factor", they appeared excited by the technology and the opportunity to use it.

Even though the use of eBooks was an incidental use of the PDAs , it was the use of eBooks that was the focus of an article about the project that featured in the Times Education Supplement, titled "A Library in the Palm of their hands"(Caldwell, 2003).

Lessons Learned.

One student had been less enthusiastic than most of the group about using the PDA until they had discovered that the device could be used as an eBook reader, this then gave them an additional reason to use the device. This suggests that students should be given as much flexibility and freedom in device use as possible to allow them to serendipitously discover their own uses of the technology. If they do not find their own uses it is worth enlightening them to potential uses and giving the students the important “awareness of capability” (as described earlier the theory diffusion innovation, and Technology Acceptance Models).

4.1.3 Phase 3

Overview of Project

This phase was to be a repeat of phase 3 but with 3rd Year electrical engineering undergraduates chosen partly for convenience as they were located in the same building as the researchers.

A random selection of students were chosen from the cohort to take part, and the selection was made to ensure equal number of male and female participants.

The Technology

The same Sony Clie SL10s that had been used in Phases 1 and 2.

Changes from Previous Phase

A machine to use for hot-syncing was made available in a lab that could be accessed during the hours students would normally be on campus (At this time there were no 24 hour access labs for undergraduate students).

Summary of Results

At first meeting the group appeared to be very enthusiastic about taking part and having the use of the PDAs unfortunately their enthusiasm was short lived and the students interest in the device faded very quickly. No log data was collected during the project as the students either said they didn't have the PDA with them or it was found that all data been lost on the device. Data loss was always blamed on the batteries having gone flat. It does seem surprising that electrical engineering students should have had such apparent difficulty in remembering to change batteries or to follow the correct procedure to change them. With the benefit of hindsight it is possible this was an early manifestation of a problem identified later in the willingness for students to co-operate in the project.

To establish why the students had lost interest in using the PDAs informal interviews were held during a lab session. The students indicated that there was no point in using

the PDAs as their mobile phones could provide much greater functionality than the PDA. Students said the PDA looked out of date, even though it was only a year old, as it only had a monochrome screen whereas their phones had colour screens. Although the screen on their phones was smaller than the PDA one, the phone screen had better contrast in office lighting.

Lessons Learned.

The speed at which the PDAs had become apparently obsolete was a surprise. Only a few months before the summer school students had described the same device as being “cool”. This was the first indication that technology ageing was going to be a problem both for the project and potentially for the use of PDA and other mobile devices in education. It seemed that there was little point in repeating the project without using more up to date PDAs for which additional funding would be needed.

4.1.4 Phase 4

This phase was delayed until additional funding had been secured to purchase new PDAs. Eventually additional funding of £10,000 was secured from the University of Glasgow Chancellors fund.

Overview of Project

Phase 4 was a refinement of Phase 3 with a 1st year cohort of technology undergraduate students based at the Robert Clark Centre (RCC) on a Bachelors of Technology Education (BTechEd) course.

The students from the RCC also attended lectures in the department of electrical and electronic engineering. The reason for choosing the group was that they worked together as a cohort in all of their subjects and so attended all lectures and lab sessions en-mass. We did not want a group that was fragmented between different lectures as this might obfuscate usage patterns of the PDAs. The drawback of involving the entire year was the removal of any subjects to use as a control group, but the entire year was needed to allow them all to work together.

It was planned that the students would potentially use the device throughout their time at university. As was shown in the previous chapter, in projects where the PDA had been loaned the amount of use reduced throughout the project and students did not appear to form any bond with the device. It was believed that if they were potentially able to keep the device then they were more likely to take ownership and ‘appropriate’ the PDAs. This would increase the likelihood of them customising the device by buying and installing additional applications. It was anticipated that in these circumstances the fall off in device use throughout the project seen in earlier phases would not occur.

PDAs were also given to members of staff who would be tutoring the group. This was to provide a PDA friendly environment, to encourage the staff to incorporate PDA use

into their courses and also to try to replicate the interaction and information sharing that had occurred during phase 2 with the Summer School students.

In this phase of the project the labs needed adaptation and configuration to support the syncing of the PDAs. To achieve this required the help and support of computing support staff and so PDAs were given to members of the computing support team. It was thought giving PDAs to support staff would also help with technical support and in the set-up and configuration of the computer clusters.

It was believed that having provided PDAs to both tutors and support staff would mean they would become familiar with the capabilities of the PDAs and be able to provide assistance to the students with their PDAs.

The Technology

The device chosen was the PalmOne Zire 72S which had a colour display, a camera, MP3 player a voice recorder.

This was at a time when a majority of phones did not have sound recording or camera facilities and MP3 players were not yet commonplace. It was hoped that these features would provide significant impetus to the students to carry the devices with them either through the inherent usefulness of the features, or their 'wow factor' with friends and family and if the device was with the student most of the time, then this would help engender a sense of ownership which would subsequently lower barriers to use of core PDA function as noted in chapter 2. The sense of 'ownership' of a device extends beyond physically owning the device, a phenomenon referred to by (Jones, 2005) as 'appropriation', and is identified as an important motivating factor in the use of mobile devices.

Unlike the PDAs used in the earlier phases, these had a rechargeable battery and supported removable non volatile storage using Secure Digital (SD) memory cards. The use of an SDCard was also required to provide the MP3 player capability. The camera had additional educational potential, specifically, we planned for its use in a design course to enable the collection of images to form a design folio.

Changes from Previous Phase

To counter the problem with lack of syncing encountered in the earlier phases, an entire lab of 30 machines that was regularly used by the students was configured to enable syncing. This required suitable hardware and software to be installed on the machines so that all the student had to bring was their device, and ensured that barriers to syncing were lowered as far as possible.

An important requirement of the syncing process was that when the students synced in the lab that their personal data would be stored securely and privately in their campus hosted student account area, while the logging data collected by AppLog and the system messages generated by the hotsync process were stored in a central location

accessible only to the researcher. The preparation, configuration and testing of of the computing lab and PDA desktop software to support easy PDA syncing took researchers and members of the computing support team, three months. A reminder that providing infrastructure and institutional support is not a trivial exercise and explains some of the reluctance of IT support departments to embrace mobile learning.

The logging system used a modified version of AppLog to record when the devices were used. As the version of operating system used by the PDAs had changed significantly (from PalmOS4 to 5) the underlying mechanisms of AppLog had to be modified, which required a rewrite of portions of AppLog and extensive testing. Unfortunately the changes that had been made to the operating system meant it was no longer practical to detect when beaming occurred on the device.

Some additional software was pre-installed on the device: a simple quiz application for delivering self assessment questions , an application to facilitate both viewing and editing of "Office Documents" (Word and Excel) and a PDF viewer.



Figure 4.1: PDAs Charging

Overview of the Trial

Since this was the most extensive phase of the project, there was the opportunity to make significant refinements and evaluation. to our data collection techniques during the trial. This overview therefore falls naturally into two sections i)preparation, distribution and initial impression of PDA usage and ii)optimisation of data collected.

The PDAs were introduced six weeks into the cohort's first term, to allow the students to first settle into the routines of university life. Prior to distributing the PDAs the course tutor and researcher explained to the students the purpose of the project, what

data would be collected, who would see the data and how the data would be used. It was made clear that any personal data on the PDA would not be visible to the research team or their tutors. The students were also told that they were allowed to install games on the PDAs, this was explicitly stated as many institutions have policies that prohibit the installation of games on university computers.

The students were then asked to complete a questionnaire in order to help to clarify their familiarity with mobile technology, the types of device they already owned or planned to buy and if they had a part-time job. Full results of this questionnaire can be found in Appendix B.

The PDAs were charged in advance of handing them out so that the student could use the device as soon as they received it. When the PDAs were issued the students showed *considerable* enthusiasm and as they investigated the devices many gave the impression of being very technically adept. Within a few minutes of receiving their PDA some of them were trying to setup Bluetooth communication with their phones in order to connect to the Internet. The session gave them chance to explore the devices and to ask questions about PDA use and operation. The impression at that time was that the students were at totally ease with using the technology and would not need much help. After the handout session the students were encouraged to explore the devices themselves for a few weeks before using them for the revision purposes.

For the first few days after the handout, the students were observed using the PDAs and showing them to other students. In the following weeks it was noticed during lectures that some of the students appeared to be using the devices to communicate silently and via Bluetooth/infra-red beaming. This was not a great surprise as during the initial handout some students had admitted that they sometimes used the Bluetooth facilities of their phones in order to chat during lectures. The camera appeared to be popular with them as they were taking photos of each other during the lectures.

In the use of the camera we were witnessing the early days of an easy to use and always with you camera. In 2011 it is difficult to appreciate what a big change in the use of photography was occurring at this time.

During some of their lectures and the practical lab sessions support staff were available to answer technical questions and assist the students to sync their devices. However the students rarely, if ever made an effort to sync their machines even when prompted. Informal enquiries of the students suggested most of them had connected their PDA to their home PC mainly to facilitate the transfer of MP3 audio files, photographs and games. The MP3 facility of the device required the use of an additional memory card for the device. (at this time a 1GB card cost approximately £50) so the fact they were using the MP3 facility implied they considered the financial outlay for a card worthwhile. That the students had made such a purchase suggested that the sense of ownership that we had predicated and not be been present with loaned devices in the earlier phases had taken place.

Gathering the log data proved to be problematic as the students did not sync their

machines in the computer lab. In order to collect the device activity logs it was essential that the students performed the sync of their PDAs whilst on campus but there were no practical or ethical means of forcing them to do so. The students appeared to be very "marks strategic" and getting them to do anything that did not directly and obviously benefit their course results was difficult. Attempts were made to encourage them to sync by explaining the benefits for exchanging and backing up data on while campus but without a measurable increase in the rate of syncing.

It had been hoped that by providing students with a PDA, and lowering barriers to syncing as far as was technically possible in the time available, that the students, who understood the rationale behind the project, would reciprocate by providing the logs. However, whether due to lack of technical ability, a "marks strategic" attitude, or some additional concern, this did not seem to be the case

From observation it was apparent that the students were using games on the PDAs and this provided an idea of how to offer them something tangible in exchange for improved cooperation. As a developer I had contacts with a leading UK based PDA games company, Astraware. I approached Astraware and asked if they would donate registration codes for some of their products that could be used as an incentive to get the students to sync their PDAs. At the time Astraware games typically cost £15-20 each. Astraware kindly agreed to do so and a weekly prize draw for 3 games was held for all students who had synced their PDA during the previous week, but this did not produce even a marginal, measurable improvement.

The failure of the students to sync their PDAs meant that log data from the devices was not being collected. As the students were unwilling to sync their PDAs with the lab computers an alternative method was attempted.

The alternative mechanism required enhancements to AppLog and the creation of an additional data collection application. The modification of AppLog was to enable it to support "beaming", a mode of data transfer using infra-red or Bluetooth. The additional data collection application which was named TeksLogs was designed to receive the logs beamed from AppLog and intended to run on the tutor's and researchers PDAs.

This required extensive and time consuming testing of both applications. Also the upgrading of AppLog on the students PDAs could not be completed in a single session as the students did not all have their PDA with them.

The beaming facility in TeksLogs also enabled the tutor to automatically send new materials to the student's PDA, such as additional quiz questions, thus making the process mutually beneficial. It was hoped that this would encourage student co-operation.

An unexpected consequence of the beaming of the logs was that without the additional information that could be derived from the hotsync logs it was not possible to identify applications that were using unregistered creator ID. To resolve this issue AppLog was further modified so that as well as sending the activity logs, a list of applications on the device along with their associated creator codes was also sent, this

allowed most applications to be identified unless the application had been deleted from the PDA prior to the log upload.

After these changes had been made a few logs were successfully collected. However a new, more interesting problem was then revealed. When asked to sync, the majority of the students normally claimed they did not have their PDA with them and were vague or evasive about the reason for not having brought the PDA. If the students were pushed for an answer, their typical responses were that the device had been forgotten or the battery was flat.

During the project student interviews were planned to verify and triangulate data from the logs. Volunteers were sought to take part in interviews about their experiences, during a morning lecture. In an attempt to encourage students to participate an incentive of food and drink during the morning lecture was offered.

The interviews occurred before the detailed exploration of the log data described in the next chapter had occurred. At the time it was our perception that no useful log data had been acquired and the tools, such as Graaf, to examine the data had not yet been written.

From the interviews it became apparent that the PDAs were being used and carried by the students more frequently than enquiries and requests for them to sync had previously indicated. It was also found that some students had found imaginative ways of using the PDAs, such as photographing books to remember their titles and recording concerts to show friends. It was not clear what had inspired these uses, whether they were original ideas or if they had been influenced by each other or from ideas found on the web. The spread of such social practices via the Internet is described by Lankshear as 'internet memes' (Lankshear and Knobel, 2006). These unexpected uses are a reminder that "the unexpected consequences of technologies always outweigh the expected ones, both positive and negative"(Norman, 2007, pp 101).

As the interviews had indicated that the student were using the PDAs a further attempt was made during lectures and labs to collect the log data from the students. Prior to the scenario about to be described, the students had been asked as a class or in small groups if they had their PDAs with them. In the weeks following the interviews, students were asked individually if they had their PDA with them, they tended to divert attention from themselves and instead named colleagues who had brought their PDA with them; the named colleagues often indicated, in turn, that the person who had named them did actually have their own PDA with them. This denial suggests that their actions may have been influenced by sociological factors. It is possible that students were nervous about being seen to make mistakes in the use of the PDA in front of either their peers or academic staff. It is also possible that there was a certain element of guilt or embarrassment that they were not fulfilling perceived expectations of using the PDAs for much other than games, even though we had reassured them that our interest in how the PDAs were actually used had no judgemental character. Such sociological and peer pressure problems have been

predicted in other evaluation situations “Evaluation may raise issues of self-esteem, social standing and status” (Traxler and Riordan, 2003).

As power was claimed to be a problem AppLog was modified to log battery state (this meant another round of time consuming testing of the modified application and the installing of the new version on student PDAs), the few logs that contain battery logging data are shown in figure A.47.

Lessons Learned

Preparing the devices for distributing to the students required surmounting several practical difficulties. The PDAs could not be charged too far in advance as in the sleep state the battery discharged after two weeks. Charging required locating somewhere secure with an adequate number of mains sockets . Whilst this may sound trivial, in many institutions finding a suitable secure location may not be straightforward. Figure (4.1) shows about half of the devices being charged.

Results

The questionnaire data indicated that most of the students had part time jobs and ranging from 6-27 hours per week. (average/median) . What was surprising was that two of the group did not own a mobile phone. The questionnaire is more fully discussed in the next chapter.

Chapter 5

Results

This chapter presents the results from the trials conducted throughout the project. The chapter begins with a reminder of what questions the research had been designed to answer followed by an review of what the sources of data were. The chapter is composed of 4 sections.

1. Results from the logging system,
2. Results from interviews,
3. Results from VLE Access logs, and
4. Discussion of points arising

The majority of data was objectively collected by the AppLog logging system, with additional results provided by questionnaires, interviews and observation as summarised in table 5.1 on the next page.

Additional data was collected in phase 4 regarding the students, including summative exam results and the use of the VLE (Virtual Learning Environment). This potentially enabled more comprehensive exploration of correlations between the students and their use of the educational technologies available to them. Though as will become apparent the amount of data collected for PDA usage made this of limited use.

The main part of this chapter focusses on the results from the logging system which provided a view of the patterns of PDA in each phase of the project, as introduced in the previous chapter.

5.1 Data from Logging System

5.1.1 Introduction

The overall project aim was to evaluate the use of PDAs as a platform for CAA (Computer Aided Assessment), but before attempting to make such an evaluation it was important to reliably ascertain if and when the PDA was being used by the student.

Project Phase	PDA Log	Questionnaire	Observation	Interviews	VLE Logs	Comments
1	Yes	Yes	Yes	Yes		
2	Yes	Yes	Yes	No		
3	No	No	Yes	Yes (informal)		Limited Data collected
4	Yes	Yes	Yes	Yes	Yes	

As stated in chapter 3 no was data collected in Phase 3 other than informal unstructured interviews.

Table 5.1: Data Sources In Each Project Phase

An extension of verifying if and when the PDA was used was to determine which PDA applications were being used, and when - information which would indicate which applications were most useful to the students.

The data from the logging system enabled a view of the patterns of PDA use. In general terms when it was used, for how long and what for.

PDA use is first examined from the perspective of the length of time an instance of use lasted, then at when the PDA was used during the day or week and then by which applications were used. Then we investigate how the use of the PDA changed throughout each project phase to see if the pattern of reduced use reported in the research literature is observed. Then we compare how different measures of PDA use can be assessed to indicate if the PDA was 'useful'. The final view of results from the logging system show which applications were the most used and which applications were used together. The data derived from the logging system is shown graphically in figure 5.1 and a summary of project parameters derived from the log files are summarised in 5.7.

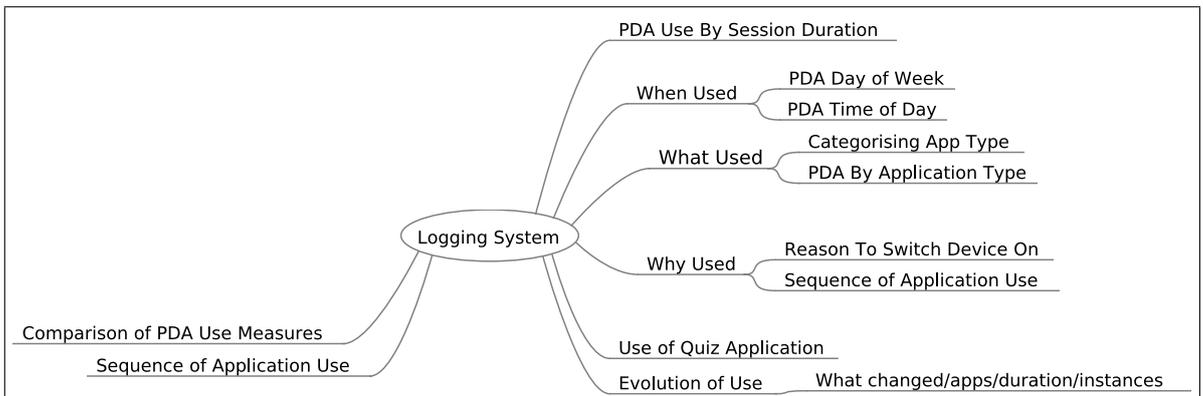


Figure 5.1: Data From Logging System

The software to assist in the exploration of the data was written as part of the analysis process and its functionality was influenced and informed by the characteristics of the data that were collected in each project phase. The AppLog application directly extracted PDA session lengths, application use counts, and use lengths. However, of

itself this data could not readily be used, due to its volume and fine grained nature. Of far more importance was the secondary information derived from this raw data, in which patterns of use could more readily be seen.

5.1.2 Measures of PDA Use

Before proceeding to explain how useful information was derived from AppLog the parameters that will be used in this thesis to characterise device use will be defined and explained. The key parameters are laid out in Table 5.2 (note that the naming format of many of these parameters avoids the use of spaces - this allowed consistency when naming variables in the actual computer codes used to extract their values). Identifying the parameters that are used to represent device use was an iterative process.

The amount of log data collected for each participant varied, and ranged from a few days to 20 weeks. The range of data collected for the participants can be seen in figure 5.2 on the following page. Within each phase the time-span of the logs collected for each student were not contiguous, as can be seen in figure 5.3 on the next page.

These variations mean that direct comparisons of PDA use between students cannot be made without first converting the directly extracted results into a suitable common unit of measurement.

Daily use was selected as the common unit of measurement as it is a natural division of time and has been used in other studies such as Greenberg (2004); Wishart (2006). Daily averages of use were calculated in two ways: The cumulative total use divided by the duration of the log data for the user and the cumulative use divided by the number of days upon which the device was *actually used*. These are indicated in the results as *per log days* and *per actual days*. Treating these separately became important, as data regarding users that only used the PDA intensively on some days but made no use of the PDA in between those days would give a false impression of how much the PDA was used. This information is retained by averaging over the log duration and over the actual days on which the device was used.

The process of exploring the log files to derive usage parameters, statistics and graphs, occurred in parallel with the development, testing and refinement of the analysis tool. In the phase 1 and summary data was produced in tabular format utilising Perl scripts (Wall *et al.*, 2000). The textual tabular data was visualised using a graphing application that I wrote for the purpose.

The majority of exploration and analysis of AppLog data was performed after the end of phase 4 of the project as the analysis application, Graaf, was not completed until this time. The reason for the late development of Graaf was that the data was initially explored using a variety of separate tools such as spreadsheets and statistical analysis programs such as SPSS (Statistical Program for Social Sciences), but once the data was examined it became apparent that a more interactive means of exploring the data was vital, as it took too long to filter, navigate and cross check information.

The requirement to interactively explore the results necessitated the development of Graaf, which was initially written to enable the visualisation and selective filtering of the data to isolate events of interest, but its functionality was enhanced as required throughout the project for example to provide basic statistical analysis and batch processing of results to provide summary reports of results.

The data analysis could not have been performed with traditional tools, as the volume of highly complex data, and number of different independent ways that the data needed to be visualised, was found to have been more than any commercial package available could provide.

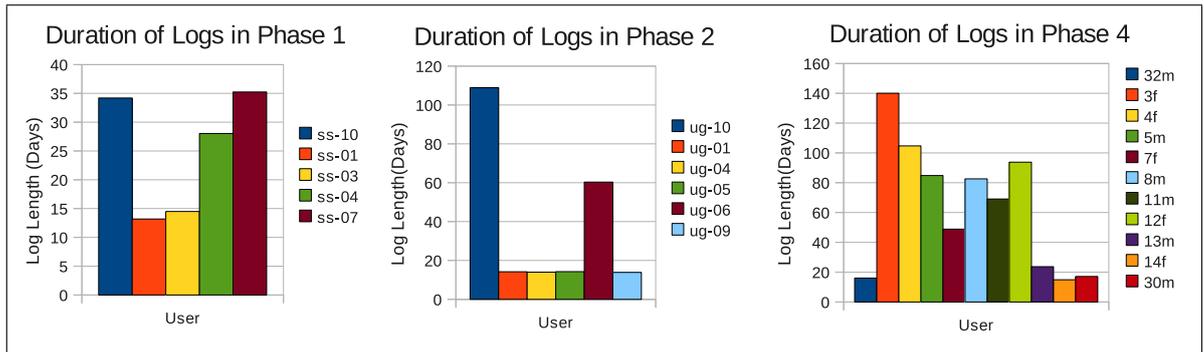


Figure 5.2: Duration of Collected PDA Logs

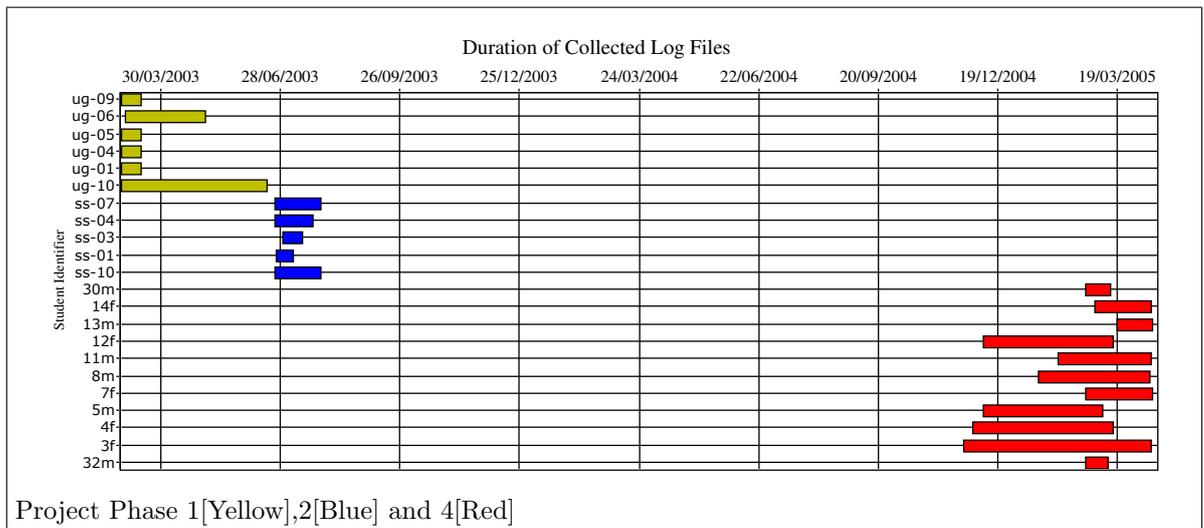


Figure 5.3: Extent of PDA Log Data Collected for each Project Phase

5.1.3 Categorising of Application Types

The applications used on the PDA were grouped into categories, the groupings are summarised in Table 5.3. Grouping, rather than looking at individual applications use, was necessary due to the wide variety of applications that can be used. For example there were 71 game applications and 11 photo applications used by students during the project. Grouping applications into categories (for example media, organiser, document, music etc) can give a better broad indication of a users' primary use of the device than concentrating on individual applications.

The full list of applications and the categories to which they were assigned is given in Appendix F.

5.1.4 Data Cleaning and Filtering

Data cannot be assumed to be free of errors and so data cleaning was applied at various stages of the analysis of the collected log readings. The process of filtering data to isolate events of interest is functionally similar to the mechanisms for identifying anomalous values and so the functions for both of these were implemented in Graaf's filter module. Combining their functionality made testing and verifying program behaviour easier. The purpose of the data cleaning process is to remove spurious or erroneous readings from the data, whilst filtering is used to isolate or remove specific subsets of results. The filtering functions allowed the separation and examination of events from specific days, times, session lengths, and applications.

During the process of testing and debugging the Graaf application, anomalies and errors were identified in the data. Some erroneous values could be easily detected and removed at the point that Graaf read in the log-files whilst others were only apparent after derivation of additional parameters from the data.

The most obvious errors were events of extremely long or negative duration. When unusually long events were examined in the log files they fell into two categories; 1) an application had prevented power off from occurring (14 occasions) or 2) the user had altered the time or date on the device (2 occasions). Events with negative durations were always due to the user having changed the calendar date on the device. Any extremely long events, that is those lasting over 3 hours, appeared to be due to application hang ups and were deleted from the logs. Graaf was modified to detect and provide notification of such anomalies and where appropriate to remove them.

Some unusual or extreme values in the log-files were found to be due to operating system features combined with user modes of operation. Other operating system related artifacts were not apparent until additional results were derived from the log data and these are explained later in section on 'short duration events' on page 83

There is a greater chance of observing more meaningful patterns once suitable filtering has been applied to the log data and the filtering strategies that will now be described are illustrated with an example from the collected data.

5.1.5 Comparison between Different logging Phases

Phase 1 and 2 were intended as pilot studies to test and refine the logging and data collection mechanisms but useful data was also collected in these phases. As the same PDAs were used in phases 1 and 2 a direct comparison of the log results can be made, but as the PDAs used in phase 4 of the project had different capabilities, such as the ability to play music and take photos, direct comparisons of usage patterns are not as straightforward. To enable a more representative comparison between all project

phases the results from Phase 4 are also presented with all uses of applications that required the enhanced capabilities, such music and photo applications removed.

Where practical any charts showing all applications and those not showing photo, game or music (referred to in places as NoPGM) have the same scale. The exception to this is where the differential is so great that the filtered chart would be unreadable or show very little perceptible detail. Where charts have been scaled differently this is noted in the figure.

5.2 Results

5.2.1 PDA Use By Duration of Time of Use

Based upon reports from the literature (Palm, 2001) and the author's own experience as a PDA user it was expected that the distribution of length of times for the use of each application would be biased towards shorter time durations. The session length for the use of an application is defined as the time from which an application was launched until the time the user switched to another application or the PDA was switched off and is referred to throughout this chapter as the time of a 'run'. The graphs in figures 5.4, 5.8, 5.9 and 5.10 are frequency distributions of the duration of use of applications. The charts show durations of a usage session on the Y axis and the number of occurrences of that length of session on the Z axis to give a frequency distribution of session lengths.

From the distribution of run times shown in figure 5.4 the distribution can be seen to be biased towards short uses with the highest frequency of run lengths being at the lower limit of time on the left of the graph.

The application runtime lengths range from 2 seconds to over 2 hours in the 3 projects. The annotated figures 5.8, 5.9, 5.10 show the run times in each project phase. The longest sessions of use have been annotated to show which applications were used. The long runtime length values appear to be plausible uses of the device, for example the use of the address book for 2.5 hours may be extreme but it is possible this was while addresses were being added.

In phases 1 and 2 the longest runtimes were between 20-30 minutes (1200-1870 seconds). The longest sessions of use have been annotated on the charts and the majority of these were due to the use of games or the music playing facility.

With such a wide range of possible lengths of runtime there is a strong probability there will be many time periods that have only occurred once. The logging system time resolution was 1 second. So there are only 60 possible values for runtime below a minute but 1200 for sessions below 20 minutes. A recognised method for displaying the distribution of a wide range of values is to group them into ranges so that an overall shape of the distribution can be observed. Figure 5.4 shows the distribution of runtime of all users in all projects phases grouped into chunks of 60 seconds. From the grouped chart it can be seen that the largest frequency of events are at the lower limit of the

session duration and the frequency reduces as the session length increases. The pattern of decay was compared against standard types of decay, utilising SPSS and appears to be a log-normal distribution.

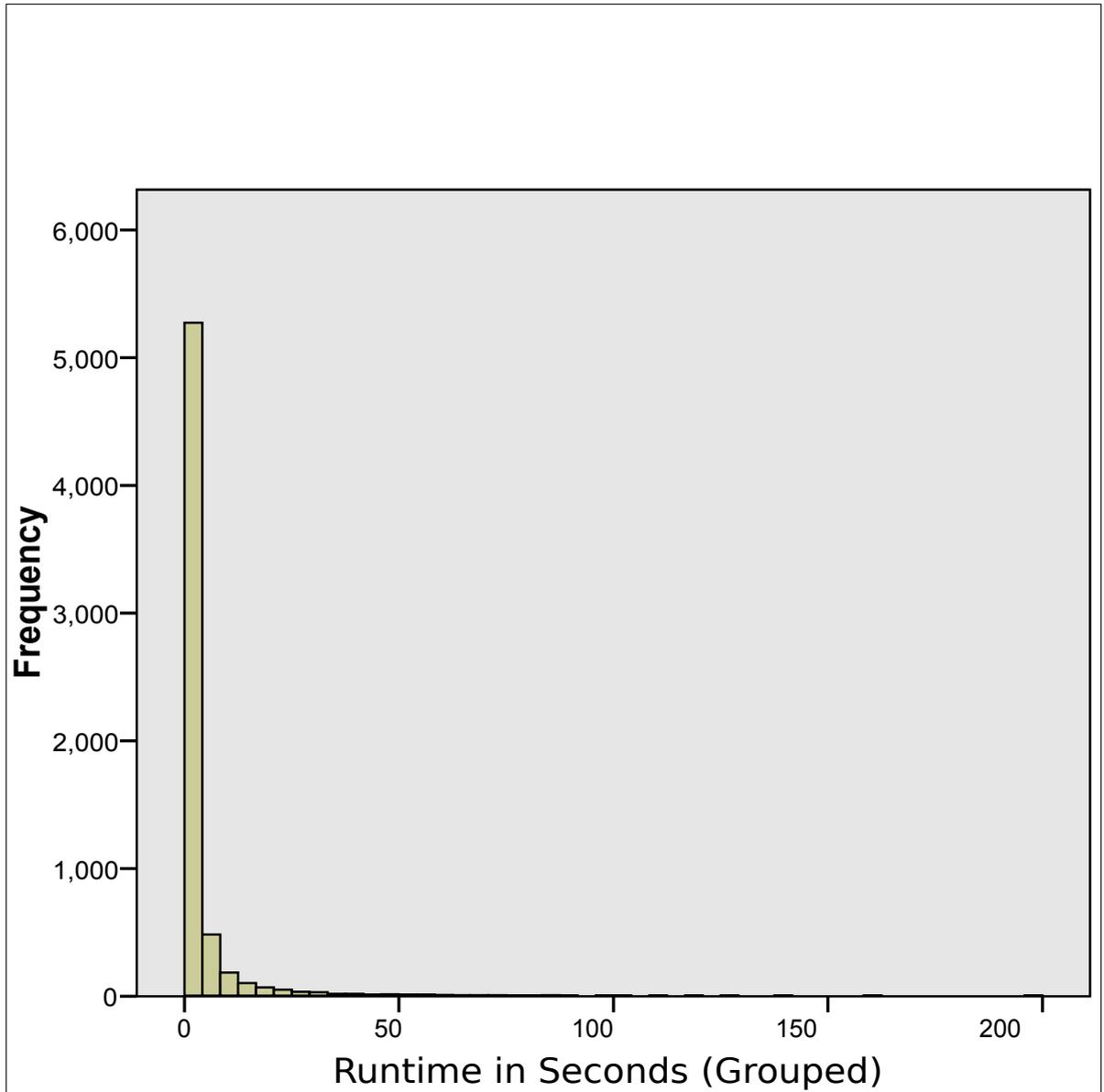


Figure 5.4: Distribution of Usage Sessions with Values Grouped in Ranges of 5 Seconds.

Examination of Short Duration Events

To understand some of the circumstances in which applications appear to have been used for very short periods it is important to be aware of the operation of the physical buttons on the PDA. The PDAs used in each phase had a number of buttons on them. One button is dedicated to switching the device on and off and the other buttons, referred to as hard buttons to differentiate them from on screen icons, are used to provide a quick way to launch applications. The application buttons are initially configured to launch memopad, calendar, address book and home screen applications but can be associated with different applications through a configuration utility. The

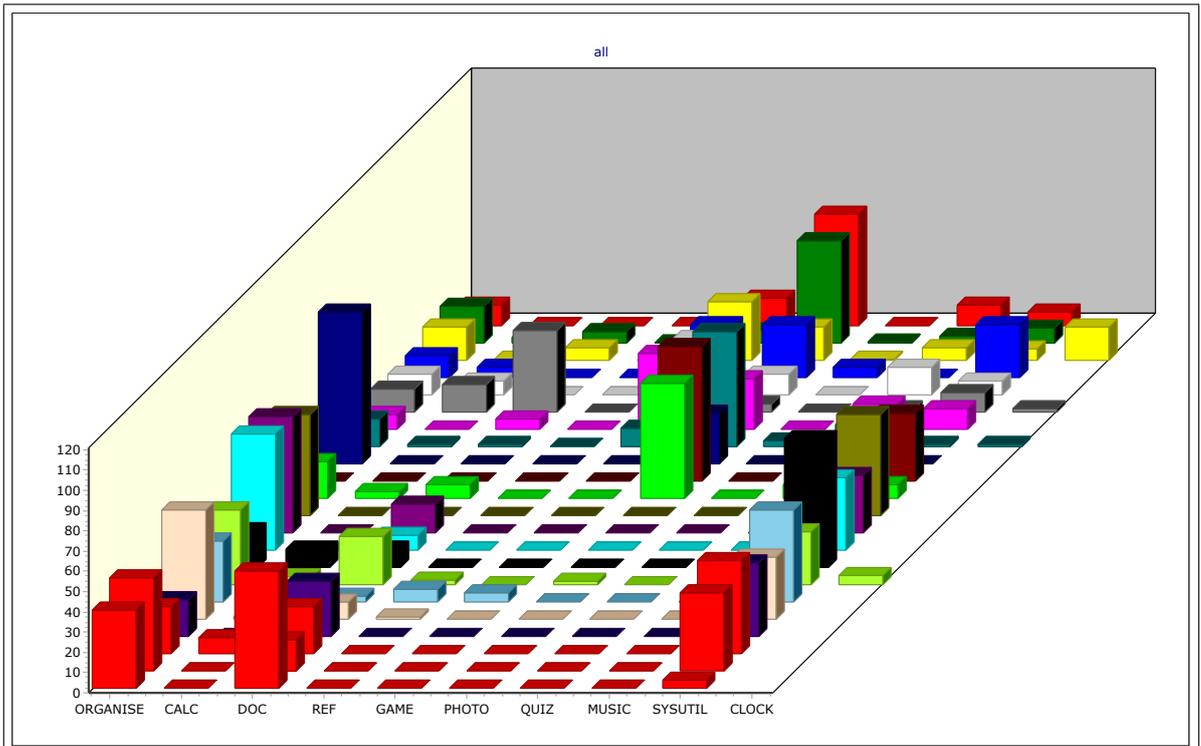
hard buttons can also be used to switch the PDA on. If the PDA is in its powered off state, then when the application button is pressed the device is powered on then launches the application associated with the button.

This can be illustrated by the following situation: If a user was running the memo application at the point the device was switched off, then when the device is woken up it is still in the memo application. If the PDA was woken by using one of the application launch buttons, for example the calendar application hard button, then after switching it on the PDA will initially be running the memo application but will then quickly switch to the calendar with the result that the memo application appears to have been used for zero seconds. On this reasoning all events of zero seconds can both be explained and safely filtered from the data.

There are also some applications that do have short run times due to their implementation, for example the camera control application on the PDA used during phase 4 is actually composed of two applications: one to view images the other to take a photograph. The photo taking function is sub-launched from within the photo viewer application and this switching is seen as an application launch event with a duration of less than two seconds.

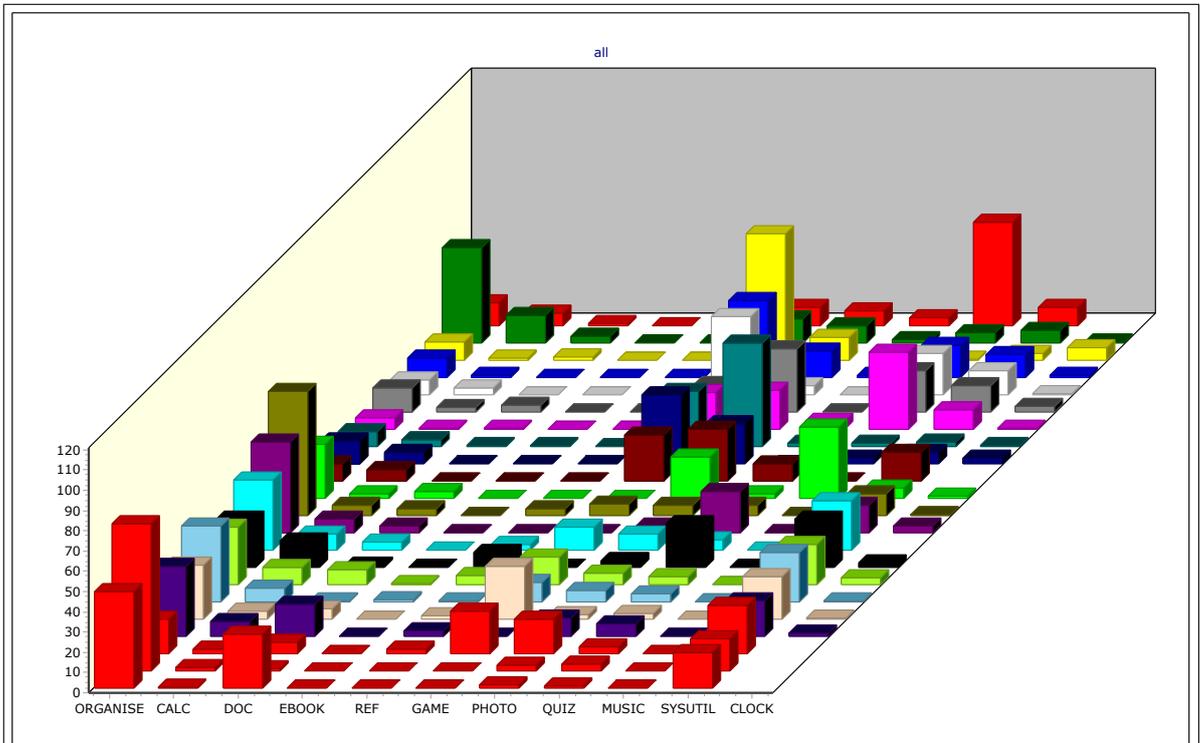
There are some situations where an application could be productively used for very short time periods of time. For example when the PDA is briefly switched on in order to consult what was on screen when the device had previously been powered off (for example to check the result of a calculation or to confirm an appointment time).

A closer examination of events with a duration of 2 seconds or less was made to see if there were any common factors, for example whether particular application types were those used for short periods. To do this Graaf's filtering function was used produce two sets of results —one that only contained events of 2 seconds or less and the other of events lasting more than 2 seconds. These are shown in the charts in figure 5.5 which show the proportion of launches plotted against each application family. The proportion of applications appears to be similar to those of applications used for more than 2 seconds shown in figure 5.6 . The results do not show any particular applications responsible. This suggests that many of the short events may be artifacts of switching between applications, perhaps from swapping applications immediately after switching the PDA on.



(Z axis is the number of uses of an application, X axis Application Type of Application, Y axis The Student)

Figure 5.5: Instances of Application uses with a duration under 2 Seconds



(Z axis is the number of uses of an application, X axis Application Type of Application, Y axis The Student)

Figure 5.6: Instances of Application uses with a Duration Over 4 Seconds

Sequences Of Short Events

A sequence of short events can also be generated by a user cutting and pasting information between applications. The Palm operating system only allows a single application to be run at a time and so a cut and paste operation requires switching between applications. Rapid switching between applications may also be the result of the user playing with the buttons on the PDA or of the buttons being accidentally pressed whilst the device is being carried in a bag or pocket.

Accidental Launches

It is likely that some application launches are unintentional maybe, due to inaccuracy of tapping on the screen and selecting the wrong icon or from choosing the wrong application (attempting to perform the correct action on the wrong object is known as a description error (Norman, 1988, pp107)). In these instances it would be likely that the user would quickly realise that they had chosen wrong application and then launch the correct one with the result that the duration of use of the incorrect application would be short. This suggested another simple filtering strategy, that of removing events that had a short duration. For filtering purposes, it can be difficult to differentiate short usage events from occasions where an application is launched by mistake.

Grouped Chart Limitations

The grouped chart used earlier to illustrate the frequency of runtime lengths is good for visualising the overall shape of the usage distribution but it has the drawback that it can hide interesting features of the data. An example of the type of feature that may be hidden in a grouped chart can be seen in figure 5.7, which shows the distribution of session lengths for all PDA use for all project phases, but in this chart session lengths have not been grouped.

Peak at 120 Seconds An obvious feature of interest in the distribution occurs at approximately the 120 second point where there is a second peak value. Similar peaks can also be seen on each of the individual project traces as shown in figures 5.8, 5.9, 5.10.

The most likely cause for the peak in session length distribution times that occurs around the 120 second point is related to the automatic power saving feature of the PDA which powers the PDA off after a definable period of user inactivity.

The default timeout period for the automatic power saving function is 2 minutes but this can be set from 30 seconds to 3 minutes in increments of 30 seconds. It is possible to set other timeout periods using 3rd party applications but there was no indication from the logs that any of the users had used any applications that could do this.

A hypothesis for the presence of this peak is that it is due to sessions where an application was launched but there was no user interaction, either because the user made no more use of the application or they only needed to read what was on the

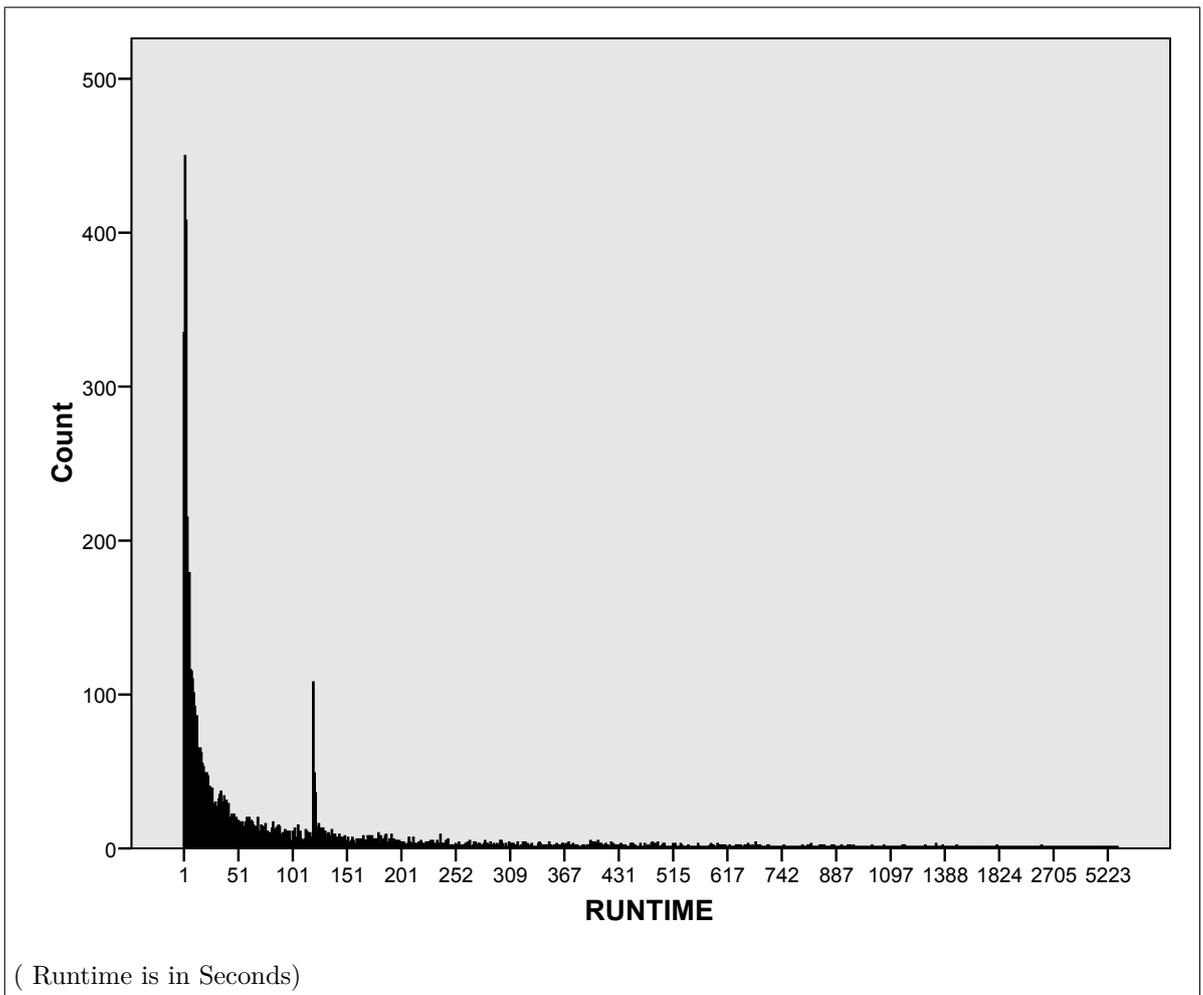


Figure 5.7: Runtime Distribution

screen , after which the user then allowed the device to switch itself off. The sessions under two minutes are where either the device was switched off after use or another application was launched. The peak at 120 seconds indicates that a number of users rarely turned the device off, and chose to allow the PDA to automatically switch off.

After the peak at 120 seconds there is a fall off in frequency with a similar shape to the range from 1 to 120 seconds. The activity after the 120 second peak can be seen more clearly when the chart is plotted with a logarithmically scaled Y Axis as shown in figure 5.11. It is likely that many of these sessions are where the PDA was used for a period of time up to two minutes within an application and then allowed to automatically power off. Effectively what is seen is the default power off period offset by the length of time the application was used.

The circumstances are illustrated in 5.12. Time period A is the time during which the user was actively using the application, that is they were interacting with the application through screen clicks or use of other inputs on the PDA. Time B is the automatic power off period. Thus if when a user has finished using an application they neither launch another application or they switch the PDA off the then the duration of use in the logs will appear to last for a total time of A+B.

A usage pattern in which a user always allow the device to automatically switch off

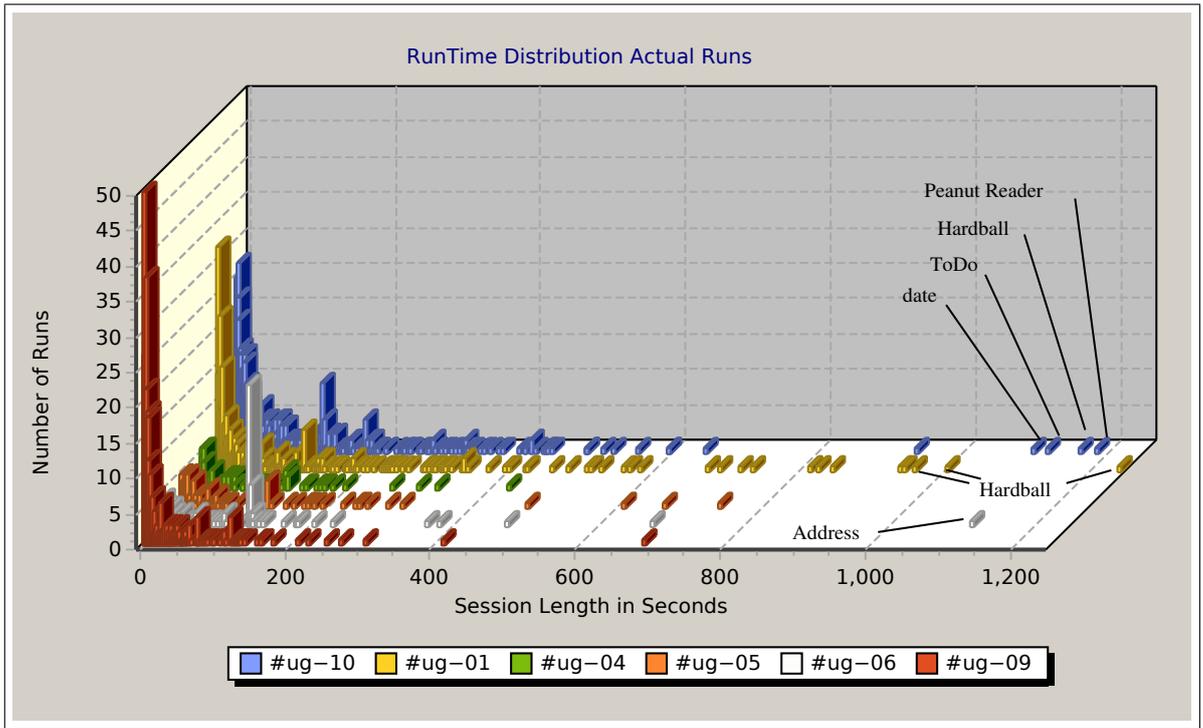


Figure 5.8: Runtime Distribution Phase 1

after the time-out period reduces the certainty of how long sessions of usage actually were. Proportionally this will have a greater distorting effect on sessions at the lower end of the session length range as short uses of the application will, due to the device being left until it powered off, appear to be longer than they actually were as illustrated in figure 5.12.

A mechanism of correcting for such an error may be needed in similar future work and so a means of calculating the size of the effect was attempted as now explained.

The Effect of the Automatic Power-off

To quantify the size of error introduced on session lengths by the automatic power-off function a calculation was made. Graaf was modified to apply some processing to the AppLog data, as described by the following algorithm. If an event was of a duration greater than 120 seconds, which is the default timeout period, and occurred immediately before the device powered off then 120 seconds was subtracted from the session length thus removing the effect of the timeout. Events of session lengths of less than the default time-out period were left unprocessed.

The algorithm above will not remove the effect of situations where an application was used for a few seconds, left idle for a time and then another application launched before the power off function timed out. Such use would also give the impression the application had been used for longer than it actually was.

The logging system did not differentiate between a power off due to the automatic timeout and the use of the power switch.

The original uncorrected values are shown in tables 5.4 to 5.6. The correcting al-

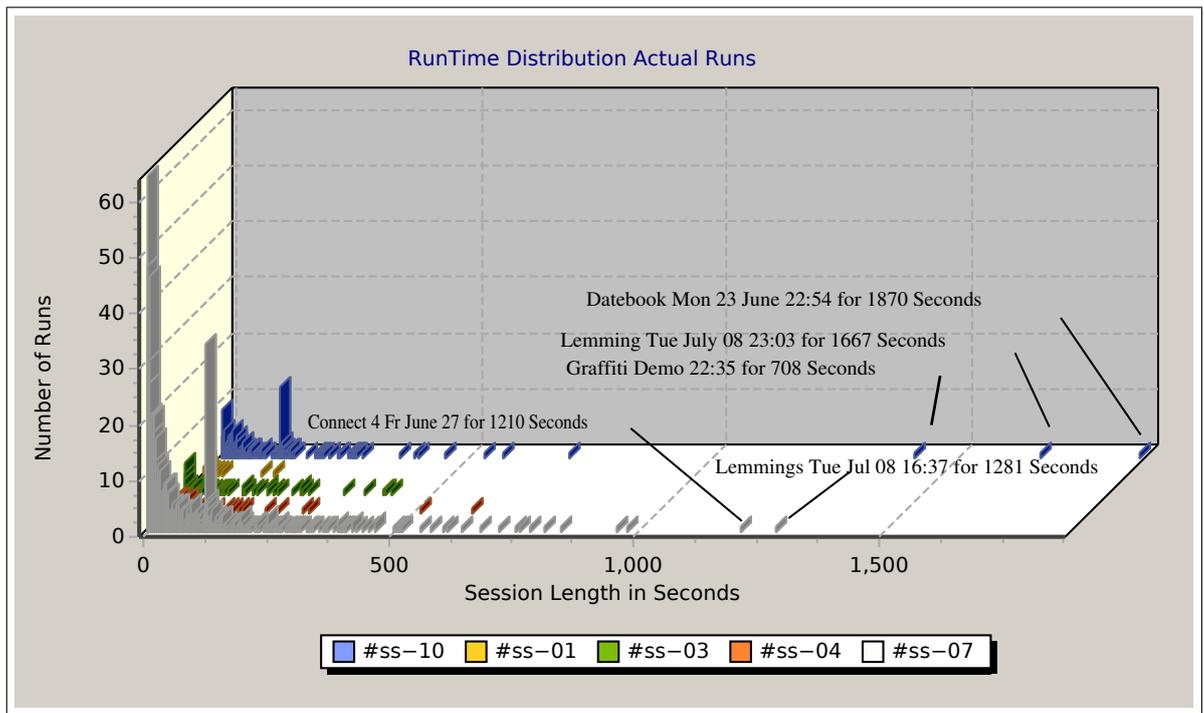


Figure 5.9: Runtime Distribution Phase 2 (Summer School)

gorithm was applied to all the events in each phase of the project and the values for each phase are shown in figure the amount of difference the correction algorithm had is shown in table 5.5 on page 100 absolute values in seconds and as a percentage of the uncorrected value in table 5.6 on page 100. It appears in worse case situation the error is 25% and that only changed the median runtime result from 28 seconds to 21 seconds.

Reasons For Using Both Absolute And Relative Values Of PDA Usage

Absolute and proportional measures of PDA use were both used when studying the log information: Absolute measures, such as on how many occasions the PDA had been used, are useful for determining which users made greatest and least use of the device.

Proportional measures were the best way of comparing the patterns of use between users. This meant that although some users made much less total use of the PDA, on the occasions they did use it their profile of use could be compared to other participants.

Absolute values of usage are of limited value for comparison between users unless the log data collected covers the same amount of time. Averaging the data could lose subtle usage patterns. In situations where differing durations of log periods have been collected then proportional comparison of values can provide more insight. The benefits of these two perspectives is illustrated in figures 5.13 to 5.17 below.

Figure 5.13 shows the amount of use made of the PDA by each student on each day of the week over the course of phase 1. The X axis shows the day of the week, the Z axis the number of total number of occasions the PDA was used on each day.

The chart appears to clearly show that user ug-10 made greater use of the PDA than the rest of the group and that ug-06 and ug-05 used the device much less. The

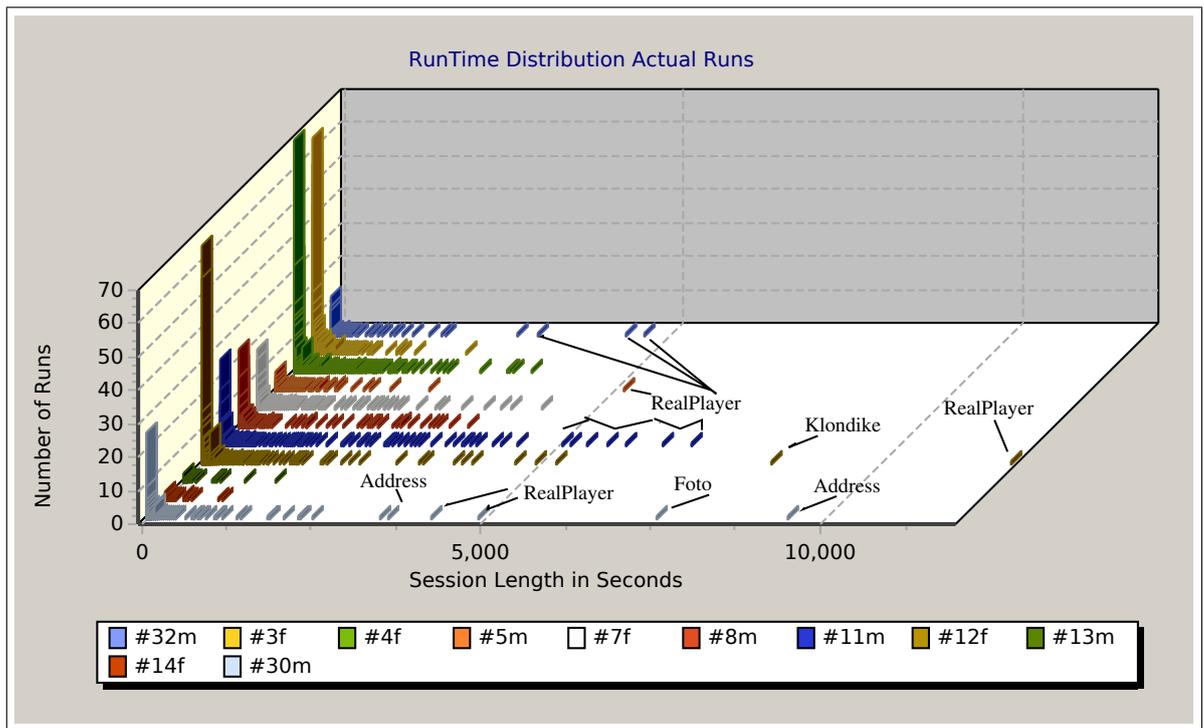


Figure 5.10: Runtime Distribution Phase 4

chart gives an view of how much PDA use varied in the group. The problem with this approach is that the amount of log data for the users was not of the same duration as can be seen in figure 5.2.

Rather than attempting to 'correct' for the variation in amounts by averaging over the duration of the log period a proportional view of the data was taken. The reason for choosing not to average out the result in this circumstance is that averaging increases the possibility of removing items of interest.

Viewing the amount of use by day of week and time of day was used to find if any clusters of use occurred, for example as became apparent during the analysis, to identify if the PDA was mostly used on the days when the class were together in a lecture or at lectures where one of the project team was present.

5.2.2 PDA Use By Day Of Week

Having considered the length of application use, we next consider on which days of the week the PDAs were used. Both the absolute and proportional charts are used here to show the benefit of the proportional chart for comparing use between participants.

Figures 5.13, 5.15, 5.17 show the distribution of use by day of week for each phase with the actual number of runs.

Figures 5.14, 5.16 and 5.18 also show the amount of use on each day of the week but these charts are proportional. The chart shows the percentage of time, relative to the user's total use of the device on each day of the week.

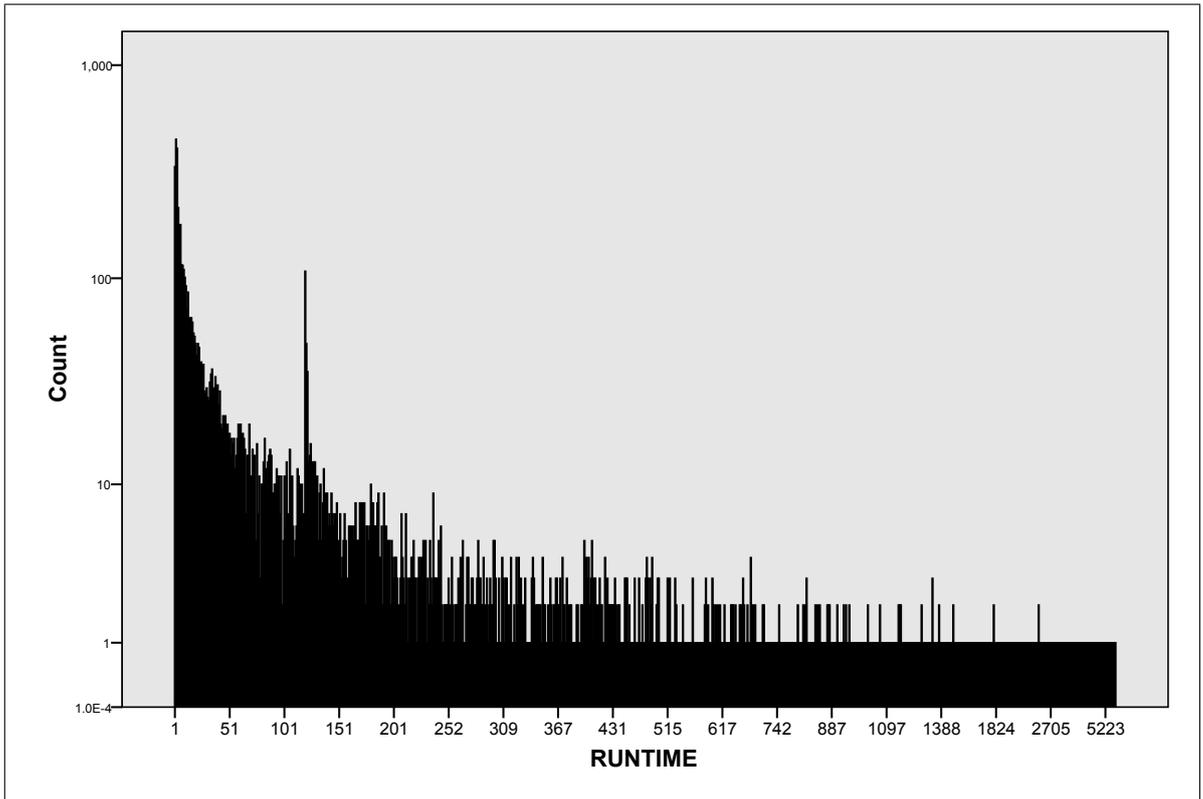


Figure 5.11: Run Distribution Log Scale

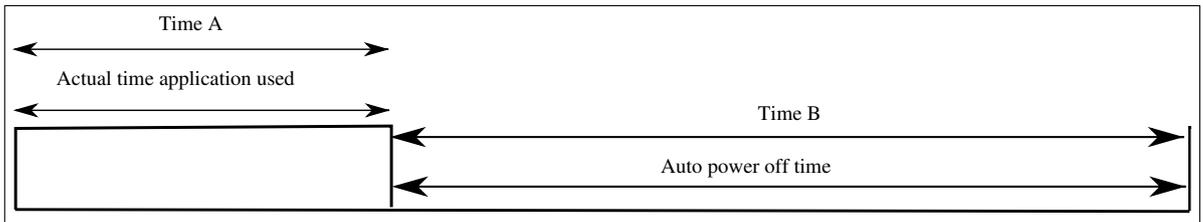


Figure 5.12: Automatic Power Off

Phase 1

In Phase 1, the proportional results show that peak usage days were Monday and Friday, although the absolute usage results show a wide disparity between the amount of use made of the PDA s between the different students - for instance the absolute chart shows that UG-06 did not use the PDA very often compared to the rest of the group. In phase one the labs and lectures which the group attended together with one of the project team in attendance were Monday and Fridays, clearly indicating that this use was either due to the students wanting to be seen using the PDA, or having an incentive to carry the PDA to sync it, or in case the project team asked questions about it (which would naturally lead to increased use). It should again be noted that there was no compulsion or need to use the PDA as part of the lectures or laboratories in this phase of the project - PDA use was optional, and for those students who found it beneficial. The implication of these results is that the increased use is the result either of social pressures (wanting to be seen, worried that they would be asked about the PDA) or simply that students were reminded about the PDA when there was an upcoming lab session where one of the project team may be present.

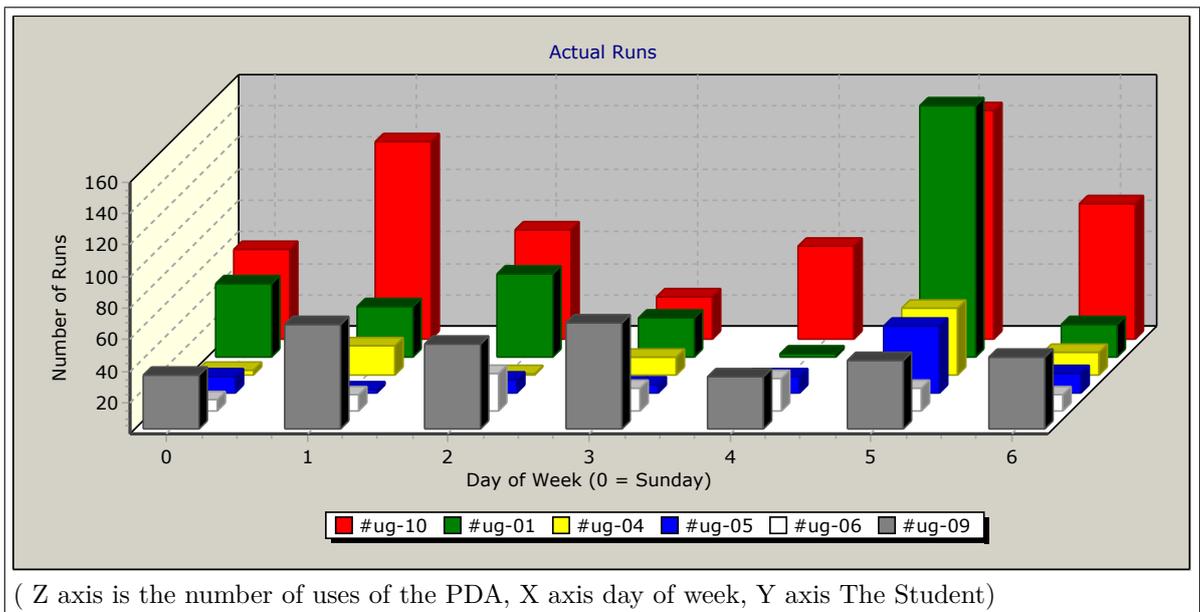


Figure 5.13: Session Distribution by Day of Week Phase 1 Absolute Values

This question cannot be answered with the data available but we will return to it when we consider the data describing the time of day that PDA use was maximal.

Our interpretation that the students PDA use was as the result of the presence of one of the project team is further confirmed by noting that the proportional results of figure 5.14 shows that of the total number of occasions that the students ug-01,ug-04, ug-05 used the PDA, 40% of those uses were on a Friday, the day of the lecture where one of the project team was present.

Phase 2

The graph of the distribution of usage sessions by day shows peaks for Monday and Tuesday. The summer-school lecture and practical days were held on Tuesdays and Wednesdays, so the usage on the Monday is most likely to indicate preparation for the week's summer school sessions. This is in agreement with the analysis we made directly above. We also note that one of the students(ss07), whilst their peak usages was Mondays and Tuesdays they continued to use the PDA, with some drop off in activity, throughout the rest of the week, whereas the other students had a much lower absolute PDA usage.

Unlike in phase 1 in phase 2 there were specific uses for the PDAs in the phase 2 lab sessions, for example the resistor colour code calculator. Also the lab sessions were an opportunity for the students to exchange information about uses they had found for the PDA.

All of the summer school students attended sessions in maths, physics, and engineering, but student ss-07 also attended the chemistry summer school. Some of the extra use made of the PDA by student ss07 was of a chemistry specific application (a periodic table of elements). Student ss-07 used considerably more applications (42 applications) on the PDA than any of the other summer school students (the rest used

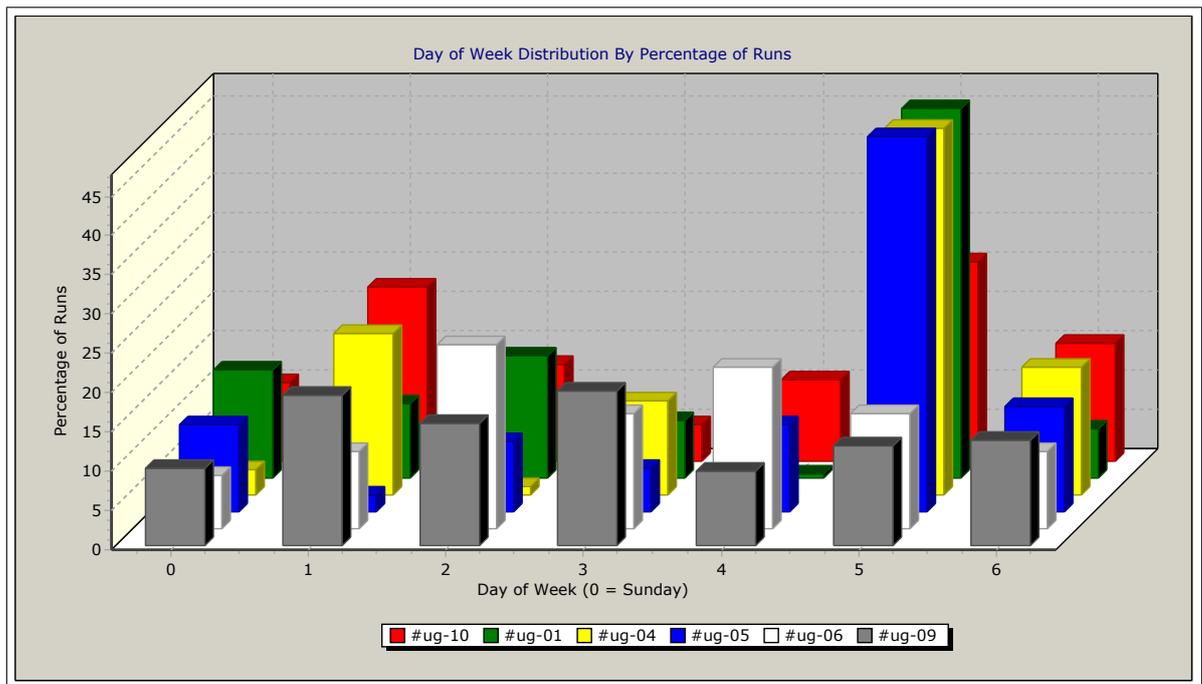


Figure 5.14: Session Distribution by Day of Week Phase 1 Relative Values

under 12 applications),

The results show that student ss-07s PDA use was spread over the whole week, compared to the other summer school students whose usage dropped significantly outside the formal lab sessions. This supports our hypothesis that a user forms a much greater bond with a device once they have discovered their own uses for it, and thus their overall use increases and is much more widespread. Usage spread throughout a week rather than being concentrated on lab and lecture days where one of the project team is present may act as an indication that a student has appropriated the PDA and found additional uses for it. This will be considered later in this chapter.

Phase 4

The phase 4 results have some similar characteristics to the early stages but important differences.

For most users in this phase their peak usage days were those where they were at a lecture or lab session where one of the project team was present. This again agrees with the results of phase 1 and phase 2. For students in phase 4, the days at which there were lectures with one of the project team present were Tuesdays and Wednesdays (day number 2 and 3).

However the difference to earlier phases is that the PDA usage of students in this phase is more evenly spread across the week than for students in the earlier phases. The author posits 3 reasons for this. Firstly and most importantly these PDAs contained multimedia tools, camera and music player, which were not otherwise available to handheld users at this time and had an obvious use outside of the narrow delivery of formative assessment tools. This was a key reason the PDA was chosen for this project

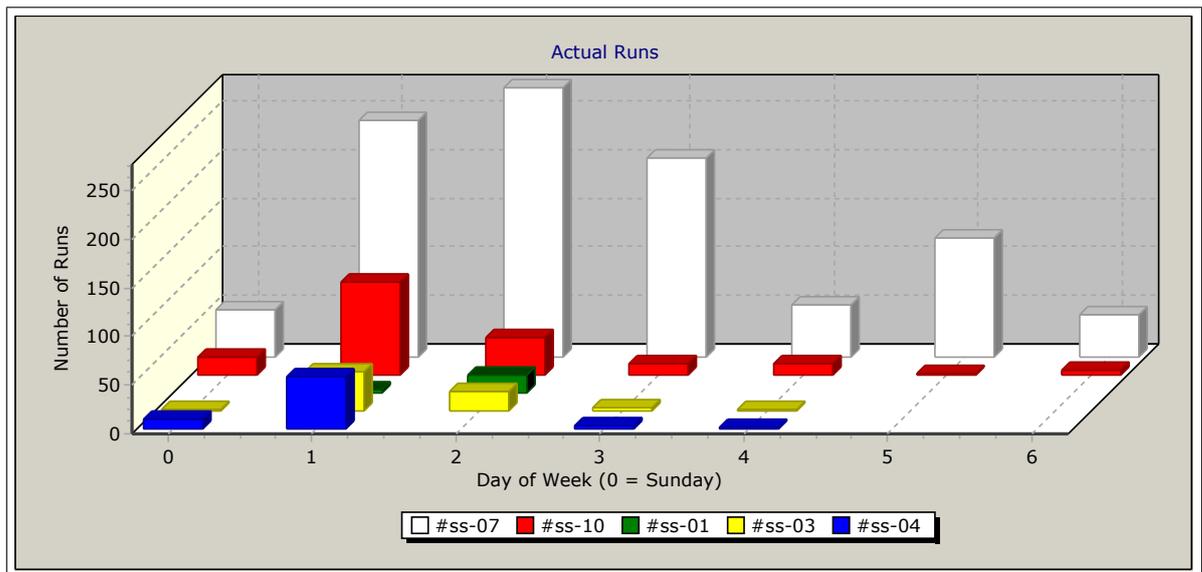


Figure 5.15: Session Distribution by Day of Week Phase 2 Absolute Values

phase and the results, which will be shown in detail below in Section 5.2.6 do indeed show an absolute increase of use of all PDA usage compared to phases 1 and 2. Secondly this effect was amplified as the project team invited one of the other course lecturers to specifically use the camera as an integral part of the students design exercises.

Thirdly the size of this cohort was significantly greater than in phase 1 and 2 and the cohort remained together for all of their level 1 university modules. It is our belief that this developed a critical mass where students would instigate other students' PDA usage as opposed to the triggers only coming from project team members, and that this smoothed out PDA usage throughout the week. Whilst there is no objective evidence in the PDA logs to backup this position, project team members often found groups of these students together using PDAs outside the normal lecture times, which is supporting evidence for this position.

Student 13m's apparently high PDA use at the weekend is not as significant as it first appears. In total student 13m only used the PDA on 26 occasions. This is where the chart showing actual number of uses is of benefit for Phase 4 (this is shown in the Appendix in table 5.20. This is a warning that small amounts of PDA use can give misleading impression of how the PDA was used.

Summary of Use by Day of Week

In summary, results showing the day-of-the-week PDA usage from all phases of the project indicate that students' PDA use was highest when there was either a reminder that the resource was available to them or some self perceived social pressure to be seen to use their PDA, otherwise PDA use fell off. Whether the major impetus was from reminders or social pressure cannot be seen from this dataset, and as will be seen below, will require a more fine grained view of when PDAs were used by students during each day. Two additional interesting conclusions can be drawn from the data. Firstly, evidence based on results from a phase 2 student, and the phase 4 student was

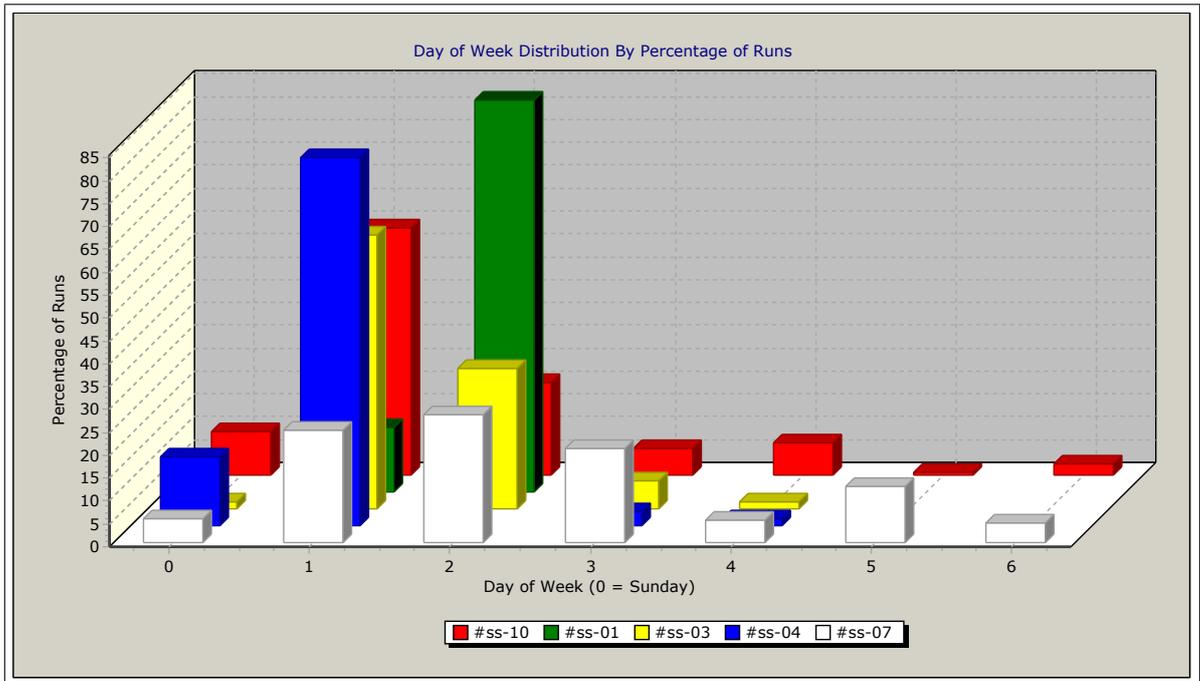


Figure 5.16: Session Distribution by Day of Week Phase 2 Relative Values

that when the students find an independent and personal use of the PDA, this leads to increased overall use, and use outside those days when students are explicitly reminded of PDA benefits. Secondly, when a larger cohort of students who associate with each other throughout the week are using PDAs together, usage increases.

5.2.3 PDA Use By Time Of Day

Figures 5.19, 5.20, 5.21 show at what hour of the day the PDAs were used during each project phase. The majority of use in all project phases occurs between 08:00 and 22:00 with only 3 of the students using the PDA in the early hours of the morning. Some of the extreme values on the charts indicating the use of the PDA either late at night or early in the morning have been annotated on the charts of 'actual runs' to show which applications were used at these times. It was found more informative to use the charts of actual runs to illustrate the use of the PDA at extreme times, as the real values made it more obvious if it was just "one off" use or a more regular routine. Making the examination of such features easy was one of the design requirements of Graaf as it enabled such events to be quickly cross referenced to the original activity logs thus providing confidence that the data was being processed correctly. The Graaf system itself was one of the novel results of this work.

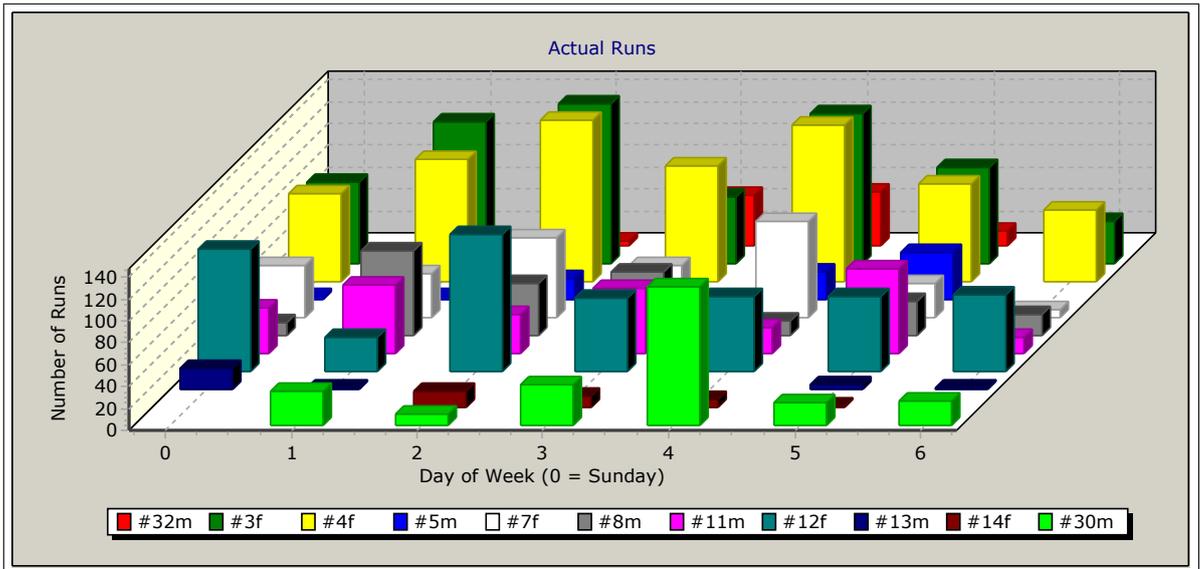


Figure 5.17: Session Distribution by Day of Week Phase 4 Absolute Values

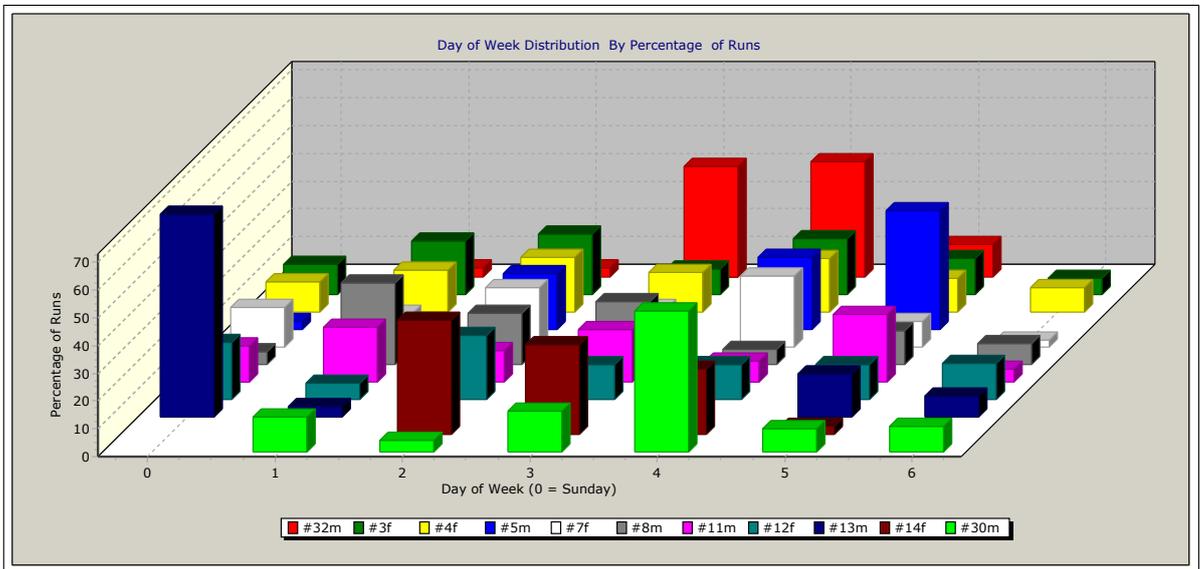


Figure 5.18: Session Distribution by Day of Week Phase 4 Relative Values

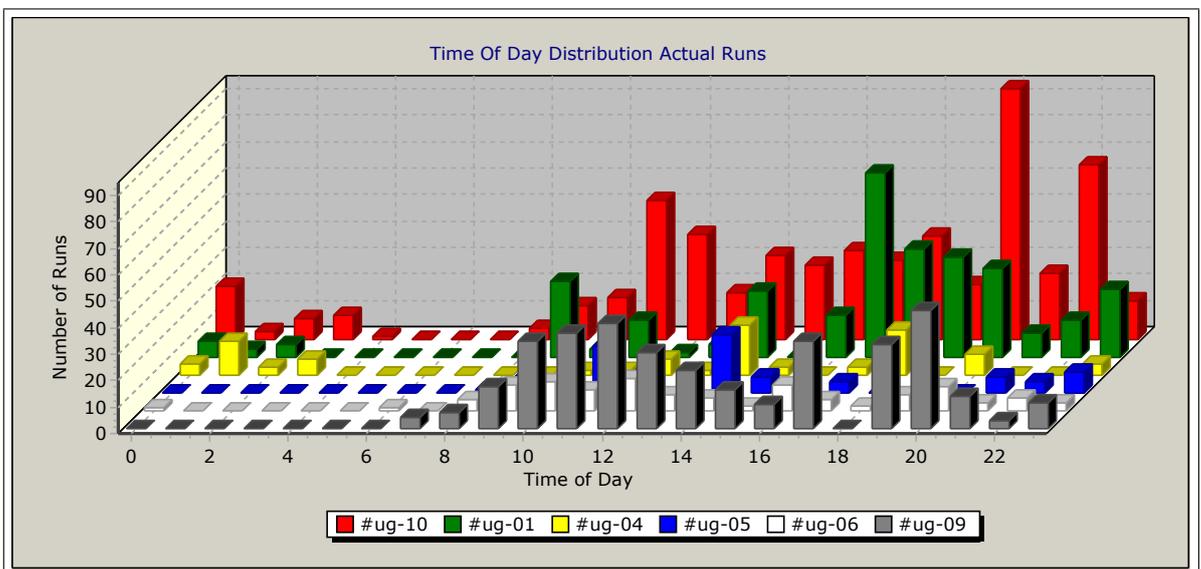


Figure 5.19: Session Distribution by Time of Day Phase 1 Absolute Values

Parameter Name	Description
NumbApps	The number of applications that have been used on the device throughout the logging period.
PercentageDaysOnWhichUsed	Throughout the duration the log data encompasses the percentage of days on which the device was used.
RuntimeValues	The runtime is the duration of use of an application
AveRuntimePerLogsDays	The aggregate runtime throughout the log period divided by duration in days of log
AveRuntimePerActualDays	AverageRuntimePerLogDays multiplied by the Percentage of days on which the PDA was used.
AveRunTime	Total runtime divided number of total number of runs
Runs	A run is an instance of using an application on the PDA
AveRunsPerLogDays	The aggregate number of PDA uses throughout the log period divided by duration in days of log
AveRunsPerActualDays	AverageRunsLogDays multiplied by the Percentage of days on which the PDA was used.
Interval Values	This is the interval between applications being used on the PDA
Sleep Values	This is the amount of time for which the PDA is powered off
Number of Sleep Events	The number of occasions the PDA went to Sleep (Power off State)
Day Factor	A measure used to indicate over how much of a day the PDA was used. Discussed in more detail on page

Table 5.2: Definition of PDA Use Measures Used In This Chapter

Category	Description	Comments and example Applications
Unknown	Applications using unregistered identifiers	Normally games
Organise	Organisation	Calendars ToDo lists
Calc	Calculators	
Doc	Document tools,	Memo PDA, PDF Readers,
eBook	Dedicated Book Readers	
Ref	Reference Materials	Databases, Resistor code readers
Game	Games	
Photo	Camera application and image viewing	
Quiz	QuizApp and JQuiz	QuizApp and JQuiz
Music	Music Player	
Clock	Clocks	
SysUtils	System utilities	Settings and preferences setting tool, file managers

Table 5.3: Application Categories

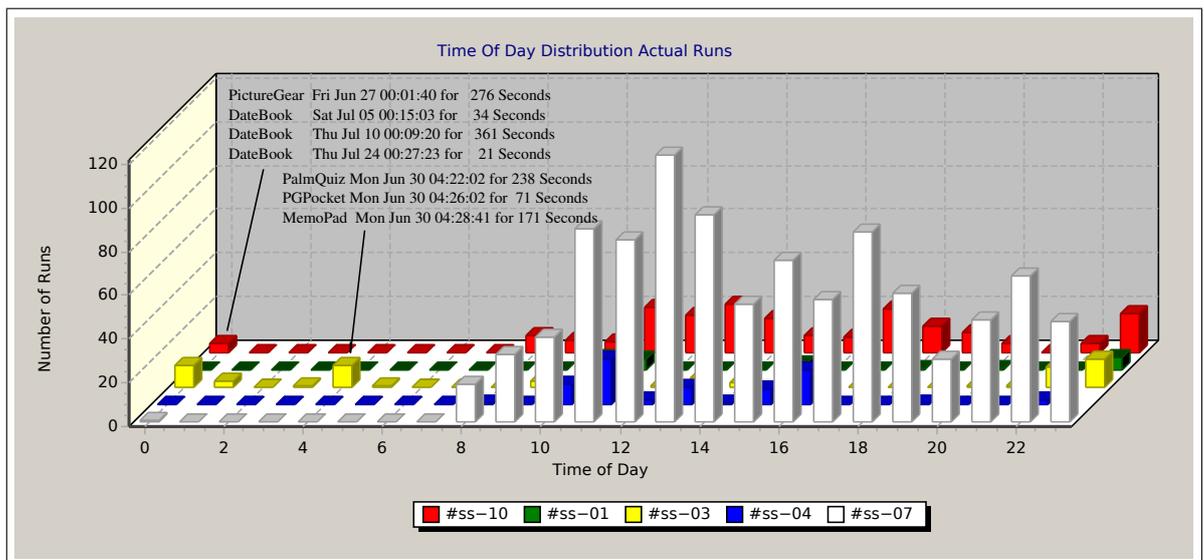


Figure 5.20: Session Distribution by Time of Day Phase 2 Absolute Values

	Phase 1	Phase 1 NoPGM	Phase 2	Phase 2 NoPGM	Phase 3	Phase 3 NoPGM
Log Length (Days)	38	38	25	25	64	64
RUNS	257	222	269	229	310	111
RUNTIME (Seconds)	19016	12947	21864	14598	80561	9811
NUMBAPPS (Seconds)	19	16	15	13	16	9
Percentage Days On Which Used	78	73	56	56	52	36
Ave Runtime Per Log Days (Seconds)	788	487	687	467	1459	209
Ave Runtime Per Actual Days (Seconds)	913	628	894	649	2580	434
Ave Runs Per Log Days	11	10	9	7	5	3
Ave Runs Per Actual Days	13	12	12	11	10	5
Day Factor Percentage	29	27	21	20	32	18
Ave Interval (Seconds)	17056	19439	25767	26854	29207	74822
Median Interval (Seconds)	2732	2753	280	385	186	527
Ave RunTime (Seconds)	76	64	75	64	262	80
Max RunTime (Seconds)	900	818	869	808	4887	1548
Median RunTime (Seconds)	32	28	32	28	38	23
Ave Sleep (Seconds)	11270	11270	34208	34208	40584	30253
Median Sleep (Seconds)	1132	1132	1818	1818	1224	1156
Number of Sleep Events	268	268	164	164	235	228

NoPGM means with Photo, Game and Music Application events removed

Table 5.4: Summary Parameters for Each Phase

	Phase 1	Phase 1 NoPGM	Phase 2	Phase 2 NoPGM	Phase 3	Phase 3 NoPGM
RUNTIME (Seconds)	-2420	-1850	-2940	-2220	-6693	-1063
Ave Runtime Per Log Days (Seconds)	-82	-56	-95	-72	-109	-19
Ave Runtime Per Actual Days (Seconds)	-79	-63	-122	-94	-188	-45
AveInterval (Seconds)	1165	1265	524	580	64	367
Median Interval (Seconds)	3	-1	-25	-18	3	-3
AveRun Time (Seconds)	-10	-10	-10	-9	-20	-9
Median RunTime (Seconds)	-8	-7	-5	-4	-5	-4

NoPGM means with Photo, Game and Music Application events removed

Table 5.5: Summary Parameters Showing Change due to Correction For Automatic Power Off

Change as %	Phase 1	Phase 1 NoPGM	Phase 2	Phase 2 NoPGM	Phase 3	Phase 3 NoPGM
RUNTIME	-12.73	-14.29	-13.45	-15.21	-8.31	-10.83
Ave Runtime Per Log Days	-10.41	-11.5	-13.83	-15.42	-7.47	-9.09
Ave Runtime Per Actual Days	-8.65	-10.03	-13.65	-14.48	-7.29	-10.37
Ave Interval (Seconds)	6.83	6.51	2.03	2.16	0.22	0.49
Median Interval (Seconds)	0.11	-0.04	-8.93	-4.68	1.61	-0.57
Ave RunTime (Seconds)	-13.16	-15.63	-13.33	-14.06	-7.63	-11.25
Median RunTime (Seconds)	-25	-25	-15.63	-14.29	-13.16	-17.39

NoPGM means with Photo, Game and Music Application events removed

Table 5.6: Summary Parameters Showing the Effect of Automatic Power Off as a Percentage

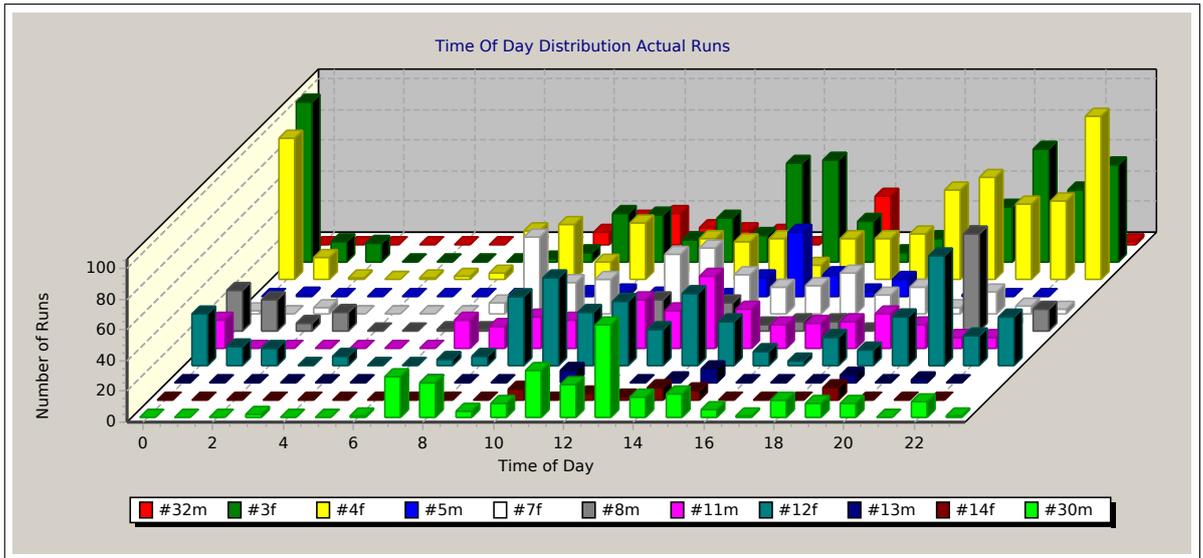


Figure 5.21: Session Distribution by Time of Day Phase 4 Absolute Values

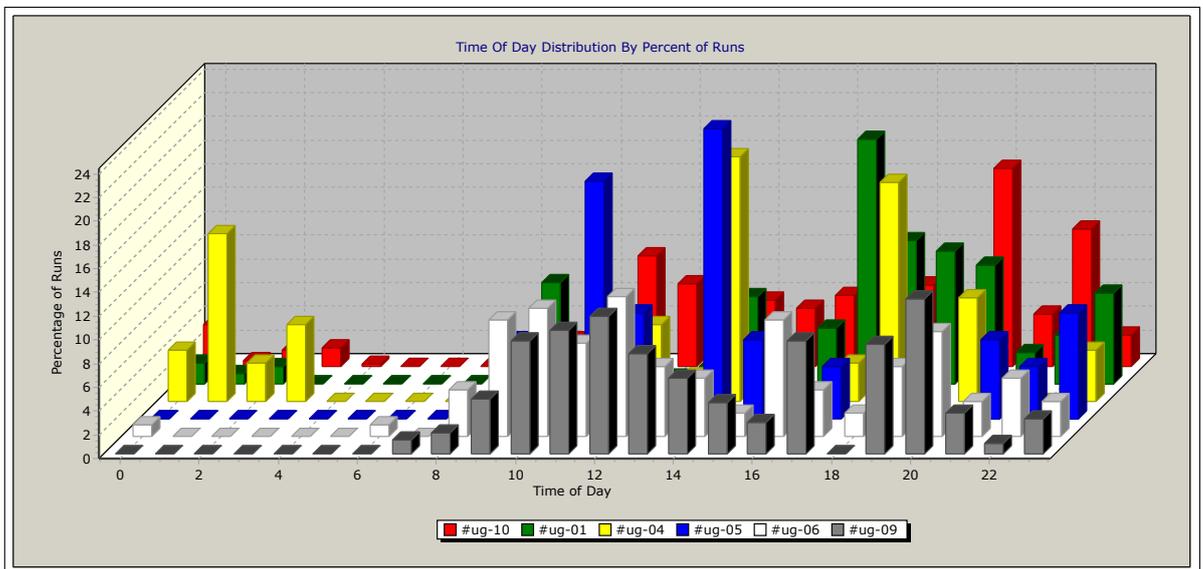


Figure 5.22: Session Distribution by Time of Day Phase 1 Relative Values

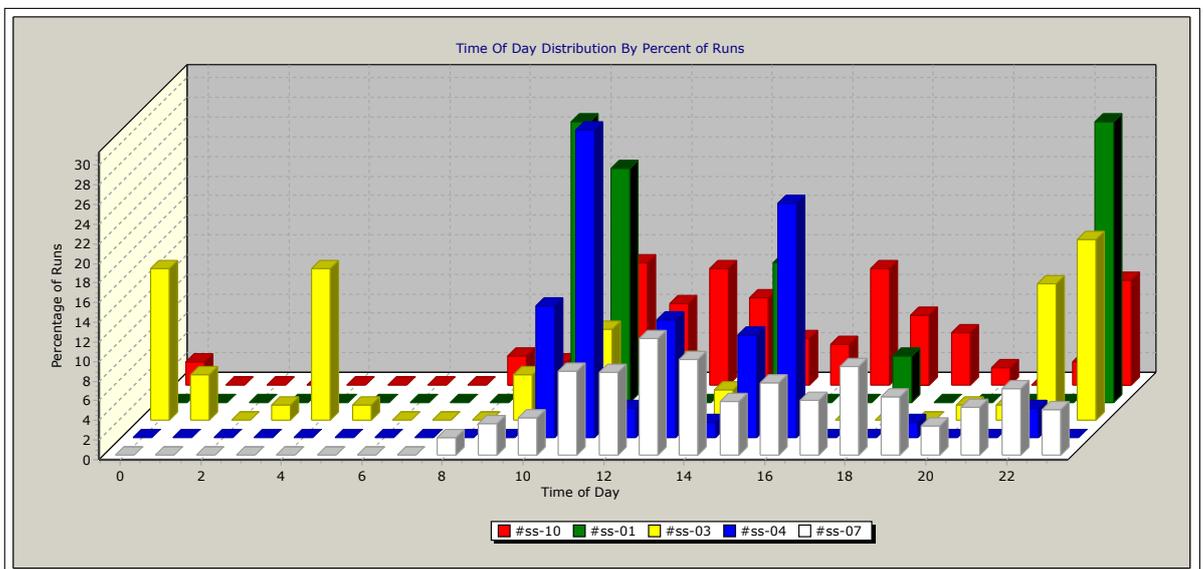


Figure 5.23: Session Distribution by Time of Day Phase 2 Relative Values

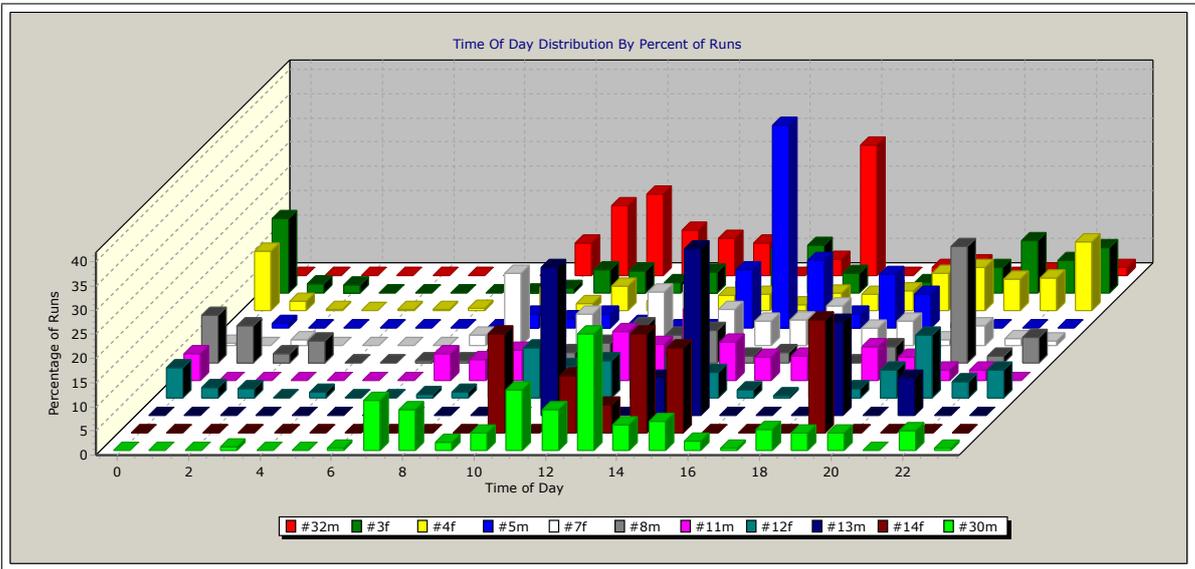


Figure 5.24: Session Distribution by Time of Day Phase 4 Relative Values

Phase 1

In section 5.2.2, when considering the daily use of the PDA made by the Phase 1 students, it was noted that they used their PDAs most frequently on the days of the week when laboratories with the project team were held. We raised the question as to whether this was due to self-perceived pressures due to the presence of project team members, or whether they were simply reminded about the benefits of PDA use on these days. This informs our analysis of the results of figures 5.19 and 5.20. There seems to be two distinct student groups. Students ug-09, ug-10 and ug-01 are frequent PDA users. Typically their use is in the morning, increasing from around 09:00 to a peak at lunchtime, and then showing some use in the afternoon, evening, and late evening - occasionally until the early hours of the morning. For them there is no spike of use at 14:00 when their laboratories with the project team were scheduled to start. The implication for these students is that the labs served as a reminder of PDA benefits, leading them to use their PDAs in the morning, peaking at lunch when morning lectures ended, again around teatime after study, and sometimes late on in the evening. Further analysis shows these students' PDA usage to be a balance between planning/organisational applications, specific function applications (a category that includes the quiz application) and games. The evidence indicates that students appear to be using their PDAs in a normal manner, consistently to their own benefit, and we might predict that such students would be progressing well in their studies, although we have no independent evidence for this. Students ug-04 and ug-05, however, show very low absolute PDA usage, and a strong peak of use at 14:00, at the point where laboratory sessions typically begin. The strong impression is that these students' PDA use is triggered only by perceived social pressure. We also note that practically all the students used their PDAs in the early and late evening. The students could also be orthogonally separated into two groups, equal in number, one (comprising of students ug-05, ug-06, ug-09) of which typically ended PDA use at 23:00, and one (comprising of students ug-10, ug-01 and ug-04) that typically used their PDA until 03:00 in the morning. Unfortunately there was no additional information about the cohort which could be used to separate these groups (for instance knowledge of part-time bar work or similar employment that would provide opportunity for late night PDA use, or information about the students' academic performance) and this is an interesting route for future investigation.

Phase 2

The number of students available in phase 2 was small (only 5), and whilst the results follow the same pattern as for phase 1, and support the conclusions drawn there, there is not enough data to make any clear additional conclusions. However, in the introduction we noted that one of the key benefits of PDAs which instigated this research was the opportunity PDAs gave for students to have access to learning tools

at any time of the day, when convenient to them. In phase 2 student ss-03 shows a clear example of this, when they access the Quiz Application and MemoPad between 04:22 and 04:28 on the morning of 30 June (as annotated in figure 5.21). This cannot be anything other than genuine use of formative assessment tools, at a time when no other source of learning tools was available.

Phase 4

The overall results from students in phase 4 follow the same general pattern as in the previous phases. However, these students uniquely had access to multimedia applications including cameras and music players. We would expect that their use of PDAs in the evening and late evening should be increased due to the availability of such application. This is indeed found to be the case, with both a higher overall PDA use, and greater use of multimedia and game applications during the evenings. Students, as in phase 1 and 2, also fell into two groups, those whose use spanned the whole day with a balanced range of applications (what we have referred to as 'normal' use in phase 1 above) and those whose use was sparse, other than at the beginning of laboratory times, where we suggest that the use was only triggered by the presence of project team members. In phase 4 students 5m and 12f fell into this category. Interestingly, we do have additional information on these students, in the form of overall examination results, and students 5m and 12f had the lowest exam results of the cohort, significantly lower than the broad mass of students.

All the students who made low use of the PDA failed in the course. It was also noted that of the 6 students who made use of the PDA late at night 5 of them passed their exams and in contrast of the 5 students who did not use the PDA late at night 4 of them failed the course. This may indicate it was the more highly motivated students and intellectually stronger students that found uses for the PDA or inclination to explore its use.

Summary of PDA Use By Time Of Day

Most students' PDA use covered the whole day, with peaks at natural break times, and in the late evening. An alternate usage pattern where PDA use was most often triggered by, as far as we can tell, the presence of project team members, was also seen, and in phase 4 students this correlated with exceptionally poor undergraduate exam results - consistent with our view in the students making very low device use were either the very bright students who determined that the PDA did not provide any useful aid to them (perhaps their phone already contained any functionality they desired) or those students that were already struggling in their studies and had started to disengage from their studies.

Other points of interest that were noted are :-

- There are manifest examples of students using their PDA at an unusual time of day for formative assessment.
- Giving students PDAs with rich multimedia applications encourage them to carry the PDA with them.
- Students who did not make any use of the PDA late at night, also had the worse exam performance. This is perhaps an indication of their level engagement with their studies.
- Use of the Quiz was limited, the reason appears to have been that the content had insufficient numbers of questions.

Amount Of Use Throughout The Day

An alternative view of how 'much' the PDA was used can be produced by combining the distributions by day and time into one visualisation. The charts in figures 5.25 on page 110 show a matrix of discrete slices of the hour of the day against day of the week to show when the device was used. The charts show the day of the week on the left hand vertical axis. The hour of the day is shown on the horizontal axis. The key on the right hand side shows the colour code for the cells. The colour of each cell is representative of the number of occasions that the PDA was used on that particular day of the week and hour. These provide a quick means of evaluating how much the device is really being used and show any peaks in activity, for example at lecture times. Combining time of day and day of week data onto one diagram makes it easier to identify areas of greatest activity that are worthy of further investigation. It also makes it easy to identify students who are only making prompted use of the PDA where activity is centred on cells that represent the days of the week and times of lectures and labs where one of the project team was present.

For example the sort of prompted use that was suggested earlier in the analysis of PDA use by day of week can clearly be seen in figure student ug-04 in 5.25 on page 110

A measure from these charts was used to provide a score based the spread of PDA over day of week and hour of day by summing the total cells in which the device had been used giving a score out of 168 (the number of hours in a week). So the number of occupied cells, represents over how much of the day the PDA is used. If for example a user only uses the PDA between 11 and 12 am each day this will yield a lower score than someone who uses the device at times distributed throughout the day.

An example of the day factor charts is shown in 5.25 ug-10 ug-04 From phase 1 and ss07 from phase 2. these were chosen to illustrate the types of activity and usage pattern that can be shown by these charts.

The peak usage for Student ug-10 is on a Friday in the mid evening and late at night. Friday was the day of the labs for this group so this could be an indication they have been reminded about the PDA by because of the lab session or took the PDA with

them for the purposes of the lab and then continued to use it throughout the evening as they had the device with them. For student ug-04 their peak usage is also on a Friday During the lab session, an example of being seen to be using the PDA, this interpretation is supported by the lack of PDA use shown throughout the rest of the week . They also show some evening use again a possible indication they had carried the PDA with them for the lab and then continued to use it as they had it with them.

The final example is an example of the most prolific user in phase 3 , this shows a user who makes significant amounts of use throughout the entire week. They show high use on Monday Tuesday and Wednesday , the summer school day that included PDA use on Monday so the high use on other days shows they were finding the PDA useful for other purposes. They were also using the PDA at other times throughout the day showing that using the PDA had become part of their daily routine. The day charts for all participants in each phase are shown in Appendix A.

5.2.4 Use By Application Type

Having now considered the distribution of PDA use from a perspective of when the PDA was used, this section considers what the PDA was used for based on the type of application used. This section gives an overall analysis of application use. The next section will examine in greater detail the quiz applications specifically written as aids to student learning.

A comparison of how the families of applications were used is shown in figures 5.26, 5.27, 5.28 which shows the amount of use for each application family as a proportion of the total use of the device throughout the project. The apparent anomaly of the use of photo applications on a device without a camera in phase 1 and 2 is due to the presence of an image viewing application.

Phase 1

For phase 1 the predominant use was of organiser applications (calendar, ToDo, Memo etc), though the extent to which the device was used varied between users. High use of the organiser functions of the PDA should not be surprising as this is the primary purpose for which PDAs were originally intended.

After the use of organiser applications the users seem to be divided between those who used games and those who used document applications. The highest users of document applications were low users of games. This shows a split between those who are finding ways to assist their studies and those who are not as academically engaged. Although as with the PDA time of day use we have no independent evidence back up this view. Either use shows that the students were finding ways to use the PDA that were useful to them. Our initial worry had been that the students would not explore the device without prompting but the collected evidence shows this not to have been the case. Quiz use was very low in this phase and not many log files were successfully

collected, a clear indication that syncing the PDAs had not been made easy enough.

Phase 2

In phase 2 the majority of application use, by time and duration, were again the organisational tools. There is however a noticeable difference in the amount of PDA between the users in phase 2.

One student, SS-07, used 4 times as many applications (42) as any of the others in the group. Even though the device was loaned for a short period student ss-07 made the device their own. They installed 16 additional applications on the PDA, evidence of a student finding their own use for the PDA.

In contrast others in the group (such as student ss04) used the PDA as a traditional “organiser” and only used the application that were already installed on the PDA.

The evidence from phase 2 limited as only one student (ss07) made significant use of the machine and there was no additional information available regarding their academic performance. For the rest of the group there is not enough usage data to make any further firm conclusions.

Phase 4

In phase 4 the biggest proportion of use for most users was not of organiser applications, as had been the case in the earlier phases, but of games, photo and music applications.

The devices used in phase 4 were, as was mentioned in 5.1.5 on page 81, chosen because of their enhanced functionality and the camera and music player were intended to appeal to students and give them an immediate reason to carry the PDA with them. The hypothesis was that the students who were using the device for music and games would, due to having the device with them, be more likely to use the PDA in additional ways. Thus the use of the photo and music applications was encouraging. The use of the music application was a strong indication that the music playing function was important to the students. To use the music playing capability of the PDA required the use of an Memory card (aka an SD or MMC Card) which they had to purchase themselves. The literal need to buy in to using the device would also have provided a strong incentive to make use of the PDA and carry it with them.

When photo, music and game applications are removed from the Phase 4 results, the next highest used applications were organiser applications. This raised the question of whether there was any indication that the use of photo, game or music applications had any influence on other uses of the PDA.

Figure 5.29 on page 112 shows a scatter-graph showing the average number of uses per day of organisation applications plotted against the use of music applications. The highest users of music application 32m and 30m also made the most use of organiser applications. Their usage is twice as high as the rest of the group. User 3f was the next

highest user of the organiser tools but was not a high user of music applications. No statistically significant conclusions can be drawn due to the number of users, however this evidence does clearly support the hypothesis that users who make use of a multi-function appliance where there are one or more applications of clear and obvious use to them, do end up exploring and using applications of less immediately obvious benefit.

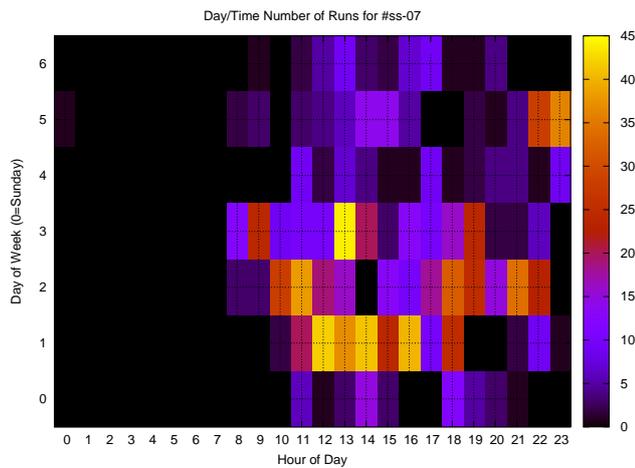
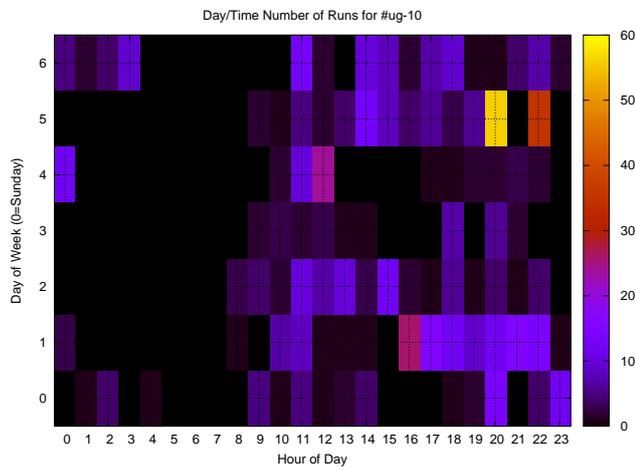
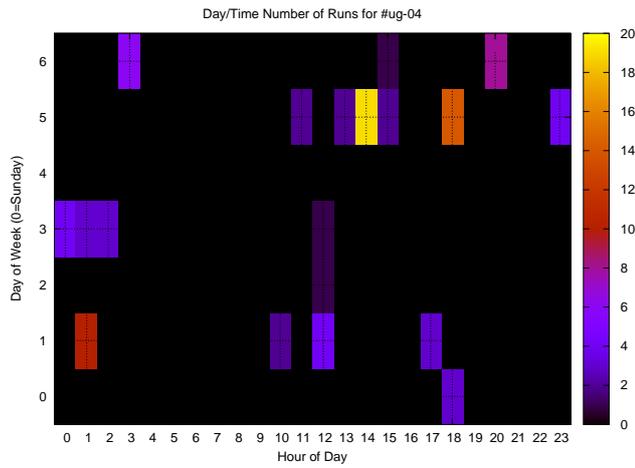
Summary of Application usage

The main use made of the PDA in Phases 1 and 2 were organiser applications and in Phase 4 music and game applications.

The PDAs used in all project phases could be used to play games but the use of games was greater amongst the Phase 4 users possibly due to the richer capability of the device. In Phase 4 the users who made most use of the music playing capability also made most use of the organiser applications strongly suggesting that as the student had the PDA with them for a purpose important to them, the music player, they then made additional use of the PDA.

Student	Log Length (Days)	Runs	Sessions	Number of Apps Used	% of Days Used	Day Factor %	Median Interval (Seconds)	Ave RunTime (Seconds)	Median RunTime (Seconds)	Number of Apps in Top 20	Ave Runs Per Session
Phase 1											
ug-01	14	340	97	30	99	33	76	107	24	20	4
ug-04	14	92	25	11	64	11	80	58	25	11	4
ug-05	14	90	44	14	84	13	163	85	27	14	2
ug-06	60	102	82	6	61	31	15980	98	85	6	1
ug-09	14	345	83	11	100	32	14	27	7	11	4
ug-10	109	570	228	40	58	55	80	80	26	20	3
Phase 2											
ss-01	13	22	7	4	15	4	34	22	7	4	3
ss-03	14	67	38	10	62	13	623	95	55	10	2
ss-04	28	68	22	9	36	7	86	67	32	9	3
ss-07	35	1005	296	42	99	52	65	77	25	20	3
ss-10	34	181	99	12	70	28	595	114	42	12	2
Phase 4											
3f	140	675	234	29	50	51	68	102	24	20	3
4f	105	745	362	28	85	69	451	274	57	20	2
5m	91	100	32	12	17	13	225	294	71	12	3
7f	49	336	157	23	74	43	197	291	47	20	2
8m	83	262	95	17	42	33	67	275	31	17	3
11m	69	318	127	21	61	36	141	515	46	20	3
12f	97	545	216	18	61	55	110	254	29	18	3
13m	24	26	11	4	21	5	53	195	44	4	2
14f	15	35	23	7	47	5	529	123	28	7	2
30m	17	250	66	13	64	23	34	275	15	13	4
32m	16	118	52	9	50	15	170	288	31	9	2

Table 5.7: Summary Project Parameters Per User



(The colour of each cell represents the number of times the PDA was used at the time of day and week and are scaled per user to make it obvious when an individuals peak uses were. The value of each colour is shown on the key at the right of each chart.)

Figure 5.25: Day Factor Charts

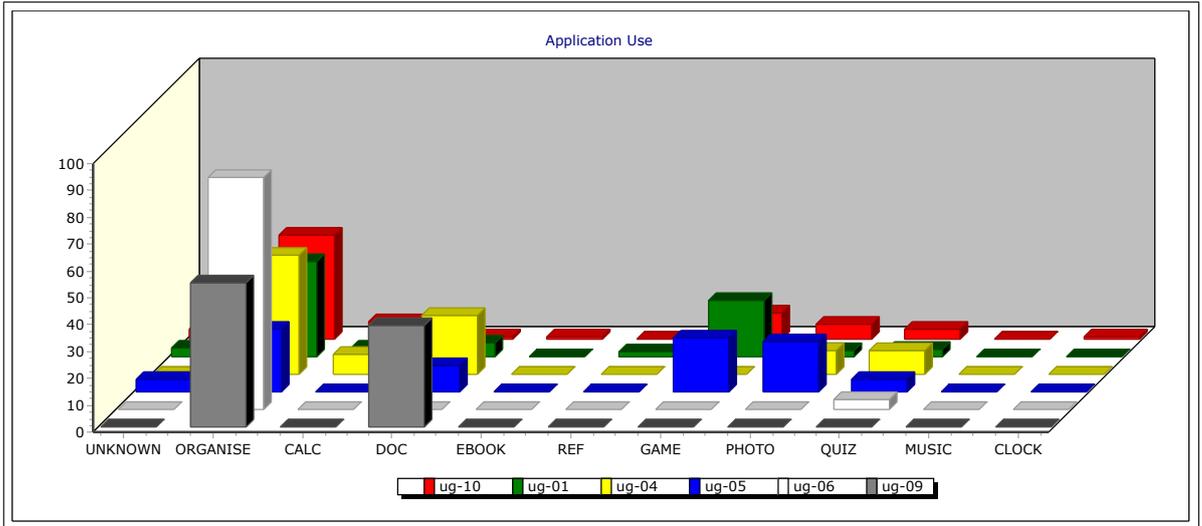


Figure 5.26: Application Family Use by Percentage of Total Uses for Phase 1

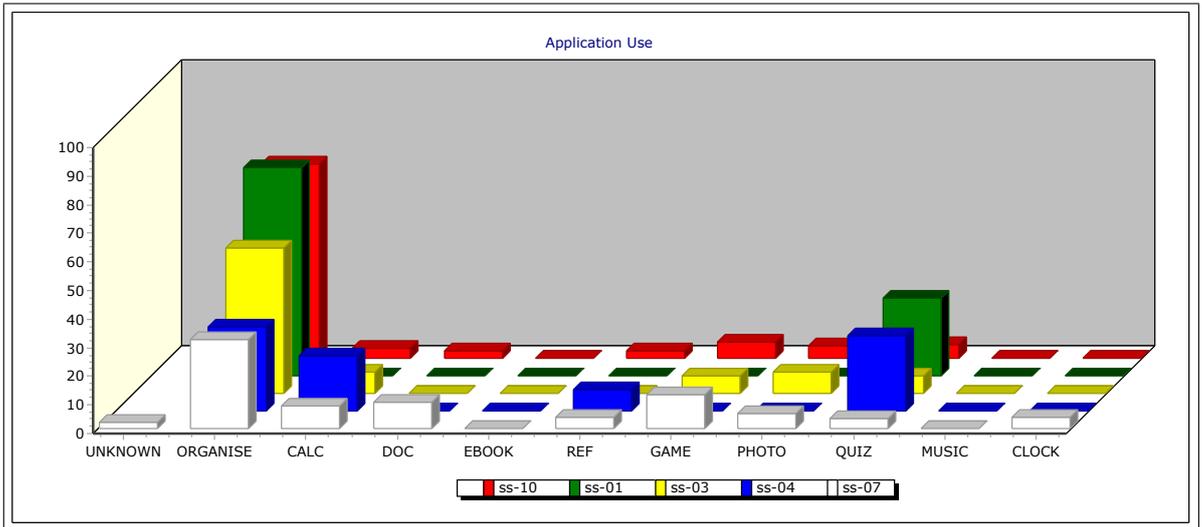


Figure 5.27: Application Family Use by Percentage of Total Uses for Phase 2

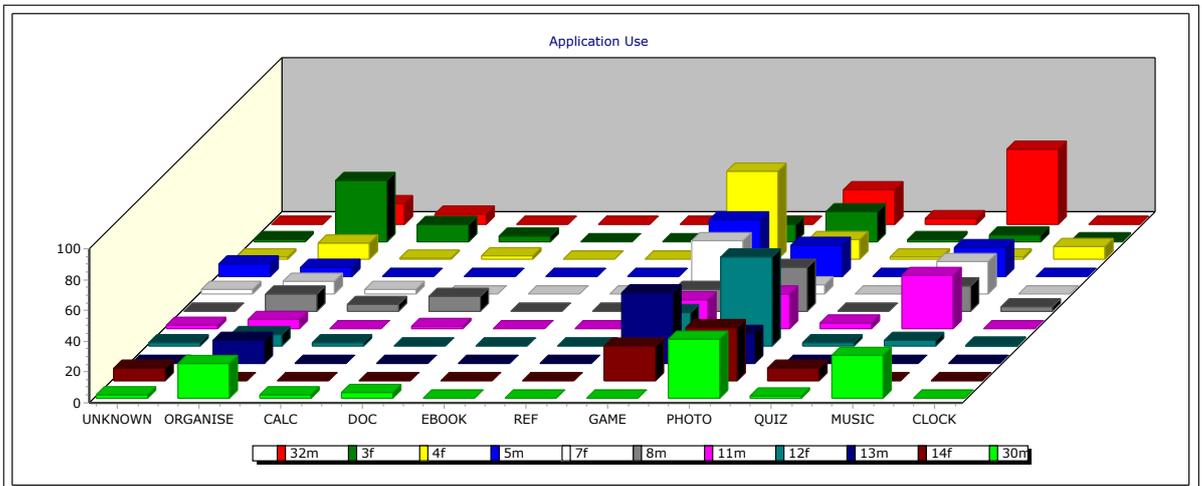


Figure 5.28: Application Family Use by Percentage of Total Uses for Phase 4

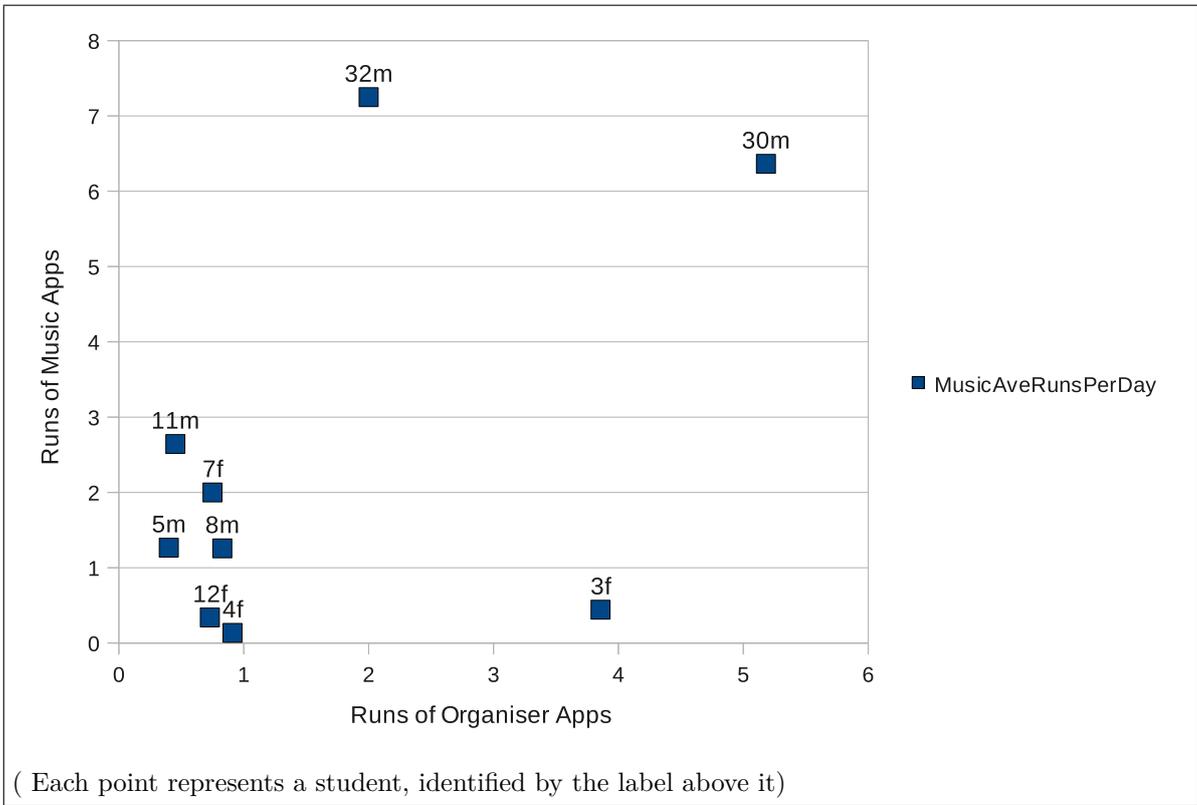


Figure 5.29: Music Use and Organiser Use

5.2.5 Examination of Use of Quiz Applications

In this section the use of the quiz application in phases 1,2 and 4¹of the project is considered.

To illustrate instances of quiz use fragments from the PDA log files are included within the text. Use of the quiz rarely occurred in isolation and most of the uses were interleaved with the use of other applications. Thus to give each instance of quiz use context, the log sections include the applications used before and after the quiz and where it aids the interpretation longer log sections are included.

From the log results it was concluded that there were 7 categories of quiz use and these are briefly explained in table 5.8 on page 116 so that they can be referred to in the subsequent discussions.

A common format is used for each project, each section is introduced with a table showing the number of instances of quiz use and the cumulative time for which the quiz was used in that week of the project phase. An example of the table is shown in Figure 5.9 which is for project phase 1. Empty cells indicate that there was no log data collected for that period. The first week of each phase is numbered 0.

Interpretation of Quiz Use

In making a judgement/conclusion about the type of use made of the Quiz applications shown in table 5.8 the factors taken into consideration were:

1. The duration of use of the application
2. The time at which it was used, i.e. both time of day and day of week.
3. The context based on the applications used before or after the quiz was used.

The rationale behind these categories and interpretation of how student use of the quiz application is assigned to each category is now explained. As per section 5.2.1, there is the possibility of completely accidental QuizApp use, with identifier 4 in table 5.8. There are also types of use often (but not always) instigated by the project team (identifier 5 and 6 in table 5.8). However the prime and intended usage of the Quiz application is to provide formative assessment to the student. Here three different modes of use are likely: evaluation/exploration of the Quiz application itself, without necessarily gaining any educational benefit in basic electronics (identifier 7); and short or long term use of the quiz application for its intended purpose (identifiers 1 and 2). Although not initially a mode of use the project team considered, the work laid out in section 4.1.4 indicates that students would, on occasion, attempt to give an impression contrary to their actual PDA usage - perhaps through peer pressure or their own expectations of the the wishes of the project team. Therefore another mode

¹as previously mentioned there were no logs collected during phase 3.

of use is added to table 5.85.8 (identifier 3) that of pretend or sham use of the quiz application.

The *duration* of use is an important indicator of use mode. The longer the session of quiz application use the more likely it is that the student was trying to gain educational benefit from the application. The difficulty in making judgement based on the duration alone is determining the minimum length of time that may indicate productive use. If the length of the usage is greater than the automatic switch off period of the PDA then the quiz must be being interacted with in some way. If the use is less than the automatic switch off time then the student has either switched to another application or turned the device off, so it is less certain that the use was productive without some additional information to give it context.

The problem of trying to interpret the mode of use based on time of day is the need for a knowledge of the student's timetable. If the application was used during the normal university working hours and was at a time when the student was in a lecture or lab where one of the project team was present the use may have been prompted or the student maybe trying to give the impression they were working , without actually doing so.

But the *time* of day can indicate if the use was made outside of normal working day in the student's own time. Use outside of normal hours is easier to interpret; if the student made use of the application in their own time then it is likely that the use is productive. Why else use the application, unless they were being especially devious in wanting to give the impression of using the PDA?

Additional context may be provided by examining what, if anything, the PDA was used for next and if the quiz application is returned to during that period of use. For example a sequence of use Quiz/Calc/Quiz would suggest the use of the quiz was real and that the calculator had been used to assist in working out the correct answer. Whereas Game/Quiz/Game/Quiz looks less likely to be real use, especially if that use occurred during normal lecture or lab times with a member of the lecturing staff present.

If the only application used during a session of PDA use was the quiz, i.e. the device was turned on in order to use the quiz and no other applications were used this also suggests real use. This interpretation would be reinforced if this sequence of events occurred in the student's own time.

Format of Log Fragments

To facilitate cross referencing, each log fragment is preceded by a unique identifier that indicates the phase of the project, the week number within the phase and the user, thus P1/W02/ug-01 means it is the log for user ug-01 during week 2 of phase 1.

Each line of the log has also been given a number to allow their referencing within the text. Where sections of the log have been removed for clarity the missing section is signified by ellipsis. Instances of quiz use have been italicised and inbold type. The

log sections are annotated with a margin note to draw attention to events of interest. The log entries have the following columns:

[line] [AppName] [AppType] [week] [duration] [Date]

[Line] is the line number added to allow referencing the event in the text

[AppName] The name of application used

[AppType] The family of application for example Game/Quiz

[Week] The week number within the project phase (starting at Week 0)

[Duration] the length of time (in seconds) for which the application was used

[Date] Date and Time of Day

In each phase of the project there were specific lecture times when the student were being taught by a member of the project team and it appears to have been an influence on when the PDAs were used and so these times are given at the start of the each project section.

In some sections of the log the first and last use of the day have been marked ** to indicate first use * to indicate last use.

Identifier	Description	Duration	Notes
1	Genuine use, short sessions.	short <minute	The sessions may be short as use of the quiz is interleaved between the use of another supporting application for example the calculator.
2	Genuine use, long sessions	long >minute	
3	Pretend use short sessions	short (seconds)	User pretending to be working rather than doing something else, such as playing games.
4	Accidental Launch	short (seconds)	Tapped wrong icon, or changed mind about what to do.
5	Diagnostic use	short <minute	These are where the application was launched by project team to check logging or operation of the Quiz
6	Beam receive		A characteristic of the operating system behaviour is that on receiving data destined for a particular program causes the application be be sub-launched. Indicated by preceding application being the beam receive application
7	Exploratory/Evaluation		Investigating the device or application

Table 5.8: Type of Quiz Uses

Quiz Use in Phase 1

User	Week							
	Week 0	Week 1	Week 2	Week3	Week 4	Week 5	Week6	Week 7
ug-01	6/137	3/825	0					
ug-04	3/134	1/19	4/111					
ug-05	2/39	1/22	1/18					
ug-06	0	1/86	2/139	1/8	0	0	0	
ug-09	0	0	0					
ug-10	3/77	6/842	11/1128	0	0	0	0	0

Empty cells indicate no log data for that period.

(Number in cell show the number of uses of quiz/cumulative time quiz used)

Table 5.9: Phase 1 Quiz Use

Interpretation of Quiz Use in Phase 1 This group of undergraduate students had their lectures delivered by a member of the project team on Friday afternoons. The use of the quiz stops within 3 weeks.

In Week 0 the launches of the quiz appear to be exploratory with only ug-01 and ug-04 using the quiz for longer than 60 seconds.

In Week 1 users ug-01 and ug-10 have used the quiz for a cumulative time of over 800 seconds, nearly ten times as much as any of the rest of the group. Points of note in this week are that ug-10 used the PDA in the evening specifically to use the quiz and ug-01 used the quiz for 800 seconds in a single session outside of normal lecture times.

Week 2 is the last time significant use of the quiz was made. Ug-10 used the quiz 11 times with a cumulative time of 1128 seconds (nearly 20 minutes). ug-10 also interleaved use of the quiz with the calculator, presumably to help answer the questions. This was that last week that ug-10 made of the quiz. The other high user from the previous week, ug-01 did not use the quiz at all this week. A pattern that is seen in this phase that recurs in the other phases is of the quiz being used around the start time of a lecture, for this phase this can be seen in the logs p1/w2/ug-04, ug-06, ug-10 at around 14:00. What is not clear is if this is attempting to look as though they are working or actually using the device, perhaps for revision before the lecture.

Phase 1 Week 0

* Phase 1 Week 0

p1/w0/ug-01

[line] [AppName] [AppType] [week] [duration] [date and time of day]

```

01: PalmQuiz      QUIZ      0    11 Fri Feb 28 09:20:48 2003 7
02: SheetToGo     DOC        0     1 Fri Feb 28 09:21:07 2003
03: Digitizer     SYSUTIL    0    14 Fri Feb 28 16:37:02 2003
04: PalmQuiz      QUIZ      0    14 Fri Feb 28 16:43:13 2003 7
05: DocsToGo      DOC        0   113 Fri Feb 28 16:45:11 2003
06: SheetToGo     DOC        0   291 Fri Feb 28 16:47:04 2003
...
07: Gen Prefs     SYSUTIL    0     5 Fri Feb 28 18:06:49 2003
08: PalmQuiz      QUIZ      0     7 Fri Feb 28 18:06:59 2003
09: prefs         SYSUTIL    0     1 Fri Feb 28 18:07:08 2003
10: Registered    UNKNOWN    0     8 Fri Feb 28 18:07:10 2003
11: PalmQuiz      QUIZ      0    93 Fri Feb 28 18:07:20 2003
12: prefs         SYSUTIL    0     1 Fri Feb 28 18:09:00 2003
13: Registered    UNKNOWN    0     7 Fri Feb 28 18:09:01 2003
14: PalmQuiz      QUIZ      0     6 Fri Feb 28 18:09:10 2003 7
15: CLIE Demo     SYSUTIL    0    55 Fri Feb 28 18:09:30 2003
16: Registered    UNKNOWN    0     7 Fri Feb 28 18:09:01 2003
17: PalmQuiz      QUIZ      0     6 Fri Feb 28 18:09:10 2003 7
18: CLIE Demo     SYSUTIL    0    55 Fri Feb 28 18:09:30 2003

```

Line 01:
This was a
test that
logging
system was
working

These are
all on the
first day the
user had the
PDA. These
look like
exploratory
launches of
the quiz

These are all on the first day the user had the PDA. As this last

session of use is outside normal hours the 93 second use at 18:07 may be genuine use of the quiz. But as the other sessions are short and include 2 uses of the Demonstration application supplied with the device these look like exploratory launches.

```

=====
===== p1/w0/ug-04 =====
=====
01: Calculator    CALC      0   60 Fri Feb 28 14:28:41 2003
02: PalmQuiz     QUIZ      0   93 Fri Feb 28 14:29:46 2003
03: Calculator    CALC      0   12 Fri Feb 28 14:31:19 2003
...
04: ToDo         ORGANISE  0  114 Fri Feb 28 23:53:01 2003
05: PalmQuiz     QUIZ      0    6 Fri Feb 28 23:56:04 2003 7
06: Cardinfo     SYSUTIL   0    2 Fri Feb 28 23:57:37 2003
...
07: Registered   PHOTO     0   90 Sat Mar 01 20:15:13 2003
08: PalmQuiz     QUIZ      0   35 Sat Mar 01 20:17:16 2003 7 or 1
09: DocsToGo     DOC       0   16 Sat Mar 01 20:20:57 2003
=====
===== p1/w0/ug-05 =====
=====
01: MemoPad      ORGANISE  0  120 Sat Mar 01 22:26:35 2003
02: PalmQuiz     QUIZ      0   20 Sat Mar 01 23:15:20 2003 7
03: Date/Time    UNKNOWN   0    6 Sat Mar 01 23:16:18 2003
...
04: HotSync      SYSUTIL   0   10 Sun Mar 02 09:21:53 2003
05: PalmQuiz     QUIZ      0   19 Sun Mar 02 16:02:19 2003 7
06: Phoinix     GAME      0   63 Sun Mar 02 21:08:57 2003
=====
===== p1/w0/ug-10 =====
=====
01: PrefsButtons SYSUTIL   0    4 Fri Feb 28 20:05:06 2003
02: PalmQuiz     QUIZ      0   25 Fri Feb 28 20:05:23 2003 7
03: PrefsButtons SYSUTIL   0    7 Fri Feb 28 20:06:09 2003
...
04: Ext_Manager  SYSUTIL   0   56 Sat Mar 01 03:39:45 2003
05: PalmQuiz     QUIZ      0   25 Sat Mar 01 03:40:45 2003 7
06: AppLog       SYSUTIL   0   45 Sat Mar 01 03:41:18 2003
...
07: GraffitiDemo SYSUTIL   0    3 Mon Mar 03 20:02:07 2003
08: PalmQuiz     QUIZ      0   27 Mon Mar 03 20:02:26 2003 7
09: Phoinix     GAME      0  431 Mon Mar 03 20:03:03 2003

```

Second day
of PDA
ownership
these look
like more
exploratory
launches

Phase 1 Week 1

```

*****
* Phase 1 Week 1
*****

```

```

=====
===== p1/w1/ug-01 =====
=====
[line] [AppName] [AppType] [week] [duration] [date and time of day]
01: PalmQuiz    QUIZ      1   4 Wed Mar 12 12:07:07 2003
02: ToDo        ORGANISE  1  11 Wed Mar 12 14:02:51 2003
03: prefs       SYSUTIL   1   1 Wed Mar 12 14:03:12 2003
04: BatteryLog  SYSUTIL   1  14 Wed Mar 12 14:04:01 2003
05: PalmQuiz    QUIZ      1   6 Wed Mar 12 14:04:24 2003 7,3,1
06: DateBook    ORGANISE  1  60 Wed Mar 12 14:04:54 2003
...
07: HardBall    GAME      1 108 Wed Mar 12 17:28:12 2003
08: PalmQuiz    QUIZ      1 815 Wed Mar 12 17:30:05 2003

09: HardBall    GAME      1 961 Wed Mar 12 17:43:44 2003
p1/w1/ug-04
01: Registered  PHOTO     1   4 Wed Mar 12 00:31:20 2003
02: PalmQuiz    QUIZ      1  19 Wed Mar 12 00:32:05 2003 1,3
03: Calculator  CALC      1   6 Wed Mar 12 00:32:24 2003
=====
===== p1/w1/ug-05 =====
=====
01: PGPocket    PHOTO     1  21 Wed Mar 12 10:01:57 2003
02: PalmQuiz    QUIZ      1  22 Wed Mar 12 11:56:50 2003 1,3
03: MemoPad     ORGANISE  1  61 Wed Mar 12 11:59:14 2003
=====
===== p1/w1/ug-06 =====
=====
01: Digitizer   SYSUTIL   1  14 Wed Mar 12 11:55:10 2003
02: PalmQuiz    QUIZ      1  86 Wed Mar 12 11:55:53 2003 1,3
03: DateBook    ORGANISE  1 124 Wed Mar 12 16:23:07 2003
=====
===== p1/w1/ug-10 =====
=====
01: MemoPad     ORGANISE  1 120 Wed Mar 12 09:31:01 2003
02: PalmQuiz    QUIZ      1 120 Wed Mar 12 11:53:49 2003 1,3
03: PalmQuiz    QUIZ      1  22 Wed Mar 12 12:06:24 2003 1,3
04: MemoPad     ORGANISE  1  65 Wed Mar 12 13:49:05 2003
...
05: DateBook    ORGANISE  1  82 Wed Mar 12 18:15:59 2003
06: PalmQuiz    QUIZ      1 266 Wed Mar 12 18:25:45 2003 2
07: PalmQuiz    QUIZ      1   5 Wed Mar 12 18:30:14 2003 1
08: BatteryLog  SYSUTIL   1  22 Wed Mar 12 18:30:31 2003
09: Registered  PHOTO     1  11 Wed Mar 12 18:31:22 2003
10: PalmQuiz    QUIZ      1 412 Wed Mar 12 18:56:42 2003 2
11: ToDo        ORGANISE  1  32 Wed Mar 12 20:21:47 2003
12: All the above are on the same day.
...
13: PalmQuiz    QUIZ      1  17 Thu Mar 13 11:05:42 2003 1,3

```

08: significant about of quiz use, outside of normal hours

02: Out of hours, so why pretend, unless for our benefit

The quiz uses by ug-05 ug-06 and ug-10 all happen at the same time 11:55

06: This is in the evening and the PDA was switched on specifically to use the quiz

```

14: Phoinix      GAME      1  68 Thu Mar 13 11:06:05 2003
15: Gen Prefs   SYSUTIL   1   6 Thu Mar 13 11:07:22 2003

```

Phase 1 Week 2

```
*****
```

```
* Phase 1 Week 2
```

```
*****
```

```
=====
```

```
===== p1/w2/ug-04 =====
```

```
=====
```

```
[line] [AppName] [AppType] [week] [duration] [date and time of day]
```

```

01: MemoPad      ORGANISE  2 120 Fri Mar 14 13:30:23 2003
02: PalmQuiz    QUIZ      2  21 Fri Mar 14 13:58:46 2003
03: PalmQuiz    QUIZ      2   3 Fri Mar 14 14:01:07 2003
04: PalmQuiz    QUIZ      2  14 Fri Mar 14 14:04:24 2003
05: DateBook    ORGANISE  2   3 Fri Mar 14 14:04:52 2003
06: Registered  PHOTO    2 149 Fri Mar 14 14:05:52 2003
07: PalmQuiz    QUIZ      2  73 Fri Mar 14 14:09:03 2003
08: DocsToGo    DOC       2  35 Fri Mar 14 14:10:20 2003

```

```
=====
```

```
===== p1/w2/ug-05 =====
```

```
=====
```

```

01: PalmQuiz    QUIZ      2  18 Fri Mar 14 11:06:07 2003
02: DocsToGo    DOC       2   3 Fri Mar 14 11:16:17 2003
03: MSGate      SYSUTIL   2 246 Fri Mar 14 11:16:33 2003

```

```
=====
```

```
===== p1/w2/ug-06 =====
```

```
=====
```

```

01: PalmQuiz    QUIZ      2  76 Fri Mar 14 13:59:20 2003
02: PalmQuiz    QUIZ      2  63 Fri Mar 14 14:01:19 2003
03: MemoPad     ORGANISE  2  27 Fri Mar 14 14:09:55 2003
04: MemoPad     ORGANISE  2  84 Fri Mar 14 14:27:31 2003

```

```
=====
```

```
===== p1/w2/ug-10 =====
```

```
=====
```

```
[line] [AppName] [AppType] [week] [duration] [date and time of day]
```

```

01: PalmQuiz    QUIZ      2 122 Fri Mar 14 11:15:59 2003
02: EasyCalc    CALC      2 104 Fri Mar 14 11:32:32 2003
03: PalmQuiz    QUIZ      2 125 Fri Mar 14 11:34:19 2003
04: EasyCalc    CALC      2  10 Fri Mar 14 11:39:44 2003
05: PalmQuiz    QUIZ      2 126 Fri Mar 14 11:39:55 2003
06: Phoinix     GAME      2  44 Fri Mar 14 13:23:46 2003
07: MSGate      SYSUTIL   2  64 Fri Mar 14 13:25:01 2003
08: PalmQuiz    QUIZ      2 128 Fri Mar 14 13:49:55 2003
09: HotSync     SYSUTIL   2  81 Fri Mar 14 14:00:06 2003
10: PalmQuiz    QUIZ      2 128 Fri Mar 14 14:01:34 2003
11: PalmQuiz    QUIZ      2 110 Fri Mar 14 14:09:07 2003
12: EasyCalc    CALC      2  84 Fri Mar 14 14:10:57 2003
13: HotSync     SYSUTIL   2  11 Fri Mar 14 14:19:10 2003

```

ug-04, ug-06,
ug-10 use
the quiz
at similar
time, around
14:00. Start
of lecture

This looks like
genuine use,
using the
calculator to
solve the
questions.

```

14: EasyCalc    CALC      2  55 Fri Mar 14 15:16:52 2003
15: PalmQuiz   QUIZ      2 156 Fri Mar 14 15:18:19 2003

```

This looks like genuine use by ug10 with the calculator being used in order to assist in answering the questions. The duration of the uses of just over 120 seconds, may indicate using the quiz, then allowing the device to power off, possibly during which time the user was thinking about the question.

The use made by ug-04, ug-06, ug-10 at around 14:00 may be using the PDA at the start of the lecture, either to be seen using it or to do a bit of pre lecture revision.

```

16: EasyCalc    CALC      2 117 Fri Mar 14 15:50:12 2003
17: PalmQuiz   QUIZ      2 123 Fri Mar 14 15:52:13 2003
...
18: EasyCalc    CALC      2  58 Fri Mar 14 16:18:00 2003
19: PalmQuiz   QUIZ      2 108 Fri Mar 14 16:19:03 2003
20: EasyCalc    CALC      2 119 Fri Mar 14 16:20:51 2003
21: PalmQuiz   QUIZ      2  88 Fri Mar 14 16:23:12 2003
22: ToDo        ORGANISE  2  45 Fri Mar 14 20:27:01 2003
23: MemoPad     ORGANISE  2  78 Sat Mar 15 14:49:00 2003
24: PalmQuiz   QUIZ      2  42 Sat Mar 15 15:03:34 2003
25: Phoinix     GAME      2  16 Sat Mar 15 15:35:31 2003

```

This also looks like genuine use, again using the calculator to solve the questions.

This is quite short but based on the amount of use made of the quiz the day before it may be genuine use. During the recorded use of the quiz during week 2 all but two occurred on the day of a lecture with one of the project team present and only one outside of normal working hours.

Phase 1 Week 3

```

*****
* Phase 1 Week 3
*****
=====
===== p1/w2/ug-06 =====
=====
01: PalmQuiz   QUIZ      3  8 Tue Mar 25 09:14:27 2003
02: MemoPad     ORGANISE  3  5 Tue Mar 25 10:13:52 2003

```

Looks like a spurious launch

Summary of Quiz Use in Phase 1 ug-10 used the quiz during the first 3 weeks and then made no further use of the quiz. A similar pattern can be seen from user ug-01 who used the quiz for a long time during week 2 and made no use of it the following week. The clear indication is that the students felt that they had mastered the material by this point

Quiz Use in Phase 2

User	Week							
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
ss-01	6/243		0					
ss-03	2/263	0	1/122	1/424				
ss-04	14/805		4/702	0	0			
ss-07	26/2161	3/244	7/280	0	0	0	0	0
ss-10	8/501	1/271	0	0	0			

Empty cells indicate no log data for that period.

(Number in cell show the number of uses of quiz/cumulative time quiz used)

Table 5.10: Phase 2 Quiz Use

Interpretation of Quiz Use in Phase 2 The summer school students had lecture and lab sessions with member of project team on Tuesday and Wednesdays.

Phase 2 Week 0 The cumulative use of the quiz ranges from 243 seconds to 2161 seconds and the amount of times the Quiz was used from 2 to 26 occasions.

* Phase 2 Week 0

=====
 ===== p2/w0/ss-01 =====
 =====

[AppName] [AppType] [week] [time] [date and time of day]

```
01: PalmQuiz    QUIZ    0    20 Tue Jun 24 10:53:27 2003
02: DateBook    ORGANISE 0    3 Tue Jun 24 10:53:47 2003
03: ToDo        ORGANISE 0    2 Tue Jun 24 10:53:52 2003
04: MemoPad     ORGANISE 0    6 Tue Jun 24 10:53:54 2003
05: PalmQuiz    QUIZ    0    40 Tue Jun 24 10:55:46 2003
06: PalmQuiz    QUIZ    0    22 Tue Jun 24 10:56:26 2003
07: PalmQuiz    QUIZ    0    9 Tue Jun 24 11:38:28 2003
08: DateBook    ORGANISE 0    7 Tue Jun 24 11:38:37 2003
09: MemoPad     ORGANISE 0    1 Tue Jun 24 11:38:44 2003
10: ToDo        ORGANISE 0    5 Tue Jun 24 11:38:45 2003
11: MemoPad     ORGANISE 0    7 Tue Jun 24 11:39:28 2003
12: ToDo        ORGANISE 0    9 Tue Jun 24 18:11:43 2003
13: ToDo        ORGANISE 0    32 Tue Jun 24 23:09:06 2003
14: PalmQuiz    QUIZ    0    145 Tue Jun 24 23:10:04 2003
15: PalmQuiz    QUIZ    0    7 Tue Jun 24 23:12:37 2003
16: DateBook    ORGANISE 0    6 Tue Jun 24 23:13:11 2003
17: ToDo        ORGANISE 0    12 Tue Jun 24 23:13:17 2003
18: MemoPad     ORGANISE 0    15 Tue Jun 24 23:13:29 2003
```

Late night
use, looks
like real use

=====
 ===== p2/w0/ss-03 =====
 =====

```
01: Address     ORGANISE 0    49 Mon Jun 30 03:57:52 2003
```

```

02: PalmQuiz      QUIZ      0    238 Mon Jun 30 04:22:02 2003
03: PGPocket      PHOTO     0     71 Mon Jun 30 04:26:02 2003
04: MemoPad       ORGANISE  0    171 Mon Jun 30 04:28:41 2003
05: PalmQuiz      QUIZ      0     25 Mon Jun 30 09:12:16 2003
06: Address       ORGANISE  0     48 Mon Jun 30 09:12:41 2003
07: MemoPad       ORGANISE  0     81 Mon Jun 30 09:16:21 2003

```

Use in the
early hours
of the
morning,
looks like
real use

```

=====
===== p2/w0/ss-04 =====
=====

```

```

01: DateBook      ORGANISE  0      2 Mon Jun 23 11:20:48 2003
02: Address       ORGANISE  0     52 Mon Jun 23 11:20:50 2003
03: ExtManager    SYSUTIL   0     53 Mon Jun 23 11:21:58 2003
04: PalmQuiz      QUIZ      0     32 Mon Jun 23 11:23:15 2003
05: PalmQuiz      QUIZ      0     44 Mon Jun 23 11:23:48 2003
06: PalmQuiz      QUIZ      0     44 Mon Jun 23 11:26:01 2003
07: PalmQuiz      QUIZ      0     24 Mon Jun 23 11:26:52 2003
08: Address       ORGANISE  0     72 Mon Jun 23 11:29:46 2003
09: Calculator    CALC      0      3 Mon Jun 23 11:31:02 2003
10: EasyCalc      CALC      0      5 Mon Jun 23 11:31:10 2003
11: Address       ORGANISE  0     41 Mon Jun 23 11:32:36 2003
12: PalmQuiz      QUIZ      0     11 Mon Jun 23 12:57:45 2003
13: PalmQuiz      QUIZ      0     98 Mon Jun 23 12:58:01 2003
14: Address       ORGANISE  0     11 Mon Jun 23 13:01:09 2003
15: HotSync       SYSUTIL   0     12 Mon Jun 23 13:03:26 2003
16: PalmQuiz      QUIZ      0     79 Mon Jun 23 13:05:34 2003
17: Address       ORGANISE  0     41 Mon Jun 23 16:38:43 2003
18: PalmQuiz      QUIZ      0     47 Mon Jun 23 16:40:27 2003
19: PalmQuiz      QUIZ      0     25 Mon Jun 23 16:42:07 2003
20: Address       ORGANISE  0     35 Mon Jun 23 16:43:43 2003
21: Calculator    CALC      0     71 Mon Jun 23 16:45:25 2003
22: Address       ORGANISE  0     59 Mon Jun 23 16:46:49 2003
23: Address       ORGANISE  0     24 Mon Jun 23 16:47:50 2003
24: Address       ORGANISE  0     21 Mon Jun 23 16:48:16 2003

```

These uses
are during
the lectures

```

...
25: PalmQuiz      QUIZ      0     39 Mon Jun 23 16:48:55 2003
26: PalmQuiz      QUIZ      0     41 Sun Jun 29 13:18:45 2003
27: PalmQuiz      QUIZ      0    280 Sun Jun 29 13:19:29 2003
28: MemoPad       ORGANISE  0     18 Sun Jun 29 13:24:31 2003
29: Calculator    CALC      0      9 Sun Jun 29 13:25:14 2003
30: EasyCalc      CALC      0      7 Sun Jun 29 13:25:41 2003
31: PalmQuiz      QUIZ      0     34 Sun Jun 29 14:03:36 2003
32: ExtManager    SYSUTIL   0      2 Sun Jun 29 15:52:24 2003
...
33: PalmQuiz      QUIZ      0      7 Mon Jun 30 10:01:53 2003
34: Electronics  REF       0     21 Mon Jun 30 10:02:11 2003
35: Electronics  REF       0     61 Mon Jun 30 10:02:32 2003
36: Calculator    CALC      0     22 Mon Jun 30 10:03:33 2003

```

A gap in use
of a week.
This looks
like revision
prior to
Monday
lectures

```

=====
===== p2/w0/ss-07 =====
=====

```

```

=====
01: MemoPad      ORGANISE  0    74 Mon Jun 23 11:25:32 2003
02: PalmQuiz    QUIZ      0     6 Mon Jun 23 11:26:50 2003
03: Calculator  CALC      0     1 Mon Jun 23 11:26:56 2003
04: PalmQuiz    QUIZ      0    29 Mon Jun 23 11:27:08 2003
05: *XACCBearRX SYSUTIL   0     1 Mon Jun 23 11:27:37 2003
06: PalmQuiz    QUIZ      0    17 Mon Jun 23 11:27:38 2003
07: *XPUTBeamTX SYSUTIL   0    27 Mon Jun 23 11:27:55 2003
08: DocsToGo    DOC       0    26 Mon Jun 23 11:28:26 2003
09: ToDo        ORGANISE  0    60 Mon Jun 23 11:28:56 2003
10: ToDo        ORGANISE  0     8 Mon Jun 23 11:30:06 2003
11: MemoPad     ORGANISE  0    16 Mon Jun 23 12:33:24 2003
12: Mail        EMAIL     0    13 Mon Jun 23 12:33:44 2003
13: HotSync     SYSUTIL   0     2 Mon Jun 23 12:33:59 2003
14: PalmQuiz    QUIZ      0    38 Mon Jun 23 12:34:05 2003
15: ToDo        ORGANISE  0    13 Mon Jun 23 12:34:51 2003
16: Date/Time   UNKNOWN   0    21 Mon Jun 23 12:35:35 2003
...
17: Registered  UNKNOWN   0     3 Mon Jun 23 16:22:01 2003
18: PalmQuiz    QUIZ      0   148 Mon Jun 23 16:22:06 2003
19: Ext_Manager SYSUTIL   0    10 Mon Jun 23 16:24:48 2003
20: Calculator  CALC      0     8 Mon Jun 23 16:24:58 2003
...
21: MSGate      SYSUTIL   0    44 Tue Jun 24 18:37:15 2003
22: Registered  UNKNOWN   0     3 Tue Jun 24 18:38:02 2003
23: PalmQuiz    QUIZ      0    45 Tue Jun 24 18:51:00 2003
24: PGPocket    PHOTO     0     4 Tue Jun 24 18:51:51 2003
25: Mail        EMAIL     0    50 Tue Jun 24 18:52:11 2003
...
26: MemoPad     ORGANISE  0    13 Tue Jun 24 21:08:16 2003
27: PalmQuiz    QUIZ      0   284 Tue Jun 24 21:08:34 2003
28: TicTacToe_3d GAME      0   130 Tue Jun 24 21:13:22 2003
29: HotSync     SYSUTIL   0    60 Tue Jun 24 21:16:14 2003
30: Mail        EMAIL     0   292 Tue Jun 24 21:17:16 2003
31: WorldAlarm  CLOCK     0     4 Tue Jun 24 21:22:08 2003
32: WorldAlarm  CLOCK     0    88 Tue Jun 24 21:22:14 2003
33: Connect4    GAME      0    85 Tue Jun 24 21:23:55 2003
34: CLIE Demo   SYSUTIL   0    27 Tue Jun 24 21:25:28 2003
35: PalmQuiz    QUIZ      0    35 Tue Jun 24 21:27:42 2003
36: Calculator  CALC      0    15 Tue Jun 24 21:28:17 2003
37: PalmQuiz    QUIZ      0    36 Tue Jun 24 21:28:34 2003
38: Calculator  CALC      0    10 Tue Jun 24 21:29:10 2003
39: PalmQuiz    QUIZ      0    24 Tue Jun 24 21:29:22 2003
40: Calculator  CALC      0    23 Tue Jun 24 21:29:46 2003
41: PalmQuiz    QUIZ      0   108 Tue Jun 24 21:30:10 2003
42: MemoPad     ORGANISE  0     3 Tue Jun 24 21:41:57 2003
43: PalmQuiz    QUIZ      0   254 Tue Jun 24 21:42:02 2003
44: Ext_Manager SYSUTIL   0    35 Tue Jun 24 21:46:21 2003
45: Address     ORGANISE  0     1 Tue Jun 24 21:47:12 2003

```

Quiz interleaved with the calculator but very short uses.

Beaming (05:) may explain the short launches of the quiz

Use of the quiz interleaved with the calculator. This is late evening so looks like real use

This shows the PDA being used late in the evening for applications

```

46: ChemTable REF 0 90 Tue Jun 24 22:12:15 2003
47: Calculator CALC 0 24 Tue Jun 24 22:13:45 2003
48: EasyCalc CALC 0 266 Tue Jun 24 22:18:11 2003
49: ChemTable REF 0 34 Tue Jun 24 22:22:43 2003
50: Calculator CALC 0 33 Tue Jun 24 22:23:17 2003
51: ChemTable REF 0 1 Tue Jun 24 22:23:52 2003
52: EasyCalc CALC 0 108 Tue Jun 24 22:23:57 2003
53: DateBook ORGANISE 0 101 Tue Jun 24 22:52:17 2003
...
54: WorldAlarm CLOCK 0 3 Wed Jun 25 08:04:25 2003
55: MemoPad ORGANISE 0 54 Wed Jun 25 08:54:53 2003
56: PalmQuiz QUIZ 0 117 Wed Jun 25 09:15:55 2003
57: TicTacToe_3d GAME 0 35 Wed Jun 25 09:17:54 2003
58: PalmQuiz QUIZ 0 28 Wed Jun 25 09:30:39 2003
=====
===== p2/w0/ss-10 =====
=====
01: PalmQuiz QUIZ 0 100 Mon Jun 23 15:10:46 2003
02: Registered PHOTO 0 83 Mon Jun 23 15:20:38 2003
03: GraffitiDemo SYSUTIL 0 99 Mon Jun 23 16:02:49 2003
04: GraffitiDemo SYSUTIL 0 6 Mon Jun 23 16:59:56 2003
05: MemoPad ORGANISE 0 17 Mon Jun 23 17:00:02 2003
06: ToDo ORGANISE 0 3 Mon Jun 23 17:00:19 2003
07: MemoPad ORGANISE 0 33 Mon Jun 23 17:00:22 2003
08: Address ORGANISE 0 17 Mon Jun 23 17:15:12 2003
09: DocsToGo DOC 0 12 Mon Jun 23 17:15:33 2003
10: PalmQuiz QUIZ 0 58 Mon Jun 23 17:16:12 2003
11: ToDo ORGANISE 0 3 Mon Jun 23 17:17:10 2003
12: MemoPad ORGANISE 0 22 Mon Jun 23 17:17:13 2003
13: Calculator CALC 0 145 Mon Jun 23 17:17:35 2003
14: Calculator CALC 0 6 Mon Jun 23 17:20:54 2003
15: MemoPad ORGANISE 0 34 Mon Jun 23 17:21:00 2003
16: PalmQuiz QUIZ 0 6 Mon Jun 23 17:21:58 2003
17: GraffitiDemo SYSUTIL 0 536 Mon Jun 23 17:23:26 2003
18: MemoPad ORGANISE 0 29 Mon Jun 23 17:32:29 2003
19: DateBook ORGANISE 0 29 Mon Jun 23 22:35:06 2003
20: GraffitiDem SYSUTIL 0 708 Mon Jun 23 22:35:49 2003
21: DateBook ORGANISE 0 74 Mon Jun 23 22:48:31 2003
22: DateBook ORGANISE 0 1870 Mon Jun 23 22:54:42 2003

```

The calculator
being used in
between using
the ChemTable
application

Phase 2 Week 1 Frequency of use from 1 to 4 occasions and
the cumulative amount of time from 244 to 702 seconds

```

*****
* Phase 2 Week 1
*****
=====
===== p2/w1/ss-07 =====

```

```

=====
01: MemoPad      ORGANISE 1      1 Mon Jun 30 13:23:33 2003
02: DateBook    ORGANISE 1      5 Mon Jun 30 13:23:34 2003
03: DateBook    ORGANISE 1     31 Mon Jun 30 13:23:39 2003
04: HotSync     SYSUTIL 1    113 Mon Jun 30 16:59:21 2003
05: PalmQuiz    QUIZ      1    156 Mon Jun 30 17:24:53 2003
06: MemoPad     ORGANISE 1      1 Tue Jul 01 08:51:11 2003
07: PalmQuiz    QUIZ      1     61 Tue Jul 01 09:21:42 2003
...
08: Electronics REF        1     30 Tue Jul 01 17:22:49 2003
09: EasyCalc    CALC       1     88 Tue Jul 01 17:23:19 2003
...
10: PalmQuiz    QUIZ      1     27 Tue Jul 01 18:06:25 2003
11: EasyCalc    CALC       1     16 Tue Jul 01 18:15:22 2003
22: DateBook    ORGANISE 1     44 Tue Jul 01 19:58:54 2003

```

```

=====
===== p2/w1/ss-10 =====
=====

```

```

01: HotSync     SYSUTIL 1     20 Mon Jun 30 11:42:23 2003
02: DateBook    ORGANISE 1     20 Mon Jun 30 12:49:40 2003
03: Electronics REF        1     20 Mon Jun 30 14:56:03 2003
04: PalmQuiz    QUIZ      1    271 Mon Jun 30 14:56:23 2003
05: Registered  PHOTO    1    118 Mon Jun 30 15:01:28 2003

```

<p>Long quiz use in the afternoon following the morning lecture</p>

Phase 2 Week 2 Frequency of use 1 to 11 and cumulative time 122 to 1128

```

*****
* Phase 2 Week 2
*****
=====
===== p2/w2/ss-03 =====
=====
01: DateBook    ORGANISE 2      2 Wed Jul 09 23:42:54 2003
02: Address     ORGANISE 2     75 Wed Jul 09 23:42:56 2003
03: MineSweeper GAME       2     12 Wed Jul 09 23:44:27 2003
04: PalmQuiz    QUIZ      2    122 Thu Jul 10 16:09:32 2003
05: DateBook    ORGANISE 2      2 Mon Jul 14 00:48:40 2003
06: Address     ORGANISE 2      6 Mon Jul 14 00:48:42 2003
07: MemoPad     ORGANISE 2     15 Mon Jul 14 00:48:50 2003

```

=====
 ===== p2/w2/ss-04 =====
 =====

01:	DateBook	ORGANISE	2	42	Mon	Jul	07	15:54:36	2003
02:	EasyCalc	CALC	2	127	Mon	Jul	07	15:55:30	2003
01:	HotSync	SYSUTIL	2	173	Mon	Jul	07	15:57:41	2003
02:	HotSync	SYSUTIL	2	32	Mon	Jul	07	16:07:11	2003
03:	DateBook	ORGANISE	2	147	Mon	Jul	07	16:13:03	2003
04:	DateBook	ORGANISE	2	14	Mon	Jul	07	16:15:30	2003
05:	Calculator	CALC	2	2	Mon	Jul	07	16:18:44	2003
06:	<i>PalmQuiz</i>	<i>QUIZ</i>	2	625	Mon	Jul	07	16:18:52	2003
07:	Calculator	CALC	2	18	Mon	Jul	07	16:29:37	2003
08:	<i>PalmQuiz</i>	<i>QUIZ</i>	2	18	Mon	Jul	07	16:30:00	2003
...									
09:	Electronics	REF	2	84	Wed	Jul	09	22:27:19	2003
10:	<i>PalmQuiz</i>	<i>QUIZ</i>	2	38	Wed	Jul	09	22:28:43	2003 *
...									
11:	<i>PalmQuiz</i>	<i>QUIZ</i>	2	21	Thu	Jul	10	19:28:54	2003 **
...									
12:	HotSync	SYSUTIL	2	228	Sun	Jul	13	15:48:12	2003

Another indication that some students did hotsync their PDAs at home.

Swapping between Quiz and Calculator so looks like genuine use

=====
 ===== p2/w2/ss-07 =====
 =====

01:	<i>PalmQuiz</i>	<i>QUIZ</i>	2	19	Tue	Jul	08	09:00:01	2003
02:	EasyCalc	CALC	2	76	Tue	Jul	08	10:27:57	2003
03:	*XPUTBeamTX	SYSUTIL	2	27	Tue	Jul	08	10:47:28	2003
...									
04:	Address	ORGANISE	2	2	Tue	Jul	08	12:54:40	2003
05:	*XPUTBeamTX	SYSUTIL	2	10	Tue	Jul	08	12:54:42	2003
06:	Lemmings	GAME	2	100	Tue	Jul	08	12:55:23	2003
07:	EasyCalc	CALC	2	16	Tue	Jul	08	12:57:03	2003
08:	<i>PalmQuiz</i>	<i>QUIZ</i>	2	4	Tue	Jul	08	12:57:30	2003
09:	TicTacToe_3d	GAME	2	139	Tue	Jul	08	12:57:41	2003
10:	ChemTable	REF	2	2	Tue	Jul	08	13:00:09	2003
11:	DocsToGo	DOC	2	5	Wed	Jul	09	13:41:20	2003
12:	WordView	DOC	2	109	Wed	Jul	09	13:41:25	2003
13:	MemoPad	ORGANISE	2	69	Wed	Jul	09	13:43:14	2003
14:	DocsToGo	DOC	2	2	Wed	Jul	09	14:25:35	2003
15:	<i>PalmQuiz</i>	<i>QUIZ</i>	2	47	Wed	Jul	09	14:25:53	2003
16:	EasyCalc	CALC	2	16	Wed	Jul	09	14:26:40	2003
17:	<i>PalmQuiz</i>	<i>QUIZ</i>	2	94	Wed	Jul	09	14:26:58	2003
18:	MemoPad	ORGANISE	2	12	Wed	Jul	09	16:40:30	2003
19:	ToDo	ORGANISE	2	21	Wed	Jul	09	16:40:42	2003
20:	Address	ORGANISE	2	90	Wed	Jul	09	16:41:03	2003
21:	Mail	EMAIL	2	104	Wed	Jul	09	16:43:10	2003
22:	MemoPad	ORGANISE	2	93	Wed	Jul	09	16:45:04	2003
23:	Lemmings	GAME	2	842	Wed	Jul	09	16:46:39	2003
24:	MineSweeper	GAME	2	6	Wed	Jul	09	17:00:45	2003
25:	DateBook	ORGANISE	2	2	Wed	Jul	09	17:00:51	2003

This appear to be transient launches of the quiz.

```

...
26: DateBook      ORGANISE 2    15 Sat Jul 12 13:58:41 2003
27: DateBook      ORGANISE 2    40 Sat Jul 12 16:50:16 2003
28: PalmQuiz      QUIZ      2    46 Sat Jul 12 16:52:03 2003
29: TicTacToe_3d GAME      2    79 Sat Jul 12 17:38:49 2003
30: Palm SFCave  GAME      2   243 Sat Jul 12 17:40:10 2003
31: Lemmings      GAME      2   102 Sat Jul 12 17:44:39 2003
32: HotSync       SYSUTIL  2    36 Sat Jul 12 17:46:40 2003
33: BatteryLog    SYSUTIL  2    60 Sat Jul 12 17:47:28 2003
...
34: DateBook      ORGANISE 2    10 Sun Jul 13 11:34:08 2003
35: PalmQuiz      QUIZ      2    60 Sun Jul 13 11:34:23 2003
36: Palm SFCave  GAME      2    89 Sun Jul 13 11:35:27 2003
37: TicTacToe_3d GAME      2     5 Sun Jul 13 11:36:59 2003
38: MineSweeper  GAME      2    55 Sun Jul 13 11:37:14 2003
39: Electronics  REF       2    75 Sun Jul 13 11:38:18 2003
...
40: Lemmings      GAME      2   147 Sun Jul 13 13:26:34 2003
41: BatteryLog    SYSUTIL  2    43 Sun Jul 13 13:30:03 2003
...
...
42: ChemTable    REF       2     2 Sun Jul 13 15:19:13 2003
43: PalmQuiz      QUIZ      2    10 Sun Jul 13 15:19:22 2003
44: Palm SFCave  GAME      2    36 Sun Jul 13 15:41:09 2003

```

The PDAs
organisa-
tional tools
were being
used at
weekends.

Phase 2 Week 3

```

*****
* Phase 2 Week 3
*****
=====
===== p2/w3/ss-03 =====
=====
01: PalmQuiz      QUIZ      3   424 Mon Jul 14 11:41:25 2003
02: MineSweeper  GAME      3   290 Mon Jul 14 11:48:36 2003
03: MemoPad       ORGANISE  3    88 Mon Jul 14 14:02:22 2003

```

Significant
use during
one session
before the
lunchtime
break

Summary of Quiz Use in Phase 2 The pattern of use made by ss-07, of using the quiz for a few weeks quite intensively, then not using it again is similar to that of ug-10 in the phase 1 of the project. The intense use, followed by no further use strongly suggest that these students believed they had gained all the benefit they could from the content of the quiz.

This view is supported in section 5.3 on page 180 below, as when students discussed the quiz application in one-to-one interviews, a number of students noted that they had completed the proffered quiz questions and requested more. The results are clear for student

ss-07. However, without considerably more log data from additional phase 1 or phase 2 students, this conclusion can only be considered anecdotal.

Quiz Use in Phase 4

The focus of interest in this section is the use of the PDA made by the students in phase 3 of the project. The table of quiz use for phase 4 is shown in figure 5.11. The naming of the participants in this phase also indicates the students gender using a suffix to their user identification: m=male, f=female

For this undergraduate group of students the days on which their lectures were delivered by one of the project teams were Tuesday and Wednesday.

Interpretation of Quiz Use in Phase 4 There is now an interpretation of some of the quiz use sessions from the log files. It can be seen in table 5.11 that the majority of use of the Quiz occurred after week 10. The factors that changed after week 10 were the course tutor and the area of syllabus. The tutor from week 10 was one of the project team who was particularly proactive at encouraging the use of the PDA and persuading students to transfer the log data.

Weeks 0 to 5 In this period there is only evidence of 3 launches of the quiz application. In week 0 user 4F on Tue Nov 30 (during lab/lecture session) 14:16 for 13 seconds followed by a few seconds use of a game. In week 1 user 12F on Tue Dec 07 (week 1) (during lab/lecture session) 14:17 for 8 seconds , followed by the use of games for the rest of the afternoon. In week 2 user 12F Sun Dec 12 (week 2) 19:17 for 14 seconds, this one of the few sessions of use that did not occur during a scheduled lab session. The implication is that the use during the lab session was an attempt to conceal the fact that students were mainly playing games.

Week 6 The quiz was used on 4 occasions by user 12F. Sun Jan 09 23:45 for 13 seconds. Tue Jan 11 (during lab/lecture session)11:40 for 22 seconds and at 11:51 for 78 seconds. It is likely that these usages of the quiz application are related to the fact that there was an exam on Monday January the 10th. So this example of quiz use could have been looking at the quiz before the exam to decide if it provided any useful revision content then verifying that they had

User	Week of Project																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
3f	0	0	0	0	0	0	0	0	0	0	0	0	0	7/1171	0	2/1122	0		0	0
4f	1/13	0	1/14	0	0	0	1/7	0	0	0	2/100	5/290	2/179	1/15	0					
5m		0	0		0	0		0	0	0	0	0			0					
7f												0	0	0	0	0	0	0	0	0
8m								0	0	0	0	0	0	0	0	0	0	0	0	0
11m										0	0	7/1622	3/138	1/50	0	0	0	0	0	0
12f	0	1/8	0	0	0	4/40	0	0	0	0	0	6/203	0	0	0					
13m																	0	0		0
14f														0	3/180	0	0			
30m														2/24	1/398	1/49				
32m														2/63	2/63					

Empty cells indicate no log data for that period.

(Number in cell show the number of uses of quiz/cumulative time quiz used)

Table 5.11: Phase 4 Quiz Use

taken the correct approach to a similar question in the previous days exam.

Week 11 User 4f on Tue Feb 08 19:15 two cumulative sessions totalling 100 seconds. This was exclusive use of the PDA for the quiz application, the previous use of the PDA had occurred 75 minutes before the use of the quiz. After the quiz had been used it was a further 45 minutes before the PDA was used again.

Week 12 Use of the quiz has increased with 3 students using it. Student 12F Wed Feb 16th (all during lab/lecture session) starting at 09:36 where there were the 3 sessions of use totalling 181 seconds and a further 2 at 10:30 totalling 3 seconds and a session of 16 seconds at 10:53. My interpretation is that it was an attempt to be seen to be using the quiz, this conclusion is drawn from the short period of use and that the applications used immediately before and after the short quiz use were games.

Student 4F Wed Feb 16th (all during lab/lecture session) 5 sessions totalling 290 seconds (4,10,91,134,51) that there are some longer sessions it is more likely that this was genuine use of the quiz rather than hiding game use.

Student 11m Wed Feb 16th 3 sessions totalling 485 seconds, Mon Feb 21st 2 sessions totalling 208 seconds, Wed 23rd Feb 3 sessions totalling 138 seconds(all during lab/lecture session). But outside of normal hours Sat Feb 19th 1 session of 525 seconds, and Tue Feb 22 at 08:06 1 session of 404 seconds.

Week 13 This week 5 students made use of the quiz though the extent of use varies from 24 to 1171 seconds.

Student 3F Wed Feb 23(week 13) (during lab/lecture session) 8 seconds. The next application launched was AppLog. This session was a test to ensure that the use of AppLog was being correctly recorded.

Fri Feb 25 (week 13) 01:03 491 seconds. This session of use is not during a lab or lecture session and was also late at night which suggests it was genuine use as this was in their own time.

Mon Feb 28th (week 13) 22:01 two consecutive sessions with a total of 100 seconds and the last use of the PDA on that day.

Week 15 Tue March 01st (week 15) (during lab/lecture session) 14:07 the first use of the day.

Tue Mar 8th(week 15) at 23:37 for 1121 seconds. The final use of the day before a lab/lecture session so possibly being used to prepare for a class test,

Summary of Quiz Use in Phase 4 From these results it appears that majority of times the Quiz application was launched was during the lectures and lab sessions at which one of the project team was present. But the longest sessions all occurred outside of lecture times: for example in early morning 08:06 (404 seconds by user 11m), late at night 23:37 (1121 seconds by user 3f) or at the weekend Saturday at 14:07 (525 seconds by user 11m). These uses are taken as evidence of students using the quiz application independently for formative assessment at their own instigation and supports the conclusion obtained in phase 1 and phase 2. A detailed consideration of table 5.11 and the subsequent log fragments also support our hypothesis that students would use the quiz application until they felt that no further learning could be obtained from it over a period of 1-3 weeks. An additional novel aspect of quiz application use can be seen in phase 4. Alone in this phase, the times when students initially make concerted use of the quiz application vary. In phases 1 and 2 quiz application was instigated by the project team. All students started using the quiz application at the same time and there was a small amount of stagger to the point where they ended quiz use due to differences in when each student had 'consumed' the content. However in phase 4 students had a number of weeks to become familiar with PDA use before the content could have become relevant to them (most of the PDA quiz questions were on a.c. circuit theory, applicable to their second semester). The students initial, concerted use of the quiz application is staggered over a period of 4 weeks, with each student having 'consumed' the content some 3 weeks later. Clearly the evidence shows students discovering the relevance of the quiz application material for themselves over this period, a far more mature and self directed indication of learning than in phase and phase 2.

Phase 4 Week 0

```

=====
===== p4/w0/4f =====
=====
[AppName] [AppType] [week] [time] [date and time of day]
01: Solitaire GAME 0 2 Tue Nov 30 14:07:32 2004
02: blocks GAME 0 2 Tue Nov 30 14:07:36 2004

```

```

03: blocks      GAME      0 157 Tue Nov 30 14:07:39 2004
04: Bubbles    GAME      0   3 Tue Nov 30 14:13:26 2004
05: Quizzler   QUIZ      0  13 Tue Nov 30 14:16:48 2004
06: prefs      SYSUTIL   0   7 Tue Nov 30 14:17:10 2004
07: Solitaire  GAME      0   6 Tue Nov 30 14:17:20 2004*

```

One short use of the quiz during a lab session, so probably being seen to be using the quiz.

Phase 4 Week 1

```

=====
===== p4/w1/12f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Quizzler   QUIZ      1   8 Tue Dec 07 14:17:39 2004**
02: 3DBlockout GAME      1   2 Tue Dec 07 14:20:09 2004
03: 3DBlockout GAME      1   2 Tue Dec 07 14:20:13 2004
04: BubblesOS5 GAME      1   3 Tue Dec 07 14:20:17 2004

```

Phase 4 Week 2

```

=====
===== p4/w2/4f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Bucky      GAME      2  67 Sun Dec 12 19:14:34 2004
02: Crazyfaces GAME      2  54 Sun Dec 12 19:16:05 2004
03: Quizzler   QUIZ      2  14 Sun Dec 12 19:17:10 2004
04: blocks     GAME      2 273 Sun Dec 12 19:17:27 2004
05: BubblesOS5 GAME      2 1270 Sun Dec 12 23:37:25 2004*

```

Phase 4 Week 6

```

*****
* Week 6
*****
=====
===== p4/w6/12f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Calendar   ORGANISE  6   4 Sun Jan 09 23:45:53 2005
02: Quizzler   QUIZ      6  13 Sun Jan 09 23:46:23 2005
03: Quizzler   QUIZ      6   1 Sun Jan 09 23:46:38 2005
04: Clock-PcLK CLOCK     6   4 Sun Jan 09 23:46:46 2005
05: RealOne    MUSIC     6   2 Sun Jan 09 23:46:52 2005
06: Photos     PHOTO     6  36 Sun Jan 09 23:46:55 2005*
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Capture    PHOTO     6   2 Tue Jan 11 07:30:52 2005**
02: Photos     PHOTO     6   2 Tue Jan 11 07:30:54 2005

```

```

03: Quizzler QUIZ 6 22 Tue Jan 11 11:40:47 2005
04: Calculator CALC 6 3 Tue Jan 11 11:45:03 2005
05: Contacts ORGANISE 6 30 Tue Jan 11 11:45:07 2005
06: Contacts ORGANISE 6 128 Tue Jan 11 11:45:39 2005
07: Contacts ORGANISE 6 141 Tue Jan 11 11:47:48 2005
08: Clock CLOCK 6 1 Tue Jan 11 11:50:54 2005
09: Quizzler QUIZ 6 78 Tue Jan 11 11:51:00 2005
10: Photos PHOTO 6 21 Tue Jan 11 11:52:37 2005
11: Calculator CALC 6 1 Tue Jan 11 11:53:16 2005
12: BubblesOS5 GAME 6 4 Tue Jan 11 11:59:28 2005

```

Phase 4 Week 7

```

*****
* Week 7
*****
=====
===== p4/w7/4f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: NotePad ORGANISE 7 3 Fri Jan 14 10:31:30 2005
02: Clock CLOCK 7 1 Fri Jan 14 10:31:33 2005
03: Tasks ORG 7 5 Fri Jan 14 10:31:35 2005
04: Quizzler QUIZ 7 2 Fri Jan 14 10:31:49 2005
05: Tasks ORG 7 32 Fri Jan 14 10:32:03 2005

```

Phase 4 Week 11

```

*****
* Week 11
*****
=====
===== p4/w11/4f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Solitaire GAME 11 63 Tue Feb 8 18:02:08 2005
02: Quizzler QUIZ 11 78 Tue Feb 8 19:15:23 2005
03: Quizzler QUIZ 11 22 Tue Feb 8 19:16:42 2005
04: Solitaire GAME 11 1166 Tue Feb 8 20:02:47 2005

```

Phase 4 Week 12

```

*****
* Week 12
*****
=====
===== p4/w12/12f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Bucky GAME 12 42 Wed Feb 16 10:39:08 2005

```

```

02: Lemmings    GAME      12      2 Wed Feb 16 10:41:20 2005
03: Quizzler   QUIZ      12      4 Wed Feb 16 10:41:28 2005
04: Expenses   ORGANISE  12      3 Wed Feb 16 10:42:23 2005
05: Quizzler   QUIZ      12     10 Wed Feb 16 10:42:27 2005
06: Applog     SYSUTIL   12     12 Wed Feb 16 10:42:38 2005
07: Quizzler   QUIZ      12     91 Wed Feb 16 10:43:36 2005
08: Quizzler   QUIZ      12    134 Wed Feb 16 10:47:27 2005
09: prefs      SYSUTIL   12     34 Wed Feb 16 10:49:46 2005
10: Quizzler   QUIZ      12     51 Wed Feb 16 10:50:37 2005
11: Bubbles    GAME      12   2275 Wed Feb 16 23:18:23 2005
12: Photos     PHOTO     12     10 Wed Feb 16 23:56:30 2005

```

===== User 12F =====

```

[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Quizzler   QUIZ      12      2 Wed Feb 16 09:36:28 2005**
02: Quizzler   QUIZ      12     20 Wed Feb 16 09:39:21 2005
03: Quizzler   QUIZ      12    159 Wed Feb 16 09:50:39 2005
04: Quizzler   QUIZ      12      2 Wed Feb 16 10:30:46 2005
05: Quizzler   QUIZ      12      1 Wed Feb 16 10:32:39 2005
06: Capture    PHOTO     12      2 Wed Feb 16 10:52:02 2005
07: Photos     PHOTO     12     10 Wed Feb 16 10:52:04 2005
08: Capture    PHOTO     12      2 Wed Feb 16 10:52:16 2005
09: Photos     PHOTO     12     17 Wed Feb 16 10:52:18 2005
10: Capture    PHOTO     12     67 Wed Feb 16 10:52:35 2005
11: Photos     PHOTO     12      5 Wed Feb 16 10:53:42 2005
12: Quizzler   QUIZ      12     19 Wed Feb 16 10:53:48 2005
13: Froggy     GAME      12     66 Wed Feb 16 23:09:42 2005

```

* last use of day

** first use of day

=====

===== p4/w12/11m =====

=====

```

[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Applog     SYSUTIL   12     19 Wed Feb 16 10:40:04 2005
02: DocsToGo   DOC       12      2 Wed Feb 16 10:41:11 2005
03: Quizzler   QUIZ      12     18 Wed Feb 16 10:41:23 2005
04: Quizzler   QUIZ      12    173 Wed Feb 16 10:48:29 2005
05: Quizzler   QUIZ      12    294 Wed Feb 16 10:51:27 2005
06: RealOne    MUSIC     12   1307 Wed Feb 16 12:53:25 2005
07: Capture    PHOTO     12      6 Wed Feb 16 13:37:23 2005
...
08: RealOne    MUSIC     12    119 Sat Feb 19 08:33:07 2005**
09: RealOne    MUSIC     12     84 Sat Feb 19 14:06:07 2005
10: DocsToGo   DOC       12      2 Sat Feb 19 14:07:38 2005
11: Quizzler   QUIZ      12    525 Sat Feb 19 14:07:49 2005
12: prefs      SYSUTIL   12      4 Sat Feb 19 14:16:34 2005
13: RealOne    MUSIC     12     83 Sat Feb 19 14:16:46 2005
...
14: RealOne    MUSIC     12   3664 Mon Feb 21 10:13:46 2005**
15: Quizzler   QUIZ      12    197 Mon Feb 21 14:49:37 2005

```

```

16: Quizzler QUIZ 12 11 Mon Feb 21 14:52:57 2005
17: RealOne MUSIC 12 21 Mon Feb 21 14:53:08 2005
18: DocsToGo DOC 12 443 Mon Feb 21 14:53:36 2005
19: RealOne MUSIC 12 982 Mon Feb 21 15:01:06 2005
...
20: RealOne MUSIC 12 418 Tue Feb 22 07:59:38 2005**
21: Quizzler QUIZ 12 404 Tue Feb 22 08:06:42 2005
22: RealOne MUSIC 12 3076 Tue Feb 22 08:13:47 2005

```

Phase 4 Week 13

```
*****
```

```
* Week 13
```

```
*****
```

```
=====
```

```
===== p4/w13/4f =====
```

```
=====
```

```
[line][AppName][AppType][week][time][date and time of day]
```

```

01: Applog SYSUTIL 13 17 Wed Feb 23 09:36:07 2005
02: Calcul-8! CALC 13 7 Wed Feb 23 09:36:45 2005
03: Quizzler QUIZ 13 5 Wed Feb 23 14:43:48 2005
04: Solitaire GAME 13 827 Wed Feb 23 22:41:24 2005
05: Quizzler QUIZ 13 174 Wed Feb 23 22:55:14 2005
06: blocks GAME 13 459 Wed Feb 23 22:58:10 2005
07: Solitaire GAME 13 115 Wed Feb 23 23:05:53 2005

```

```
=====
```

```
===== p4/w13/3f =====
```

```
=====
```

```
[line][AppName][AppType][week][time][date and time of day]
```

```

01: Applog SYSUTIL 13 14 Wed Feb 23 09:47:45 2005
02: Calcul-8! CALC 13 80 Wed Feb 23 09:48:01 2005
03: Quizzler QUIZ 13 8 Wed Feb 23 09:49:24 2005
04: Applog SYSUTIL 13 2 Wed Feb 23 09:49:35 2005
05: Calculator CALC 13 5 Wed Feb 23 10:00:48 2005

```

```
...
```

```

06: Capture PHOTO 13 4 Fri Feb 25 00:47:52 2005
07: Calendar ORGANISE 13 662 Fri Feb 25 00:48:05 2005
08: Memos-PMem ORGANISE 13 261 Fri Feb 25 00:59:15 2005
09: Quizzler QUIZ 13 491 Fri Feb 25 01:03:39 2005
10: prefs SYSUTIL 13 1 Fri Feb 25 01:12:09 2005

```

```
...
```

```

11: Calcul-8! CALC 13 373 Mon Feb 28 21:55:19 2005
12: Tasks-PTod ORGANISE 13 3 Mon Feb 28 22:01:36 2005
13: prefs SYSUTIL 13 1 Mon Feb 28 22:01:46 2005
14: Quizzler QUIZ 13 27 Mon Feb 28 22:01:53 2005
15: Quizzler QUIZ 13 73 Mon Feb 28 22:02:28 2005*(last
16: Quizzler QUIZ 13 264 Tue Mar 01 14:07:23 2005*(first
17: Quizzler QUIZ 13 24 Tue Mar 01 14:11:51 2005
18: Quizzler QUIZ 13 284 Tue Mar 01 14:12:18 2005
19: VoicePad UNKNOWN 13 8 Tue Mar 01 14:17:02 2005

```

This looks like determined use of day) quiz use use of day)

Line 15 was last use of the day, Line 16 indicates first use of

```

20: Memos-PMem ORGANISE 13 131 Tue Mar 01 14:18:52 2005
21: Tasks-PTod ORGANISE 13 6 Tue Mar 01 14:21:08 2005
=====
===== p4/w13/11m =====
=====
01: Solitaire GAME 13 93 Tue Feb 22 16:59:46 2005
02: PacMan GAME 13 61 Tue Feb 22 17:01:39 2005
03: blocks GAME 13 518 Tue Feb 22 17:02:56 2005 *
04: RealOne MUSIC 13 6001 Wed Feb 23 07:40:47 2005**
05: Quizzler QUIZ 13 7 Wed Feb 23 09:21:01 2005
06: Capture PHOTO 13 4 Wed Feb 23 09:21:45 2005
07: Quizzler QUIZ 13 113 Wed Feb 23 09:21:54 2005
08: Quizzler QUIZ 13 18 Wed Feb 23 09:23:59 2005
09: Applog SYSUTIL 13 61 Wed Feb 23 09:36:56 2005
10: Applog SYSUTIL 13 13 Wed Feb 23 09:37:57 2005
11: RealOne MUSIC 13 2393 Wed Feb 23 11:02:19 2005 *
=====
===== p4/w13/30m =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: RealOne MUSIC 13 12 Wed Feb 23 11:47:17 2005
02: Calcul-8! CALC 13 24 Wed Feb 23 11:50:06 2005
03: Quizzler QUIZ 13 9 Wed Feb 23 11:50:36 2005
04: Calcul-8! CALC 13 1 Wed Feb 23 11:50:46 2005
05: Quizzler QUIZ 13 15 Wed Feb 23 11:50:52 2005
06: Applog SYSUTIL 13 16 Wed Feb 23 11:51:12 2005
07: RealOne MUSIC 13 21 Wed Feb 23 11:51:38 2005
08: Calendar ORGANISE 13 98 Wed Feb 23 11:52:14 2005
09: Expenses ORGANISE 13 11 Wed Feb 23 11:54:05 2005

```

The use of the quiz in this log section (p4/w13/30m) is very short and although the calculator was used in between quiz launches, 1 second would appear to be too short to be useful. It is possible the student realised they didn't need the calculator and switched back to the quiz to look at the question in more detail before using the calculator for a more realistic 15 seconds.

Phase 4 Week 14

```

*****
* Week 14
*****
=====
===== p4/w14/4f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: blocks GAME 14 3 Sun Mar 6 18:18:07 2005
02: BubblesOS5 GAME 14 18 Sun Mar 6 18:18:13 2005
03: Quizzler QUIZ 14 15 Sun Mar 6 18:18:46 2005

```

```

04: Solitaire  GAME      14 1491 Sun Mar  6 20:14:37 2005
=====
===== p4/w14/11m =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Quizzler  QUIZ      14   50 Mon Mar 07 12:53:33 2005**
02: RealOne   MUSIC      14   52 Mon Mar 07 12:54:25 2005 *
=====
===== p4/w14/30m =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: SheetToGo DOC       14  214 Mon Mar 07 18:49:47 2005
02: Photos    PHOTO      14    6 Mon Mar 07 18:53:28 2005
03: Quizzler  QUIZ      14  398 Mon Mar 07 18:53:42 2005
04: VoicePad  UNKNOWN   14    4 Mon Mar 07 19:00:29 2005
05: RealOne   MUSIC      14   22 Mon Mar 07 19:00:59 2005

```

Long use over 6 minutes and outside of normal lab time suggests genuine use, the use of the SheetToGo (the spreadsheet application) implies the device was seen as more than a mobile games device by this student.

```

=====
===== p4/w14/14f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Applog    SYSUTIL   14   12 Wed Mar 02 10:07:19 2005
02: Quizzler  QUIZ      14    5 Wed Mar 02 10:20:55 2005
03: Quizzler  QUIZ      14    9 Wed Mar 02 10:21:47 2005
04: VoicePad  UNKNOWN   14   58 Wed Mar 02 10:23:21 2005
05: Photos    PHOTO      14   15 Wed Mar 02 10:26:06 2005
06: VoicePad  UNKNOWN   14   89 Wed Mar 02 10:50:50 2005

```

These two launches (line 2,3) look spurious, both are short and during a normal lab time. It is possible these were the result of having something beamed to the device. The uses are not interleaved between the use of games so this is not an example switching briefly to the quiz application in order to pretend to be working.

```

07: Quizzler  QUIZ      14  166 Thu Mar 03 19:12:32 2005
08: Photos    PHOTO      14   28 Thu Mar 03 19:19:46 2005
09: Capture   PHOTO      14   13 Thu Mar 03 19:20:14 2005

```

The PDA was switched on specifically to launch the quiz application

The PDA was switched on specifically to launch the quiz application and that fact coupled with the duration of the session suggests real use.

Phase 4 Week 15

```
*****
* Week 15
*****
=====
===== p4/w15/3f =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Tasks-PTod ORGANISE 15    2 Tue Mar 08 23:36:09 2005
02: Memos-PMem ORGANISE 15   33 Tue Mar 08 23:36:23 2005
03: Quizzler  QUIZ      15 1121 Tue Mar 08 23:37:02 2005 (last use of day)
```

This is a long session of quiz use, 18 minutes, it is late at night and was the last use of the PDA that day. This looks like a student wrapping up their working day.

```
=====
===== p4/w15/30m =====
=====
[line] [AppName] [AppType] [week] [time] [date and time of day]
01: Calendar  ORGANISE 15  3447 Thu Mar 10 15:52:26 2005
02: Contacts  ORGANISE 15    2 Thu Mar 10 18:42:59 2005
03: RealOne   MUSIC    15   19 Sat Mar 12 12:26:55 2005
```

The use of the Calendar application for nearly an hour, suggest the PDA had been found useful as an organisational tool.

```
04: Quizzler  QUIZ      15   49 Sat Mar 12 12:49:43 2005
05: RealOne   MUSIC    15   10 Sat Mar 12 12:51:38 2005
06: Calendar  ORGANISE 15   41 Sat Mar 12 12:51:50 2005
```

This appears to be the PDA was switched on and the quiz was the first application launched,so probably genuine use. Student 30m had the highest graded exam result of the group an appears to be an organised and motivated individual.

In phase 4 the repeated use of Quiz and Calculator that were seen in phases 1 and 2 also occurred , in this case with student 30m

Summary and discussion of quiz use in all three project phases

Detailed logging of the quiz application showing when it, and the PDA in general, were used has provided information on formative assessment previously unavailable, and unique in the literature Trinder *et al.* (2002). Researchers for the first time had objective data on the proportion of student time spent carrying out a formative assessment exercise compared with other PDA use, and information on the range of usage patterns across a student cohort.

As can be seen from 5.7 on page 109 in each phase there are similar patterns of use: those that used the PDAs a lot, those that used it very little - who seemed to ignore the PDA and occasional users.

However, introducing additional data, both from the logging process and from external information was found to give a far greater insight into how the students approached their learning. Extensive mining of the data set led to the conclusion that the most important additional information associated with the logging data were 1) the time of day the PDA and applications were used, 2) information on student timetables including laboratory and lecture times 3) how long the quiz application was used, and 4) which applications were used before and after any instance of quiz application use.

As an example of how this additional information can give insight, we consider phase 1 and phase 2

In phase 1 there was some use of the quiz during the first 3 weeks of PDA use. For the remaining 4 weeks no more use was made of the quiz application the interpretation is that students had “used” all the questions and saw no further benefit in using the application.

A similar pattern of use was seen during phase 2. In phase 2 the quiz was used during the first 4 weeks for which log data was collected. For the remaining 4 weeks there was no evidence of quiz use in the logs. The hypothesis that the students had “consumed” the quiz content was supported by the Applog evidence of phase 4 and independently the feedback in questionnaires from phase 2 in which two of the students had commented that they needed more questions.

In phase 4, we also saw clear evidence, due to the staggered use of the quiz application, of students taking control of their own learning.

A combined use of a number of data sources, primarily here logging use, time of day, and period of highest use leads to the conclusion that the students had reviewed all the quiz application questions available to them, and moved to other modes of PDA use, or dropped PDA use completely. In this case, as will be detailed in section 5.3 on page 180 below, we have additional information from student interviews which confirms that this was the case, as students, in one-to-one discussion with their interviewers repeatedly requested further question sets.

An additional important result was the ability, using logging data and specifically including information on which applications were used before and after periods of quiz application use, to confidently categorise modes of quiz application use - most importantly showing phases of educational benefit including exploration of the formative assessment tools, and both short bursts and long periods of use of these tools. This ability to categorise use objectively will be of benefit to future research in the field. In addition, we showed evidence of a completely novel mode of use - the short burst to give a false impression of study.

It was shown that although the usage log can show when the PDA was used, to interpret if the application was being used in a productive way needs additional infor-

mation. The suggested additional data were the time of day it was used, for how long it was used and what applications were used before and after the instance of use.

Having summarised the results from this section of the work, we note two points of significance to future research in this area

Although it has been possible to make an informed interpretation of how an application is used based on the length of application use and looking at the application in the context of those applications that were used at around the same time, the ambiguous nature of the log results highlights the need for triangulation of log data. If this validation of the interpretation of use is achieved by using an interview it needs to be conducted close to the event so that there is a good chance the user can remember what they were doing and also recall their motives for doing so.

This would also require much more frequent uploading of the collected log data, with current devices that have easy network connectivity this may be possible. This could be practical when dealing with a small group but for a larger study would be impractical without a large number of staff regularly interviewing students.

5.2.6 Evolution Of Use In Each Phase

In this section the focus is on how student use of the PDA evolved throughout their experience of using it.

A pattern of use reported in mobile learning projects such as (Robertson *et al.*, 1997) (Sharples *et al.*, 2005) is that the amount of PDA use decreases as the project progresses. The reduction in use has been attributed to a number of factors. For example in (Greenberg, 2004) it was suggested that the reduction in use, as measured by total session times for specific applications, was the result of users' improved knowledge of how to use the device, thus allowing them to perform functions on the device with greater speed. Another explanation in the research literature (Sharples *et al.*, 2005), in projects where the PDA is loaned to students is that they stop integrating the PDA into their daily use as the time to hand the device back approaches. There is little point adding appointments to the diary for dates beyond when the student will have the device.

Also, a PDA (or in current technology terms a smartphone) is a configurable, programmable and adaptable device with functionality that can be customised through installing extra application programs. The situations, locations and times when a mobile device are used also change. It is thus likely that the pattern of use of such a device may change throughout its ownership.

It is the view of the author that there are different types and amounts of fall off in the amount of use of PDAs or other mobile devices during a project. The first occurs in the first few days and is due to the users' initial exploration of the device to find what it can do and how the applications work (Waycott, 2005a). The next reduction occurs over a longer period of time and is a combination of increased familiarity and

the loss of novelty value. the initial period of high usage has been called a “gadget honeymoon” (Stead, 2005). Rather than thinking of this as a fall off in use the correct view is that when a device is first used there is an abnormally high frequency of use.

In projects where a device is loaned for a fixed period of time then a contributory factor to the fall off in use can be due to knowing that the device is going to be handed back. Nor is there much incentive for a user to purchase software or peripherals that can only be used with the same type of device. A further falloff in use may occur if the user acquires their own technology that has superior capabilities to the institutionally supplied device.

When considering ‘a reduction in use’ it is important to be clear about which aspect of PDA is being measured, for example the amount of times the device is used, the amount of time for which it is used or the number of applications that are utilised. These parameters are amongst those that are now examined for each project phase.

In the following series of charts and tables there are results that include the use of all applications and an additional set with the instances of games, music and photography applications removed. This is to provide a more equitable comparison of use between the media capable PDAs used in phase 4 and the simpler PDAs used in phases 1 and 2. The filtered results are labelled NoPGM(No Photo, Game or Music).

Number of Uses Per Week The first parameter considered is the number of instances, or runs of use in the course of a week. This measure is the number of occasions upon which an application was launched. The number of runs for each phase is shown in figures 5.30-5.32. Each chart shows the number of uses of the PDA on the vertical axis and the week of use on the horizontal axis. It was found that grouping the graphs by user rather than by week makes it much easier to see any project trends.

In phases 1 and 2, there is an obvious reduction of use in the first two weeks and the trend for the following weeks is generally a reduction in use. There are some exceptions to this that will be considered in a moment.

Phase 1 The reduction in use in Phase 1 between the first and second week is summarised in Table 5.12, The tables show the amount of use made of the PDA in weeks as a percentage of the amount of use made in the first week. In each table the actual number of runs is shown in brackets. The first line of the table (without a percentage) is the number of occasions the PDA was used on the first week. So for example the table in Table 5.12 shows that in the second week ug-09 used the PDA 233 times in the first week and only 53% as many occasions in the second week.

Phase 2 For most of the users in phase 2 there is a similar pattern of use to those in phase 1, with a sharp reduction of use in the first two weeks and a further fall-off throughout the project.

Students ss10 and ss04 appear to have been active during the first week. Student

ss01 doesn't seem to be interested in the PDA. All continue to fall off in use, other than a peak in week 3 which is explained below.

The exception to this pattern of use is ss-03 who only used the PDA 7 times in the first week even using the PDA to check the time a few times per day in the second week would have looked like a big increase in use.

A feature of phase 2 is that there is an increase in use between the second and third week (the yellow bar in the charts). This increase is predominantly due to a specific game. For student ss-10 case the increase in uses can be accounted for by 10 runs of the game lemmings and in student ss-07s case 18 uses of lemmings and twice as many uses of memopad(28 runs) compared to the previous week. This looks like one of the group obtained a copy of lemmings and it was passed to others in the group.

Lemmings was not the only increase in application use for weeks through, from the logs the increase in use for each user is:

Student ss01 only used the PDA 3 times in the third week of use and as is shown later the duration of use was less than a minute.

Student ss03 increased use of Calculator , organiser application, quiz and a specific game(lemmings).

Student ss04 increased use Calculator, game(lemmings) and quiz and reference applications. The increase is not as significant as it may first seem. In the previous week student ss04 had only used the PDA twice. The most used applications in week 0 was 14 uses of the quiz and in week 3, 4 uses of the quiz.

Student ss07 increased use of organiser, Calculator, game (lemmings)

Student ss10 increased use of organiser and games

It is very obvious that student ss07 found the PDA useful to them throughout the summer schools and made much greater use of the PDA than the rest of the group. Student ss-07 made 1005 application runs compared to the next highest user who was student ss-10 who used the PDA on 181 occasions.

The pattern of use for group is that the amount of use decreases as hand back time approaches as was expected. This supports the idea that in fixed length projects the student will not "appropriate" the device.

Phase 4 For phase 4 there are only results for two users that cover the first weeks of use and these show a different progression. The usage of student 4F increases greatly between week + 2 and +3 (due almost entirely to the playing of games)

Two views of the amount of use, results with all applications and those with the photo game and music applications removed.

Students 32m, 5m,13m,14f show very little use and for 30m and32m there are only results for a couple of weeks. The usage pattern for the other students 3f,4f,7f,11m and 12f do not show the same obvious fall off in use seen in phases 1 and 2. A decrease in use is obvious for student 8m who ultimately withdrew from the course, and so the lack of PDA use may follow other external factors. An interesting feature is shown for

student 3f who shows an initial fall over the first 5 weeks but then their use increases. The results with the photo, game and music removed show this was largely due to the student finding other non entertainment uses for the PDA.

The lack of general fall off in use indicates that the phase 4 students, (other than those who seemed to be hardly using the PDA or providing us with any log data) did “buy-in” to using the PDA more than the students in the earlier phases.

In summary, the bulk of the data for these phases does agree with previous work in the field showing a drop off in use. There are exceptions, and these occur when a student discovers, in their exploration of the PDA, some application which has particular value for them.

	ug10	ug01	ug04	ug05	ug09
Week 0	(234)	(263)	63	(72)	223
Week +1	22%(53)	24%(64)	17%(11)	11%(8)	53%(119)
Week +2	37%(88)	5%(13)	28%(18)	14%(10)	1.3%(3)

Number in () indicates number of runs

Table 5.12: Phase 1 Fall Off In Number Of Uses Relative To First Week

	ss10	ss01	ss03	ss04	ss07
Week 0	(99)	(19)	(7)	(46)	(446)
Week +1	24%(24)		286%(20)	4%(2)	28%(126)
Week +2	42%(42)	16%(3)	486%(34)	37%(17)	53%(237)
Week +3	7%(7)		86%(6)	4%(2)	26%(116)
Week +4	9%(9)				16%(70)
Week +5					2%(10)

Number in () indicates number of runs

Table 5.13: Phase 2 Fall Off In Number Of Uses Relative To First Week

	3f	4f
Week 0	(93)	(8)
Week +1	39%(36)	512%(41)
Week +2	96%(89)	475%(38)
Week +3	24%(22)	1162%(93)
Week + 4	89%(32)	188%(15)

Number in () indicates number of runs

Table 5.14: Phase 4 Fall Off In Number Of Uses Relative To First Week

Number of Applications Used The next measure of use considered is that of the number of applications used each week. These are shown in figures A.29

A.30

A.31

Phase 1 Figure A.29 shows a similar pattern of reduction as the chart showing the number of runs earlier in this section. In addition the number of applications run per week falls off significantly as the time to hand back the PDA approaches.

Phase 2 Figure A.30 shows a similar pattern of reduction as the chart showing the number of runs of the application. The increase in use during the third week can also be seen in this data, which reinforces the fact that the increase in use was partly due to installing and trying out additional applications.

This also shows users were making more active use of the PDAs and that they had found out how to install applications. Again suggesting the devices were being explored a part of the gadget honeymoon mentioned in the introduction.

It is also apparent that User ss-07 has used considerably more applications each week. One of the students was attending summer school lectures in chemistry as well as electronics and it seems likely it was ss-07. Additional information to support this belief was their use of the chemical periodic table application.

The exception to the weekly fall-off in use pattern was student ss03, who shows a peak of usage in the 3rd week, which was due to some intense use of organiser applications during week 3. This increase appears after the PDA has received something via beaming late at night 22:46 on July07. There is no indication in the logs of any of the project participants having beamed anything so this is most likely have been interaction with someone outside the group.

As noted for phase 1, the number of applications run per week falls off as the time to hand back the PDA approaches.

Phase 4 Figure A.31 shows an interesting feature in that there is not a clear fall off in the number of applications used, nor does the number remain stable. This suggests that the students were finding new applications to install and use and continuing to explore the uses of the PDA. This is very noticeable for student 3f and 4f who show a fall off in the number of applications used for the first 3-4 weeks then an increase in the number of applications used.

In summary, the bulk of the data for phases 1 and 2 does agree with previous work in the field showing a drop off in use. There are exceptions, and these occur when a student discovers, in their exploration of the PDA, some application which has particular use for them.

Falloff did not occur in an obvious way for the students in phase 4 who had been given an open-ended use of the PDAs. Use was shown to vary for some of the students as they found new applications to install on their PDAs.

These results strongly indicate that our hypothesis that some use falls off due to students realising that they have to hand back the PDAs is supported by the objective evidence

Week 11	Week 12	Week 13	Week 14	Week 15
[5]ToDo	[8]DateBook	[6]MemoPad	[4]MemoPad	[1]HotSync
[4]DateBook	[2]prefs	[2]DateBook	[4]DateBook	[1]MemoPad
[2]EasyCalc	[2]Date/Time	[1]ToDo	[1]Address	[1]DateBook
[2]Date/Time	[2]WorldAlarm			
[1]MemoPad	[1]MemoPad			
[1]prefs	[1]BatteryLog			
[1]Registered	[1]Gen Prefs			
[1]Calculator				
[1]PrefsButtons				
[1]Ext_Manager				
[1]HardBall				
[1]Graffiti Demo				

Table 5.15: Fall off in Use for User UG10

Week 5	Week 6	Week 7	Week 8	Week 9
[8]MemoPad	[2]MemoPad	[3]MemoPad	[5]MemoPad	[1]DateBook
[5]DateBook	[1]DateBook	[3]DateBook	[5]DateBook	[1]Address
[2]Address	[1]Address			

Table 5.16: Fall off in Use for User UG06

The Most Used Applications Another measure of application use was to list the most often used applications per user in each week of the project, to produce a top 20 list of most used applications. This was to discover, which applications were the last ones used when there is a reduction in use.

Top 20 Applications Used Table 5.15 and 5.16 show the most used applications for ug10 and ug06 in phase 1. The most used application is at the top of the table. The number in square brackets indicates the number of times the application was used during the week. It can be seen that in some cases the total number of applications was far lower than 20. (For example user 13 m only used 4 applications).

For both users the applications that they used most often were organiser applications, calendar and memopad.

This data supports the view that whilst there will be an initial period when lots of applications are sampled, that the patterns of use will then shortly (within a week or two as evidenced by these tabled results) settle to a situation where those applications that the student finds truly helpful are used.

Duration of Use Per Week The next measure of use considered is the cumulative total time of all uses made of the PDA in a week. These are shown in figures 5.36, 5.37, 5.38. It should be noted that the usage time per week totals are in minutes, a departure from the more typical measure of seconds used in this thesis.

Phase 1 For each user in phase 1 the cumulative duration of use per week decreases over the course of the project. The difference between un-filtered and NoPGM results shows that around half of the usage time for ug-01 and ug-05 is accounted for by games.

Phase 2 It is more clearly shown that ss-01 made very little use of the PDA and that ss-10 and ss-07 made much greater user than the rest of the group. The difference between un filtered and NoPGM results shows proportion of games for user ss-07 used in the third week (Yellow on the charts) was higher than other weeks.

Phase 4 Any reduction in use is not as obvious, in contrast to the earlier phases. The reason this is less clear may be because the data was collected over a longer period of time and the amount of data varies between users to a much greater extent than in earlier project phases. For the purpose of comparison consider the users for whom most data is was available: 3F,4F ,11m and 12F. The first point to note is the difference between the un filtered and NoPGM results (those excluding Photo, Game and Music applications) is so great that the charts have been rescaled.

The discovery of games is an example of students discovering a useful application to them. The additional spikes in usage correlates with the spikes of usage of the quiz application noted in the previous section. Although there the usefulness of the Quiz application was for at least one student instigated by the closeness of a class examination.

The NoPGM results also show that the students were using the PDAs for purpose other than for photography, games and music. User 3F and 4F show an initial fall off over the first few weeks, then an increase in use. The first peak is likely to be while they explored the PDA , the initial novelty of the device - the gadget honeymoon' (Stead, 2005)followed by a fall off in use. The later increase in use is when the students find other uses for the device, presumably as they were carrying the PDA for photo, music and game purposes..

This is in contrast to phase 1 and 2 where the amount of use per week decreased each week. The implication is that the phase 4 students were appropriating the PDAS.

Is the Reduction Due To Shorter Sessions Or Less Use? In previous studies it has been suggested that the reduction in weekly usage time can be due to the users increased familiarity with how to use the PDA and applications (Robertson *et al.*, 1997). To examine such a reduction in the amount of time spent using an application could be detected figures 5.39, 5.40, 5.41 show the median of runtime per week. Tables 5.17 to 5.19 show the average time per session, that is the cumulative application usage per week divided by the number of application launches. The gap in week 1 of figure 5.40 for user ss-04 indicates that the only applications they had used that week had been photo, game or music

It was shown above that the amount of PDA use does, in terms of the number

User	ug-10	ug-01	ug-04	ug-05	ug-06	ug-09
Week 0	59	108	62	67		30
1	93	106	56	162	107	20
2	94	94	46	153	84	24
3	77				78	
4	124				93	
5	67				127	
6	99				119	
7	107				101	
8					91	
9					30	
10						
11	70					
12	57					
13	150					
14	94					
15	97					

Table 5.17: Mean Runtime (Seconds) Phase 1

User	ss-10	ss-01	ss-03	ss-04	ss-07
Week 0	109	25	98	38	62
1	100		75	138	91
2	134	3	82	134	87
3	127		234	114	94
4	103				71
5					164

Table 5.18: Mean Runtime (Seconds) Phase 2

of applications used, number of uses per week and total cumulative time per week decrease as the project progresses. This is largely due to a reduction in the number of applications used as the user gets to know the device and evaluate which applications are most useful to them.

Over the same periods of time the the median of runtime and average run time per session of use both increase which suggests that either there is less use of applications for a short time or an increase in the amount of time spent within an application. This is consistent with the user focussing on the applications they found useful. So the question raised above is only partial answered. What is clear is that there is some fall off in use, but the aspect of measured use that reduces is dependent on an individual. A reduction in use can be due to someone finding the PDA less useful or paradoxically due to them having identified a smaller subset of applications that are particularly useful.

User	32m	3f	4f	5m	7f	8m	11m	12f	13m	14f
Week 0		101	25							
1		142	395	143				33		
2		98	331	211				1354		
3		169	293					237		
4		128	621	444				277		
5			342					372		
6			240	14				121		
7		203	198					230		
8		58	367	574		67		132		
9		174	217	278		128		717		
10			118			281	483	912		
11		83	198	1719		146	414	154		
12		70	219			412	445	189		
13	124	103	343		351	685	861	73		20
14	342	125	200	440	277	708	1543			146
15	119	60	387		208	1812	665	80		115
16		145			171	812	814		368	141
17					728	1567				
18		103			236		160			
19									175	

Table 5.19: Mean Runtime (Seconds) Phase 4

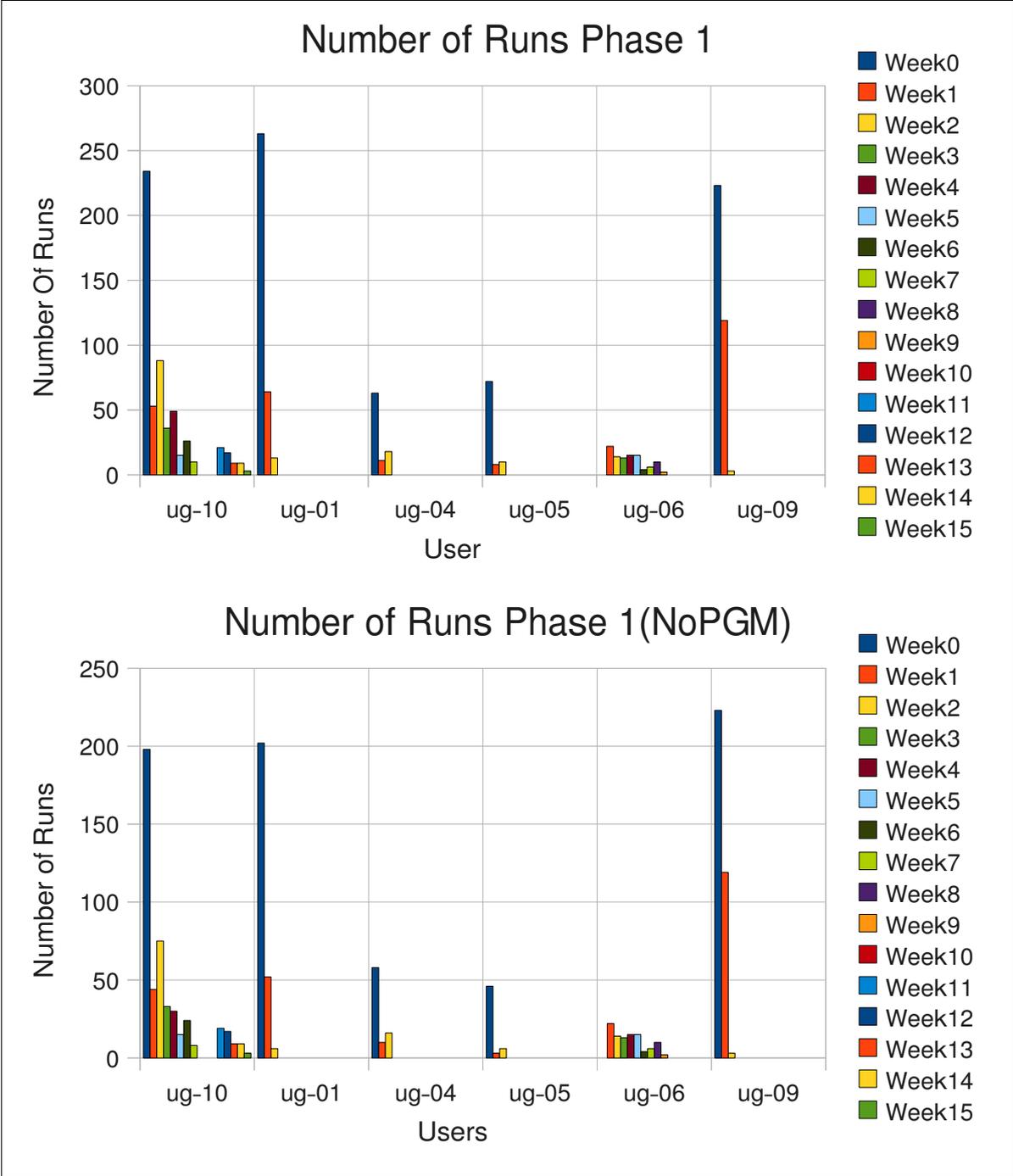


Figure 5.30: The Number of Times the was Used Per Week Phase 1

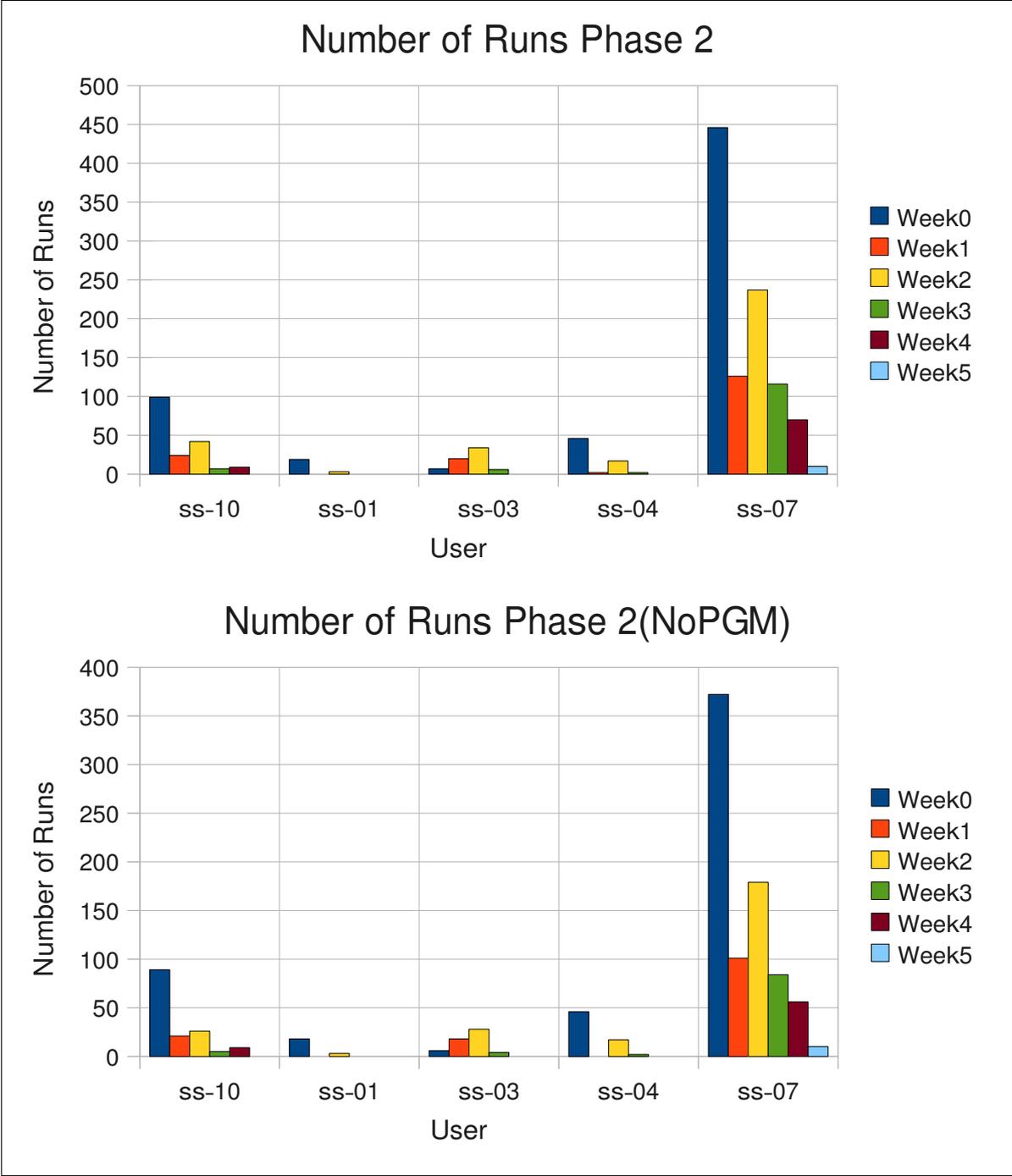


Figure 5.31: PDA Runtime Per Week Phase 2

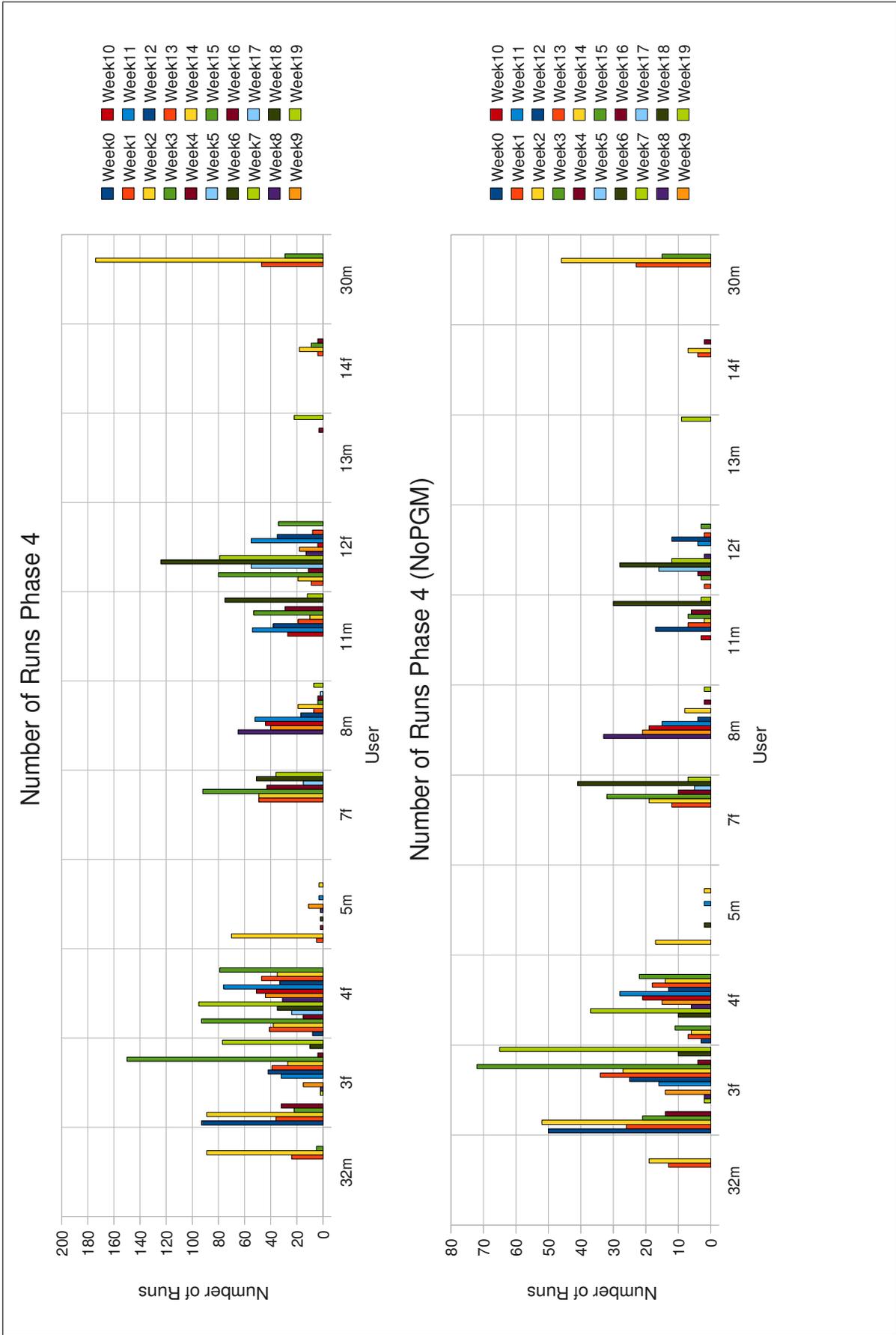


Figure 5.32: PDA Uses Per Week Phase 4

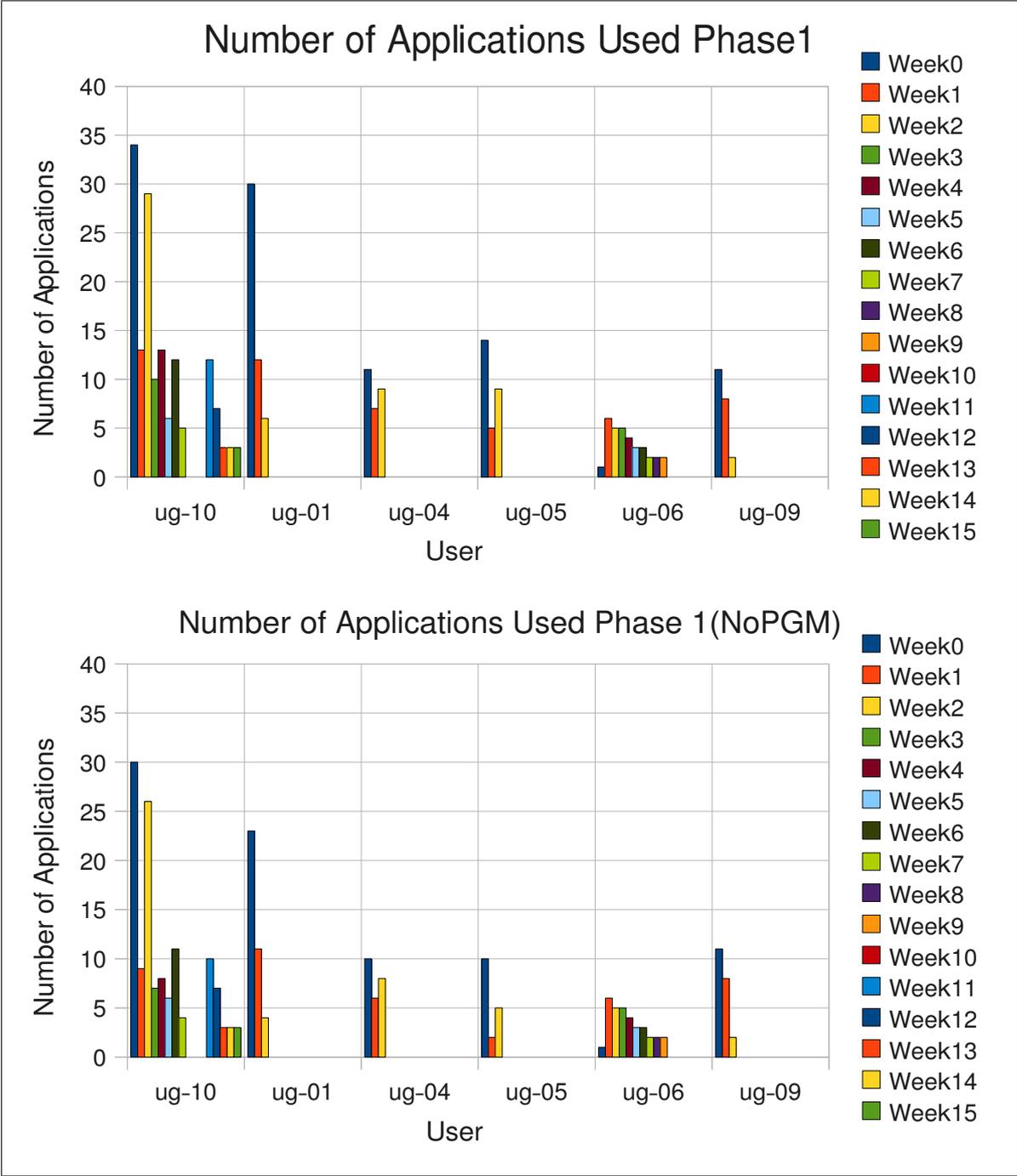


Figure 5.33: Graph Applications Per Slice Phase 1

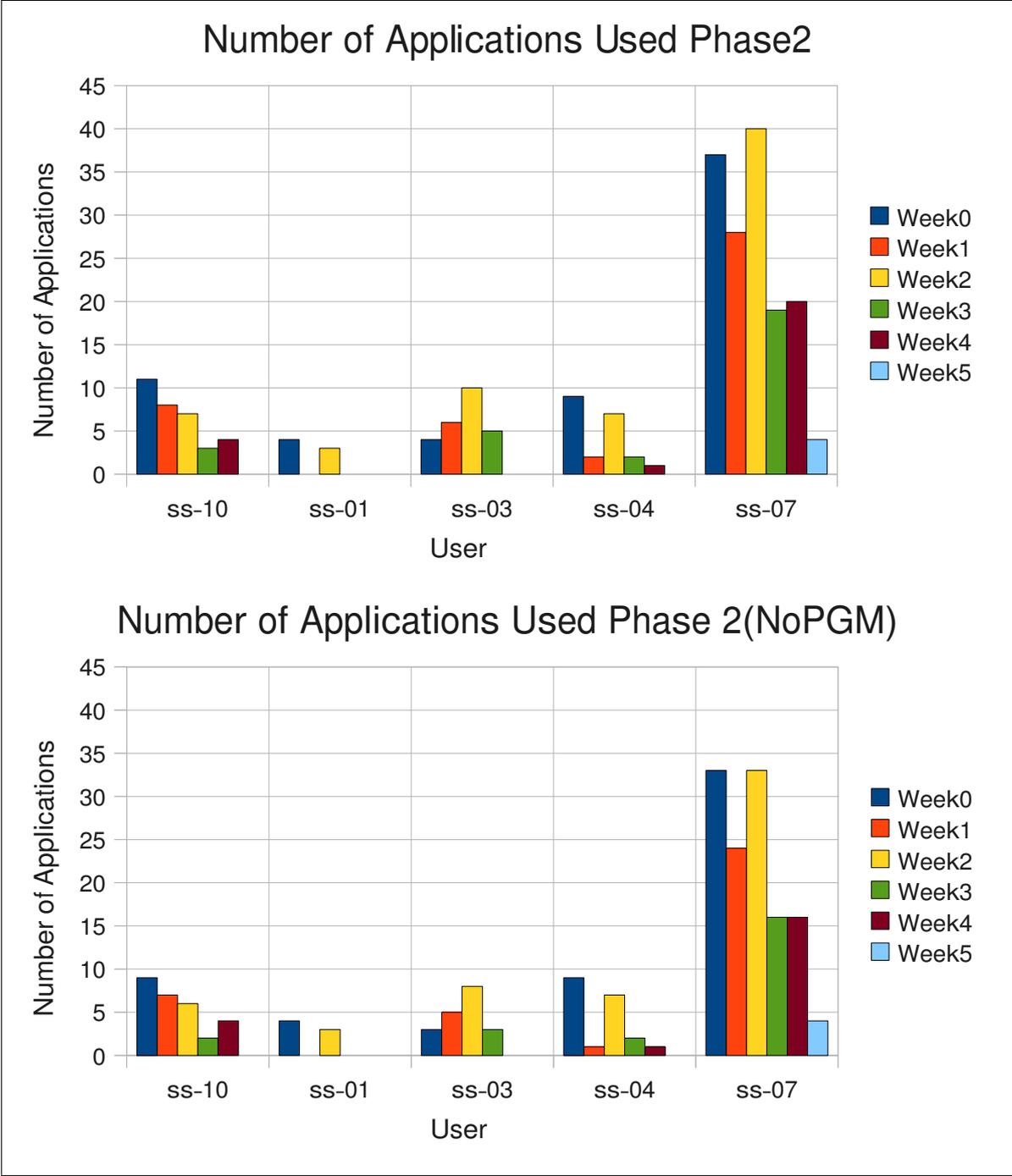


Figure 5.34: Graph Applications Per Slice Phase 2

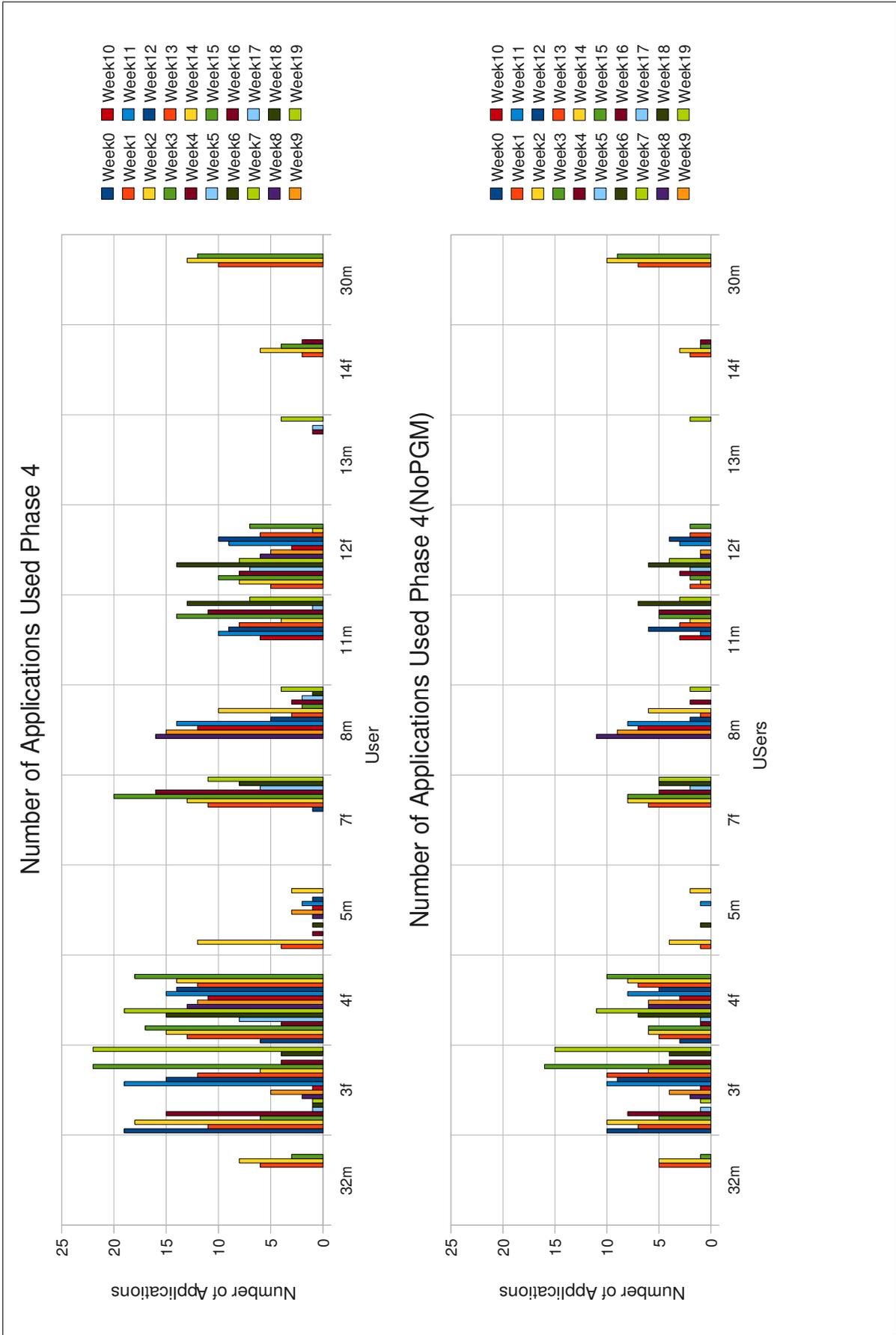


Figure 5.35: Chart Applications Per Slice Phase 4

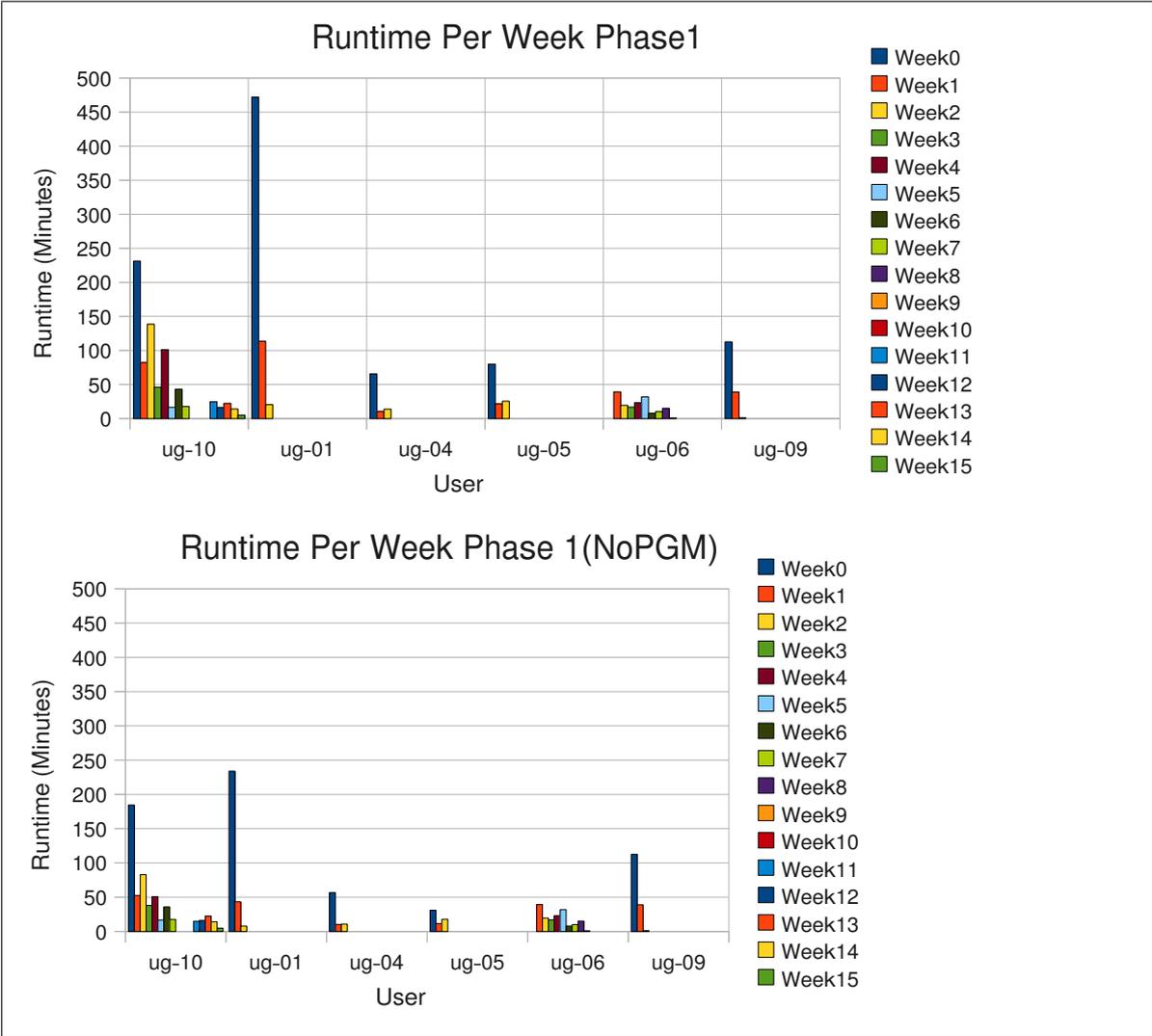


Figure 5.36: Runtime Per Week Phase 1

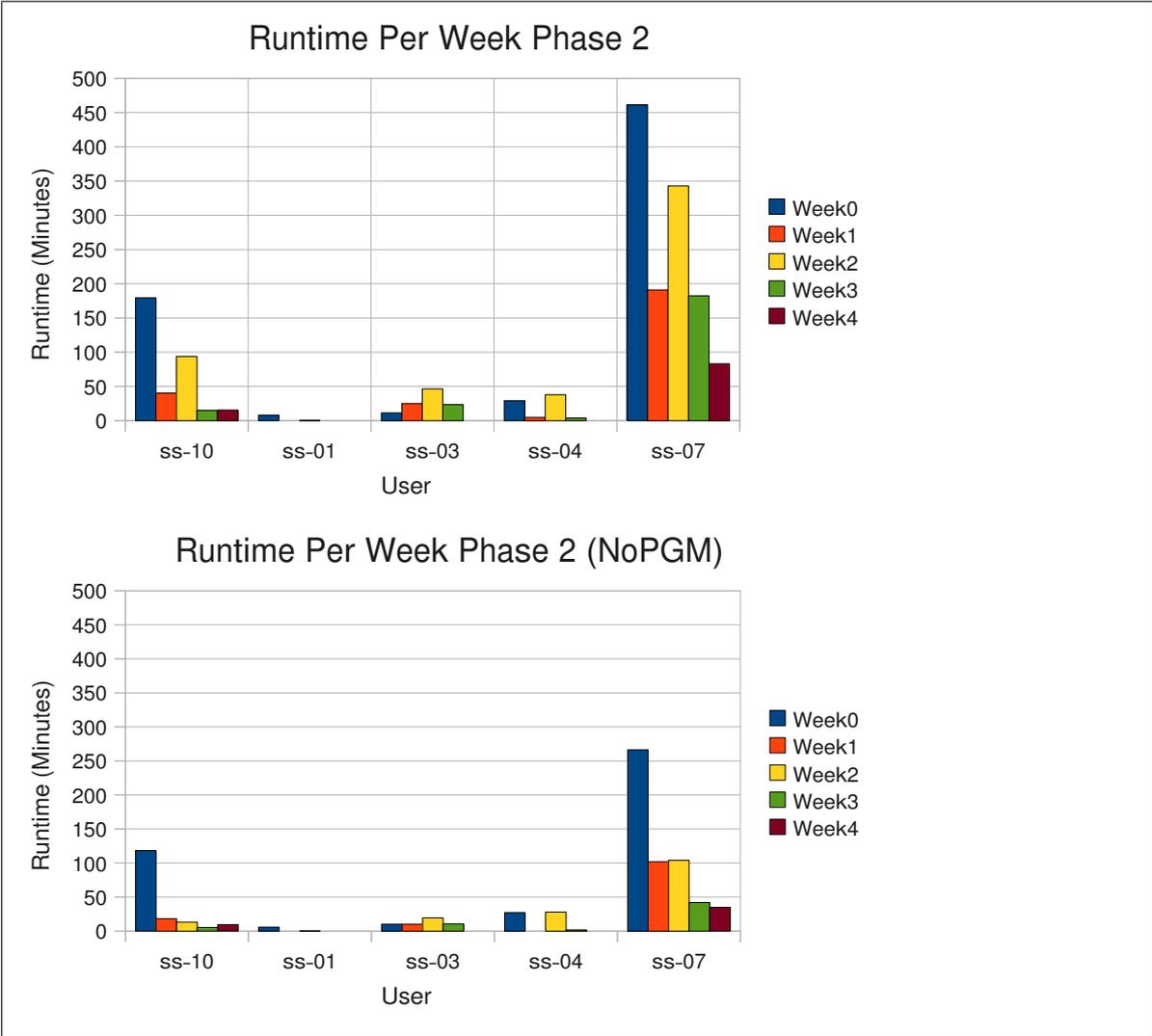


Figure 5.37: Runtime Per Week Phase 2

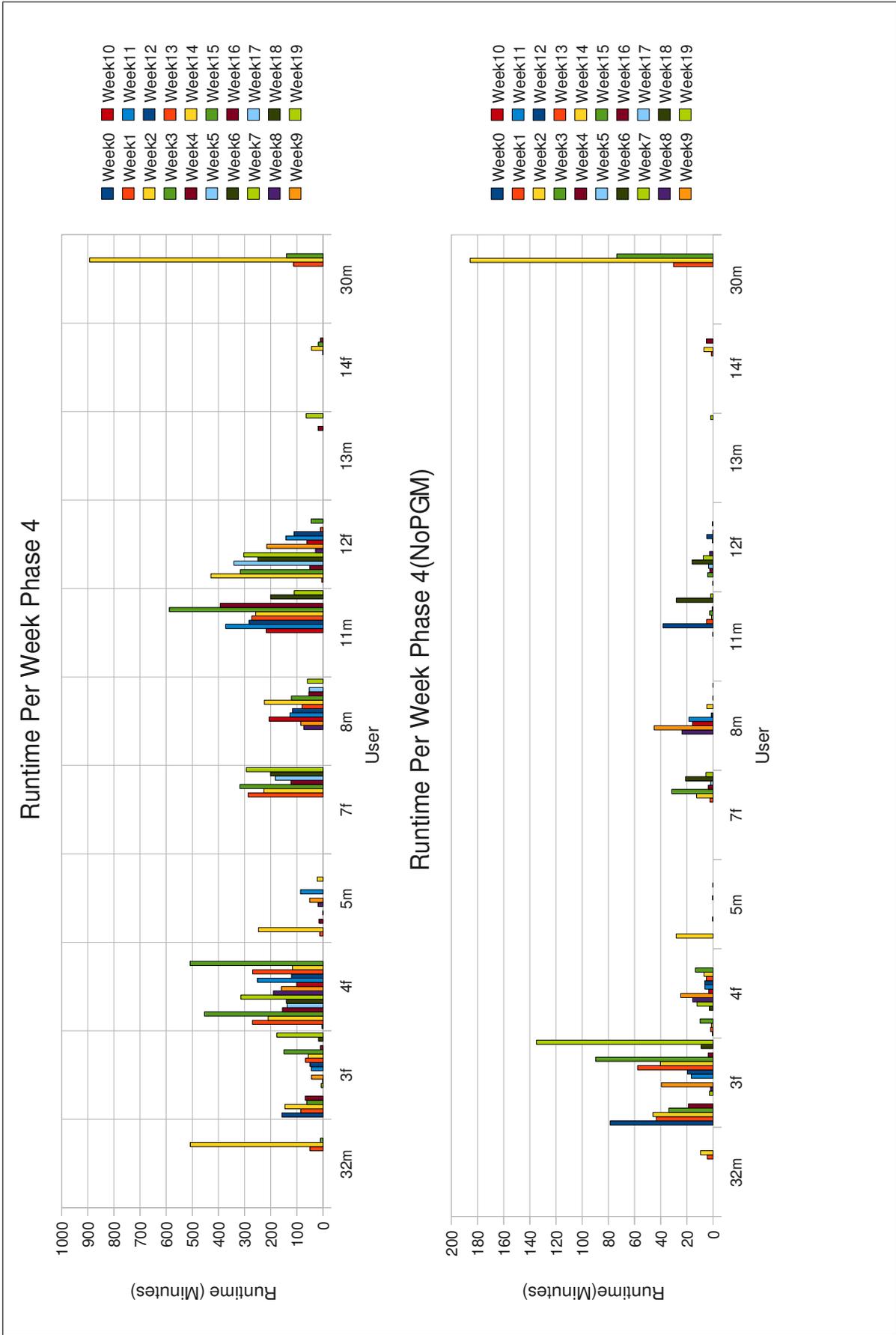


Figure 5.38: Runtime Per Week Phase 4

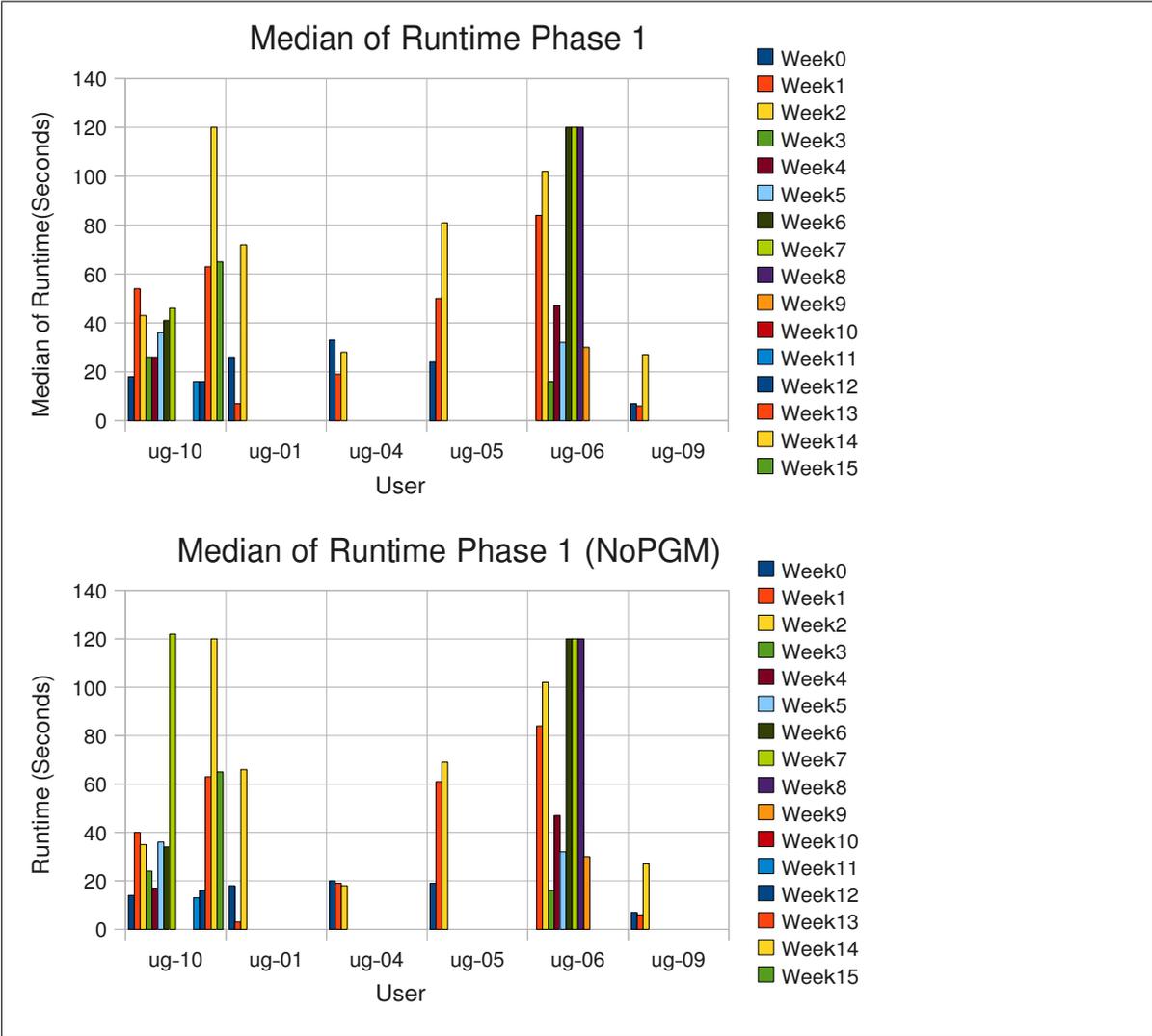


Figure 5.39: Median of Runtime Phase 1

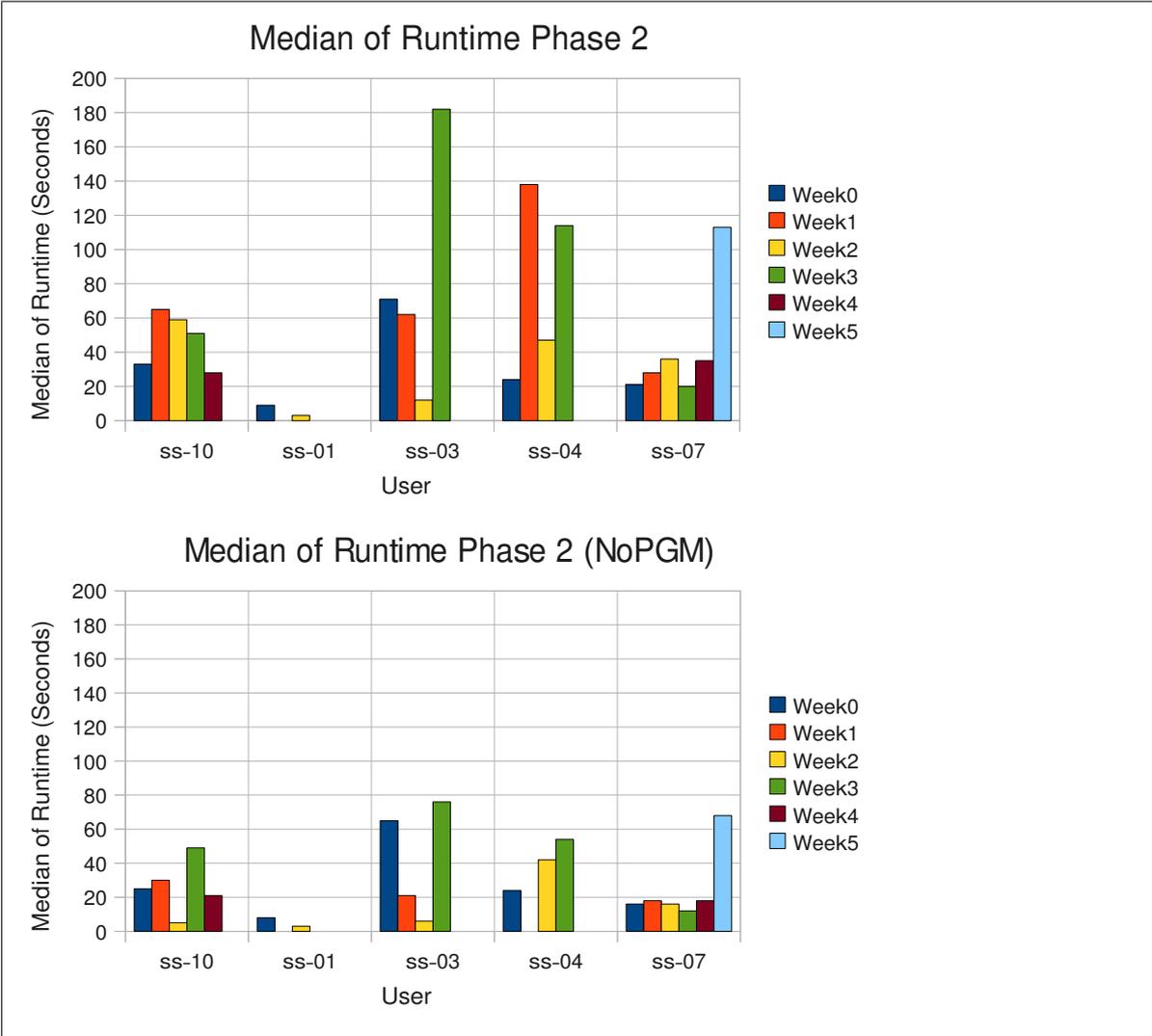


Figure 5.40: Median of Runtime Phase 2

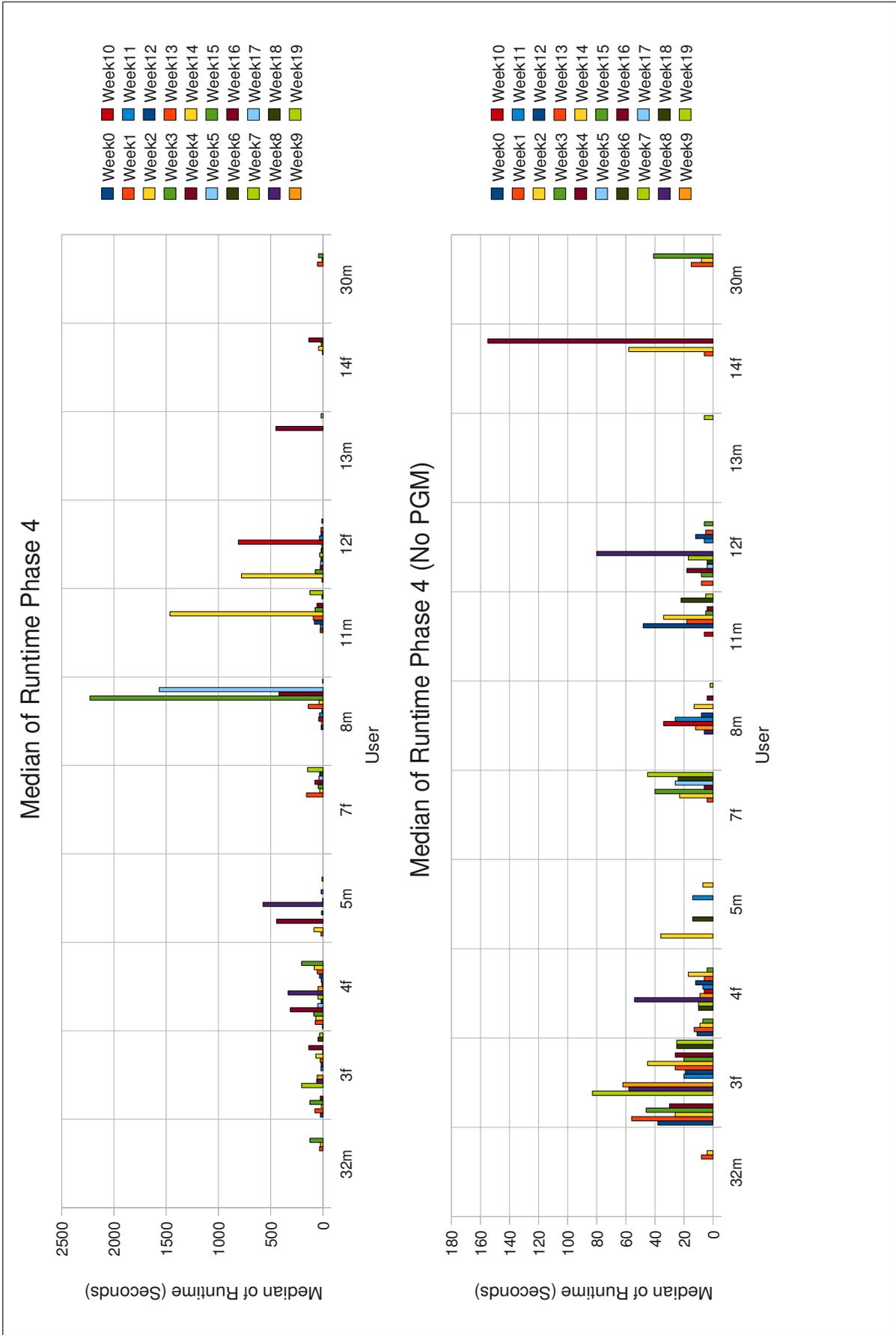


Figure 5.41: Median of Runtime Phase 4

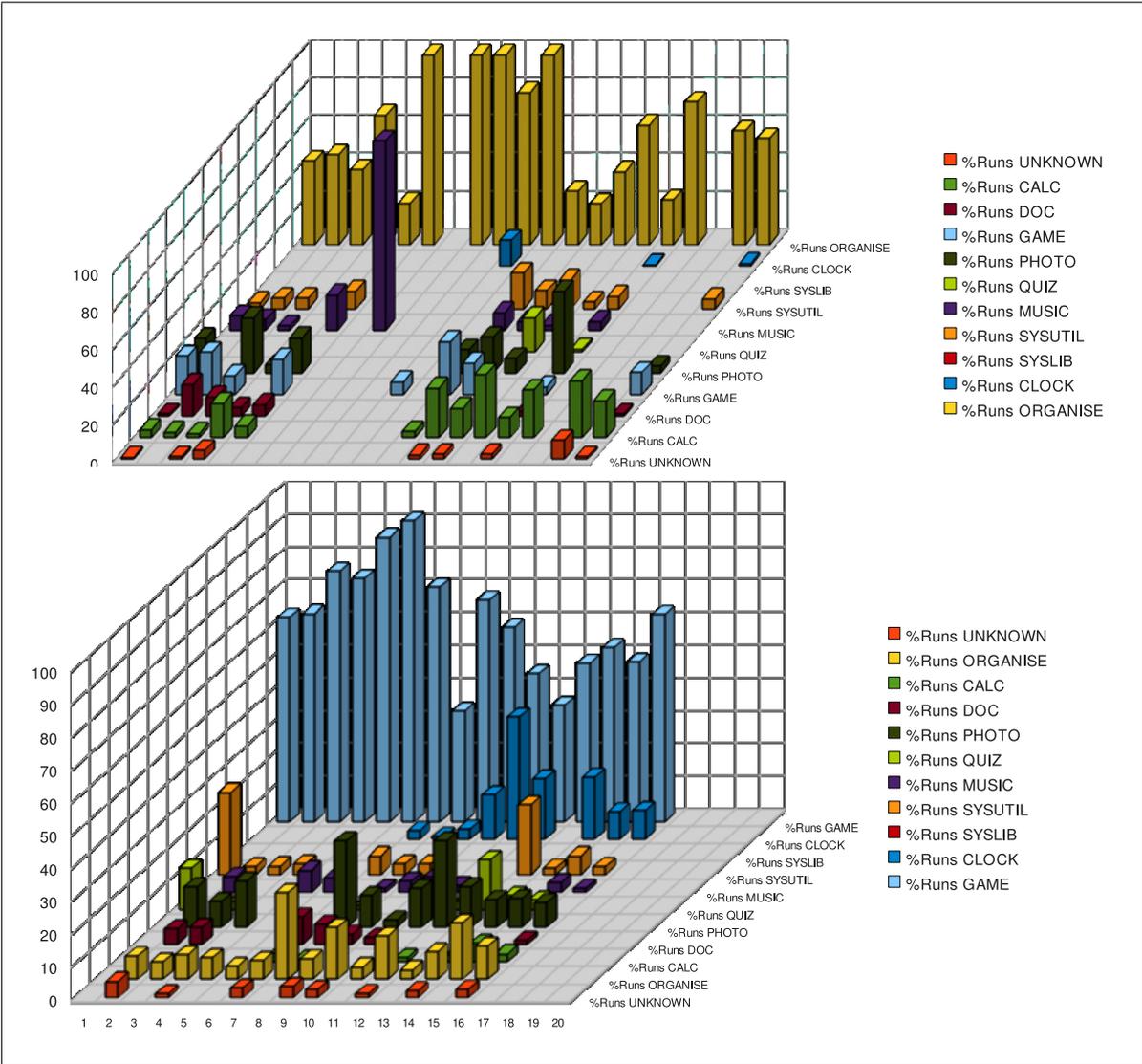


Figure 5.42: Evolution 3f 4f Phase 4

Alternative Visualisation of Phase 4

As a final examination of the evolution of use over the course of a project and the different perspectives of the percentage of time, the percentage of runs and the weekly runtime for each type of application are shown in figures 5.42 and 5.43. The users selected are 3F and 4F as it is for those that the greatest amount of weekly data was collected. These figures are included to show the outputs of the Graaf software used for interactive analysis of log data. They are more suited to interactive data exploration sessions (where the 3D viewpoint can be altered at will on a computer screen to focus on specific aspects of the data-sets) than reproduction on the printed page. However, they are reproduced here to give the reader insight into the data analysis process carried out, which eventually led to: number of applications run, number of applications used, runtime per week, and median runtime, being selected as the most useful figures of merit in the description of the evolution of student use of their PDAs and PDA applications.

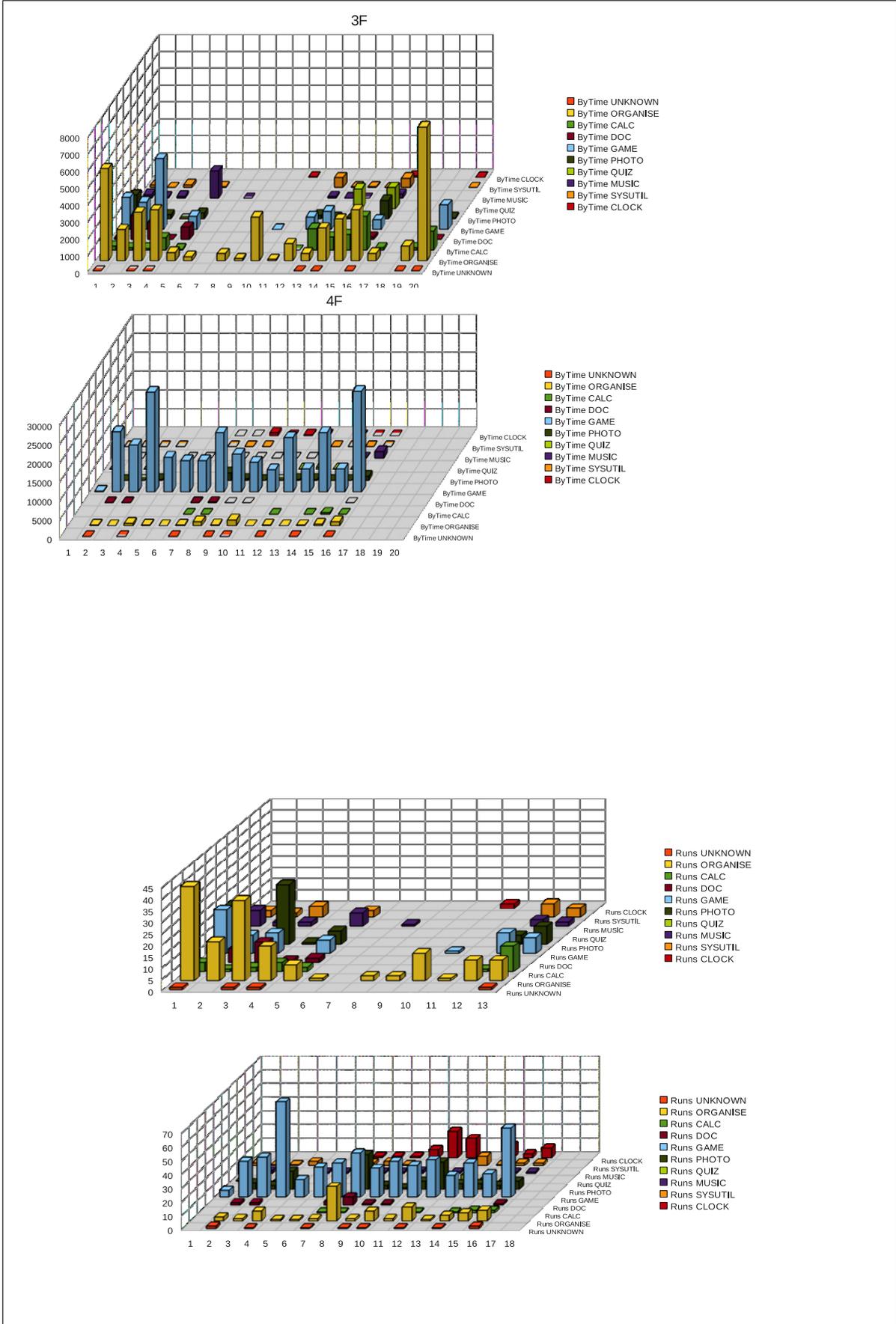


Figure 5.43: Evolution 3f 4f in Phase 4 By Time and Runs

Section Summary

In this section it has been shown that a reduction in the number of applications used occurs as projects progress. It is suggested that the high use in the early stages was due to the users exploring the device and its applications, the so called “gadget honeymoon” (Stead, 2005). It was shown that even when the number of applications used and number of uses of the PDA decrease the duration of use appears to increase.

The number of applications used is an indication of how much a user has explored a device. The use of applications that have been added to the device also show an willingness of the user to invest time in making the device useful to them.

The views of the author stated in the introduction of this section of the author that there are different type and amounts of fall off in the amount of use of PDAs or other mobile devices during a project is supported by the evidence presented in this section. The first occurs in the first few days and is probably due to the users initial exploration of the device to find what it can do and how the applications work (Waycott, 2005a). The next reduction occurs over a longer period of time and is probably a combination of increased familiarity and the loss of novelty value. the initial period of high usage referred has been called a “gadget honeymoon” (Stead, 2005). Rather than thinking of it as a fall off in use the correct view is that when first used there is an abnormally high frequency of use.

In phase 1 and 2 where the device was loaned for a fixed length of time, distinct fall-off in use was shown.

In terms of how many times the device was used the amount of times the PDA was used in the first week was much higher than the uses in the subsequent weeks.

5.2.7 The Reason for Switching the PDA On

In this section the reasons for which the student switched the PDA on are considered. Earlier in this chapter the number of occasions that applications were used was the focus, here it is the number of times that the PDA was switched on and the reason for doing so. Before proceeding it is necessary to clarify the terminology that is used and define a 'session'. The process of switching the PDA on, using one or more applications and then switching it off will be referred to here as a 'session'. This is a different definition to the one used earlier in the chapter. To clarify- , previously sessions were individual instances of *application* use, here a session is the time between the PDA being switched on and the time the PDA is switched off.

Taking the view that the reason for switching the device on can be determined from the first application used, a set of results was compiled in table 5.20.

The table has been split into two sections. "Applications most often first launched" and 'Second launched'. The columns headings are now explained. 'Sessions' indicates the number of occasions that the PDA was switched on and used before the device was either switched off or the automatic power off occurred. A session of use may comprise of the use of one or more applications. 'AppFamily 1st' is the application that was most frequently the first launched application type, 'runs' indicates the number of instances that an application from that family was the first application used and the percentage is 'runs' relative to total sessions.

The 'Second Launched' section is the application family that was most frequently the second application used after the PDA was switched on. The final column the "Sessions > 2" is how many occasions that a session of use comprised of more than one application.

In addition to the table a set of pie charts showing the first launched application family for each user are shown in figures 5.44, 5.45, 5.46 and 5.47 (phase 4 has been spread over 2 pages for clarity)

Phase 1 In group 1 for all the participants for which data was collected the first application used in each session of use was from the organiser family .

Phase 2 In group 2 for all but one user (ss-04) applications from the organise family were the primary reason for switching the PDA on. User ss-04 had made very low use of the PDA , their most frequently first used application following switching the PDA on (sysutil) had only been used on 8 occasions. So there are insufficient results from this user to make any useful conclusions on their PDA use.

As the original central function of PDAs was to provide the facilities of diary and organiser tools the popularity of these functions is perhaps not surprising, but another possibility exists for why the use of organiser applications appears to be the main reason for switching the PDA on.

Application most often first launched					Second Launched	
User	Sessions	AppFamily 1st	Runs	%	AppFamily 2nd	Sessions >2
Phase 1						
ug-01	97	ORGANISE	38	39	GAME	44
ug-04	25	ORGANISE	19	76	ORGANISE	17
ug-05	44	ORGANISE	11	25	SYSUTIL	19
ug-06	82	ORGANISE	74	90	ORGANISE	15
ug-09	83	ORGANISE	49	59	ORGANISE	62
ug-10	228	ORGANISE	119	52	ORGANISE	92
Phase 2						
ss-01	7	ORGANISE	5	71	ORGANISE	4
ss-03	38	ORGANISE	19	50	ORGANISE	15
ss-04	22	SYSUTIL	8	36	QUIZ	16
ss-07	296	ORGANISE	120	41	ORGANISE	169
ss-10	99	ORGANISE	67	68	ORGANISE	28
Phase 4						
3f	234	ORGANISE	101	43	ORGANISE	118
4f	362	GAME	222	61	GAME	137
5m	32	GAME	12	38	GAME	20
7f	157	GAME	50	32	GAME	73
8m	95	MUSIC	33	35	PHOTO	35
11m	127	MUSIC	67	53	MUSIC	60
12f	216	PHOTO	110	51	PHOTO	134
13m	11	GAME	9	82	SYSLIB	3
14f	23	GAME	7	30	PHOTO	7
30m	66	MUSIC	25	38	MUSIC	37
32m	52	MUSIC	32	62	MUSIC	23

Table 5.20: Launch Reasons All Phases

The PDA can be switched on by two means, by using the power button or by using one of the application buttons. By using the application buttons the PDA is both switched on and the application associated with the button is immediately launched. As the application buttons are by default associated with applications classed as being of the organiser type then it was possible that the apparent use of the organiser applications was just an side-effect of using the organiser buttons to switch the device on. To evaluate if this was the case is the purpose of the “Second Launched” section of table 5.20 on the previous page, which shows from what family the second application used in a session was from.

The columns of the “Second Launched” section show the application family that was most often the second application used in a session and the number of sessions for which that was the case. The reason for comparing the second application launched was to see if there was any indication that the application button had only been used to switch the device on and then the next application used was the one for which the device had really been switched on.

In all but 3 cases the second application used during a session of use was from the same family of applications, which suggests that the first launched application was the genuine reason for use rather than a side effect of the convenience of using the application buttons to switch the PDA on.

The 3 exceptions were student ug-01 - whose second used application was from the game family, student ug-05 whose second used application was from the systuil family and student ss04 -was the quiz. Evidence from later in this chapter shows that ug-01 only switched from using organise to game applications on 8 occasions, so their primary reason for use was really organise applications. ug-05 logs show that the user of a systuil never followed the use of an organise family application, so again this suggests their primary reason for switching the PDA on was to use the organise applications. ss04 only shows 2 instances of switching from organise to quiz, so again their primary use was organise applications.

Phase 4 The majority of this group use for the PDA was for games (5 users) and Music (4 users). The exceptions were user 12f whose primary purpose was to use photo applications and user 3f whose main use was organiser applications. User 3f ,in contrast to the rest of the group ,made very little use of games or the music player.

The 3 phases can be considered as two groups, those using the PDA with the monochrome display ,phases 1 and 2 and those in phase 3 using the PDA that had a colour screen, media player, camera facilities and more processor power.

It was not surprising that games were used more on the more powerful devices as these enabled games with richer graphics and interaction. But it is possible that the lack of games use on the simpler devices was because it was at a time before devices , such as phones, were taken seriously as a game playing platform.

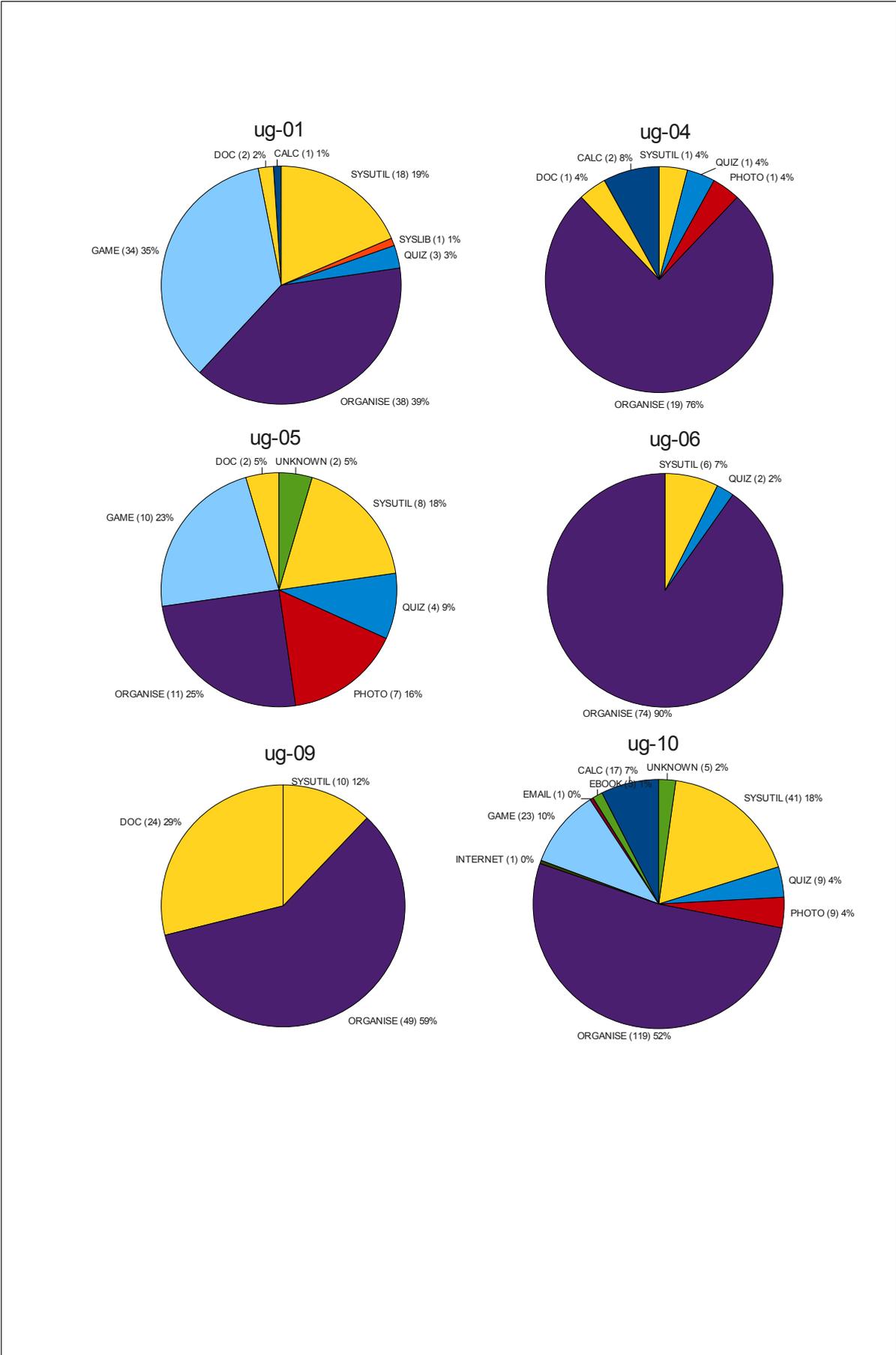


Figure 5.44: Phase 1 Launch Reason by Application Family

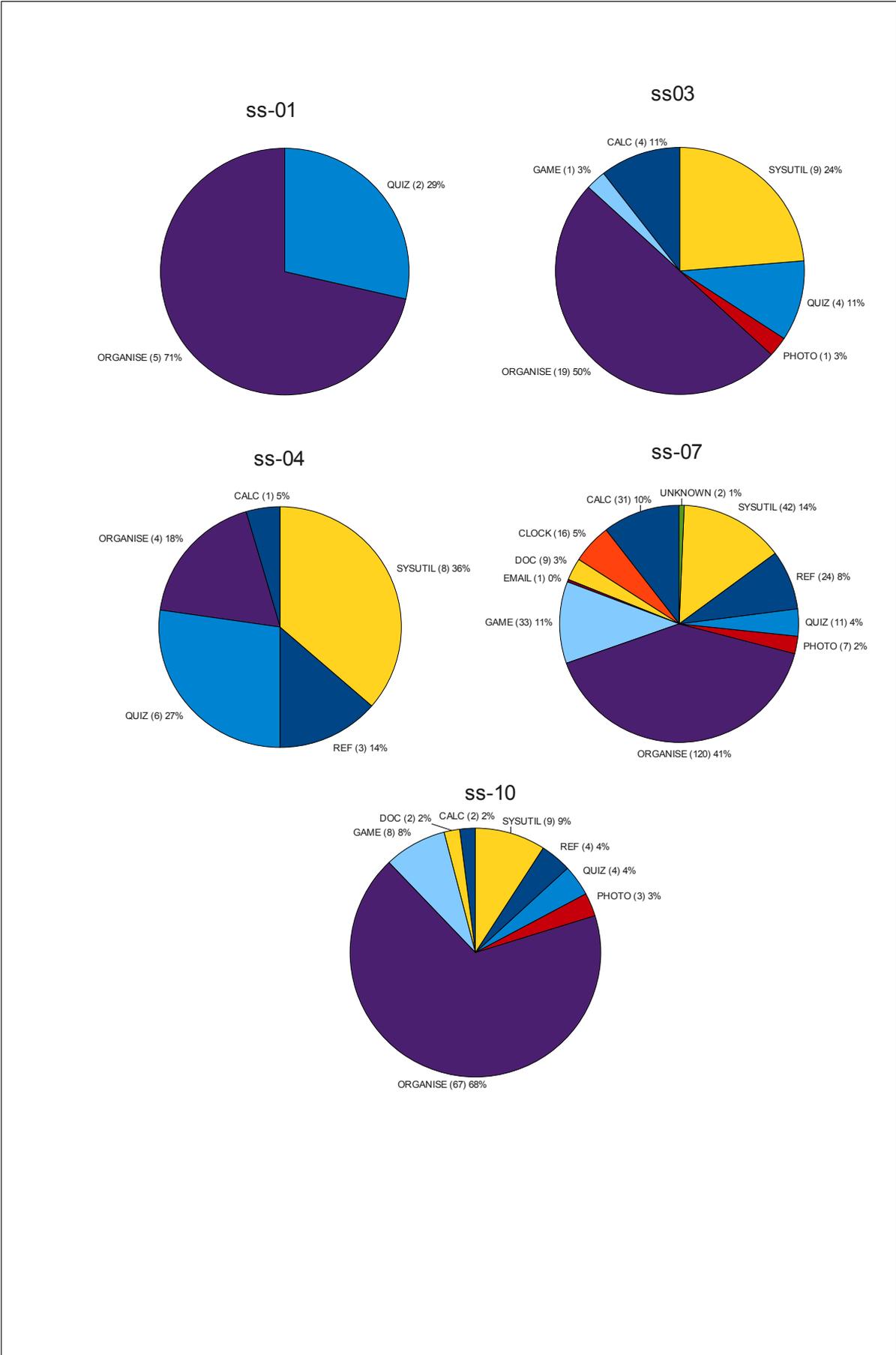


Figure 5.45: Phase 2 Launch Reason by Application Family

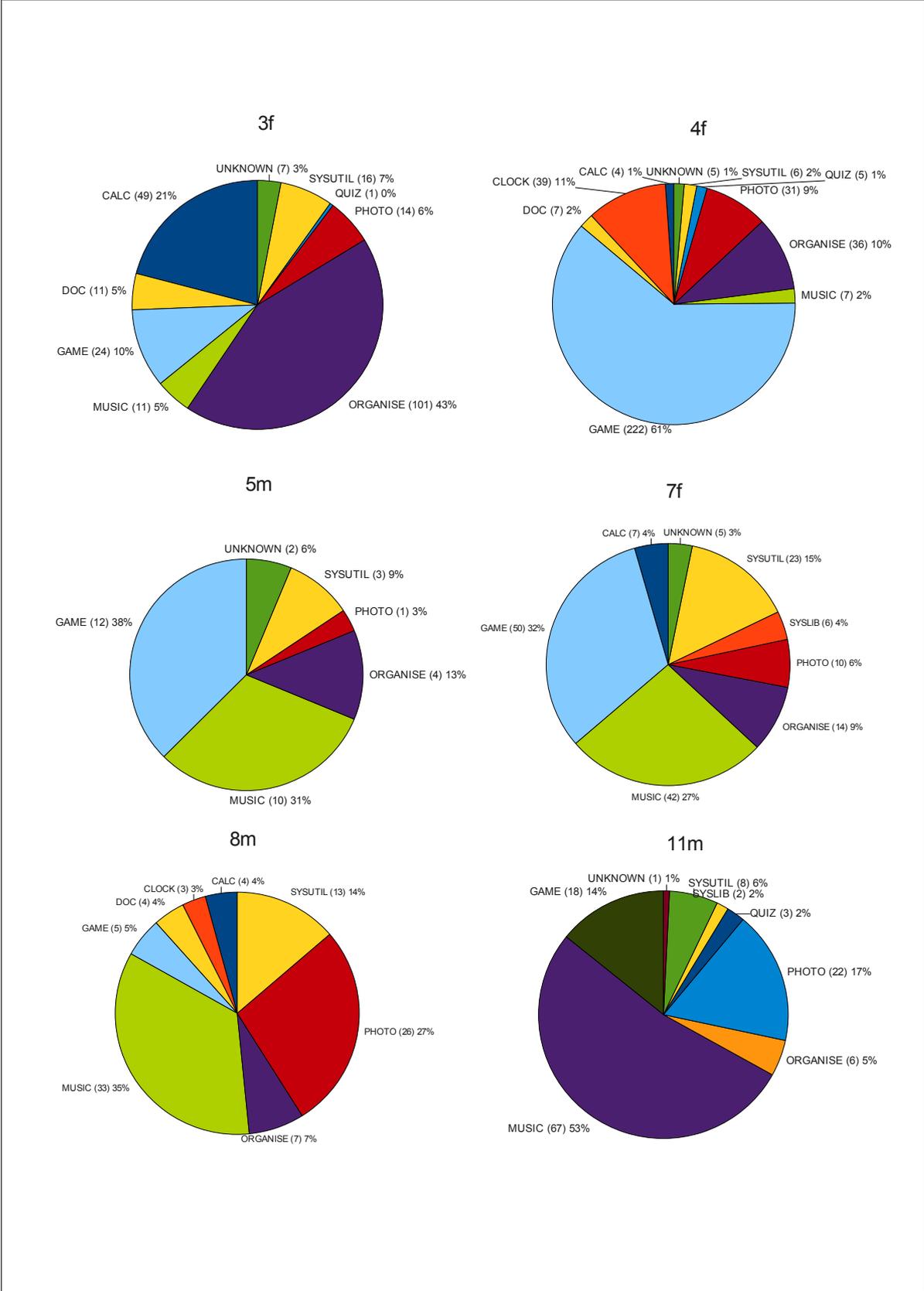


Figure 5.46: Phase 4 (a) Launch Reason by Application Family

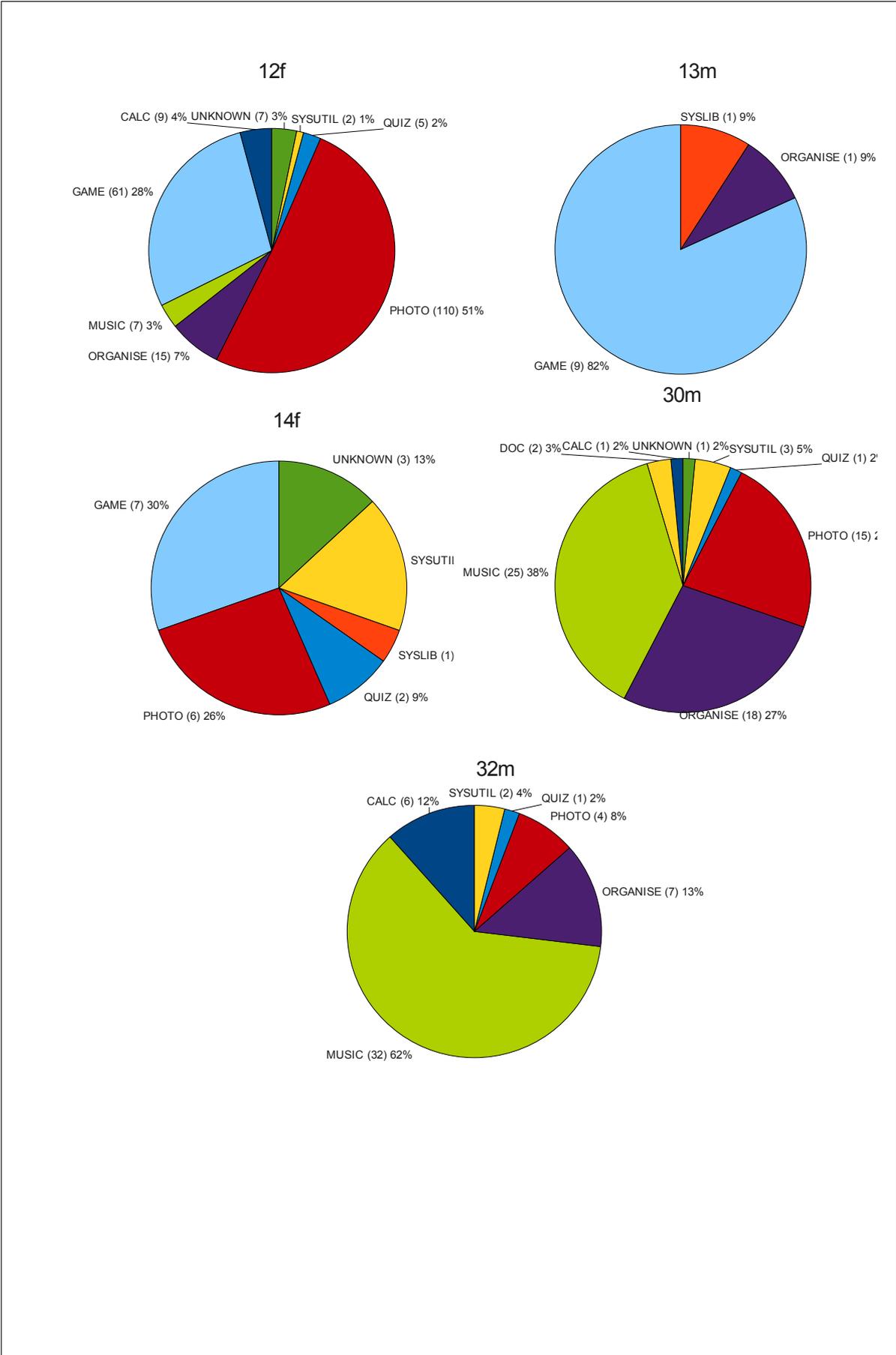


Figure 5.47: Phase 4 (pt2)Launch Reason by Family

5.2.8 Sequence Of Application Use

The pattern of application use is now explored i.e. which applications are used together. For example, if an organiser application is used what sort of application is likely to be used next- for example another organiser application or a music application? A table was produced for each user to show the number of occasions upon which the use of an application type followed another. The figures showing the number of occasions are included in the Appendix, but the pattern can be seen more clearly in the diagrams that will first be described as they are somewhat novel.

Interpreting The Charts

The type of diagram used in figures 5.48 to 5.51 were originally developed by Krzywinski, M. et al. for visualising Genome sequences (Krzywinski *et al.*, 2009). The software they wrote to produce the diagrams is called “Circos”. Here the diagrams are used to visualise patterns of application use, for example if the student used an organiser application what application did they use next? As has been the strategy so far applications were grouped into families or types of application.

Before reporting on what the charts reveal there is an overview of how to interpret the charts. Around the circumference of the charts are the names of the family of application and from these flow “ribbons”(as they are called in the Circos documentation). Where ribbons are in contact with the outer edge of the circle is the source of the ribbon and at the end where there is a slight gap is their destination.

In some cases ribbons flow back towards their source segment and this indicates where the use of a particular application family type is followed by the use of another application from the same family. So for example, using a ToDo list (an organiser application) followed by the Calendar would be such a situation.

As an example of the use of these charts consider the chart for user 13m shown in 5.51 on page 179. There was very little usage information collected for user 13m but this does mean the chart provides a straightforward example. User 13m only used 4 types of application - game, organiser, syslib and photo.

The green ribbon flowing from organise towards photo indicates those occasions where the user went from using an organiser application to a photo application.

The blue ribbon flowing from photo to organise shows the reverse - the number of occasions that following the use of a photo application they then used an organiser application which means they went from organiser to photo application more often than from photo to organiser.

There are two ribbons flowing from the game segment; one from game to syslib and another that leads back to game. The one leading back indicates the occasions upon which the use of a game application was followed by the use of another game application.

The gradations on the outer circumference show the number of times that a sequence

of application use occurred. The number in brackets next to each of the figures indicates the number of sessions of use for which data was collected and upon which the chart was calculated.

What The Charts Convey

Considering the charts from all phases it is apparent that the charts vary from the simple ones with few application types (each application type is represented by a colour), such as student ug-06 to those with more application types used and much more cross-over of the ribbons, such as student 8m. The charts for students ug-06 (from phase 2) and 8m (from phase 3) represent similar number of sessions of use, so what contributes to the variation of their appearance?

The Circos charts make it easy to identify those users who make very specific targeted use of the PDA. Targeted use is shown by the simpler charts with very little or no movement between application families compared to those of more independent learners who move around between applications. These charts give us more data in identifying targeted vs more general users than the charts earlier in this chapter.

Phase 1 Typically, users can be seen to move from document to organiser type applications and less from organiser to document. But on the majority of occasions they switch to another application from the same family as indicated by the looped back ribbons.

Student ug-09 used only 3 types of application - Organise, Doc and SysUtils, the majority of the use being document or organise type applications (the SysUtils application provides access to device settings). Student ug-09 shows very little evidence of moving between application families but there are only 21 days of log information. For most of this group there are only 3 weeks of log data, the exceptions are 109 days for ug10 and 60 days for ug06.

There appear to be two types of users, the first uses either a small number of applications or small numbers of types of application. This sort of use suggests a targeted usage either due to lack of imagination in usage of the PDA (suspected where usage is high but little swapping) or little interest (suspected where usage very low). In phase 1 a 3rd of students fall into this group and 2/3 in more normal usage patterns. Our suspicion is that the targeted users are either very bright or those struggling in their studies but have no further supporting evidence. This suspicion will be revisited in phase 4 where additional information was collected about the students course results.

Previous results show the amount and time of day are normal, but use is very targeted, these students very rarely use the PDA other than the purpose for which they initially switched it on.

Although the number of sessions of use for students ug-09 and ug-06 is very nearly the same (83 and 82 launches respectively) other aspects of use were different. In a session of use student ug-09 used more applications during the session, this is indicated

by the larger number of instances of uses shown on the outer axis. This is verified in table 5.20, which shows that on 62 occasions student ug-09 did use more than one application during a session of use whereas on only 15 occasions did student ug-06 use more than one application during a session of use. Also 5.7 on page 109 which shows that the averaged number of application uses per session for student ug-09 was 4 but for student ug-06 only 1.

In comparison students ug-04 and ug-05 charts represent a lower number of sessions but show similar characteristics to the others in the group, such as when using more than one application within a session, they tend to stay within the same application family. Students ug-04 and ug-05 also show the use of Quiz and Calculator together which strongly indicates they were actively making use of the quiz and not just going through the motions for the sake of appearance. Student ug-05 tends to stay within an application family, which shows they make targeted use of the PDA.

In the phase1 group there was far greater usage information for user ug-10 than the rest of the group (109 days of log data compared to 21 for most of the rest of the group). Student ug-10 shows a similar pattern of use to the rest of the group with large proportion of use of the organiser application and the use of the Quiz and Calculator together. Student ug10 was one of the few students in the phase 1 group who had used games, although they only switched from game to game during a session of use on 9 occasions , which is something that contrasts with patterns of use for the phase 4 group. So perhaps this was an exceptional mode of PDA operation.

This suggests a use strategy where the PDA is used for a very specific purpose but when the task is completed the student then considers the implication that work has on their day. Or perhaps it is a case of having completed a task that while the PDAs is in their hand and switched on it becomes habit to have a check of outstanding jobs or upcoming deadlines.

Phase 2 In this group there is a large differential in the amount of log data collected, for ss-01 and ss-03 there is only 2 weeks of log data compared to the rest of the group for who there were 4-5 weeks of logs.

Phase 2 results exhibit are similarities with phase 1. All of the group, though in varying numbers exhibited the pattern of using applications from the same family. ss-04 and ss-07 both show switching from using the quiz to the calculator and vice versa.

One member of the phase 2 group does stand out as having made far greater use of the PDA. ss-07 has 296 sessions of use and a total of 1005 runs of applications, compared to the nearest next highest user with 100 sessions of use and 180 runs of applications. In the course of sessions of use ss-07 switched between more application types than the rest of the group as shown by the amount of crossover of lines on the chart. Their use of games is similar to ug-10 in phase 1 in that they moved from using a game to another game on relatively low number of times, only 25 occasions.

Phase 4 A big change from the previous phases is that for most of the users the greatest application use is of music, photo or game applications. The photo and music facilities were not available on the earlier devices.

The photo and game applications also show frequent re-use of applications from the same family (as shown by the loop-backed ribbons). For the photo application some of this is due to the way the photo application worked, i.e. the main photo application launching a sub function to take a photo and these were not differentiated in the results.

However even with the differences caused by photo and game applications we still note three distinct types of user. Those with low usage and quite simplistic swapping between application families (if at all), this includes students 5m,13m,14f. We have exam results for these students and we note that 5m,13m,14f all obtained failing grades which shows they were struggling with their studies and perhaps out of their depth.

The second type of user show a relatively low set of PDA use (other than as music players)but more complex swapping between applications, this includes students 30m and 32m. Students 30m and 32m are at the other extreme of exam results and were the best two students in the class. This strongly supports the suspicions raised in phase 1 that the targeted users are either very bright or those struggling in their studies.

Students 30m and 32m used the PDA mainly as a music player. (as can be seen from the graphs in 5.47). It can also be seen from 5.29 that 30m and 32m used the organiser applications more times per day than the rest of the group. This suggests that as they had a reason to carry the PDA with them, the music application, they had also then found other uses for it.

Unlisted Creator Codes The Circos charts show that applications of the same type are often used together in a session of PDA use. This is shown by instances of ribbons looping back to their source family. It appears that the PDA is often switched on to primarily use a particular “family” of applications, for example it would be likely that having added a deadline to a calendar that there may be reason to also add an entry to a ToDo list. The loop backed ribbons may also help to identify “unknown” applications i.e. those with unlisted Palm creator ID codes. The Palm creator ID being an application identifier that is supposed to be globally unique to an application and be registered with the owners of the Palm Operating system. It was suggested in earlier chapters that those applications which had unregistered Palm creator codes, were most likely to be games. This assertion was based upon the examination of applications without registered creator codes and my prior knowledge as a developer which had been gained from discussions with the worldwide Palm developer community.

This is also supported by the pattern of use in these charts showing that a large proportion of uses of “unknown applications” were preceded by the use of a Game application and also that on those occasions were the unknown applications use followed on from the use of another application that was from the Game category.

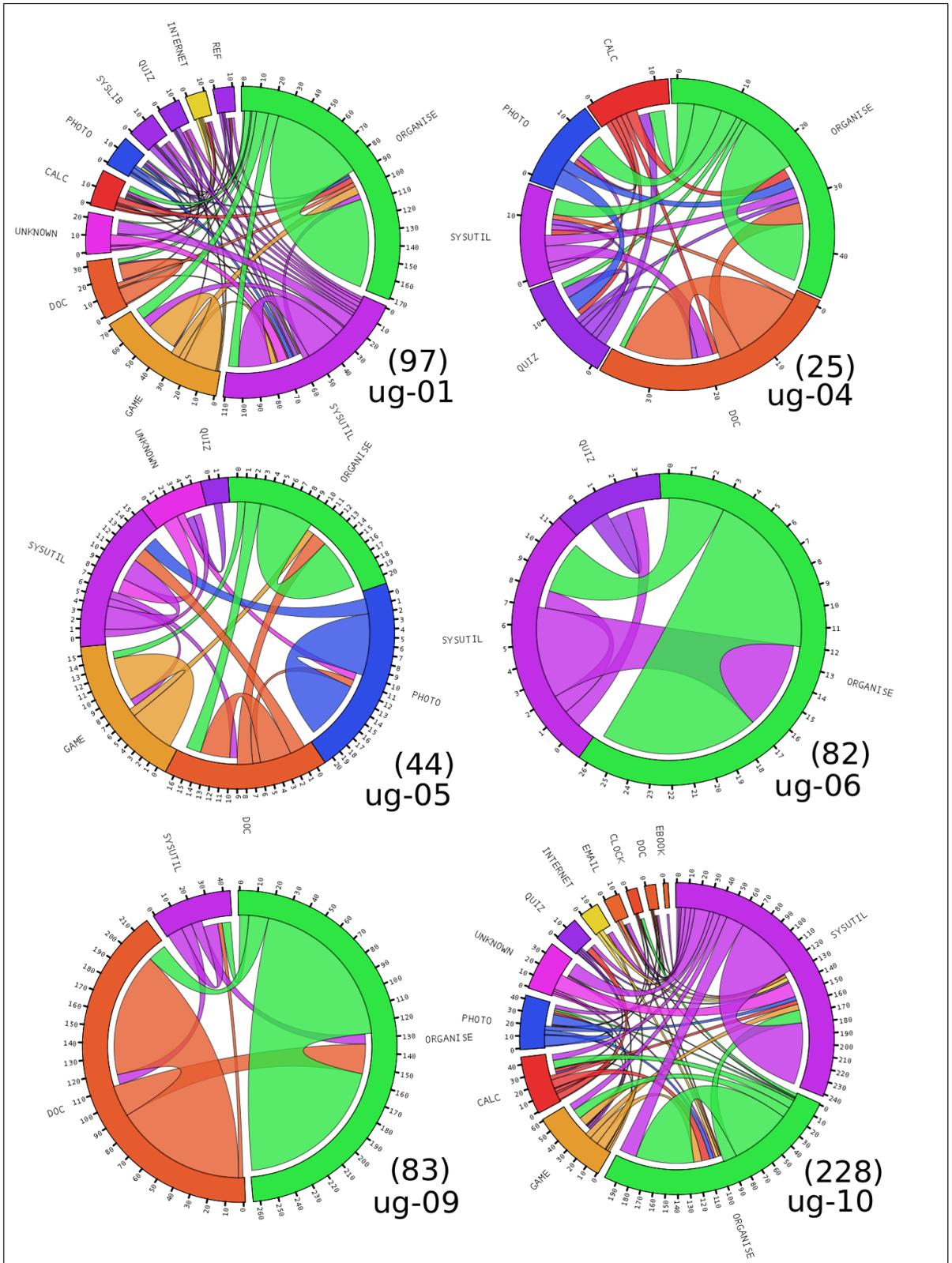


Figure 5.48: Phase 1 Application Family Use Sequence

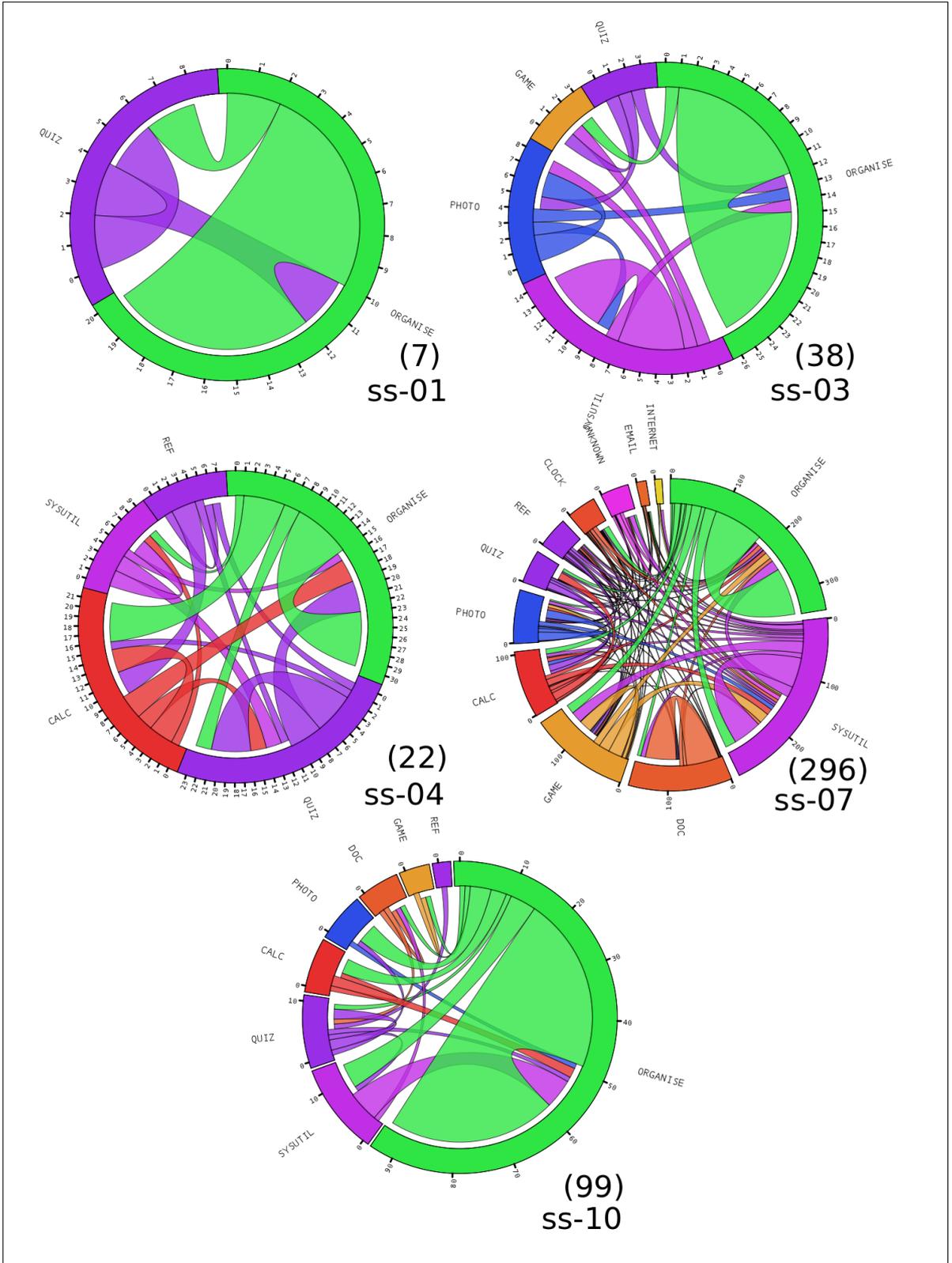


Figure 5.49: Phase 2 Application Family Use Sequence

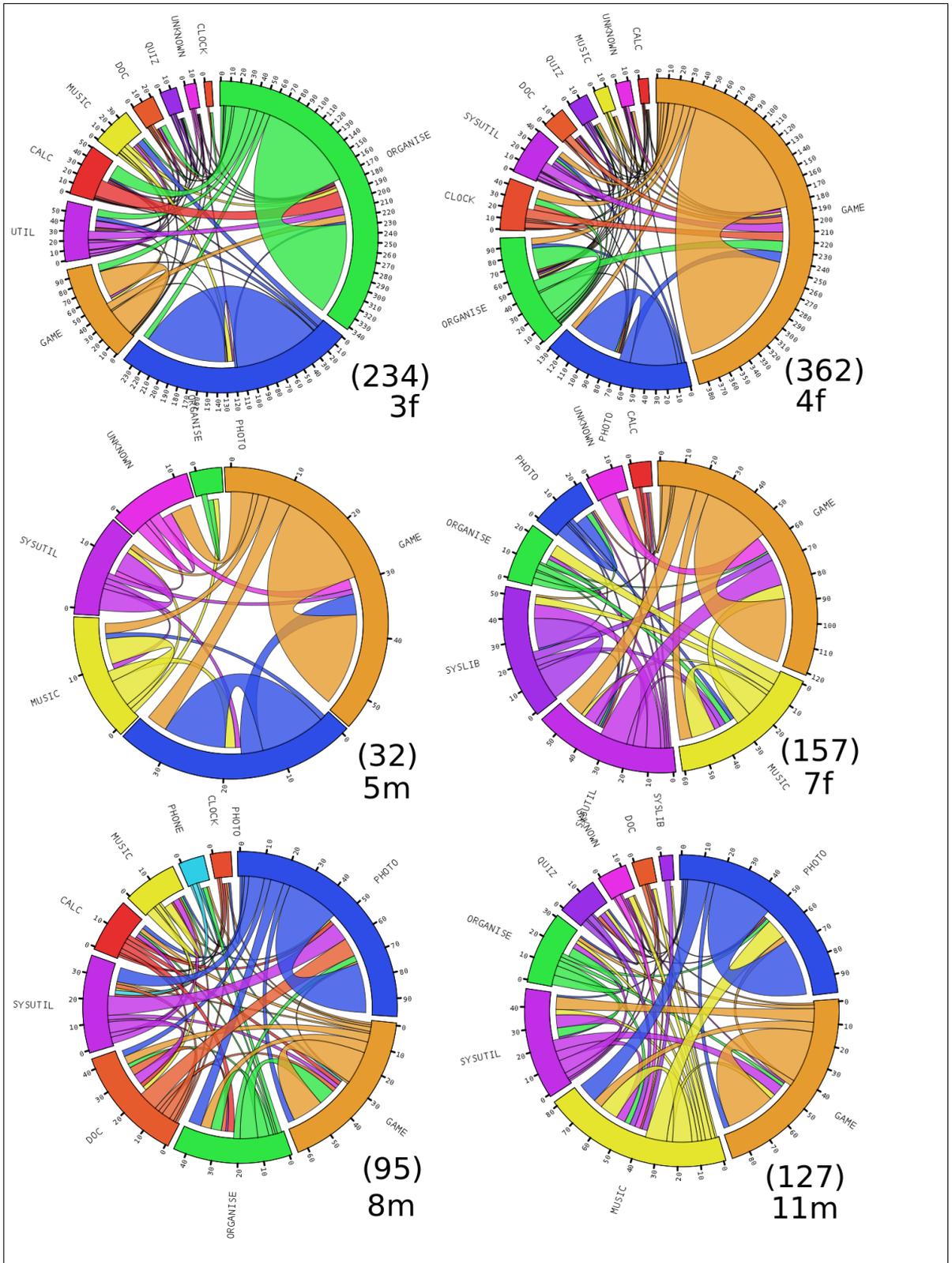


Figure 5.50: Phase4 Application Family Use Sequence (Part 1 of 2)

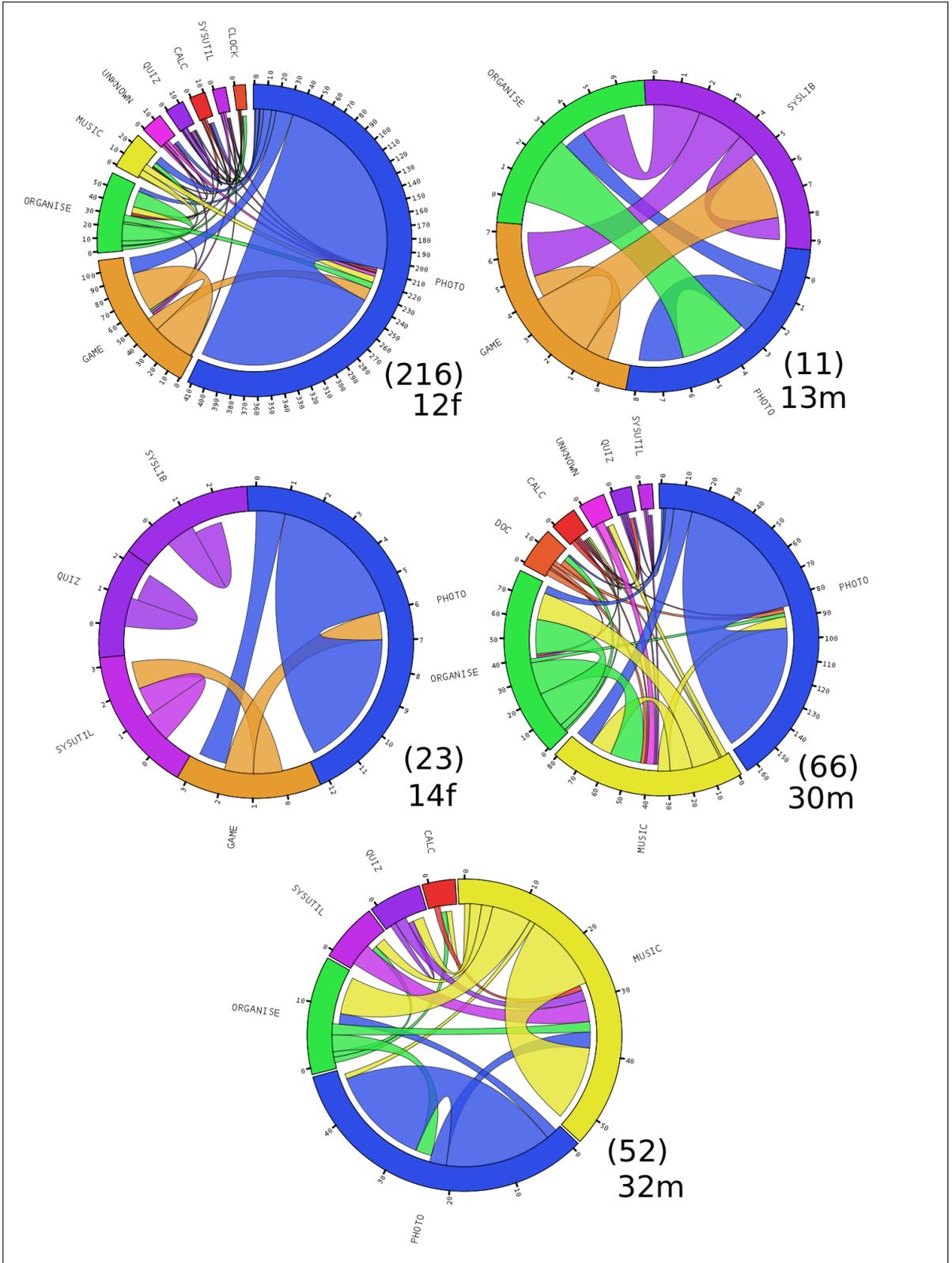


Figure 5.51: Phase 4 Application Family Use Sequence (Part 2 of 2)

Conclusion

The charts produced by the Circos application, as well as showing which applications are used together, have revealed information that would have required far more work in the examination of log files or tables of information. The charts can quickly give an impression of how much the PDA was used in real terms and the mix of the type of uses and the pattern of swapping between type of application during a session of use. In all phases of the project it is shown that generally if an organiser application was used it was likely that it would be followed by the use of another organiser application. The lack of switching between families of application indicated either a very targeted use of the PDA or of the user pretending to be using the PDA when one of the project team was present. Very targeted use of the PDA suggests a user who is either very bright or one who is struggling with their studies

5.3 External Sources of Information

In addition to the information gathered via the logging system additional data was collected from questionnaires, interviews, student interaction with the University of Glasgow VLE and exam results. Whilst some of these results are mentioned above where necessary, in this section all of these results are examined in detail.

5.3.1 Questionnaires

Questionnaires were used at the start of phase 4 to gauge students' familiarity with mobile technology, flag possible obstacles to PDA use which could be overcome prior to their introduction, and to gain an indication of likely levels of co-operation. To this end, questions were asked regarding: students' past experience of technology and specifically mobile technology; their familiarity with the human-computer interface of small form-factor devices (i.e. data entry and screen size typical of PDAs and mobile phones); any pre-existing interest in PDAs; and the level of nascent interest in PDAs once the project had been explained to them in general terms. The summary of results is shown in table 5.22.

Students were given the option to completely anonymise questionnaire results (de-barring cross-correlation against any subsequently collected data) and all students took up this option. However, since the prime purpose of the questionnaires was to inform the final technical logistics of data collection - to make sure that nothing had been overlooked in the physical roll out of the project, this was always expected to be the case.

A number of points can be drawn from the students' questionnaire answers. Almost all students owned a mobile phone, and were therefore familiar with the human computer interfaces associated with handheld technology. Because of this no barriers to use of PDA technology due to concerns with data entry on small form factor devices,

Application Family	CALC	CLOCK	DOC	EBOOK	EMAIL	GAME	INTER -NET	MUSIC	ORG	PHONE	PHOTO	QUIZ	REF	SYS LIB	SYS UTIL	UN - KNOWN
CALC	21	1	7	0	0	6	2	4	52	0	13	26	5	0	20	3
CLOCK	2	7	1	0	1	13	0	1	14	0	5	1	2	0	8	1
DOC	0	2	188	0	2	10	0	4	44	0	16	4	3	0	17	0
EBOOK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EMAIL	0	1	0	0	0	1	0	0	4	0	0	0	0	0	6	0
GAME	7	12	5	0	0	371	2	18	51	1	38	5	2	5	58	15
INTERNET	1	0	0	0	0	1	0	0	5	0	2	0	0	0	8	0
MUSIC	2	0	4	0	0	16	0	59	43	0	34	4	0	5	10	7
ORG	55	27	40	0	4	73	0	33	595	2	46	17	2	0	79	7
PHONE	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2	0
PHOTO	15	2	6	0	1	42	0	42	35	0	529	6	1	1	37	4
QUIZ	20	2	3	0	0	12	0	6	14	0	6	25	2	0	18	3
REF	10	1	2	0	0	2	0	0	5	0	3	3	5	0	6	0
SYSLIB	0	0	0	0	0	6	0	6	2	0	0	0	0	21	3	1
SYSUTIL	19	3	37	2	5	76	12	21	80	0	29	15	6	10	195	36
UNKNOWN	2	0	0	0	0	19	1	9	12	0	9	3	0	0	33	11

Table 5.21: Sequence Of Application Use. All Project Phases Combined

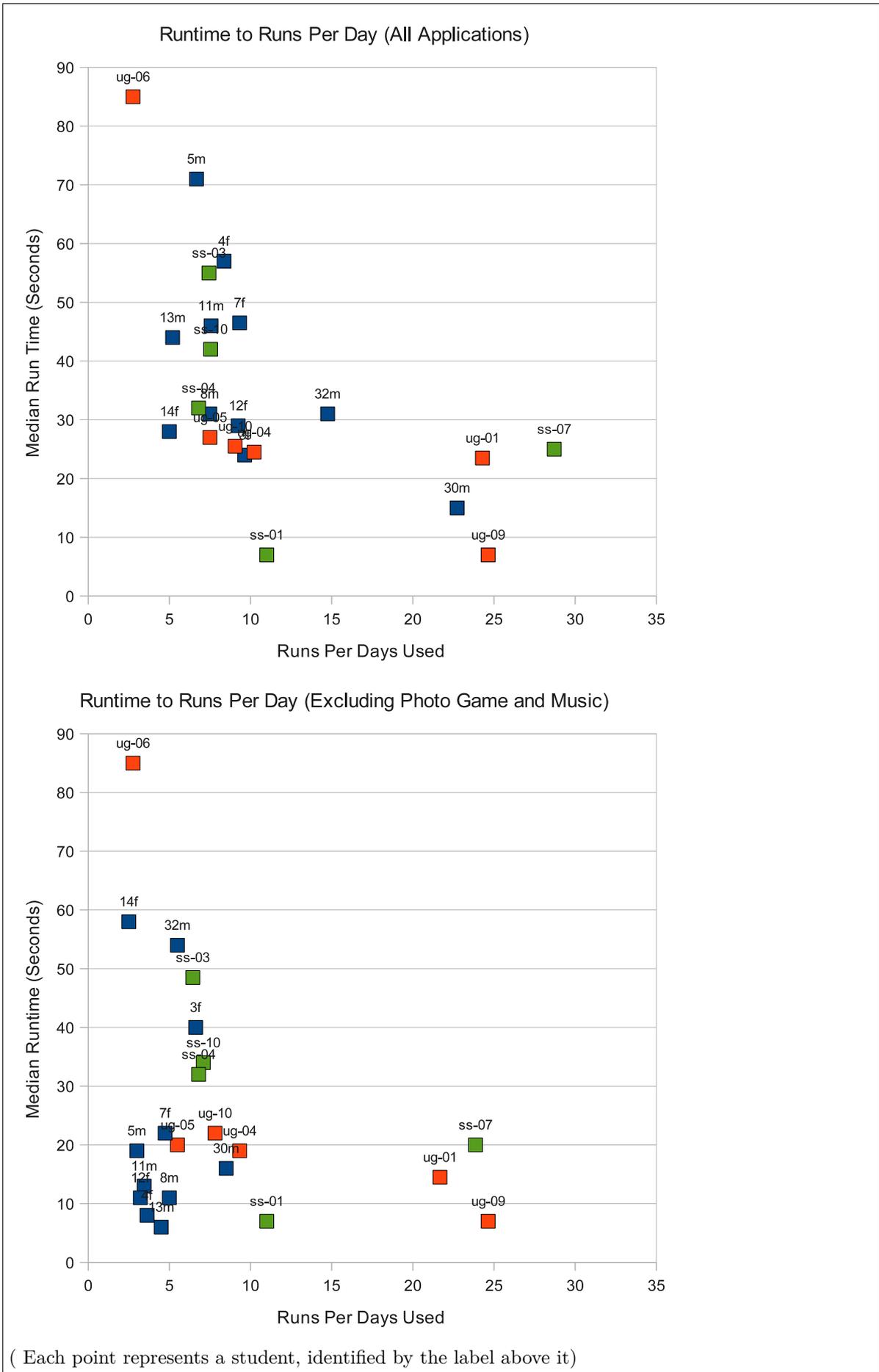


Figure 5.52: RunTime compared to Runs Per Day

or accessing data through small screens were expected. These expectations were clearly confirmed from the PDA logging data. All students, even those with minimal logging data in phase 4 managed to download and play games, and use organiser applications such as the address book and calendar without obvious difficulty - and the project team witnessed high levels of PDA use from day one. For students with logging data available the learning phase was measured to be less than a week. In fact, logistical problems that did arise during the active data collection period of phase 4 were all with the syncing and charging of PDAs, never with the human-computer interface or infra-structural problems. Over half of the students already owned some means of playing music on the move, with a fairly equal split between mini-disk (10), MP3 player (8) and CD player (3). This indicated that the majority of students were comfortable carrying additional electronic equipment in addition to their phone, and some of them were willing to carry something as large as a portable CD player. It also indicated that portable music was important to the phase 4 cohort. Since the PDAs in phase 4 could all function as a portable MP3 music player, this suggested that our choice to specify a PDA with music playing capabilities would significantly lower usage barriers, and help ensure that students would make regular use of their PDAs during the project. It is interesting to note that the three students in this phase who supplied comprehensive PDA logging data and were subsequently interviewed regarding PDA use all replied to Q11d "Is there anything your phone cant (sic) do that the PDA can" with "MP3" or "play music". The one non PC owner stated that they did intend to get one, and this student indicated that they already had term-time internet access (implying that they had access at home through a friend or family member). As the potential of the PDA could be significantly enhanced by being able to synchronise to a home PC, and in the process load and store new applications, calendaring and contact details, the fact that each student had access to a PC increased the opportunities for students to take ownership of their PDA. From the questionnaire results it was shown that a relatively small proportion of students either already own, can see the immediate need for (only 25% use a diary) or are planning on getting a PDA - this indicates that this cohort is not one which would normally purchase a PDA, and so will only discover its affordances for them during the project - they are more likely to investigate, but without a predilection. The high proportion of students (2/3) having a part time job, indicates that revision tools outside of normal University and home study may be something they would see as a benefit. To summarise, the results of the questionnaires indicated that this cohort of students were exactly those who had the technical ability, and motivation to gain from PDA use.

5.3.2 Interviews From Phase 4

Although informal interactions occurred as part of the earlier project phases, formal interviews were used 15 weeks into the 20 weeks of phase 4. As will be discussed

Question	Responses (N=36)	%	Comments
Own A Mobile Phone	34	94.44	
Phone Has Camera	25	69.44	
Think SMS Would Be Useful For Course Info	29	80.56	
Own a Digital Camera	18	50	
Own an MP3 player	8	22.22	
Own a MiniDisk	10	27.78	
Own a Personal CD Player	7	19.44	
(Own some type of music player)	19	52.78	
Own A PC	29	80.56	
Own A Laptop	12	33.33	
(Own a computer PC or Desktop)	35	97.2	
Own PDA	2	5.56	
Own A Games Console	24	66.67	
Intend To Get MP3 Player	13	36.11	
Intend To Get A Digital Camera	12	33.33	
Intend To Get A PC	1	2.78	
Intend To Get Laptop	6	16.67	
Intend To Get A PDA	13	36.11	
Intend To Get A Games Console	1	2.8	
Intend To Access VLE From Home	26	72.22	
Own Other Gadgets	0	0	
Have Term Time Internet Access	35	97.22	
Use Online Forums	5	13.89	
Use IRC(Internet Relay Chat)	0	0	
Use MSN	31	86.11	
Have a Part Time Job	22	61.11	
Part Time Job Hours per week	16 hours average		Ranged from 6-22 Hours
Use Diary Or Organiser	9	25	
Think PDA Would Be Useful	32	88.89	

Table 5.22: Phase 4 Tech Questionnaire

in detail in Chapter 6, during the data collection period of this phase an unusual lack of co-operation from the students in returning logging data was experienced, and the researchers wanted to more fully understand this student behaviour. As a result, many of the interview questions (1,2,5-8) specifically concentrated on student habits in carrying and synchronising their PDA, and others (11a-e) probed students' views of their PDAs, both in isolation and in comparison with their mobile phone. In addition, students were asked (9-10) about other online resources. The interviews were carried out 1-on-1 by two members of the project team and lasted approximately 15 minutes per interview. Students were selected at random from the cohort and invited to interview during a scheduled laboratory session, at the end of this session. Eight students agreed to take part. The only incentive to take part was free coffee and buns.

The interview questions, and the students' responses to them, are shown in figures 5.23 to 5.26. AppLog data was only available for 3 of the phase 4 interviewees and where this was the case the identifier has been marked with an asterisk.

The prime, and unexpected, result of these interviews will be discussed in more depth in Chapter 6, but was that the students, who we believed were being uncooperative by not using the PDAs were not only using them, but using them in interesting ways. However, although students were using their PDAs, they were being uncooperative in logging that use. For instance, students 24F and 14F had novel and creative uses for their PDAs independent of the typical organiser usage, and of the uses that the project team and course lecturers expected even although we did not obtain comprehensive logging data of this use: 14F - "useful for arts, gigs, show samples to people", 24F - "catalogue pages, classroom layouts, pictures of books". Student 24F was particularly enthusiastic about using the PDA and how useful it was. This user had found many uses for the PDA, such as recording pupils' project work in schools whilst on project placement. Future work should involve a large enough sample of students to have log data from these sorts of students, to confirm and analyse their creative PDA use. In addition, the interviews indicated that almost all students had bought SD cards - a significant indication of appropriation of their PDA.

An analysis of the differences between those interviewees who did give PDA log data and those who did not shows some interesting contrasts. Those who did give log data said that they synced their PDAs every 2-3 days. Those who did not, said that they synced their PDAs regularly, but their view of 'regularly' tended to be fortnightly (16M) or monthly (14F). Those that did not give us log data were far more likely to give negative or or neutral answers to question 8 "would you miss the PDA", whereas those who did give us log data could immediately think of affordances that they would lose - typically the ability to play music. Extending this point, when asked about the affordances of the PDA in contrast to their own mobile phone, all these students again said "mp3" or "music" whereas the students who did not give us log data typically mentioned the camera. Interestingly, at this point in the technology cycle the camera

was an almost unique affordance to the PDA, whereas the MP3 player was not unique, but was a significant improvement on typical mobile phone players. In addition those who did give us log data were 70% more likely to use the University's VLE off-campus - suggesting that those who took their studying home with them off-campus, and hence used the University VLE, were much more comfortable in logging data with the project team.

As a result, our suggestion is that future researchers develop a habit of frequent syncing amongst students, if good logging data is to be obtained. In addition, our results suggest that devices should be chosen with affordances which are understood by the student, and which perform better than devices they might already own, in order to obtain good logging data. Affordances which are groundbreaking, may not yet be perceived as having enough benefit for the user.

Finally, it was found that there were some significant inconsistencies between what students said they did with the PDA during interview, when the students had a clear perception of what they felt was the 'right' answer, and the evidence from the logs. For example 32m and 11m both said that they did sync their device, but there is no evidence of them having done so consistently over the entire data collection period. This could be because the syncing occurred during periods when the log is incomplete or because the students had not actually synced the device and were giving us the answer that they perceived to be the correct one. In any case, this indicates that the students' responses should be considered reliable only if there is additional supporting evidence to confirm their comments.

5.3.3 Student use of the university VLE

Students had access, from both on- and off-campus, to the University VLE (Moodle[ref]) which supported a number of learning resources. Key resources were: lecture notes, laboratory worksheets, tutorial question and answer sheets, class test feedback, PDA downloads (including the quiz application), external resources such as a resistor colour code calculator, and a class online forum where both classwork and PDA items could be discussed. All student access to these resources is logged in the University's central VLE server. As described in section A.B.C these VLE logs indicate which resource was accessed, the time the access took place, and the Internet Protocol (IP) number of the device accessing the VLE, which can give information on the location from where access occurred. The research team had access to these VLE logs, and thus could use them to provide additional insights into student learning - specifically on which days, and which times during the day the VLE was accessed, and whether that access was on- or off-campus. This information is summarised graphically in figures 5.57 to 5.59 and was important in giving insight into student use of learning technologies in general, as a contrast to student PDA use, and as an additional objective check to the more subjective reporting of technology use obtained through student

QNo	Student	8M*	32M*	11M*	14F
1	Is the PDA Useful	YES	YES	YES	YES
1b	What Is the PDA Useful for	Calendar DocsToGo ToDo	Diary- Organise Calendar- Group work map3 -train tetris bubble solitaire	mp3, games, camera, video, notes	design pictures, useful for arts, gigs show samples to people
2	Do You Sync	Yes	Yes	yes	yes
2b	Where Do You Sync	home	home	home	home
2c	How Often	Every couple of days		3 times week	monthly
3b	What Applications have you Installed	Webcam DocsToGo	GAMES	docs to go, games, file shrinker	lemmings solitaire battleship
4b	Size of SDCard	256	256	128	
5	Why Don't You Sync In Lab	Never occurs (didn't know it charged)	Don't think about it		
6	When Do You Carry a PDA	Most days with wallet and keys	Usually to uni, not outside uni	all the time	going to gigs
7	What Applications would make the PDA more useful	Graphics and Drawing App	tutorials,more questions, course notes	PowerPoint creating	editor for graphics stuff
8	Would you miss the PDA	Yes "It got nicked and missed it"	probably, mp3 and organiser tools	yes,MP3 games	no
11d	Is There Anything your phone cant do that the PDA can	MP3 Camera	easier to take notes, more storage,play music	MP3	camera
11e	What do others think of phone	Cynical(jealous) 'Uncle interested in business uses'	friends play games	flashy, gadget, want one	parents & neighbour impressed

Table 5.23: Phase 4 Interview Part 1

Q	Student	16M	1F	2m	24f
1	Is the PDA Useful	Yes	No	Yes	Yes
1b	What Is the PDA Useful for	Camera useful in design studies. docs to go internet mp3 games	alarm louder than mobile	scheduling things, pictures, need more training	organise. Notes and photos on placement Camera for pictures of classwork, catalogue pages, classroom layouts, pictures of books, voice memo
2	Do You Sync	Yes	no	Yes	
2b	Where Do You Sync	home			home
2c	How Often	when needed, fortnightly	no	frequently on two computers	daily
3b	What Apps have you Installed	games ping pong beam to extend trial license	no	games, had stuff beamed, lemmings	stopwatch, docs to go, lots of books, website lists
4b	Size of SDCard	128		128	128
5	Why Dont You Sync In Lab	forget to bring it, not enough machines around to make it no brainer	cause dont use it		
6	When Do You Carry the PDA	in bag 50% time at uni	no	most of time	always
7	What App would make the PDA more useful	removable battery pack/expansion battery games really draw power	no	nothing comes to mind	more quizzes related to course and revision materials
8	Would you miss the PDA	dunno, taking notes useful	no	Yes handy for organising	Yes, "not getting it"
11d	Is There Anything your phone cant do that the PDA can	not that I can think off	would camera that worked	music, camera better address on the phone	
11e	What do others think of PDA			smart	

Table 5.24: Phase 4 Interview Part 2

Q No	Question	8M	32M	11M	14F
9	Do You access the VLE from University	[7] Daily	[11] use email more than moodle	[28] daily	[8] not necessary
9b	Do You Access the VLE From Home	[246] daily (twice)	[48]	[33]	[28] every couple of nights
10	Do You Use IRC/MSN	Yes all time PC is on	no	MSN sometime	LSN every night
11a	How often do you change your phone	Not often (finance) so yearly	when need to	3 year	one/twice a year (finance dependent)
11b	Does the newness of Phone matter	Like to keep up	no	like to be up to date	
11c	what is your phones most important feature	Phone book	sms	internet access	phonebook messages
11d	Is there anything your phone cant do that the PDA can	MP3/Camera	easier to take notes, more storage,play music	mp3	camera
11e	What do others think of the PDA	Cynical (jealous) Uncle interested from business point of view	friends play games	flashy,gadget, want one	mum.dad, neighbour impressed

[n] = Number of accesses according to VLE Logs

Table 5.25: Phase 4 Interview Part 3

Q No	Question	16M	1F	2m	24f
9	Do You access VLE from Uni	[15] daily if possible. Before lecture, useful to check if lectures cancelled	[4] weekly	[19]	[25] daily
9b	Do You Access the VLE From Home	[29] every day	[14] daily	[17] lots	[51] every other day
10	Do You Use IRC/MSN	Starting to use MSN as pedagogic aid	LSN at home	no	no
11a	How often do you change your phone	yearly	3 years, but if it looks OK its OK	when needed, cracked screens	Over 2 years
11b	Does the newness of Phone matter	yes but tempered by finance	as long as it looks OK	into new gadgets, if it works	no but for kids school peer pressure
11c	what is phones most important feature	phone, text, games, web browser	text	text	
11d	Is There Anything your phone cant do that the PDA can	not that I can think of	would prefer camera that worked	music, camera better, address address on the phone	
11e	What do others think of PDA			smart	

[n] = Number of accesses according to VLE Logs

Table 5.26: Phase 4 interview Part 4

interviews. Importantly, whilst the PDA logs were only available for a few of the interviewed students, VLE logs could not be compromised by a lack of student co-operation and were thus available for all students.

On-campus use of the VLE ranged from 1 to 161 occasions with an average of 18 uses per student. Off-campus VLE use ranged from 1 to 246 occasions with an average of 49 uses per student.

In discussion of phase 4 interviews we noted significant inconsistencies between what students said they did with the PDA during interview and the evidence from the PDA logs. There is also a difference between students' estimates of their VLE use compared to the data from the VLE access logs. For example user 2m claims to have accessed the VLE from home "lots" whereas the log files only show 17 occasions. The variation between the VLE log data and the interviews supports the doubts raised about the students' accuracy in their evaluation of their PDA use. This supports our view of automatic logging as the preferred method of recording PDA use.

There was no indication from the available data of the PDA being used in conjunction with the VLE, for example 3f, 8m, 11m 12f were late night users of the PDA, but there was no indication of late night VLE access. The evidence suggests that PDA and VLE use was uncorrelated.

In general we note that VLE use is at its greatest at the beginning of the week (Monday) and falls off significantly towards the end of the working week, with practically no use on Friday. There is sporadic use by some users at the weekend. Most users (~60%) accessed the VLE in the morning, possibly in preparation for the work of the day, and then again after lunchtime. However other patterns of use were seen, with three users habitually using the VLE late into the night, and one user who only ever accessed the VLE at work, but did so both in the morning and the afternoon (indeed this student was one of the top students in the cohort).

Most interesting, are students 5m and 12f, who were noted above in section 5.2.3 to only use their PDAs when triggered by the presence of project team members. These students were two of the lowest users of the VLE, almost never using the VLE at the weekend, and only using it to any extent on Mondays. Although these students could obviously use the resource, they only did so when absolutely necessary. Their exam results were low.

5.3.4 Examination results

Uniquely, in phase 4, the project team had access to the final examination results of the student cohort under study. Anecdotal evidence has already been discussed in section 5.2.8 indicating that while most students' use of PDA applications was relatively complex (continuous swapping between applications during a session of use) those students with very poor grades and very high grades showed far less complex usage patterns (the students with very high grades seemed to be targeted users of

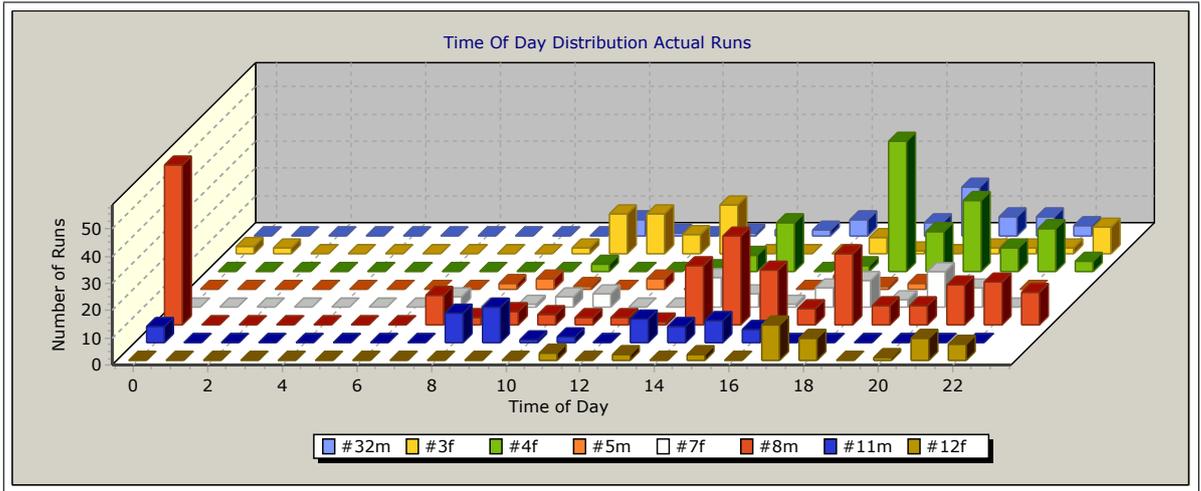


Figure 5.53: VLE Distribution by Hour (Actual Number of Uses)

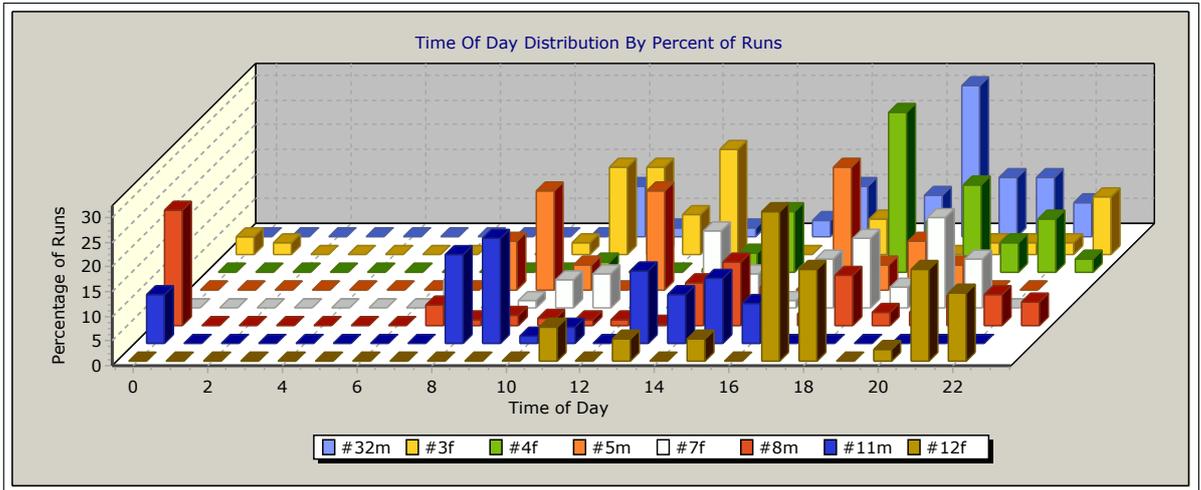


Figure 5.54: VLE Distribution by Hours (Relative)

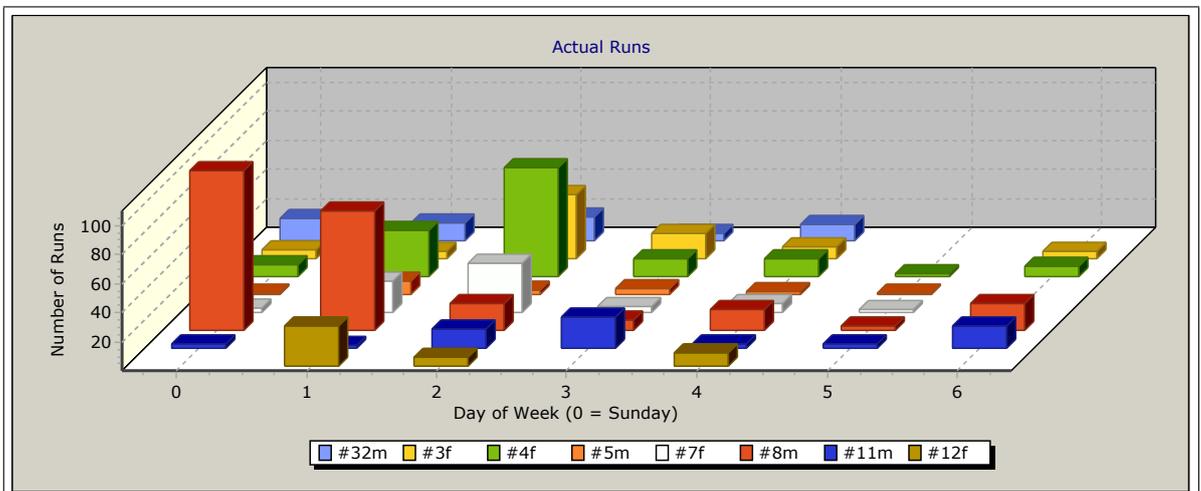


Figure 5.55: VLE Distribution by Day (Actual Number of Runs)

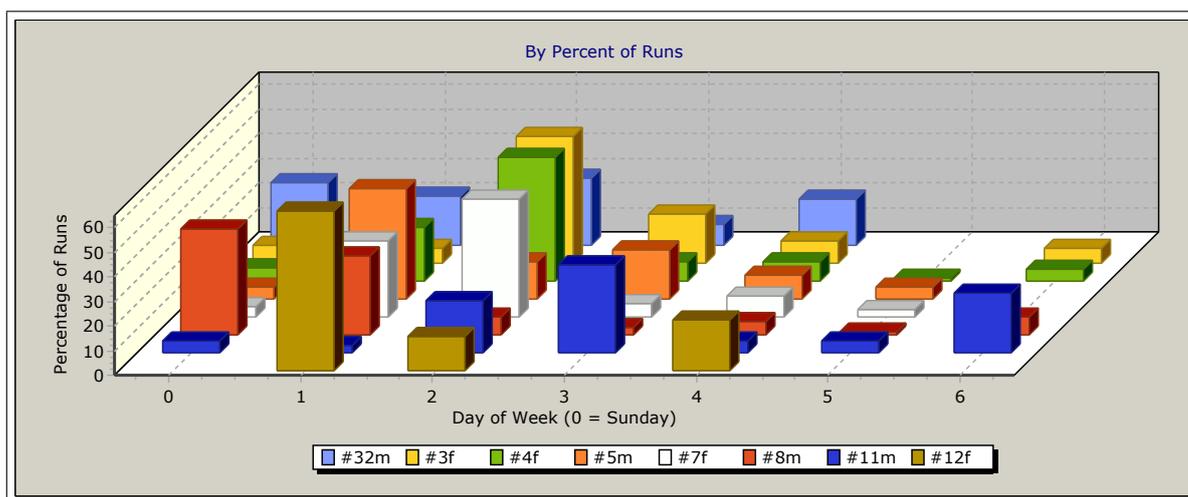


Figure 5.56: VLE Distribution by Day (Relative to Total)

PDA resources; they already knew what they wanted from the PDA before they used it and did not deviate from their usage plan after that use).

Graphs 5.57 to ?? were plotted to analyse any correlation between the exam results of the student and their use of PDAs and off-campus VLE (as our results from interviews in section 5.3.2 suggests that students with high off-campus VLE use, were also likely to be high PDA users, even if log information was not extant for all these users). The graphs show comparisons between exam results and: the total number of PDA logs provided by each student, the amount of off-campus VLE access for all students, the amount of off-campus VLE access for only those students who provided PDA logs, and the total number of logged uses of the quiz application for those students who provided PDA logs. Whilst the number of data points is too low for any of these results to show clear statistical significance, the results are interesting, and inform our hypothesis that the most motivated students both co-operated with the research project and obtained good examination results.

In figure 5.57 there does seem to be significant correlation between the number of logs submitted and exam performance - supporting this hypothesis. In figure 5.58 (the correlation between exam results and VLE use) is negative, until we remove one outlier student, and the students who withdrew from the course early and who are recorded as having received '0' for their exam results. The outliers student used the VLE off campus 246 times (75% more accesses than the next highest student) and who obtained a 'G' in their final examinations - in effect they had also withdrawn from the course, but did attend the final exam, receiving almost no marks. On removal of these spurious results, the correlation between exam results and off campus VLE access is 0.42 for the whole class and 0.24 for the students who provided VLE logs this is shown in ??. This is a positive correlation, but significantly lower than the correlation of 0.58 of figure 5.57 - again supporting our hypothesis that students who provided logs were motivated, and thus likely to obtain good exam results. In fact, more likely to obtain good exam results than those who were simply motivated to use the VLE from home.

In figure 5.59 there is an even more clear correlation between the number of times

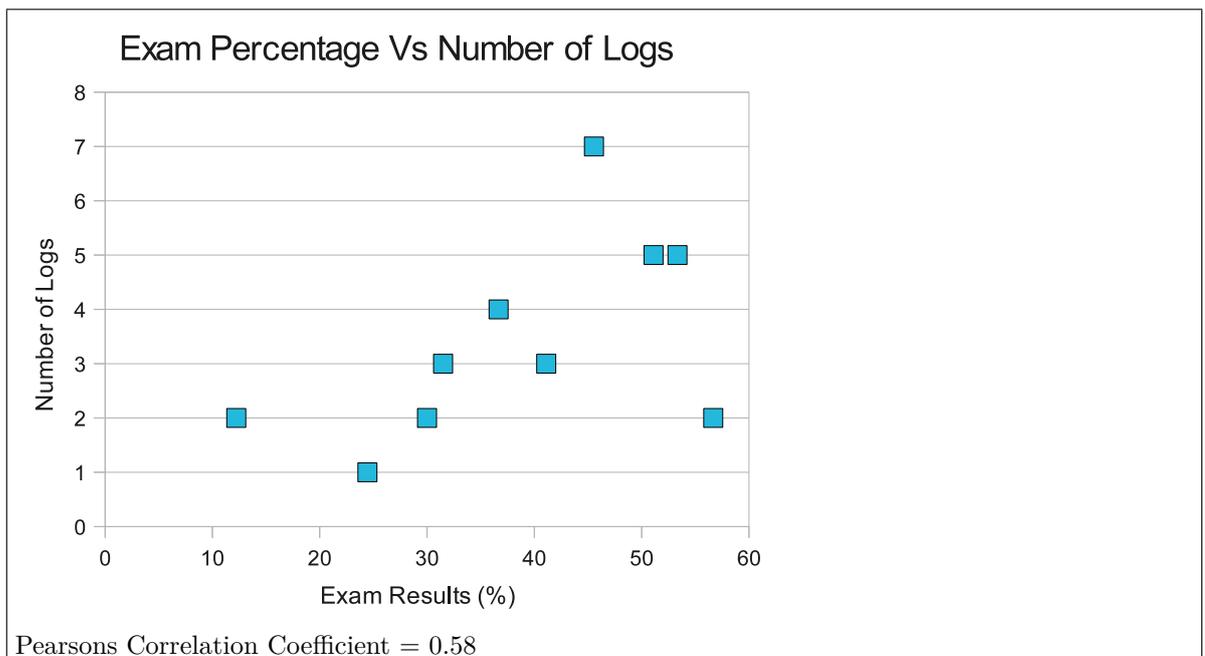


Figure 5.57: Exam Results Compared to To Number of PDA Logs Uploaded

that the quiz application was used by a student, and their final degree examination score. Whilst again the number of data points are few, these results do indicate that students either gained benefit from the quiz application - i.e. the formative assessment exercises aided their learning, or at minimum there is a strong correlation between the motivation to use the quiz application extensively and a student's final degree result. Clearly further research in this area is liable to be fruitful.

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5.3.5 Summary - external sources of information

In summary a consideration of the sources of information other than PDA logging data (questionnaires, interviews, VLE data and exam results) led to the following conclusions.

From questionnaires we confirmed that the cohort of students in phase 4 had no technical barriers to PDA use, were students who would not normally purchase a PDA, and due to our choice of PDA would have the maximum motivation to carry and use the device. From interviews we discovered that whilst log data was not forthcoming from many students, the students were not only using their PDAs, but doing so in creative ways, and there was significant evidence that students had appropriated their devices. Students who did return log data were typically those who synced their device more than once a week, and who found affordances in the PDA which were similar to ones they were already familiar with, but better. We also found that students interview data on the amount of PDA or VLE use was often inconsistent with PDA or VLE logs. Students who used their PDAs only when prompted by the presence of researchers, were also those students whose VLE use was most sporadic. Finally, we noted clear correlation between both PDA use, and quiz application use, and students final exam

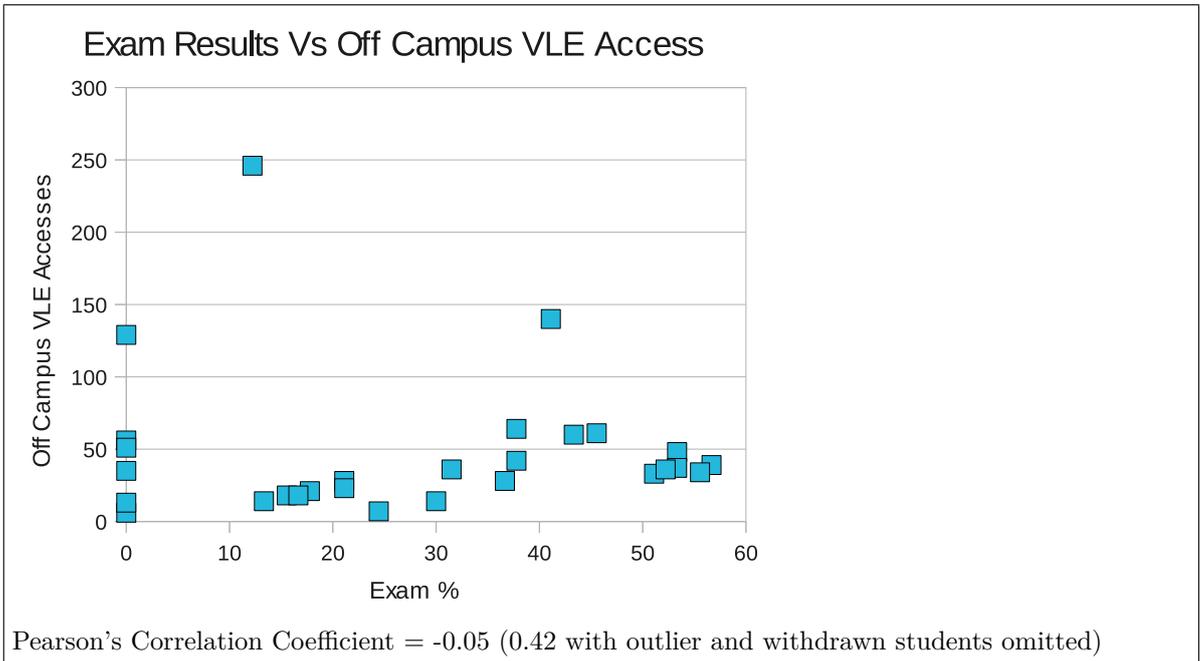
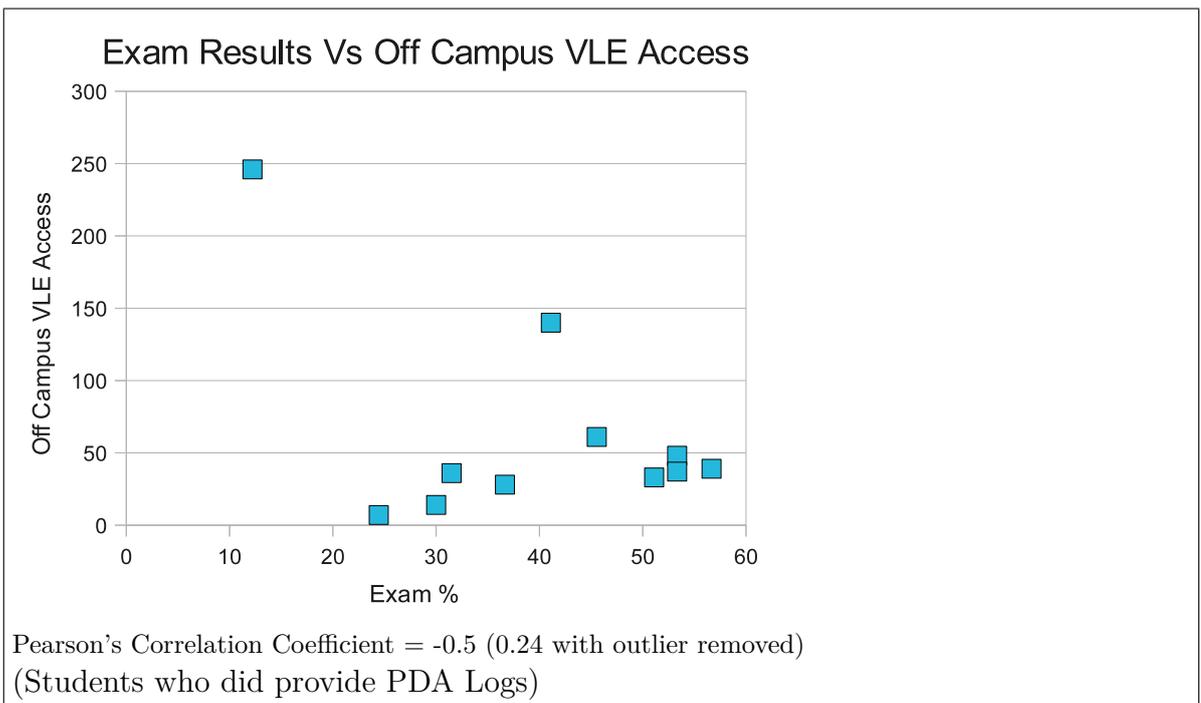


Figure 5.58: Exam Results Compared to Off Campus VLE access (Whole Class)



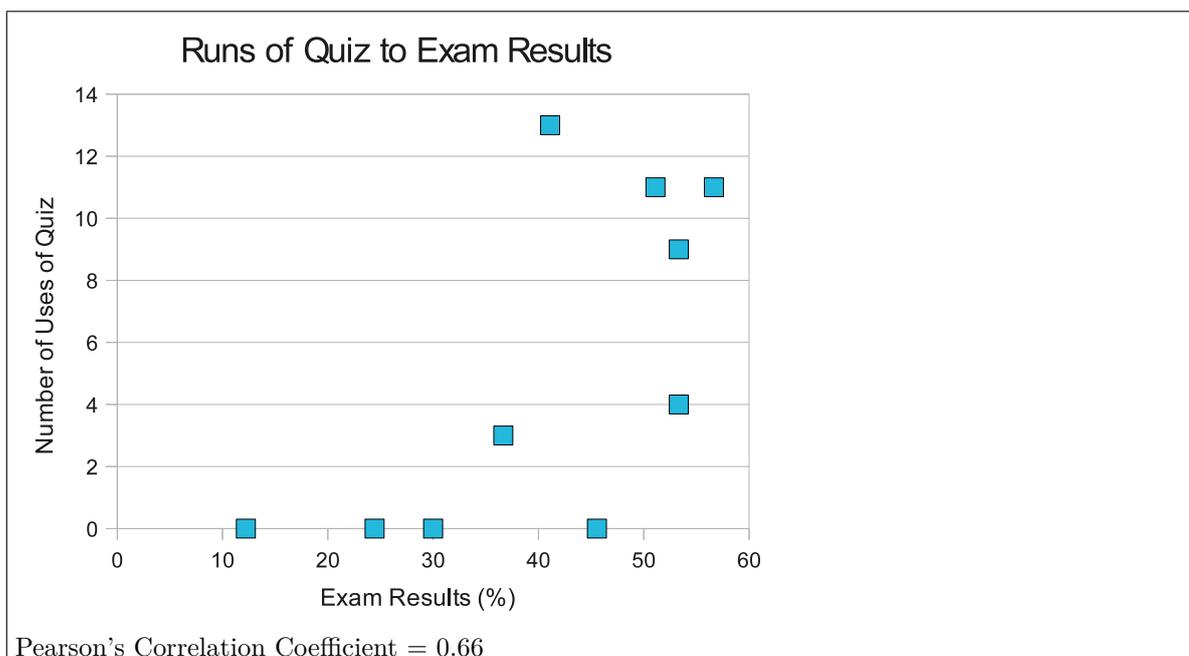


Figure 5.59: Exams To Quiz

results, implying either that the formative assessment exercises aided their learning, or a strong correlation between the motivation to use the quiz application extensively and a student's final degree result

5.3.6 Summary of Results

The findings from each of the preceding sections on the PDA logging results and other external sources of information provided insights into student patterns and modes of PDA use, the benefits to students of general PDA use and specific use of the formative assessment quiz application, and the bottlenecks which should be overcome to enhance PDA use and student learning. These are summarised below.

It was found that the data available after PDA logging was complex, with the possibility of a large number of perhaps subtle correlations in student use, often obscured by the sparsity of some of the data sets and large fluctuations in absolute and relative PDA use with time. A custom data mining and visualisation tool was written, with applicability to sparse datasets outside the bounds of the project. This tool helped the author to discover the most important measures in the data which made clear patterns of student use, and to clean and filter the data - operations which were non trivial, and will be of benefit to other researchers in the field. In addition to bespoke tools to produce traditional, histogram style, views of the data, the 'Circos chart' visualisation technique originally used to visualise genome sequences was employed for the first time to analyse student use of multiple applications in a session of PDA use.

When considering student use of PDAs and PDA applications as a function of time it was found that students' PDA use was highest when there was either a reminder that the resource was available to them or some self perceived social pressure to be seen to use their PDA. It was shown that students fell naturally into two subgroups,

and that subgroup whose PDA use was correlated only to the presence of project team members, and were thus motivated primarily by self perceived social pressure, showed exceptionally poor undergraduate exam results consistent with our view in the students making very low device use were often those who were struggling and had started to disengage from their studies. It was also shown that when the students found an independent and personal use of the PDA - and provision of rich multimedia applications produced such independent use - this led to increased overall use, and use outside those days when students are explicitly reminded of PDA benefits. When a larger cohort of closely associated students were given PDAs, each student's use increased - probably due to increased triggers of use from other students. Although most students' PDA use covered the its whole day, with peaks at natural break times and in the evening (in fact students who did use their PDAs in the late evening had higher exam results - such PDA use probably indicated heightened engagement with their studies), there were also manifest examples of students using their PDA for formative assessment at unusual times (for instance the middle of the night)

The ability to extract objective data on PDA use as a function of time at an application level is unique in the literature. When considering PDA use by application type it was shown that the main family of PDA applications in Phases 1 and 2 were organiser applications and in Phase 4 music and game applications (the PDAs used in all project phases could be used to play games but the use of games was greater amongst the phase 4 users due to the richer capability of the device). It was noted that users who made most use of music playing also made most use of organiser applications, confirming that when a student had the PDA with them for a purpose important to them (music), they then made additional use of the PDA. In all phases of the project it was shown that generally if an organiser application was used it was likely that it would be followed by the use of another organiser application. The lack of switching between families of application indicated either a very targeted use of the PDA or of the user pretending to be using the PDA when one of the project team was present. Such use of the PDA was consistent with students at the extremes of the cohort; either a user who is either very bright (and hence very targeted in their use) or one who is struggling with their studies. There was a reduction in the number of applications used as each project phase progressed, as seen in a number of previous studies. The first falloff occurred in the first few days of application use and is likely to be due to the user's initial exploration of the device to find what it can do and how the applications work. The next reduction occurs over a longer period of time and is likely a combination of increased familiarity and the loss of novelty value - this is a fall to the normal steady state usage level. In phases 1 and 2, where the device was loaned for a fixed length of time, a more distinct fall-off in use was recorded - students had no reason to appropriate the devices. This was predicted, and was one of the reasons why students in phase 4 were given the devices for an extended period of time. It was shown that even when the number of applications used and number of uses of the PDA decrease

the duration of use appears to increase.

When specifically considering the quiz application, and students' use of formative assessment, it was noted in phase 1 and 2 of the project that students "consumed" the content of the quiz application within the first three to four weeks of use, and then stopped any use of the application - seeing no further benefit in using it. This was due to the limited number of question sets that could be created by the course lecturers in the time available. In phase 4, a similar pattern was seen, although in this phase times at which students started to use the quiz application varied by as much as three weeks, whereas in phases 1 and 2 all students started using the quiz application immediately it was presented to them. Students in phase 4 were already familiar with their PDAs and this was evidence that the students were taking control of their own learning. We were also able to characterise various modes of use of the quiz application, including exploratory use, and genuine use over short and extended time periods. A completely novel mode of use was also discovered - the short burst to give a false impression of study.

From questionnaires we confirmed that the cohort of students in phase 4 had no technical barriers to PDA use, would have the maximum motivation to carry and use the PDA, and indeed were using them creatively. Students who returned log data were typically those who synced their device more than once a week, and who found affordances in the PDA which were similar to ones they were already familiar with from other devices, but better. We also found that students' interview data on the amount of PDA or VLE use was often inconsistent with PDA or VLE logs. Finally, we noted clear correlation between both PDA use, and quiz application use, and students final exam results, implying either that the formative assessment exercises aided their learning, or a strong correlation between the motivation to use the quiz application extensively and a student's final degree result.

Chapter 6

Discussion

The focus of the research evolved from one of primarily evaluating mobile Computer Aided Assessment to consider the challenges of evaluating mobile learning and associated technology more broadly and the implications such challenges pose for developing suitable research tools and methods.

The results of Chapter 5 described the successful creation of a set of data analysis tools and associated methodology to mine the data associated with PDA and VLE logging, and student interviews and questionnaires. It also lays out the results obtained in performing this analysis on four cohorts of students who made use of formative assessment applications using PDAs and discusses those results in detail. The results indicate that students can gain substantial benefit from PDA use, characterises the patterns of PDA use that correlate with successful and unsuccessful students, and flags the most fruitful areas of future research, whilst clearly signposting pitfalls to be avoided by those working in the field. In chapter 5 we tangentially noted difficulties, noticed especially in phase 4 of the research, where students seemed not to co-operate with the project team in using their PDAs, despite a number of technical means being put in place to make that co-operation relatively trivial. This lack of co-operation was completely novel behaviour, aspects of which were unknown in the literature, and resulted in much interest in the field, and three significant publications in the area. Informed by the results of chapter 5 we discuss those novel findings below along with a more general discussion of why a student is motivated to carry and use a mobile device for learning.

6.0.7 Student Cooperation

The primary reason for utilising logging as a means of data collection was to provide objective PDA usage information that did not rely on the users memory nor provide any burden for the users to record how they had used the PDA. The major failing of the system was the lack of co-operation from students in returning log files for examination.

It was thought that the reason students did not upload their usage logs in phase 1 was that the task was inconvenient for them, as the procedure had to be carried out in

the lab at specific times when the machine to transfer the logs to was available. It was a surprise that similar problems also occurred during phase 4 as it was believed that all possible steps had been taken to make syncing the PDA in a lab that the students frequently used as simple as possible. At the time it was thought perhaps this was just an unfortunate set of circumstances and a group that were unusually uncooperative. They fitted the description of strategic students given in (Bull and McKenna, 2003, p 5) that “they are reluctant to undertake work which does not count towards their final grade.” But they could not be persuaded to sync even when the incentive of offering them commercially produced games software was made (as recounted in Chapter 4).

It was only at the end of phase 4 as described 4.1.4 on page 70 that there was an indication that there was a more subtle reason. When the students were asked individually if they had their PDA with them, they tended to divert attention from themselves and instead named colleagues who had brought their PDA with them; the named colleagues often indicated, in turn, that the person who had named them did actually have their own PDA with them. However when one-to-one student interviews took place, as discussed in section 5.3.2 above, it was found that most were positive about their PDA use, and some had found creative uses for the PDA and said that they “carry it with me all the time” (Interviews were, of course, constructed to give a supportive environment for specific comments describing both the benefits and disadvantages of PDA in order to minimise bias in the interview results). Therefore it is unlikely that embarrassment at a general lack of proficiency with the PDA was the key underlying factor. Their public denial of having a PDA with them suggests that their actions may have been influenced by sociological factors.

It is possible that students were nervous about being seen to make mistakes in the use of the PDA in front of either their peers or academic staff. It is also possible that there was a certain element of guilt or embarrassment that they were not fulfilling perceived expectations of using the PDAs for much other than games, even though we had reassured them that our interest in how the PDAs were actually used had no judgemental character. Such sociological and peer pressure problems have been predicted in other evaluation situations. For example this appears to be an example of the problems as described by (Traxler and Riordan, 2003).

“Evaluation may raise issues of self-esteem, social standing and status - much of education is concerned with affluence and success signified by qualifications and employment, whilst ownership and competence with technology have a social significance and a fashion dimension” (Traxler and Riordan, 2003)

The class was drawn from a spectrum of academic ability and demographics. None of the students indicated prior PDA familiarity in pre-course questionnaires, indicating a level playing field for this specific technology. However, their use of mobile phones was prevalent, and this is generally perceived as a small group activity which in adolescence

helps to define position in peer group – critically important at this stage of these students’ lives. The PDAs were, in addition, introduced half way through the first term, where initial peer group ordering had been established over the whole class, but where confidence about the nature of peer group position and hierarchy was not yet firmly established. Thus, public displays of proficiency in PDA use, which could greatly alter a students’ relative position in a weakly established peer group, could be perceived as socially disruptive, with a ‘loss of face’ to existing peer group leaders. This has the potential to create a significant barrier to PDA use. If this explanation is key to the non co-operation of students in returning log data, it appears that successful introduction of mobile personal technologies is critically based on the very interpersonal networks and skills that are often naively assumed to be unimportant when dealing with personal technology.

It is also possible some of the reluctance to cooperate was due to the logging itself. This reluctance to use something while under observation is also noted by Wali *et al.*(Wali, 2007) , who in one study had only 1 out of 61 students agree to logging software being installed on their device. No matter how innocuous the kind of data that is collected may appear, the user is nevertheless aware that they are being watched. Seemingly innocuous log data can potentially be used to derive other information (the very reason it is being collected) e.g. proving that a user spent an entire lab playing games. This is interesting as almost all web access is traceable but that does not stop students using it. Perhaps for students it is the knowledge that the person who will see the information is someone nearby who has a social or professional relationship with them.

6.0.8 Motivation To Carry PDA

Before the mobile device is used it has to be with the student, and so there needs to be a motivation for the student to carry the device. To make the device worth carrying they needed to think it would perform some function that made it worth taking with them. There are also negative factors that may discourage carrying or using the device as part of their routine.

In phase 2 it was realised that some students saw an immediate and obvious use for the PDA that made it worthwhile to carry the PDA with them, but others needed either time to explore the PDA or to be told more about what the PDA could be used for.

One of the hooks of the PDA in phase 4 was its ability to play MP3s (usage logs show this was useful) and the fact the students needed to buy an SD card to enable this functionality shows they found that use important and worth the investment. Perhaps this was not surprising given that many were willing to carry bulkier technology such as mini-disk and CD players to provide portable audio. If the benefit gained from a device is great enough it may outweigh other consideration such as the lack of ‘coolness’, or

worse, a 'negative coolness' of the device.

Coolness And Technology Ageing

In phase 3 and 4 issues of technology ageing and coolness or “cultural capital” were exposed. The aspects of age and coolness are often correlated, although sometimes old technology can be considered as being “retro” and thus cool. Students in phase 3 and 4 did not want to be seen with something “uncool” and when the students' own technology outperformed the device being loaned to them, they tended to become “uncool”. It is also possible that as these devices had been used by previous students the PDAs were also perceived as being second-hand, which made them seem even less “cool”. A colour display became a desirable device feature between phases 2 and 3. By the time phase 3 started many of the students' phones already had colour displays whilst the project PDAs were still monochrome. Even though the monochrome display PDA was a superior device, in many areas, compared to their phones (e.g., battery life, screen size, screen contrast) it was perceived by the students to be dated.

Discussion with other researchers investigating mobile technology in 2005 revealed similar problems with the perceived age of technology. In a project reported in that year (Trinder and Trinder, 2005) students did not want to be seen with a brand new smartphone as its form factor made it look like an early mobile phone. It was dubbed a 'brick', even though at the time it was Palm computer's flagship product. This highlights the importance of coolness of a device and that its appearance can project a perceived quality to potential users quite different from its actual objective qualities. Technology ageing and the perceived coolness continue to be a problem, as reported in (Cochrane, 2008). Sometimes it is possible that the benefit that makes the device worth carrying is simply its status symbol cachet.

In Phase 4 another aspect of the desire to own cool technology disrupted the research. A new music playing device was launched by Apple that duplicated some of the PDA's functionality. The device quickly became a “cool” must have device - the Apple iPod. The iPod's desirability meant that it was a device that many people wanted to own, or be seen to own. The iPod had a high perceived cultural capital that was maximised by being visible. In the early days of the iPod its owners could be readily identified when using the device due to the distinctive white headphones and cable. The desire to be seen with the latest cool technology is not new, ownership of a device “signifies membership of a group or community” (Traxler, 2008). The iPod became an important status symbol at one point, however variations of the iPhone have now taken over this role. The speed at which technology (and status symbols) change brings many challenges to those researching mobile technologies. Techniques developed with assumptions of particular device capabilities may not be possible to repeat even a few months later as the equipment specification and capabilities may have changed.

Competition for Pocket Space

One factor in determining whether a student carries a device with them is their available pocket space. There are many items competing for space e.g. phone, wallet, keys and audio player. For most people the mobile phone is now an essential item that few would consider not taking with them. For a student the phone is their means of communication and gateway and enabler of social events. The effect of another device to carry had practical implications.

If a device's function is important enough it may be carried even if its size is inconvenient. For example, in phase 4 the questionnaire showed that 19% of the students used a portable CD player and 27% a mini-disk player. These proportions indicate that the benefit gained from owning a music player outweighed the inconvenience of carrying such a bulky devices in order to provide music on the go. The problem for the projects was that if students acquired an iPod then this functionality of the PDA was duplicated by a device which also had far greater coolness factor.

The students had to decide which of the devices most deserved their pocket space. The PDA had to compete with communication facilities of the phone, the cultural capital of the iPod. The limit of space in pockets meant the PDA had a greater chance of being left at home.

6.0.9 Motivation To Use PDA

Having covered the status and coolness factors that could influence if the PDA was carried, in the next section the task/benefit trade-offs are discussed and the reasons to use a PDA. For some students the benefit a PDA can provide may outweigh image or coolness factors. For example a student who has other responsibilities in their life, such as a job or family. The benefit of not forgetting appointments, and for them being able to study wherever they are, such as waiting to collect children from school, may outweigh considerations of "coolness". Equally for many tasks the PDA is not the ideal device. This was covered in the review of the literature. Discussions with students in Phase 4 indicated that some of them didn't see the point in using the PDA when they could wait until they got home or to the lab to use a "proper" machine.

6.0.10 Conclusions

To conclude this discussion, it has become clear during the work of this project, and in discussion with project team members and the research subjects themselves, that the factors which cause personal, highly portable devices to become essential to their users are different for different user groups, and different for members of those groups over different time periods. The key point is that personal mobile devices are *personal*. There is no single 'killer app' which makes a single device essential to all, and therefore ensures that it is carried by all. Hence when developing mobile

applications for teaching and learning, or when specifying research projects in teaching and learning, the deployment of identical technological hardware to all subjects is an inherently flawed approach, which will never be able to obtain the co-operation of all. In both the present and future, such mobile aids to teaching and learning will have to exist simultaneously on multiple devices, operating systems, and possibly applications themselves, in order to be consistently used by learners. In addition, the logging of how those learners use these systems becomes a much more complex and subtle challenge, requiring data mining over a diverse range of hardware and software, with the data transferred to central heterogeneous databases by a variety of methods - often internet or telecoms based.

However, far from being negative, this raises significant new research possibilities, combining research into learning and teaching, research into data mining, in addition to research into mobile hardware and software technologies. Such interdisciplinary research we see as the way of the future.

Chapter 7

Conclusions and Further work

As laid out in chapter 1, the overall aim of this project was to investigate the use of mobile devices in teaching and learning, and specifically to investigate the use of mobile devices, specifically PDAs in the process of formative assessment. In order to achieve this aim, three broad objectives had to be fulfilled. First, the development of the technical means to record in detail when mobile device applications were being used, and to overcome any technical or human-computer interface barriers to securing that recorded data. Second, to build appropriate tools and methodologies to analyse the resultant data,(recognising that the data-sets would be large and, because the type of data collected was completely novel to this field, liable to require considerable exploration), and the development of new measures to efficiently characterise how students used mobile device applications. Finally, to perform data analysis on several cohorts of students, to investigate patterns and modes of their mobile device use, ascertain bottlenecks to such use, and to measure where possible the benefits of mobile device based formative assessment.

In chapter 1, the importance and timeliness of the project are discussed. Fundamental properties of mobile devices (which at the start of the project were predominantly personal digital assistants or PDA, and are presently smart-phones) were introduced, including high levels of device functionality and availability to the user, coupled to significant limitations in the human-computer interface due to limited device screen size. The potential of mobile devices in learning and teaching was flagged, including a particular benefit for research into learning and teaching - the chance to obtain completely objective measures of device use through automatic logging as opposed to partially subjective measures of use through interview and questionnaire. A deficiency of previous work in this area was noted, with application usage data only collected in aggregate, without the detail of when each mobile application was used by each user. Overcoming this deficiency led directly to the aims and objectives of the project.

In chapter 2 the research literature on mobile learning was reviewed. In this chapter important factors key in research and evaluation of mobile learning were identified. The main themes were, the users, barriers to technology introduction and the potential problems of mobile learning evaluation. It was noted that for users to fully engage with

a device and integrate it into their routine requires more than the physical possession of the device a process called appropriation.

The introduction of technology may be met with resistance from its intended users. The TAM (Technology Acceptance Model) warned that trying to force people to follow a course of action may make them more likely to resist. From the Diffusion of Innovation an important factor determining how well an innovation is adopted is peoples understanding of the capability of the technology.

Warnings from the literature of potential problems that could occur in a mobile learning projects were flagged up. These included: Simple technical problems can undermine confidence in the technology and de-motivate participants. The speed of change of technology can hinder developing any understanding of its introduction (Traxler, 2007). Many findings from mobile learning projects are context specific (Kukulka-Hulme, 2007), which suggested that even methods that had been used unsuccessfully in other projects could be worth reevaluating. It was also noted in the chapter that there were no established specific methods to evaluate mobile learning ” (Kukulka-Hulme *et al.*, 2005)

Chapter 3 described the techniques used in the collection and analysis of data in the project. A bespoke mobile application was written which logged detailed application use in real time. The output from this application, data on student access to the University Virtual Learning Environment, and final student examination results, formed the main objective datasets recovered in the project. Development of a bespoke mobile application allowed for research flexibility in a new and rapidly advancing area at both the prosaic level (e.g. rapidly enabling students to 'beam' log files rather than 'sync' them, when 'syncing' was found to be less effective with a particular cohort) and strategic level (e.g. supporting the maturing UK community of researchers with software and detailed practical advice). In addition to objective logging data, select cohorts of students were also subject to questionnaire and interview, and in order to maximise the chances of collecting useful data, student cohorts already familiar with technology were chosen in each research phase.

As well as describing the method of data collection, and data obtained, chapter 3 also described the design and use of the novel data visualisation tool Graaf, written for the project, and introduced some of the techniques of data analysis perfected in chapter 5. For instance it was flagged that the educational benefit to a student of a particular mobile application might be indicated by infrequent short sessions of use, or frequent short sessions, and that additional evidence from logs such as time of day/week of application use, or which applications were used in conjunction with the one of interest could all give additional evidence as to an application's utility. Finally, the quiz applications used to offer students formative assessment opportunities when using the mobile device were described in detail.

Chapter 4 discussed the four cohorts of students who participated in these studies, including common characteristics and how the results of each project phase informed

subsequent phases. The first phase pilot study, involving 14 joint honours students in electronics and software engineering confirmed that PDA application logging worked well, and that the aims and objectives of the research were thus feasible. Researchers learned that even for technologically adept students, issues such as failure to replace batteries (which led to a loss of logging data) could prove important. Initial plans to restrict transfer of the mobile device logs to a fixed physical location (a single host PC) were found to be impractical, and the system was redesigned to work through 'beaming' or with a range of PCs accessible to students. The second phase, involving 5 summer school students tested the quiz application and quiz question set, and obtained the first specific evidence (through volunteered statements by students who 'discovered' the mobile eBook reader and the Gutenberg Project Database of free classic literature) of educational benefits of using mobile devices. In phase 3 the need to keep student mobile devices current with modern technology was made very clear as students failed to interact in any useful way with devices that they considered to be obsolete. Finally, in phase 4, a full scale trial was instigated based on the lessons learned in phases 1-3, involving a 1st year BTechEd cohort of students, with mobile devices (specifically PDAs) introduced six weeks into the cohort's first term.

In Chapter 5 the main research results of the project were laid out and conclusions drawn.

It was found that log data was complex, with subtle correlations in student use often obscured by the sparsity of the data and large fluctuations in student mobile device use. Use of Graaf helped the author to discover the most important measures in the data which made clear patterns of student use, and to clean and filter the data. 'Circos chart' visualisation was employed for the first time to analyse student use of multiple applications in a session of PDA use.

When considering student use of mobile devices and applications as a function of time it was found that use was highest when students were reminded of resource availability, or experienced self perceived social pressure to be seen to use their mobile device. Students whose mobile device use was correlated only to the presence of project team members, and were thus motivated primarily by self perceived social pressure, showed exceptionally poor undergraduate exam results consistent with a view that students making very low device use were those who were struggling and had started to disengage from their studies. When the students found an independent and personal use of the PDA - and provision of rich multimedia applications produced such independent use - this led to increased overall use, and use outside those days when students are explicitly reminded of PDA benefits. When a cohort of over 30 closely associated students were given PDAs, each student's use increased compared with previous phases - probably due to increased triggers of use from other students. Although most students' device use covered the whole day, with peaks at natural break times and in the evening (in fact, as shown by the log data, students who did use their PDAs in the late evening had higher exam results - such use probably indicated heightened engagement with their

studies), there were also manifest examples of students using their PDA for formative assessment at unusual times (for instance the middle of the night)

The ability to extract objective data on mobile device use as a function of time at an application level is unique in the literature. The main family of mobile device applications in Phases 1 and 2 were organiser applications and in Phase 4 music and game applications (the use of games was greater in phase 4 due to the richer capabilities of the PDA). Users who made most use of music playing also made most use of organiser applications, confirming that when a student had the device with them for a purpose important to them, they then made additional use of the device. A lack of switching between families of applications was shown to indicate either a very targeted user or a user pretending to be using the PDA when one of the project team was present. Such use of the PDA was consistent with students at the extremes of the cohort; very bright students were typically targeted users, as well as those struggling with their studies.

There was a reduction in the number of mobile applications used as each project phase progressed, as seen in a number of previous studies. The first falloff occurred in the first few days of application use - typical of initial exploration. Reduction in use over a longer period of time to a steady state level followed increased familiarity and loss of novelty. In phases 1 and 2, where the device was loaned for a fixed length of time, a more distinct fall-off in use was recorded - students had no reason to appropriate the devices. This was predicted, and was one of the reasons why students in phase 4 were given the devices for an extended period of time. It was shown that even when the number of applications used and number of uses of the device decreased the duration of use increased.

When using the formative assessment application, students "consumed" the content three to four weeks of use, and then stopped using the application - with negligible additional use during revision periods seen. This implied that the students were confident that they had assimilated the information. In phase 4, the time at which students started to use the quiz application varied by as much as three weeks, whereas in phases 1 and 2 all students started using the quiz application immediately it was presented to them. Students in phase 4 were already familiar with their PDAs and this was evidence that the students were taking control of their own learning.

We were able to characterise various modes of use of the quiz application, including exploratory use, and genuine use over short and extended time periods. A completely novel mode of use was also discovered - the short burst of use which is believed to have been to give a false impression of study. This conclusion was based upon the device logging entries and direct observation of the group linked to knowledge about the attitude and behaviour of the student group.

From questionnaires we confirmed that the cohort of students in phase 4 had no technical barriers to mobile device use, would have the maximum motivation to carry and use the device, and indeed were using them creatively. Students who returned log data were typically those who synced their device more than once a week, and who

found affordances in the mobile device that had been issued which were similar to ones they were already familiar with, but better. We also found that students' interview data on the amount of mobile device or VLE use was often inconsistent with mobile device or VLE logs. Finally, we noted clear association between both mobile device use, and quiz application use, and students final exam results, implying either that the formative assessment exercises aided their learning, or a strong association between the motivation to use the quiz application extensively and a student's final degree result.

The results described in chapters 2 to 5 clearly fulfilled the objectives to record and analyse student use of mobile device applications, including a specific application for formative assessment. In addition the objective to investigate patterns and modes of PDA use, ascertain bottlenecks to such use, and to measure where possible the benefits of mobile device based formative assessment was also partially successful, as shown by the results of chapter 5.

However, the research was hampered by novel student behaviour seen during this project, where students in phase 4 who were using their PDA, and seemingly obtaining educational benefit therefrom, would often fail to return logging data, despite the lowering of technical barriers and significant inducements. This lack of returned data meant that some of the results discussed in chapter 5, whilst often compelling, could not be shown to be provably significant in a statistical sense. Therefore we consider that the original aims of the research were only partially fulfilled.

After reviewing these results and detailed conclusions, in chapter 6 we discussed the additional research problems raised by this novel student behaviour, and concluded that the introduction of the PDAs had been introduced to a cohort where initial peer group ordering had been established but where confidence about the nature of peer group position and hierarchy was not yet firmly established. Public displays (including syncing of logging data) of proficiency in mobile device use, which could significantly alter a students' relative position in such a weakly established peer group, were probably being seen as socially disruptive, and this was creating a significant new barrier to mobile device use. This problem, and the conclusions reached upon it, have been published in peer reviewed publications.

In chapter 6 we also discussed more generally the motivations to carrying and using mobile devices which are the foundations to students developing the habits of using such tools in the learning process. Our experience indicates that the factors that encourage such use are highly personal, and even for a single user, differ over time. There is no single 'killer app' which makes a device essential to all, that would ensure that it is carried by all. Hence when developing mobile applications for teaching and learning, or when specifying research projects in teaching and learning, the deployment of identical technological hardware to all subjects is an inherently flawed approach, which will never be able to obtain the co-operation of all. In both the present and future, such mobile aids to teaching and learning will have to exist simultaneously on multiple devices, operating systems, and possibly applications themselves, in order

to the consistently used by learners. In addition, the logging of how those learners use these systems becomes a much more complex and subtle challenge, requiring data mining over a diverse range of hardware and software, with the data transferred to central heterogeneous databases by a variety of methods.

Throughout this thesis the scale of the work required to develop the bespoke software has remained in the background, its development was a means to an end. The amount of work required to develop such tools should not be underestimated. It was possibly only because the author is a software engineer with experience of both mobile and desktop application development that it was practical for the development of the logging and analysis tools to be undertaken by the same person who was conducting the overall research project.

7.1 Further Work

The work described in this thesis was conducted using a family of devices, PDAs, that have now been superseded by other technologies. If a similar project was conducted today using a current technology, a contemporary device would be an iPad, iPhone or Android based tablet computer.

The original objectives and some of the conclusions are now briefly revisited with some observations and speculative comments of the implications of conducting similar work using current and future mobile devices.

The main objectives were:-

- To successfully record when mobile applications, including formative assessment applications, are used. In order to do this successfully we will have to understand the technical and social barriers to successfully recording this information and overcome these barriers.

The barriers identified, such as a reluctance to co-operate with researchers and the subtle social factors influencing a group of students would seem likely to remain and require further investigation.

- To successfully build tools and methodologies to analyse this recorded data. In order to do this it will be shown below that we will have to create bespoke data analysis software and analyse complex data sets to discover the key measures required to characterise student use.

At a technical level it is almost certain that any monitoring tools on the device will need to be device dependent. The data collected is likely to have similar characteristics and present the same difficulties in interpretation, for example if the device was being used constructively or being “useful” to its user. The findings within this thesis can assist future researchers in this area particularly with regard to the best ways to interactively explore and visualise the data.

- To perform this analysis on real examples of students using mobile devices for formative assessment. We must investigate patterns of use, modes of use, measure benefits of mobile device based formative assessment on students and ascertain bottlenecks to such benefits.

In addition to the observations above it seems likely that technology will continue to rapidly evolve and making the problem of devices seeming old-fashioned and out of date even more acute.

As mobile devices and their capabilities evolve it is reasonable to expect that the patterns of use will also evolve.

Already students use a variety of devices and this may make detecting patterns of use more challenging and also hide some of the student usage patterns that have been uncovered in this thesis but an outcome of this work is we have shown such behaviours are worth looking for.

Our final conclusions immediately raise significant new long term research possibilities. This research initiated interdisciplinary research between education and engineering. A future landscape consisting of a plethora of heterogeneous mobile devices, all useful as learning aids in different ways, and all used simultaneously by cohorts of students, only strengthens the need for new initiatives in cross-disciplinary research in this area. Such research must consider new mobile technologies, the changing modes of use of such technologies, and the possible use of different generations of technology all interacting at the same time in a more technologically complex educational environment. It must consider how to collect data across this environment, and mine that data effectively in order to answer complicated educational questions, including those regarding the dynamics of learning in social groups where we not only expect students to manage their own learning, but where technology choice makes it impossible for educators to *stop* students from controlling their own learning, even if desired.

However, even in the short term, a number of items of future work are clearly profitable.

The effects of the dynamics of group size and the disruptive effect of mobile technology on peer groups of students should be studied, particularly the relationship between the timing of technology introduction and the temporal development of student peer groups.

Results that are more statistically significant should be obtained. With adequate funding, participants may be willing to use an institutionally supplied device, but as discussed above, to ensure use by a majority of students, the device would have to be 'cool', and therefore typically expensive. Even then, a cutting edge device with novel affordances that are not understood by students can itself be a disadvantage. A more practical approach may be to focus on the use of network based resources that could be accessed by different devices already owned by students, with researcher effort aimed at the quality of these resources and their optimisation for mobile use.

Investment in the production of suitable materials for use on a range of mobile devices, to investigate student use of formative assessment applications where content is effectively unlimited.

In addition, there are issues raised by this research that whilst not central to its theme, may be of considerable research interest, for instance an investigation of the use of mobile devices to students who otherwise might have no access to technology (students in phase 2 of this research, the most enthusiastic cohort, had no other ready access to computing facilities) and an investigation into the disparity between the claimed expertise of students in their use of mobile computing technology and an objective measure from their actual PDA usage.

The diversity and functionality of mobile devices continues and it seems likely these mobile learning tools will become more integrated into education. But no matter how much functionality future mobile devices contain, to be useful they need to be used.

“Manifestly it is better to use simple tools expertly than to possess a bewildering assortment of complicated gadgets and either neglect or use them incompetently” (Rolt, 1947)

A.0.2 Run Distribution (Number of Runs)

This is all usage sessions of the PDA and these charts below contain a few outliers.

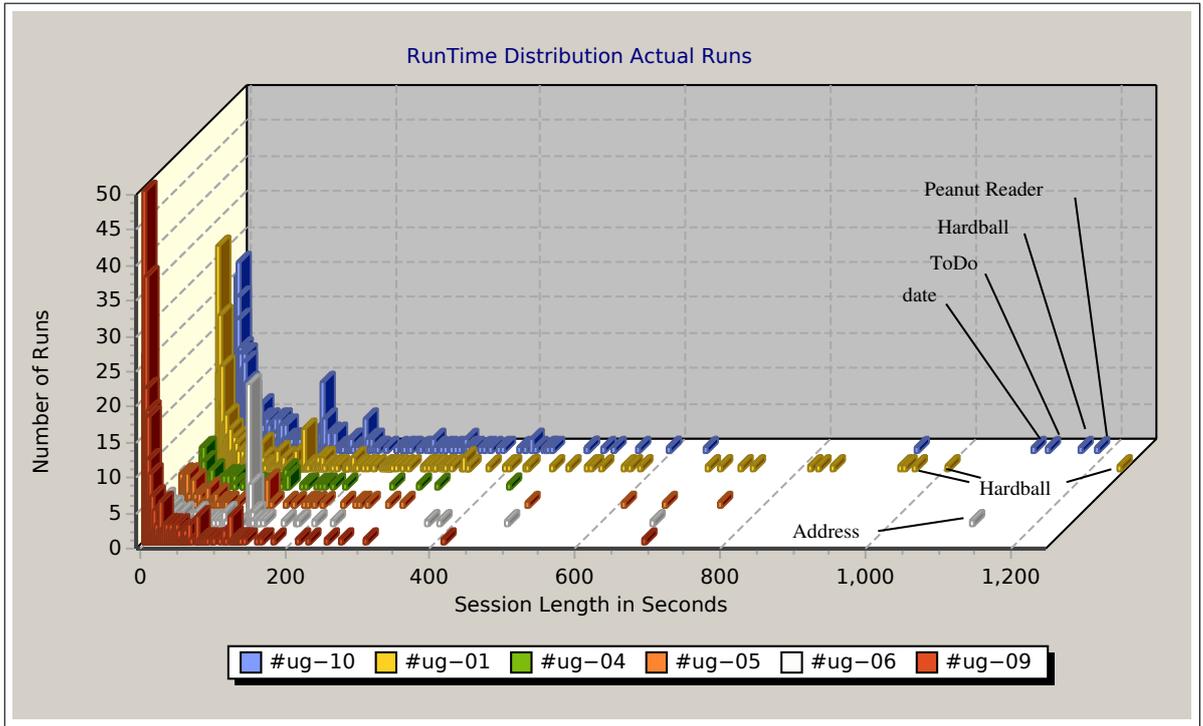


Figure A.2: Runtime Distribution Phase 1

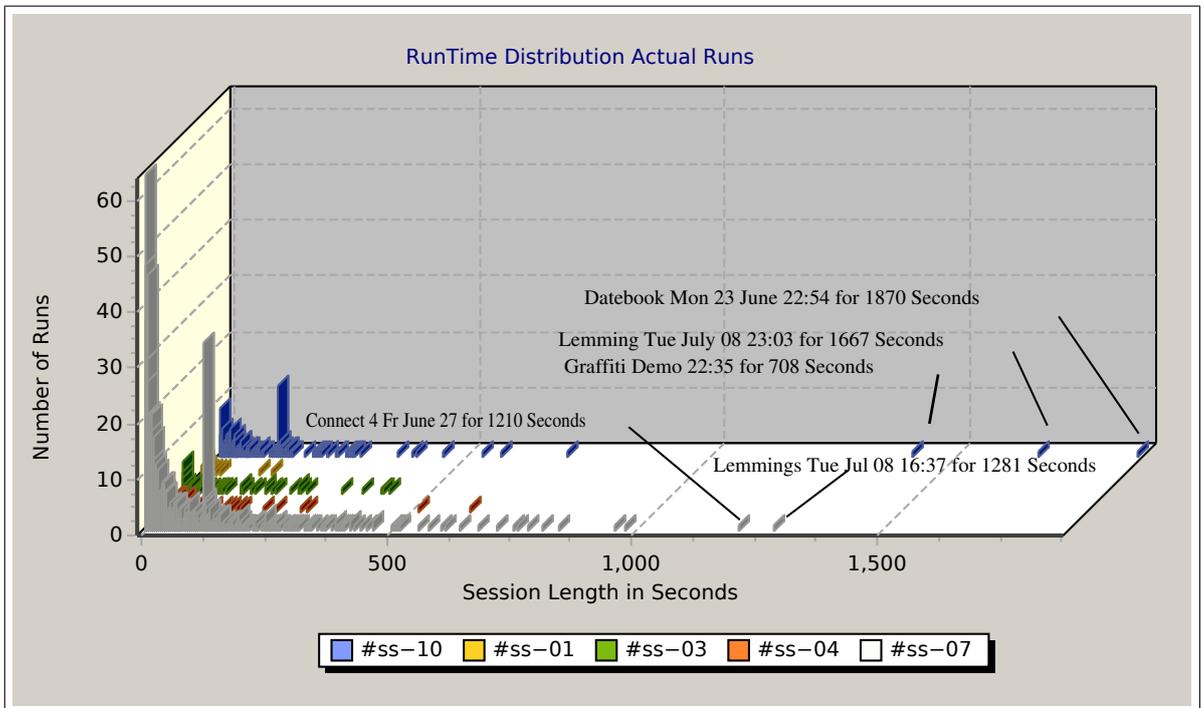


Figure A.3: Runtime Distribution Phase 2 (Summer School)

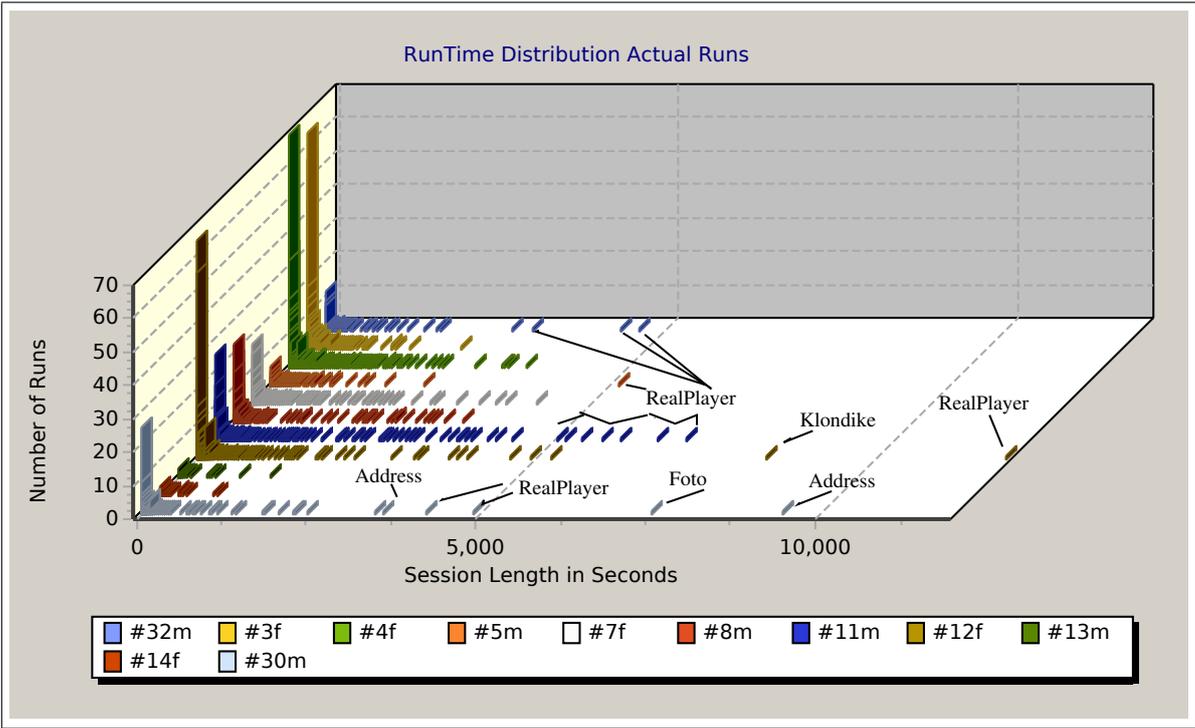


Figure A.4: Runtime Distribution Phase 4

A.0.3 Day of Week (Number of Runs)

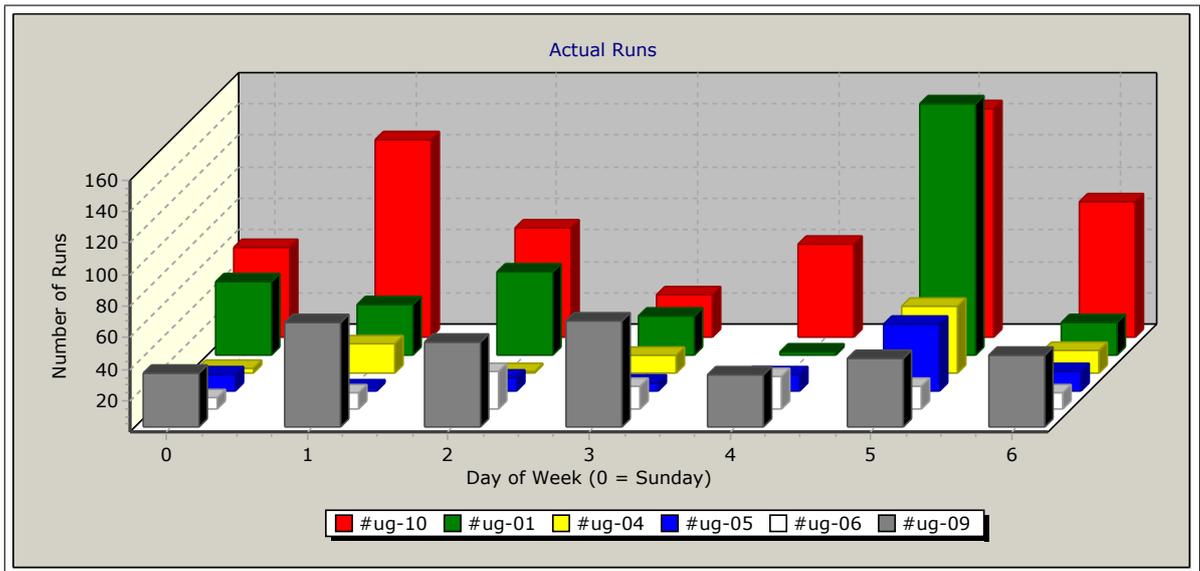


Figure A.5: Session Distribution by Day of Week Phase 1

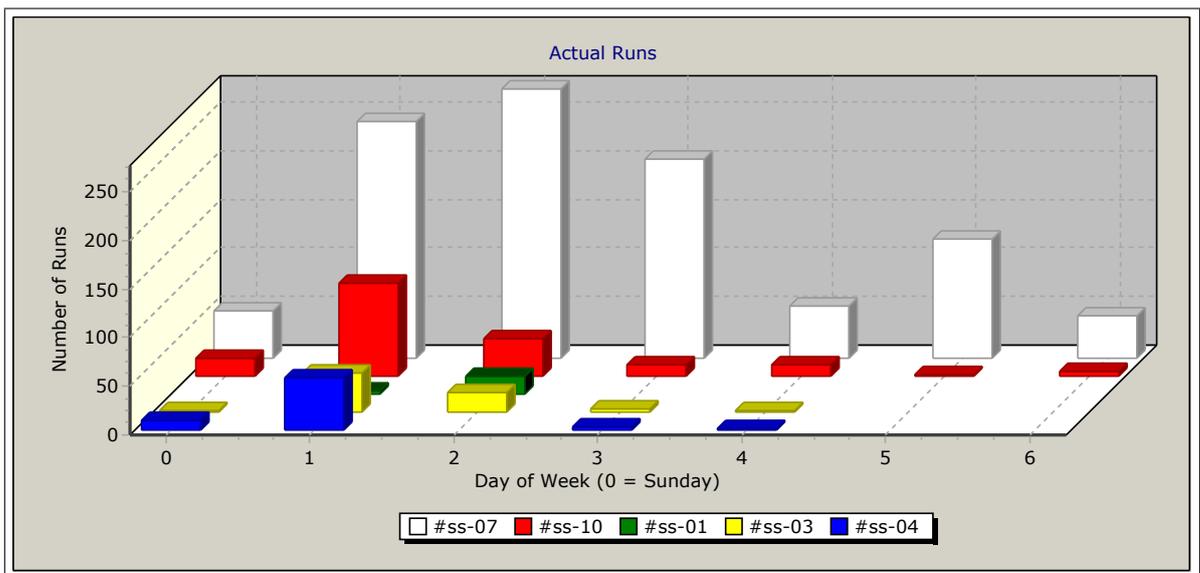


Figure A.6: Session Distribution by Day of Week Phase 2 (Summer School)

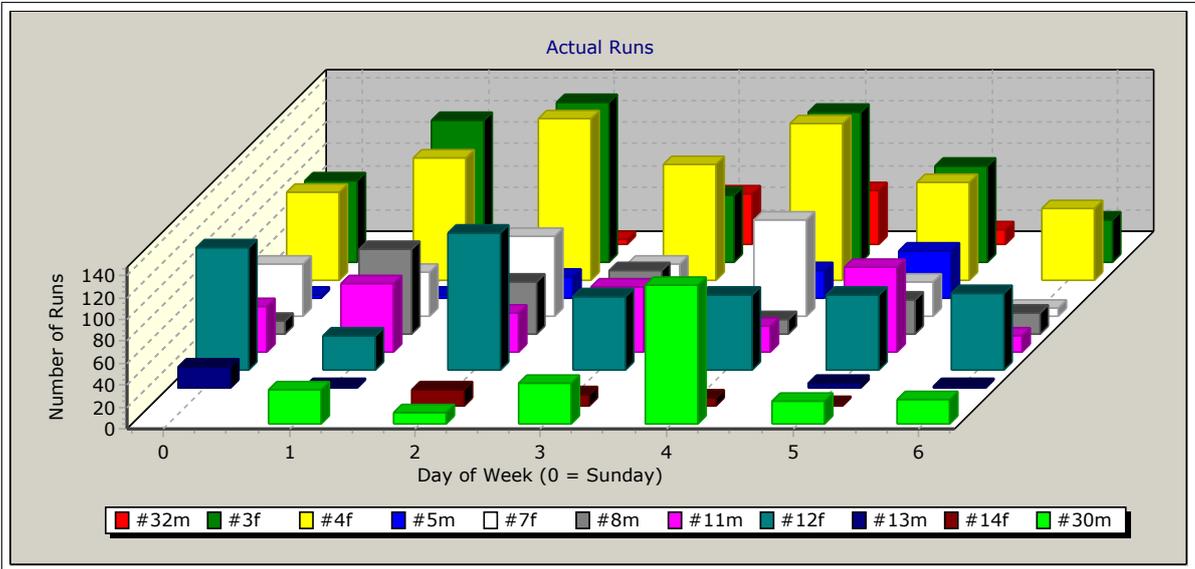


Figure A.7: Session Distribution by Day of Week Phase 4

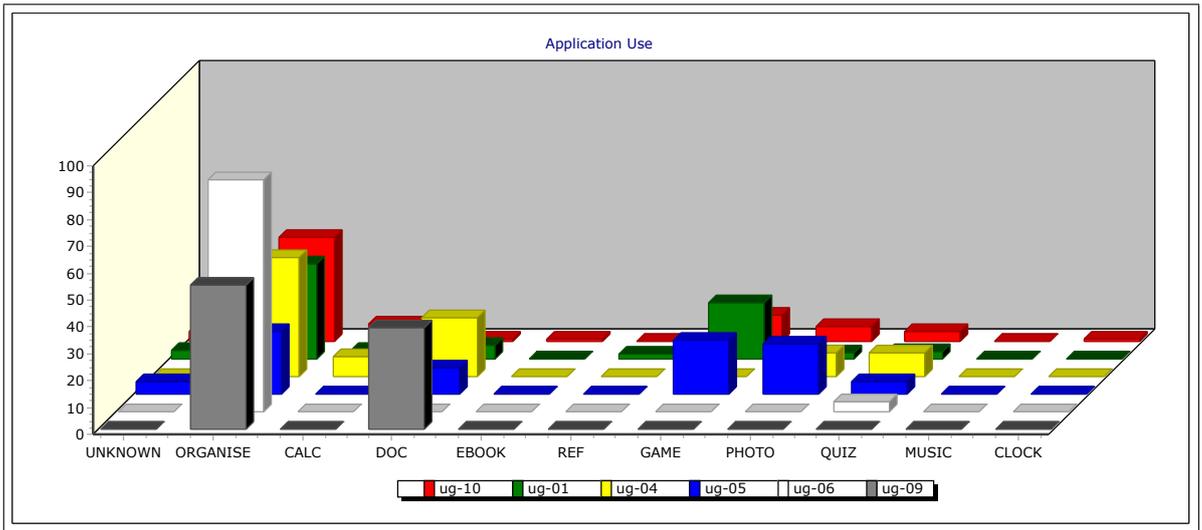


Figure A.8: Application Family Use Phase 1

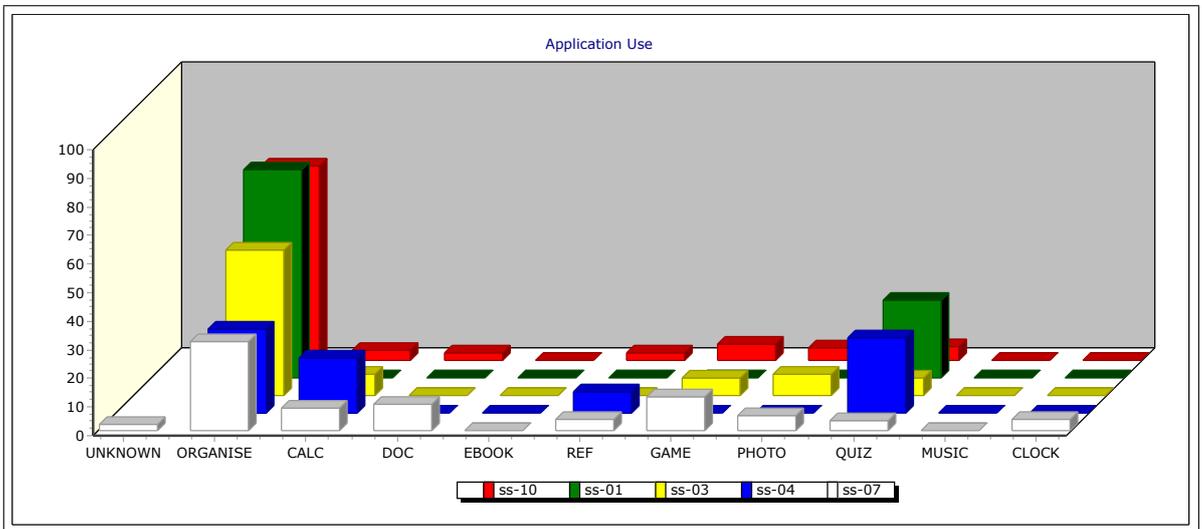


Figure A.9: Application Family Use Phase 2 (Summer School)

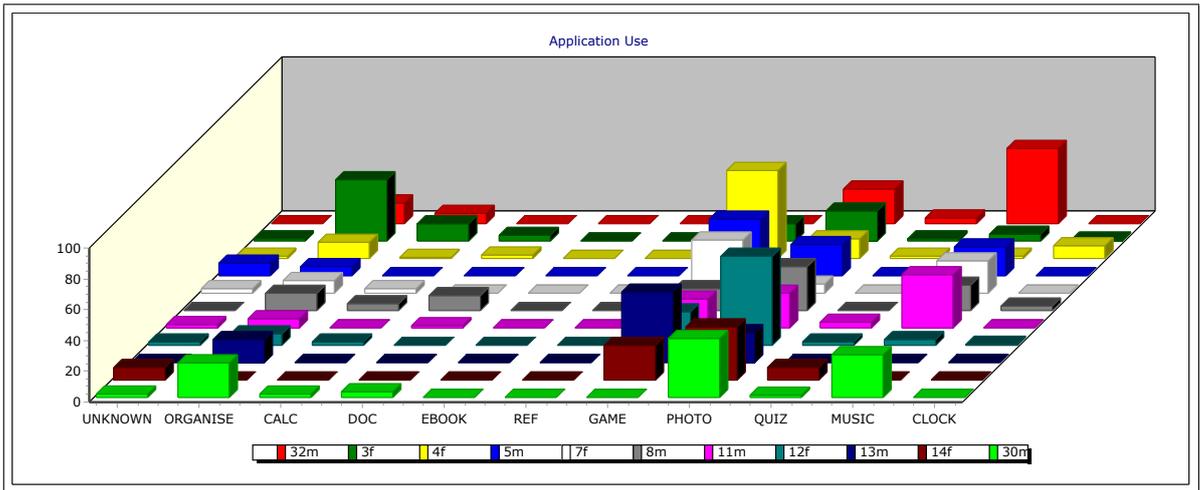


Figure A.10: Application Family Use Phase 4

A.0.4 Application Family Usage

Application Family Use Summary Tables

	ss-10-500-applog	ss-01-500-applog	ss-03-500-applog	ss-04-500-applog	ss-07-500-applog
LogLength(Days)	34.2	13.19	14.49	28.04	35.24
RUNS	181	22	67	1005	77283
RUNTIME	20640	476	6384	4537	42
NUMBAPPS	12	4	10	9	
AveInterval	16415	54260	18965	36162	3032
SD of Interval	48791	238540	69505	115947	12531
MaxInterval	390592	1095049	509099	607878	145667
MedianInterval	595	34	622.5	86	64.5
AveRunTime	114	22	95	67	77
SD of RunTime	231	37	111	109	132
MinRunTime	1	1	43	62	1
MaxRunTime	1870	145	42	62	1281
MedianRunTime	42	7	55	32	25
	ss-10-500-applog	ss-01-500-applog	ss-03-500-applog	ss-04-500-applog	ss-07-500-applog
%Runs UNKNOWN	67.96	72.73	50.75	29.41	30.95
%Runs ORGANISE	3.31		7.46	19.12	8.26
%Runs CALC	2.76				9.15
%Runs EBOOK					0.8
%Runs EMAIL					0.5
%Runs INTERNET					4.38
%Runs REF	2.76			7.35	0.5
%Runs PHONE	5.52		5.97		11.74
%Runs GAME	4.42		7.46		5.17
%Runs PHOTO					
%Runs SMS	4.97	27.27	5.97	26.47	3.59
%Runs MUSIC					19.3
%Runs SYSUTIL	8.29		22.99	17.65	
%Runs SYSLIB					3.78
%Runs CLOCK					
	ss-10-500-applog	ss-01-500-applog	ss-03-500-applog	ss-04-500-applog	ss-07-500-applog
%Time UNKNOWN	44.68	48.95	36.7	18.21	1.3
%Time ORGANISE	1.26		14.79	12.48	24.6
%Time CALC	1.08				11.97
%Time EBOOK					4.07
%Time EMAIL					1.12
%Time INTERNET	3.55			5.25	4.55
%Time REF					
%Time PHONE	18.23		21.77		31.04
%Time GAME	13.04		2.62		5.6
%Time PHOTO					
%Time SMS	4.9	51.05	14.55	43.8	5.6
%Time MUSIC					7.77
%Time SYSUTIL	13.27		9.57	20.28	
%Time SYSLIB					2.18
%Time CLOCK					

Figure A.11: Application Use Table Phase 2

	ss-10-500--applog	ss-01-500--applog	ss-03-500--applog	ss-04-500--applog	ss-07-500--applog
Runs UNKNOWN					24
Runs ORGANISE	123	16	34	20	311
Runs CALC	6		5	13	83
Runs DOC	5				92
Runs EBOOK					
Runs EMAIL					8
Runs INTERNET					5
Runs REF	5			5	44
Runs PHONE					
Runs GAME	10		4		118
Runs PHOTO	8		5		52
Runs SMS					
Runs QUIZ	9	6	4	18	36
Runs MUSIC					
Runs SYSUTIL	15		15	12	194
Runs SYSLIB					
Runs CLOCK					38
TOTALXCheck	181	22	67	68	1005
NumbApsxCheck	12	4	10	9	42
Top5ByRuns	[53]DateBook [48]MemoPad [17]ToDo [11]Graffiti Demo [10]Lemmings	[6]PalmQuiz [6]ToDo [6]MemoPad [4]DateBook	[13]MemoPad [11]Address [10]DateBook [8]HotSync [5]EasyCalc	[18]PalmQuiz [10]Address [9]Calculator [7]HotSync [6]DateBook	[114]MemoPad [103]DateBook [57]DocsToGo [52]EasyCalc [48]ToDo
Top5ByTime	[4913]DateBook [3762]Lemmings [3626]MemoPad [2692]Registered [2196]Graffiti Demo	[243]PalmQuiz [152]MemoPad [61]ToDo [20]DateBook	[1390]MineSweeper [1355]MemoPad [944]EasyCalc [929]PalmQuiz [713]Address	[1987]PalmQuiz [859]HotSync [404]Calculator [360]Address [333]DateBook	[9062]MemoPad [8417]EasyCalc [7825]Lemmings [7365]Palm SFCave [6503]DateBook

Figure A.12: Application Use Table Phase 2 Part 2

	ug-10-500-applog	ug-01-500-applog	ug-04-500-applog	ug-05-500-applog	ug-06-500-applog	ug-09-500-applog
LogLength(Days)	108.92	14.2	13.99	14.23	60.32	13.85
RUNS	570	340	92	90	102	345
RUNTIME	45557	36342	5379	7629	10015	9172
NUMBAPPS	40	30	11	14	6	11
AveInterval	16539	3620	13286	13813	51599	3478
SD of Interval	98765	15802	52370	41306	86185	12465
MaxInterval	2182646	197492	426008	311551	558869	129335
MedianInterval	80	76	80	163	15980	14
AveRunTime	80	107	58	85	98	27
SD of RunTime	143	188	78	139	143	59
MinRunTime	1	1	1	1	1	1
MaxRunTime	1185	1242	427	742	1116	689
MedianRunTime	25.5	23.5	24.5	27	85	7
%Runs UNKNOWN	3.86	3.24	4.44	4.4	86.27	53.62
%Runs ORGANISE	38.95	35.99	44.57	23.33		
%Runs CALC	6.49	3.24	7.61			
%Runs DOC	0.7	5.29	21.74	10		37.97
%Runs EBOOK	0.88					
%Runs EMAIL	1.23					
%Runs INTERNET	1.4	1.47				
%Runs REF		1.76				
%Runs PHONE						
%Runs GAME	9.65	21.18	8.7	20		
%Runs PHOTO	5.44	2.35	18.89			
%Runs SMS						
%Runs QUIZ	3.51	2.65	8.7	4.44	3.92	
%Runs MUSIC						
%Runs SYUTIL	27.19	20.59	8.7	18.89	9.8	8.41
%Runs SYSLIB		2.65				
%Runs CLOCK	0.7					
%Time UNKNOWN	0.7	0.26	0.3	0.3	88.75	70.61
%Time ORGANISE	44.28	26.67	49.3	21.6		
%Time CALC	4.86	4.51	4.54			
%Time DOC	0.18	3.38	18.48	3.29		13.85
%Time EBOOK	4.95					
%Time EMAIL	1.69					
%Time INTERNET	0.13	0.08				
%Time REF		0.84				
%Time PHONE						
%Time GAME	22.13	51.64		42.5		
%Time PHOTO	5.2	1.28	13.18	10.15		
%Time SMS						
%Time QUIZ	4.77	2.65	4.91	1.04	2.33	
%Time MUSIC						
%Time SYUTIL	9.78	7.21	9.59	21.13	8.93	15.55
%Time SYSLIB		1.47				
%Time CLOCK	1.32					

Figure A.13: Summary Table Phase 1 All Applications Part1

	ug-10-500--applog	ug-01-500--applog	ug-04-500--applog	ug-05-500--applog	ug-06-500--applog	ug-09-500--applog
Runs UNKNOWN	22	11	4	4		
Runs ORGANISE	222	121	41	21	88	185
Runs CALC	37	11	7			
Runs DOC	4	18	20	9		131
Runs EBOOK	5					
Runs EMAIL	7					
Runs INTERNET	8	5				
Runs REF		6				
Runs PHONE						
Runs GAME	55	72		18		
Runs PHOTO	31	8	8	17		
Runs SMS						
Runs QUIZ	20	9	8	4	4	
Runs MUSIC						
Runs SYSUTIL	155	70	8	17	10	29
Runs SYSLIB		9				
Runs CLOCK	4					
TOTALxCheck	570	340	92	90	102	345
NumbApsxCheck	40	30	11	14	6	11
Top5ByRuns	[78]MemoPad	[39]ToDo	[22]MemoPad	[13]MemoPad	[49]MemoPad	[106]DateBook
	[73]DateBook	[35]MemoPad	[13]DocsToDo	[11]HotSync	[29]DateBook	[65]SheetToDo
	[50]ToDo	[32]HardBall	[10]ToDo	[10]PGPocket	[10]Address	[62]DocsToDo
	[30]EasyCalc	[25]DateBook	[9]DateBook	[10]SeaWar	[6]Graffiti Demo	[45]ToDo
	[22]BatteryLog	[25]Space Trader	[8]Registered	[8]Phoinix	[4]PalmQuiz	[20]MemoPad
Top5ByTime	[7022]MemoPad	[9698]HardBall	[1031]MemoPad	[2467]SeaWar	[3946]MemoPad	[3479]DateBook
	[6210]DateBook	[6309]Space Trader	[964]ToDo	[1441]MemoPad	[2530]DateBook	[1702]ToDo
	[5136]HardBall	[3549]MemoPad	[709]Registered	[1145]HotSync	[2412]Address	[905]SheetToDo
	[5112]ToDo	[2372]DateBook	[657]DateBook	[775]Phoinix	[762]Graffiti Demo	[787]Address
	[2392]Phoinix	[2068]Address	[606]DocsToDo	[493]PGPocket	[233]PalmQuiz	[736]HotSync

Figure A.14: Summary Table Phase 1 All Applications Part 2

	32m-00ya5q44enr	3f00ya6841x4u-bj	4f00ya6841xe-p	5m-00ya6841xb-cj	7f00ya6841x2l-6j	8m-00yae945a4-3	11m-00ya6841x26-q	12f00ya6841xe-p	13m-00ya6841xe-h	14f00ya6841x0f	30m-00ya6841x9-bc
LogLengthInDays	16.1	138.99	104.71	104.71	90.77	48.97	82.72	69.06	96.91	23.68	14.97
RUNS	118	675	745	745	100	336	262	318	545	26	35
RUNTIME	34026	68660	203888	203888	29384	97873	72047	163748	138473	5079	4297
NUMBAPPS	9	29	28	28	12	23	17	21	18	4	7
AveInterval	11888	17946	12160	12160	79218	12631	27383	18822	15391	81353	38037
SD of Interval	56125	84283	30810	30810	40690	98824	60354	56018	60354	279336	33471
MaxInterval	442626	1243636	340959	340959	1559937	418085	1075538	414697	863622	1287467	595954
MedianInterval	170	68	450.5	450.5	225	197	67	141	110	53	34
AveRunTime	288	102	274	274	294	291	275	515	254	195	123
SD of RunTime	734	208	475	475	628	620	645	1162	851	330	205
MinRunTime	1	1	1	1	1	1	1	1	1	2	1
MaxRunTime	4617	2282	3524	3524	5130	4208	3388	6952	11948	1369	854
MedianRunTime	31	24	57	57	71	46.5	31	46	29	44	28
%Runs UNKNOWN		1.63	0.07	0.04	8	6.38		2.2	2.39		8.57
%Runs ORGANISE	13.56	40	10.87	10.87	6	6.04	11.07	5.97	7.89	15.38	22.8
%Runs CALC	6.78	11.11	1.07	1.07		3.27	4.98	1.26	2.57		2
%Runs DOC		3.96	2.15	2.15			9.92				3.6
%Runs EBOOK											
%Runs EMAIL											
%Runs INTERNET											
%Runs REF											
%Runs PHONE							1.53				
%Runs GAME		10.96	57.18	57.18	37	34.23	14.5	18.87	21.83	46.15	22.86
%Runs PHOTO		22.88	12.48	12.48	20	6.25	28.63	22.33	57.98	19.23	34.29
%Runs SMS											38
%Runs QUIZ		3.39	1.33	1.74				3.46	2.02		8.57
%Runs MUSIC		49.15	4.59	1.61	19	21.43	16.79	34.91	3.67		28
%Runs SYSUTIL		4.24	6.52	3.36	10	13.69	10.31	10.06	0.92		20
%Runs SYSLIB								0.94		19.23	5.71
%Runs CLOCK			0.59	8.19			2.67		0.73		
%Time UNKNOWN		0.07	0.04	0.04	5.94	0.48		0.23	0.56		3.51
%Time ORGANISE	4.38	50.9	2.49	1.97	1.65	1.97	2.18	0.64	1.11	0.2	26.01
%Time CALC	1.9	11.22	0.2	0.2		0.85	0.43		1.13		0.21
%Time DOC		5.16	0.23	0.23			0.31	0.28			1.21
%Time EBOOK											
%Time EMAIL											
%Time INTERNET											
%Time REF											
%Time PHONE							0.12				
%Time GAME		17.85	92.48	92.48	35.61	52.07	6.86	3.66	71.51	93.7	65.26
%Time PHOTO		5.16	2.4	2.4	6.96	1.32	5.97	1.87	15.77	4.17	7.49
%Time SMS											13.41
%Time QUIZ		0.38	3.51	0.48				1.18	1.01		6.88
%Time MUSIC		91.01	3.46	0.93	49.32	40.33	77.4	91.53	8.79		38.38
%Time SYSUTIL		0.39	0.17	0.52	0.52	6.59	0.59	0.07	0.06		6.75
%Time SYSLIB						0.81		0.04		1.93	10.01
%Time CLOCK		0.15	0.59	0.59		0.15			0.04		

Figure A.15: Application Use Phase 4 Part 1

Runs UNKNOWN	32m-00yja5q4deFr	3f00yja6841x4u-Hj	4400yja684Lxe9H	5m-00yja6841x1b-p0j	7f00yja6841x21-e6j	8m-00yvac9458443	11m-00yja6841x26-g	12k00yja6841xepP	13m-00yja684LxeH	14f00yja5u41x0f	30m-00yja6841x9g-bc
Runs ORGANISE	16	11	10	8	10	10	7	13	4	3	5
Runs CALC	8	270	81	6	27	27	19	43	4	4	57
Runs DOC	8	75	8	12	11	11	14	14	5	12	5
Runs EBOOK	24	24	16				4				9
Runs EMAIL											
Runs INTERNET											
Runs REF											
Runs PHONE											
Runs GAME	27	74	426	37	115	38	60	119	12	8	95
Runs PHOTO		133	93	20	21	75	71	316	5	12	
Runs SMS											
Runs QUIZ	4	9	13				11	11		3	4
Runs MUSIC	58	31	12	19	72	44	111	20		7	70
Runs SYSJTL	5	44	25	10	46	27	32	5		7	5
Runs SYSLIB							3			2	
Runs CLOCK		4	61		34	7		4			
TOTALxCheck	118	675	745	100	336	262	318	545	26	35	250
NumbApsxCheck	9	29	28	12	23	17	21	18	4	7	13
Top5ByRuns	[68]RealOne	[106]Memos-PMem	[122]Solitaire	[19]RealOne	[72]RealOne	[44]RealOne	[111]RealOne	[174]Capture-Kcpt	[12]Bejewelled	[8]Solitaire	[70]RealOne
	[18]Capture-Kcpt	[98]Calendar-PDat	[108]blocks	[12]Darts Deluxe II	[38]BubblesOS5	[42]Photos-Foto	[39]Capture-Kcpt	[142]Photos-Foto	[5]Capture-Kcpt	[8]Photos-Foto	[56]Capture-Kcpt
	[10]Contacts-PAdd	[86]Capture-Kcpt	[102]BubblesOS5	[11]Capture-Kcpt	[34]Sync	[33]Capture-Kcpt	[32]Photos-Foto	[68]BubblesOS5	[5]Sync	[7]Applog	[39]Photos-Foto
	[9]Photos-Foto	[47]Photos-Foto	[61]Clock-PcLK	[9]Photos-Foto	[25]prefs	[20]blocks	[25]Bejewelled2	[25]Calendar-PDat	[4]Calendar-PDat	[4]Capture-Kcpt	[30]Contacts-PAdd
	[6]Calendar-PDat	[46]Calculator	[60]Photos-Foto	[8]PMGX	[24]Bejewelled2	[17]DocsToGo	[11]Quizzler	[20]RealOne	[3]VoicePad-Vpad	[18]Calendar-PDat	
Top5ByTime	[30968]RealOne	[14898]Memos-PMem	[62919]BubblesOS5	[14483]RealOne	[39472]RealOne	[55767]RealOne	[149879]RealOne	[70159]BubblesOS5	[4759]Bejewelled	[2604]Solitaire	[40088]RealOne
	[569]Contacts-PAdd	[13970]Calendar-PDat	[50997]Solitaire	[4500]SDV	[35830]BubblesOS5	[4629]HotSync	[3730]Bejewelled2	[15186]Photos-Foto	[212]Capture-Kcpt	[430]Sync	[11785]Contacts-PAdd
	[520]Calendar-PDat	[3936]Calculator	[48998]blocks	[2753]Darts Deluxe II	[10852]Bejewelled2	[3394]blocks	[1933]Photos-Foto	[12739]Solitaire	[96]Sync	[300]Quizzler	[8159]Photos-Foto
	[450]Capture-Kcpt	[3862]AnotherBall	[7930]Bejewelled2	[1743]PMGX	[1636]Contacts-PAdd	[2441]Photos-Foto	[1930]Quizzler	[12171]RealOne	[10]Calendar-PDat	[290]Applog	[5557]Calendar-PDat
	[397]Calculator	[3767]Calcul43	[5250]Billiards	[1350]E-Racer	[1091]GTS Racing	[1860]Capture-Kcpt	[1134]Capture-Kcpt	[7468]blocks	[212]Photos-Foto		[1052]Capture-Kcpt

Figure A.16: Application Use Phase 4 Part 2

	ss-10-500--applog	ss-01-500--applog	ss-03-500--applog	ss-04-500--applog	ss-07-500--applog
Runs UNKNOWN					24
Runs ORGANISE	123	16	34	20	311
Runs CALC	6		5	13	83
Runs DOC	5				92
Runs EBOOK					8
Runs EMAIL					5
Runs INTERNET					44
Runs REF	5			5	
Runs PHONE					
Runs GAME	10		4		118
Runs PHOTO	8		5		52
Runs SMS					
Runs QUIZ	9	6	4	18	36
Runs MUSIC					
Runs SYSUTIL	15		15	12	194
Runs SYSLIB					
Runs CLOCK					38
TOTALxCheck	181	22	67	68	1005
NumbApsxCheck	12	4	10	9	42
Top5By/Runs	[53]DateBook [48]MemoPad [17]ToDo [11]Graffiti Demo [10]Lemmings	[6]PalmQuiz [6]ToDo [6]MemoPad [4]DateBook	[13]MemoPad [11]Address [10]DateBook [8]HotSync [5]EasyCalc	[18]PalmQuiz [10]Address [9]Calculator [7]HotSync [6]DateBook	[114]MemoPad [103]DateBook [57]DocsToGo [52]EasyCalc [48]ToDo
Top5By/Time	[4913]DateBook [3762]Lemmings [3626]MemoPad [2692]Registered [2196]Graffiti Demo	[243]PalmQuiz [152]MemoPad [61]ToDo [20]DateBook	[1390]MineSweeper [1355]MemoPad [944]EasyCalc [929]PalmQuiz [713]Address	[1987]PalmQuiz [859]HotSync [404]Calculator [360]Address [333]DateBook	[9062]MemoPad [8417]EasyCalc [7825]Lemmings [7365]Palm_SFCave [6503]DateBook

Figure A.18: Summary Table Phase 2 All Applications Part 2

	ug-10-500--applog	ug-01-500--applog	ug-04-500--applog	ug-05-500--applog	ug-06-500--applog	ug-09-500--applog
LogLength(Days)	108.92	14.2	13.99	14.23	60.32	13.85
RUNS	570	340	92	90	102	345
RUNTIME	45557	36342	5379	7629	10015	9172
NUMBAPPS	40	30	11	14	6	11
AveInterval	16539	3620	13286	13813	51599	3478
SD of Interval	98765	15802	52370	41306	86185	12465
MaxInterval	2182646	197492	426008	311551	558869	129335
MedianInterval	80	76	80	163	15980	14
AveRunTime	80	107	58	85	98	27
SD of RunTime	143	188	78	139	143	59
MinRunTime	1	1	1	1	1	1
MaxRunTime	1185	1242	427	742	1116	689
MedianRunTime	25.5	23.5	24.5	27	85	7
%Runs UNKNOWN	3.86	3.24			4.44	
%Runs ORGANISE	38.95	35.59	44.57	23.33	86.27	53.62
%Runs CALC	6.49	3.24	7.61			
%Runs DOC	0.7	5.29	21.74	10		37.97
%Runs EBOOK	0.88					
%Runs EMAIL	1.23					
%Runs INTERNET	1.4	1.47				
%Runs REF		1.76				
%Runs PHONE						
%Runs GAME	9.65	21.18			20	
%Runs PHOTO	5.44	2.35	8.7	18.89		
%Runs SMS						
%Runs QUIZ	3.51	2.65	8.7	4.44	3.92	
%Runs MUSIC						
%Runs SYSUTIL	27.19	20.59	8.7	18.89	9.8	8.41
%Runs SYSLIB		2.65				
%Runs CLOCK	0.7					
%Time UNKNOWN	0.7	0.26				
%Time ORGANISE	44.28	26.67	49.3	21.6	88.75	70.61
%Time CALC	4.86	4.51	4.54			
%Time DOC	0.18	3.38	18.48	3.29		13.85
%Time EBOOK	4.95					
%Time EMAIL	1.69					
%Time INTERNET	0.13	0.08				
%Time REF		0.84				
%Time PHONE						
%Time GAME	22.13	51.64			42.5	
%Time PHOTO	5.2	1.28	13.18	10.15		
%Time SMS						
%Time QUIZ	4.77	2.65	4.91	1.04	2.33	
%Time MUSIC						
%Time SYSUTIL	9.78	7.21	9.59	21.13	8.93	15.55
%Time SYSLIB		1.47				
%Time CLOCK	1.32					

Figure A.19: Summary Table Phase 1 All Applications Part 1

	ug-10-500--applog	ug-01-500--applog	ug-04-500--applog	ug-05-500--applog	ug-06-500--applog	ug-09-500--applog
Runs UNKNOWN	22	11	4			
Runs ORGANISE	222	121	41	21	88	185
Runs CALC	37	11	7			
Runs DOC	4	18	20	9		131
Runs EBOOK	5					
Runs EMAIL	7					
Runs INTERNET	8	5				
Runs REF		6				
Runs PHONE						
Runs GAME	55	72		18		
Runs PHOTO	31	8	8	17		
Runs SMS						
Runs QUIZ	20	9	8	4	4	
Runs MUSIC						
Runs SYSUTIL	155	70	8	17	10	29
Runs SYSLIB		9				
Runs CLOCK	4					
TOTALxCheck	570	340	92	90	102	345
NumbApxxCheck	40	30	11	14	6	11
Top5ByRuns	[78]MemoPad	[39]ToDo	[22]MemoPad	[13]MemoPad	[49]MemoPad	[106]DateBook
	[73]DateBook	[35]MemoPad	[13]DocsToDo	[11]HotSync	[29]DateBook	[65]SheetToDo
	[50]ToDo	[32]HardBall	[10]ToDo	[10]PGPocket	[10]Address	[62]DocsToDo
	[30]EasyCalc	[25]DateBook	[9]DateBook	[10]SeaWar	[6]Graffiti Demo	[45]ToDo
	[22]BatteryLog	[25]Space Trader	[8]Registered	[8]Phoenix	[4]PalmQuiz	[20]MemoPad
Top5ByTime	[7022]MemoPad	[9698]HardBall	[1031]MemoPad	[2467]SeaWar	[3946]MemoPad	[3479]DateBook
	[6210]DateBook	[6309]Space Trader	[964]ToDo	[1441]MemoPad	[2530]DateBook	[1702]ToDo
	[5136]HardBall	[3549]MemoPad	[709]Registered	[1145]HotSync	[2412]Address	[905]SheetToDo
	[5112]ToDo	[2372]DateBook	[657]DateBook	[775]Phoenix	[762]Graffiti Demo	[787]Address
	[2392]Phoenix	[2068]Address	[606]DocsToDo	[493]PGPocket	[233]PalmQuiz	[736]HotSync

Figure A.20: Summary Table Phase 1 All Applications Part 2

Runs UNKNOWN	32m-00yja5g44enf-r	4f-00yja6841xe9-I	5m-00yja6841xtb-o[]	7f-00yja6841x21-6[]	8m-00yjac945af4-3	11m-00yja6841x26-g
Runs ORGANISE	16	11	10	8	10	7
Runs CALC	8	270	81	6	27	19
Runs DOC		75	8		11	12
Runs EBOOK		24	16			26
Runs EMAIL						
Runs INTERNET						
Runs REF						
Runs PHONE						4
Runs GAME		74	426	37	115	38
Runs PHOTO	27	133	93	20	21	75
Runs SMS						71
Runs QUIZ	4	9	13			11
Runs MUSIC	58	31	12	19	72	44
Runs SYSUTIL	5	44	25	10	46	27
Runs SYSLIB					34	3
Runs CLOCK		4	61			7
TOTALxCheck	118	675	745	100	336	262
NumbApsxCheck	9	29	28	12	23	17
						21
Top5BYRuns	[58]RealOne	[106]Memos-PMem	[122]Solitaire	[19]RealOne	[44]RealOne	[111]RealOne
	[18]Capture-Kcpt	[98]Calendar-PDat	[108]blocks	[12]Darts Deluxe II	[42]Photos-Foto	[39]Capture-Kcpt
	[10]Contacts-PAdd	[86]Capture-Kcpt	[102]BubblesOS5	[11]Capture-Kcpt	[33]Capture-Kcpt	[32]Photos-Foto
	[9]Photos-Foto	[47]Photos-Foto	[61]Clock-PCLK	[9]Photos-Foto	[20]blocks	[25]Bejeweled2
	[6]Calendar-PDat	[46]Calculator	[60]Photos-Foto	[8]PMGX	[17]Docs ToGo	[11]Quizzler
Top5ByTime	[30968]RealOne	[14898]Memos-PMem	[62919]BubblesOS5	[14493]RealOne	[55767]RealOne	[149879]RealOne
	[969]Contacts-PAdd	[13970]Calendar-PDat	[59997]Solitaire	[4500]Spy	[4629]HotSync	[3730]Bejeweled2
	[520]Calendar-PDat	[3936]Calculator	[48898]blocks	[2753]Darts Deluxe II	[3394]blocks	[1933]Photos-Foto
	[450]Capture-Kcpt	[3862]AnotherBall	[7930]Bejeweled2	[1744]PMGX	[2441]Photos-Foto	[1930]Quizzler
	[397]Calculator	[3767]Calcul-8!	[5250]Billiards	[1091]GTS Racing	[1860]Capture-Kcpt	[1134]Capture-Kcpt

Figure A.22: Summary Table Phase 4 All Applications Part 2
230

	ss-10-500--applog	ss-01-500--applog	ss-03-500--applog	ss-04-500--applog	ss-07-500--applog
Diff with No Music or Photo	34.2	13.19	14.49	28.04	35.24
LogLength(Days)	-8	0	-5	0	-52
RUNS	-2692	0	-167	0	-4330
RUNTIME	-1	0	-1	0	-3
NUMBAPPS					
AveInterval	763	0	1555	0	166
SD of Interval	1000	0	2613	0	324
MaxInterval	0	0	0	0	0
MedianInterval	174	0	65.5	0	7.5
AveRunTime	-10	0	5	0	0
SD of RunTime	-19	0	3	0	0
MinRunTime	0	0	0	0	0
MaxRunTime	0	0	0	0	0
MedianRunTime	0	0	11	0	2
%Runs UNKNOWN					0.13
%Runs ORGANISE	3.14	0	4.09	0	1.68
%Runs CALC	0.16		0.6	0	0.45
%Runs DOC	0.13				0.5
%Runs EBOOK					0.04
%Runs EMAIL					0.02
%Runs INTERNET					0.24
%Runs REF	0.13			0	
%Runs PHONE					0.64
%Runs GAME	0.26		0.48		-5.17
%Runs PHOTO	-4.42		-7.46		
%Runs SMS					0.2
%Runs QUIZ	0.23	0	0.48	0	0.2
%Runs MUSIC					1.06
%Runs SYSUTIL	0.38		1.8	0	
%Runs SYSLIB					0.21
%Runs CLOCK					
%Time UNKNOWN					0.08
%Time ORGANISE	6.7	0	0.99	0	1.47
%Time CALC	0.18		0.39	0	0.71
%Time DOC	0.16				0.24
%Time EBOOK					0.07
%Time EMAIL					0
%Time INTERNET					0.28
%Time REF	0.53			0	
%Time PHONE					1.84
%Time GAME	2.73		0.59		-5.6
%Time PHOTO	-13.04		-2.62		
%Time SMS					0.33
%Time QUIZ	0.74	0	0.39	0	
%Time MUSIC					0.47
%Time SYSUTIL	1.99		0.26	0	
%Time SYSLIB					0.13
%Time CLOCK					

Figure A.23: Application Use Phase 2

	ss-10-500--applog	ss-01-500--applog	ss-03-500--applog	ss-04-500--applog	ss-07-500--applog
Runs UNKNOWN					0
Runs ORGANISE	0	0	0	0	0
Runs CALC	0	0	0	0	0
Runs DOC	0				0
Runs EBOOK					
Runs EMAIL					0
Runs INTERNET					0
Runs REF	0			0	0
Runs PHONE					
Runs GAME	0	0	0	0	0
Runs PHOTO	-8			-5	-52
Runs SMS					
Runs QUIZ	0	0	0	0	0
Runs MUSIC					
Runs SYSUTIL	0			0	0
Runs SYSLIB					
Runs CLOCK					0
TOTALxCheck	-8	0	0	-5	0
NumbApsxCheck	-1	0	0	-1	0

Figure A.24: Application Use Phase 2 Part 2

	ug-10-500--applog	ug-01-500--applog	ug-04-500--applog	ug-05-500--applog	ug-06-500--applog	ug-09-500--applog
Diff with No Music or Photo	108.92	14.2	13.99	14.23	60.32	13.85
LopLength(Days)	-31	-8	-8	-17	0	0
RUNS	-2371	-466	-709	-774	0	0
NUMBAPPS	-3	-2	-1	-2	0	0
AveInterval	953	88	1280	3262	0	0
SD of Interval	2731	180	2324	4765	0	0
MaxInterval	0	0	0	6905	0	0
MedianInterval	2	5	9	106	0	0
AveRunTime	0	1	-2	9	0	0
SD of RunTime	2	2	1	11	0	0
MinRunTime	0	0	0	0	0	0
MaxRunTime	0	0	0	0	0	0
MedianRunTime	-0.5	0	-5.5	10	0	0
%Runs UNKNOWN	0.22	0.07	4.24	1.04	0	0
%Runs ORGANISE	2.24	0.86	0.72	5.44	0	0
%Runs CALC	0.37	0.07	2.07	2.33	0	0
%Runs DOC	0.04	0.13	0.04	0.04	0	0
%Runs EBOOK	0.05	0.05	0.04	0.05	0	0
%Runs EMAIL	0.07	0.07	0.04	0.05	0	0
%Runs INTERNET	0.08	0.04	0.05	0.05	0	0
%Runs REF	0.08	0.05	0.05	0.05	0	0
%Runs PHONE	0.55	0.51	0.82	4.66	0	0
%Runs GAME	-5.44	-2.35	-8.7	-18.89	0	0
%Runs PHOTO	0.2	0.06	0.82	1.04	0	0
%Runs SMS	1.57	0.49	0.82	4.4	0	0
%Runs MUSIC	0.04	0.06	0.04	0.04	0	0
%Runs SYSUTIL	0.04	0	7.49	2.44	0	0
%Runs SYSLIB	2.43	0.35	0.68	2.44	0	0
%Runs CLOCK	0.27	0.06	2.8	0.37	0	0
%Time UNKNOWN	0.01	0.05	0.04	0.04	0	0
%Time ORGANISE	0.09	0	0.04	0.04	0	0
%Time CALC	0.27	0.06	0.68	0.37	0	0
%Time DOC	0.01	0.05	2.8	0.37	0	0
%Time EBOOK	0.27	0.06	0.68	0.37	0	0
%Time EMAIL	0.09	0	0.04	0.04	0	0
%Time INTERNET	0	0.01	0.04	0.04	0	0
%Time REF	0	0.01	0.04	0.04	0	0
%Time PHONE	1.22	0.67	4.79	4.79	0	0
%Time GAME	-5.2	-1.28	-13.18	-10.15	0	0
%Time PHOTO	0.27	0.03	0.74	0.11	0	0
%Time SMS	0.27	0.03	0.74	0.11	0	0
%Time MUSIC	0.54	0.09	1.46	2.39	0	0
%Time SYSUTIL	0.07	0.02	0.02	0.02	0	0
%Time SYSLIB	0.07	0.02	0.02	0.02	0	0
%Time CLOCK	0.07	0.02	0.02	0.02	0	0

Figure A.25: Application Use Phase 1

	ug-10-500--applog	ug-01-500--applog	ug-04-500--applog	ug-05-500--applog	ug-06-500--applog	ug-09-500--applog
Runs UNKNOWN	0	0	0	0	0	0
Runs ORGANISE	0	0	0	0	0	0
Runs CALC	0	0	0	0	0	0
Runs DOC	0	0	0	0	0	0
Runs EBOOK	0	0	0	0	0	0
Runs EMAIL	0	0	0	0	0	0
Runs INTERNET	0	0	0	0	0	0
Runs REF	0	0	0	0	0	0
Runs PHONE	0	0	0	0	0	0
Runs GAME	0	0	0	0	0	0
Runs PHOTO	-31	-8	-8	-8	-17	0
Runs SMS	0	0	0	0	0	0
Runs QUIZ	0	0	0	0	0	0
Runs MUSIC	0	0	0	0	0	0
Runs SYSUTIL	0	0	0	0	0	0
Runs SYSLIB	0	0	0	0	0	0
Runs CLOCK	0	0	0	0	0	0
TOTALxCheck	-31	-8	-8	-8	-17	0
NumbApsxCheck	-3	-2	-1	-2	0	0

Figure A.26: Application Use Phase 1

	32n-00Ma5g44enf-r	3f-00Ya6841x4u-Bj]	4f-00Ya6841xeH	5m-00Ya6841xtb-o]]	7f-00Ya6841x21-6]]	8m-00Yac945a4-3	11m-00Ya6841x26-g	12f-00Ya6841xeP	13m-00Ma6841xeH	14f-00Ma5u41xOf
Diff with No Music or Photo	16.1									
LogLength(Days)	139.99	90.77	104.71	48.97	82.72	69.06	96.91	23.68	14.97	
RUNS	-85	-164	-105	-93	-119	-182	-336	-5	-12	
RUNTIME	-31626	-5920	-6787	-40763	-60068	-152946	-34013	-212	-322	
NUMBAPPS	-3	-3	-3	-3	-3	-3	-3	-1	-2	
AveInterval	31450	5771	1998	42916	22870	25374	23568	20464	20512	
SD of Interval	75251	14977	2319	228633	98361	58365	50076	31081	26108	
MaxInterval	167922	0	0	1188127	0	272711	330182	0	3695	
MedianInterval	880	96	259.5	80	30	23.5	990.5	518	256.5	
AveRunTime	-215	21	34	-83	-56	-436	246	37	50	
SD of RunTime	-656	14	23	-272	-28	-1002	196	28	33	
MinRunTime	0	0	0	0	0	0	0	0	0	
MaxRunTime	-4341	0	0	-2866	0	-5901	-3551	0	0	
MedianRunTime	23	15	33.5	-9	-7.5	-33	92	7	52	
%Runs UNKNOWN		0.52	0.22	5.11	1.14	2.95	3.83		4.47	
%Runs ORGANISE	34.92	12.84	1.79	3.84	9.21	8	12.68	3.67		
%Runs CALC	17.46	3.57	0.18	1.26	3.81	1.68	4.13			
%Runs DOC		1.14	0.35		8.26					
%Runs EBOOK										
%Runs EMAIL										
%Runs INTERNET										
%Runs REF										
%Runs PHONE					1.27					
%Runs GAME		3.52	9.38	23.66	13.1	12.07	35.11	10.99	11.92	
%Runs PHOTO	-22.88	-19.7	-12.48	-20	-6.25	-28.63	-57.98	-19.23	-34.29	
%Runs SMS										
%Runs QUIZ	8.73	0.43	0.29			4.63	3.24		4.47	
%Runs MUSIC	-49.15	-4.59	-1.61	-19	-21.43	-16.79	-3.67			
%Runs SYSUTIL	10.91	2.09	0.55	6.39	5.24	8.57	1.47		10.43	
%Runs SYSLIB					3.87	1.27		4.58		
%Runs CLOCK		0.19	1.34		2.23		1.18			
%Time UNKNOWN		0	0	7.64	0.34	3.26	0.18		0.29	
%Time ORGANISE	57.66	4.8	0.08	2.13	10.93	9	0.37	0.01		
%Time CALC	25.1	1.06	0.01	0.61	2.18	0.37	0.37			
%Time DOC		0.49	0.01		1.53	3.91				
%Time EBOOK										
%Time EMAIL										
%Time INTERNET										
%Time REF										
%Time PHONE					0.57					
%Time GAME		1.69	3.18	45.85	37.16	34.38	23.29	4.08	5.29	
%Time PHOTO	-1.93	-5.16	-2.4	-6.96	-1.32	-5.97	-15.77	-4.17	-7.49	
%Time SMS										
%Time QUIZ	5.08	0.34	0.01			16.69	0.34		0.57	
%Time MUSIC	-91.01	-3.46	-0.93	-49.32	-40.33	-77.4	-8.79			
%Time SYSUTIL	5.11	0.24	0.01	0.66	1.55	33.02	0.02		0.55	
%Time SYSLIB				0.58	0.58	1.01		0.08	0.81	
%Time CLOCK		0.02	0.02		0.75		0.02			

Figure A.27: Application Use Phase 4

	ug-10-500-applog	ug-01-500-applog	ug-04-500-applog	ug-05-500-applog	ug-06-500-applog	ug-09-500-applog			
Runs UNKNOWN									
Runs ORGANISE	0	0	0	0	0	0	0	0	0
Runs CALC	0	0	0	0	0	0	0	0	0
Runs DOC	0	0	0	0	0	0	0	0	0
Runs EBOOK									
Runs EMAIL									
Runs INTERNET									
Runs REF									
Runs PHONE				0					
Runs GAME	0	0	0	0	0	0	0	0	0
Runs PHOTO	-27	-133	-93	-20	-21	-75	-71	-316	-5
Runs SMS	0	0	0	0	0	0	0	0	0
Runs QUIZ	0	0	0	0	0	0	0	0	0
Runs MUSIC	-58	-31	-12	-19	-72	-44	-111	-20	0
Runs SYSUTIL	0	0	0	0	0	0	0	0	0
Runs SYSLIB									
Runs CLOCK									
TOTALxCheck	-85	-164	-105	-39	-93	-119	-182	-336	-5
NumbApsxCheck	-3	-3	-3	-3	-3	-3	-3	-3	-1

Figure A.28: Apps Per Slice Phase 1

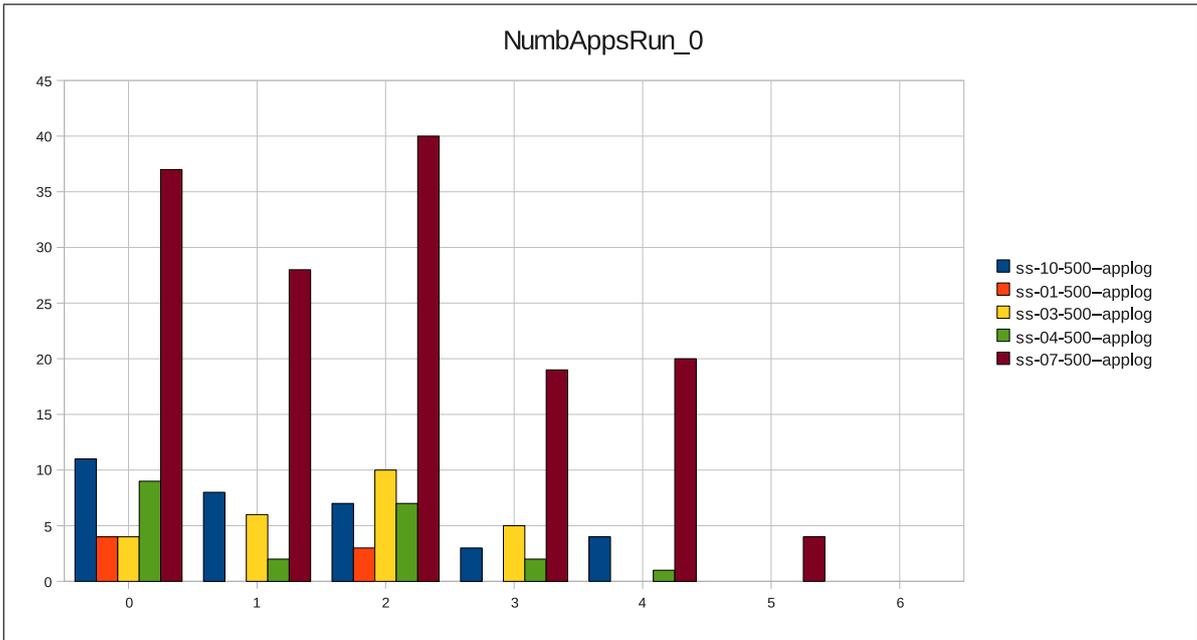


Figure A.30: Graph Apps Per Slice Phase 2

Apps Per Week Charts

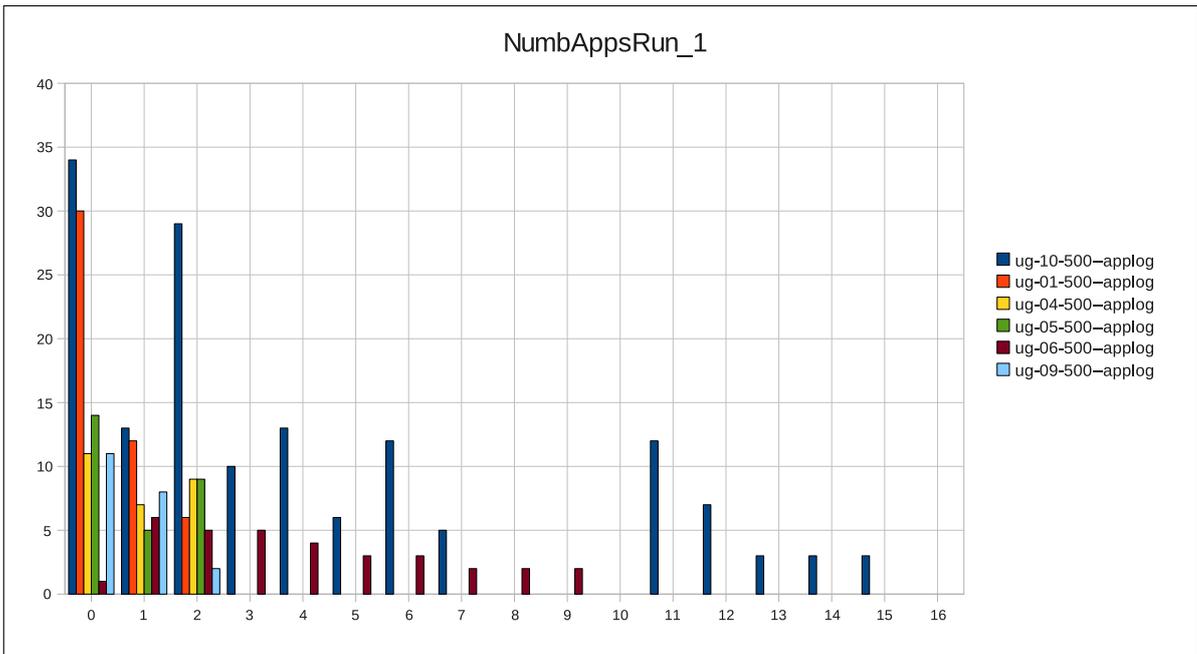


Figure A.29: Graph Apps Per Slice Phase 1

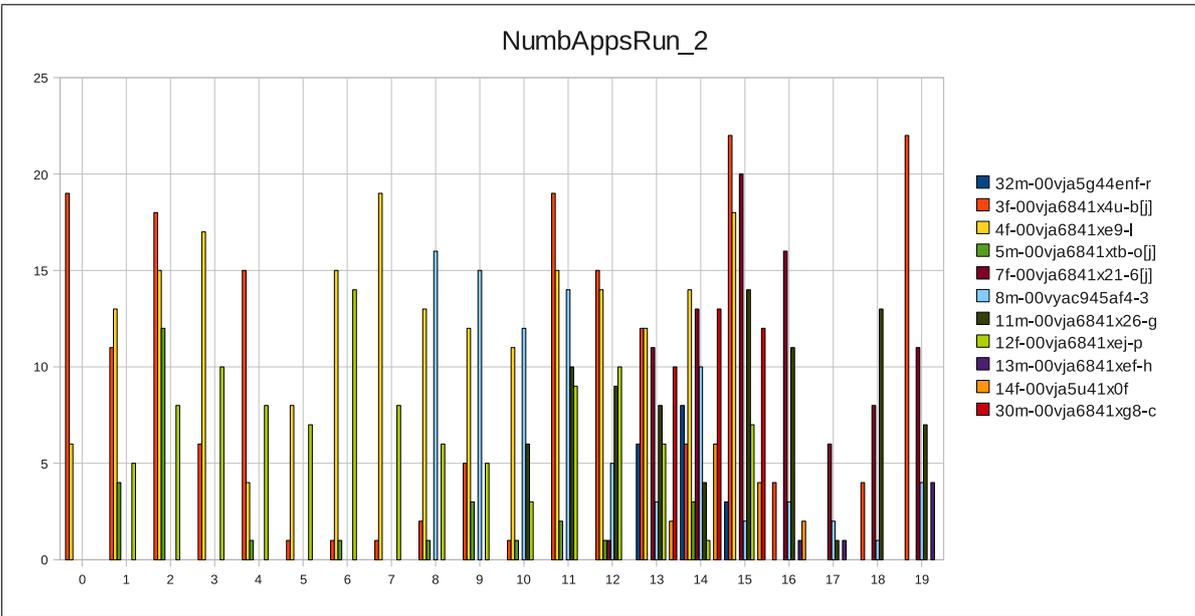


Figure A.31: Chart Apps Per Slice Phase 4

NumbAppsRun	ss-10-500-applog	ss-01-500-applog	ss-03-500-applog	ss-04-500-applog	ss-07-500-applog
0	11	4	4	9	37
1	8		6	2	28
2	7	3	10	7	40
3	3		5	2	19
4	4			1	20
5					4

Figure A.33: Apps Per Slice Phase 2

This is the number of applications used during each week of the project. It shows a fall off in the end of the project and the time to hand back the PDA approaches.

Applications Per Slice Tables

NumbAppsRun	ug-10-500-applog	ug-01-500-applog	ug-04-500-applog	ug-05-500-applog	ug-06-500-applog	ug-09-500-applog
0	34	30	11	14	1	11
1	13	12	7	5	6	8
2	29	6	9	9	5	2
3	10				5	
4	13				4	
5	6				3	
6	12				3	
7	5				2	
8					2	
9					2	
10						
11	12					
12	7					
13	3					
14	3					
15	3					
16						
17						
18						
19						

Figure A.32: Apps Per Slice Phase 1

NumbAppsRun	32m-00ja5g44enf-r	3f00ja6841x4u-b[j]	4f00ja6841xe94	5m-00ja6841xtb-o[j]	7f00ja6841x21-6[j]	8m-00yac945af4-3	11m-00ja6841x26-g	12f00ja6841xej-p
0		19	6					
1		11	13	4				5
2		18	15	12				8
3		6	17					10
4		15	4	1				8
5		1	8					7
6		1	15	1				14
7		1	19					8
8		2	13	1		16		6
9		5	12	3		15		5
10		1	11	1		12	6	3
11		19	15	2		14	10	9
12		15	14	1	1	5	9	10
13	6	12	12		11	3	8	6
14	8	6	14	3	13	10	4	1
15	3	22	18		20	2	14	7
16		4			16	3	11	
17					6	2	1	
18		4			8	1	13	
19		22			11	4	7	

Figure A.34: Apps Per Slice Phase 4

GridRunTime MEAN	ug-10-500-applog	ug-01-500-applog	ug-04-500-applog	ug-05-500-applog	ug-06-500-applog	ug-09-500-applog
0	59	108	62	67		30
1	93	106	56	162	107	20
2	94	94	46	153	84	24
3	77				78	
4	124				93	
5	67				127	
6	99				119	
7	107				101	
8					91	
9					30	
10						
11	70					
12	57					
13	150					
14	94					
15	97					

Figure A.35: Runtime Mean Phase 1

GridRunTime MEAN	ss-10-500-applog	ss-01-500-applog	ss-03-500-applog	ss-04-500-applog	ss-07-500-applog
0	109	25	98	38	62
1	100		75	138	91
2	134	3	82	134	87
3	127		234	114	94
4	103				71
5					164

Figure A.36: Runtime Mean Phase 2

Mean Runtime Tables

GridRunTime MEAN	32m-30ja5g44enfr	3f00ja6841x4u4j]	4f00ja6841xe94	5m-00ja6841xtb-oj]	7f00ja6841x21-6j]	8m-00yac945af4-3	11m-00ja6841x26-g	12f00ja6841xe-p	13m-00ja6841xeH	14f00ja5u41x0f
0		101	25							
1		142	395	143					33	
2		96	331	211					1354	
3		169	293						237	
4		128	621	444					277	
5			342						372	
6			240	14					121	
7		203	198						230	
8		58	367	574		67			132	
9		174	217	278		128			717	
10			118			281	483		912	
11		83	198	1719		146	414		154	
12		70	219			412	445		189	
13	124	103	343		351	685	861	73		20
14	342	125	200	440	277	708	1543			146
15	119	60	387		208	1812	665	80		115
16		145			171	812	814		368	141
17					728	1567				
18		103			236		160			
19		137			489	512	549		175	

Figure A.37: Runtime Mean per Slice Phase 4

Scatter Plots of the Average Runtime and Runs per Day

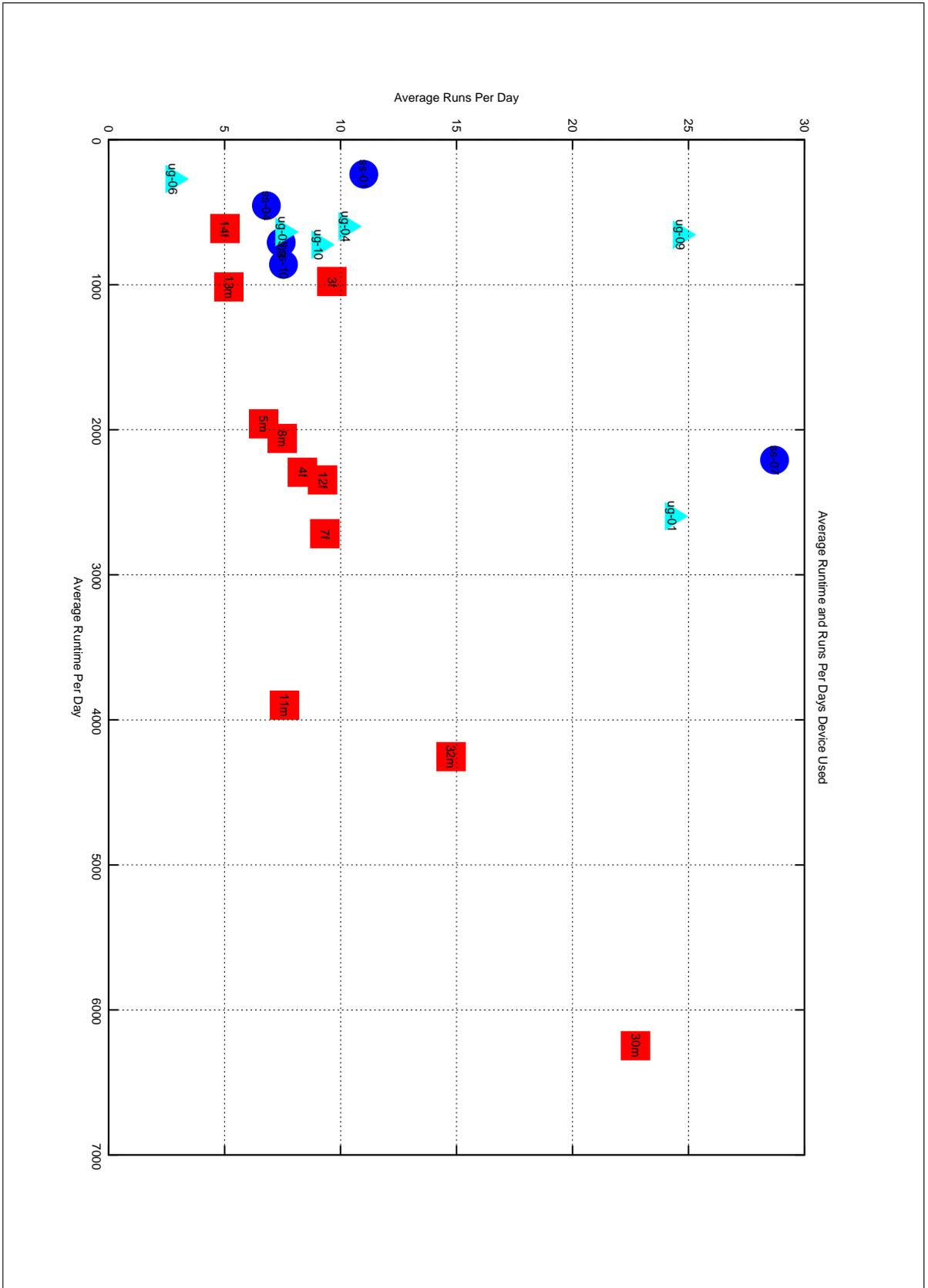


Figure A.38: Scatterplot Average Runtime Per Day against Average Runs Per Day

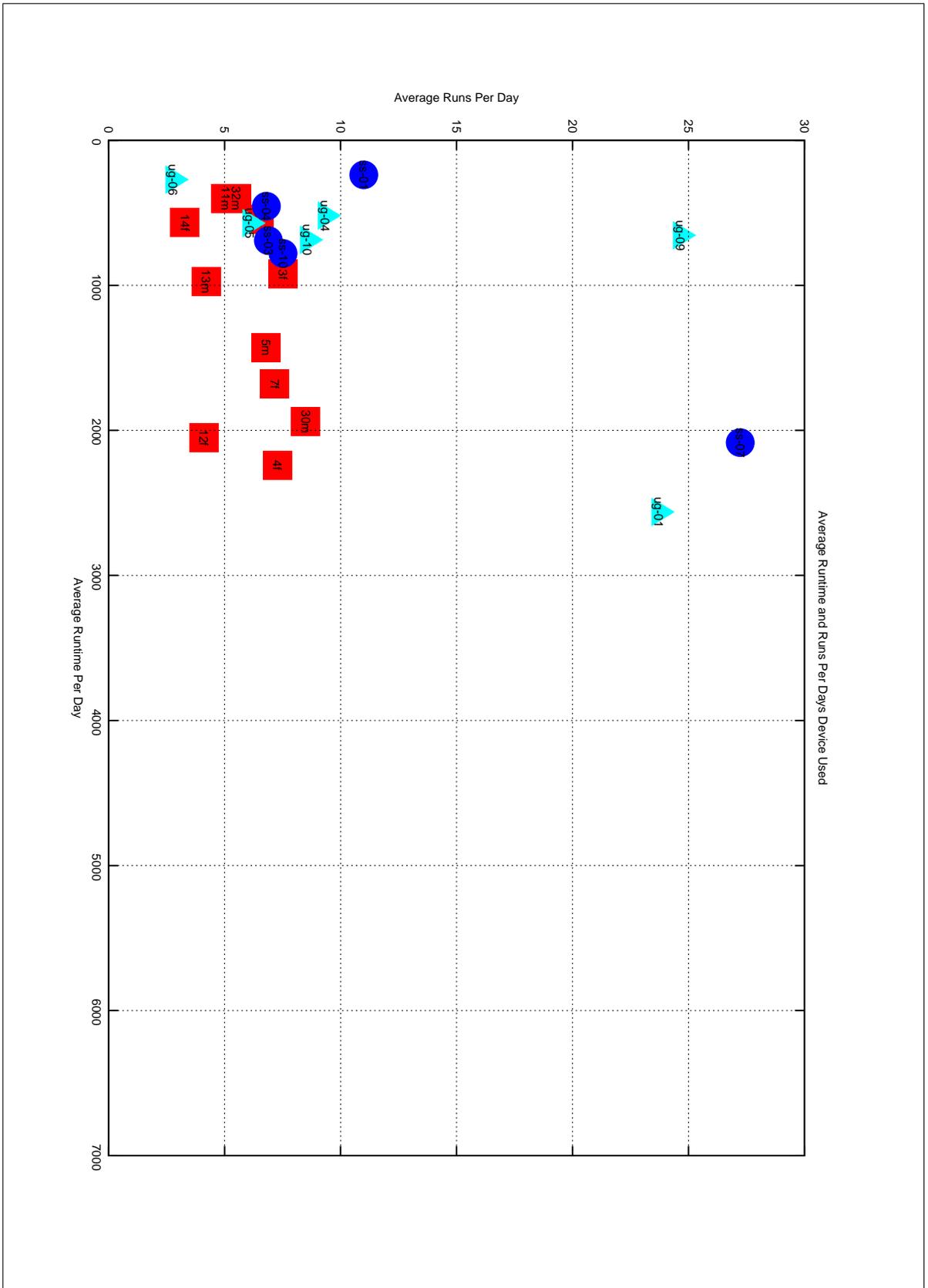


Figure A.39: Scatterplot Average Runtime Per Day against Average Runs Per Day, excluding Music and Photo Applications

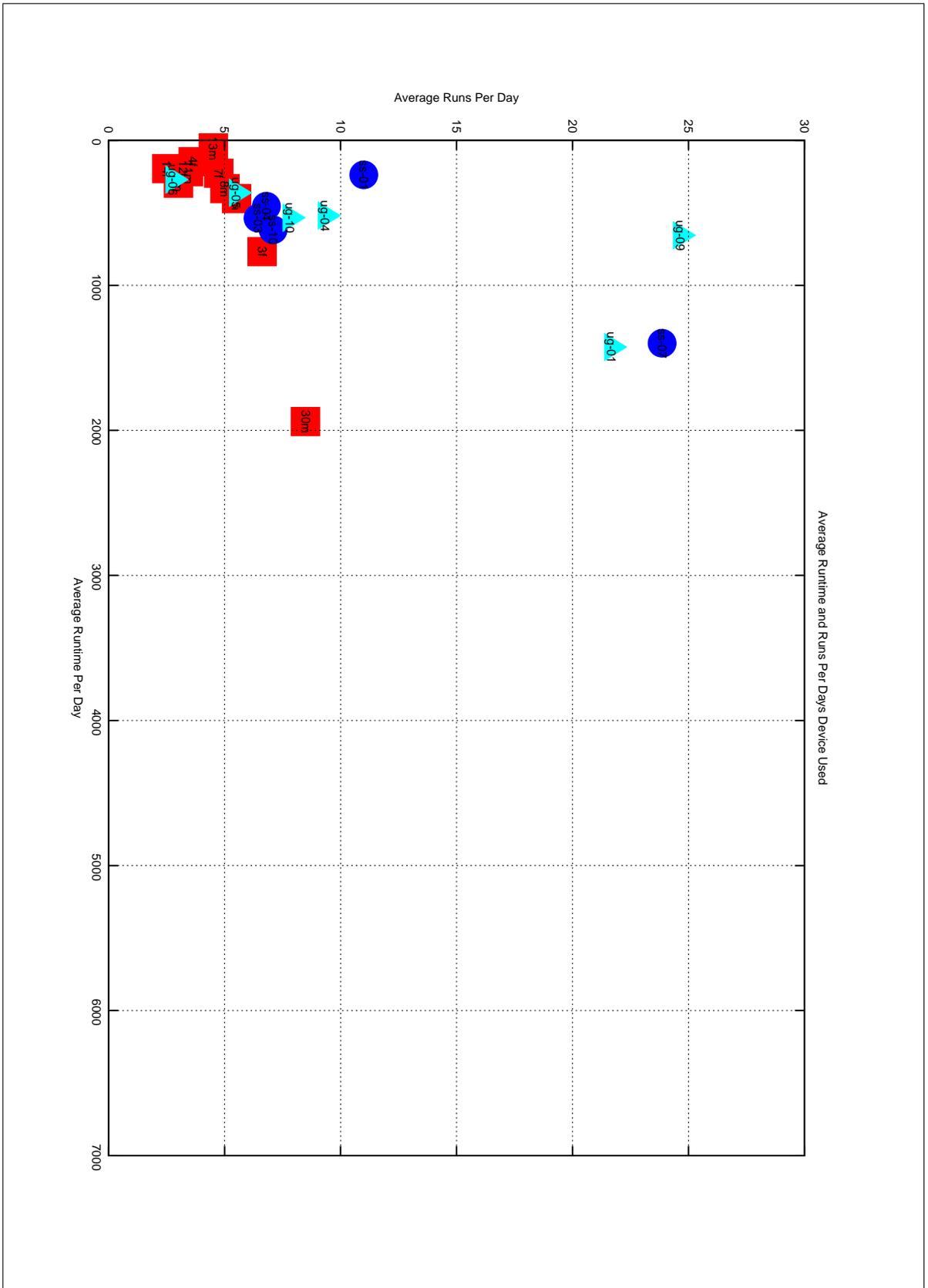


Figure A.40: Scatterplot Average Runtime Per Day against Average Runs Per Day, excluding Music Game and Photo Applications

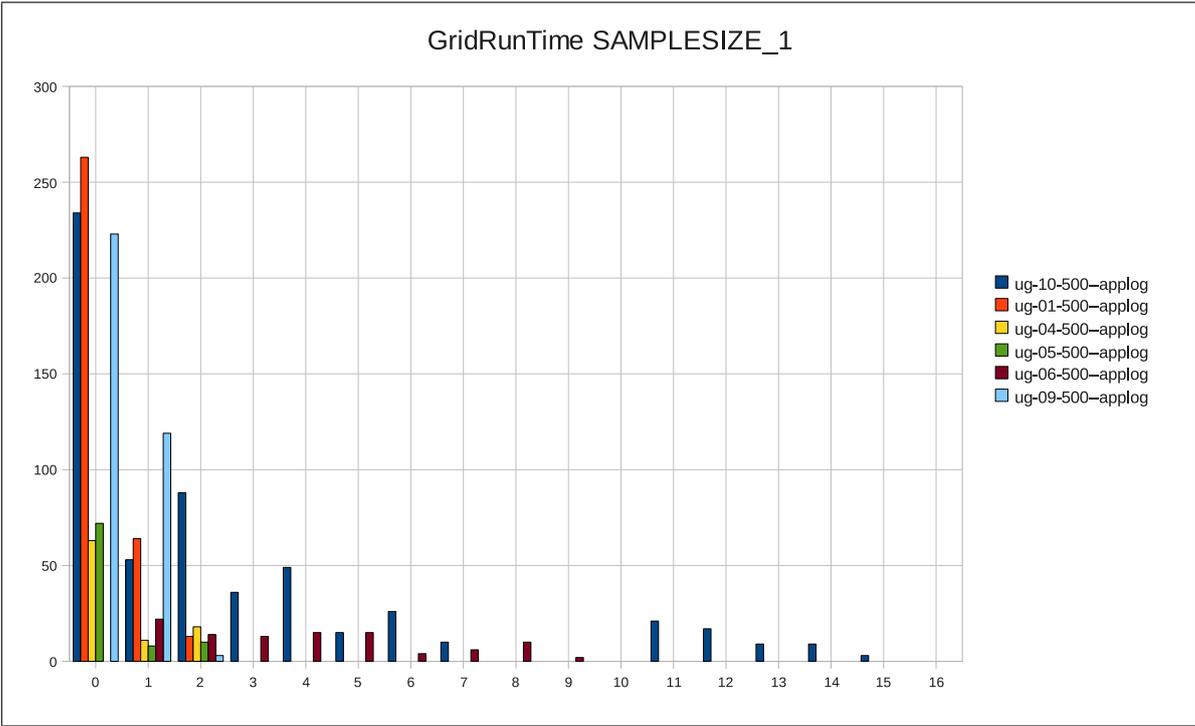


Figure A.41: Graph Runtime Per Slice Phase 1

Runs Per Week Charts

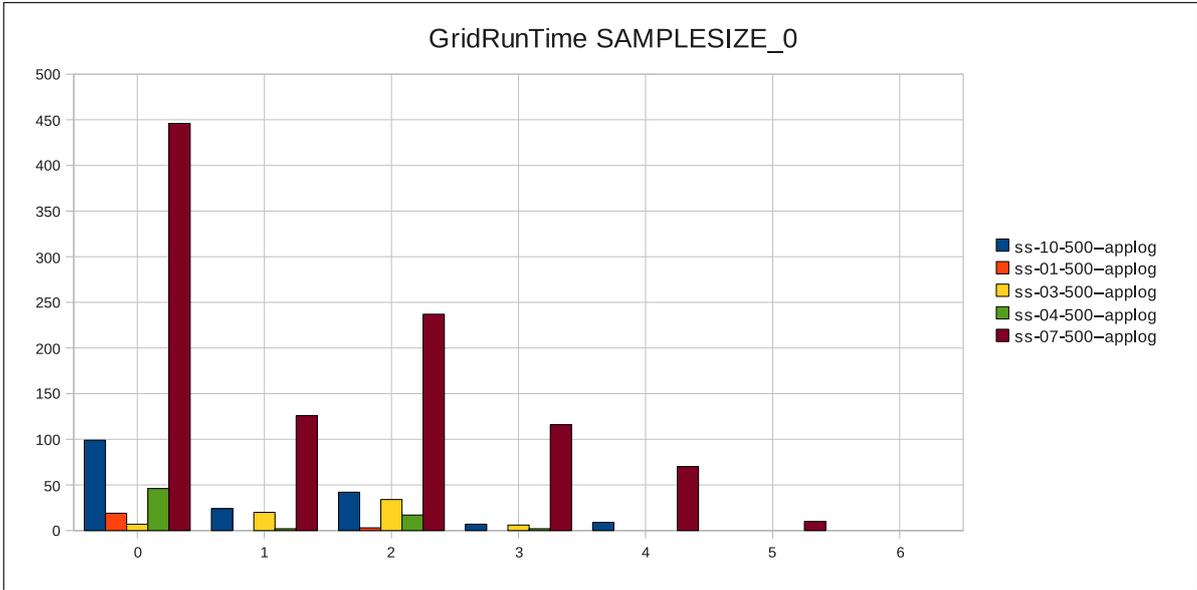


Figure A.42: Graph Runtime Per Slice Phase 2

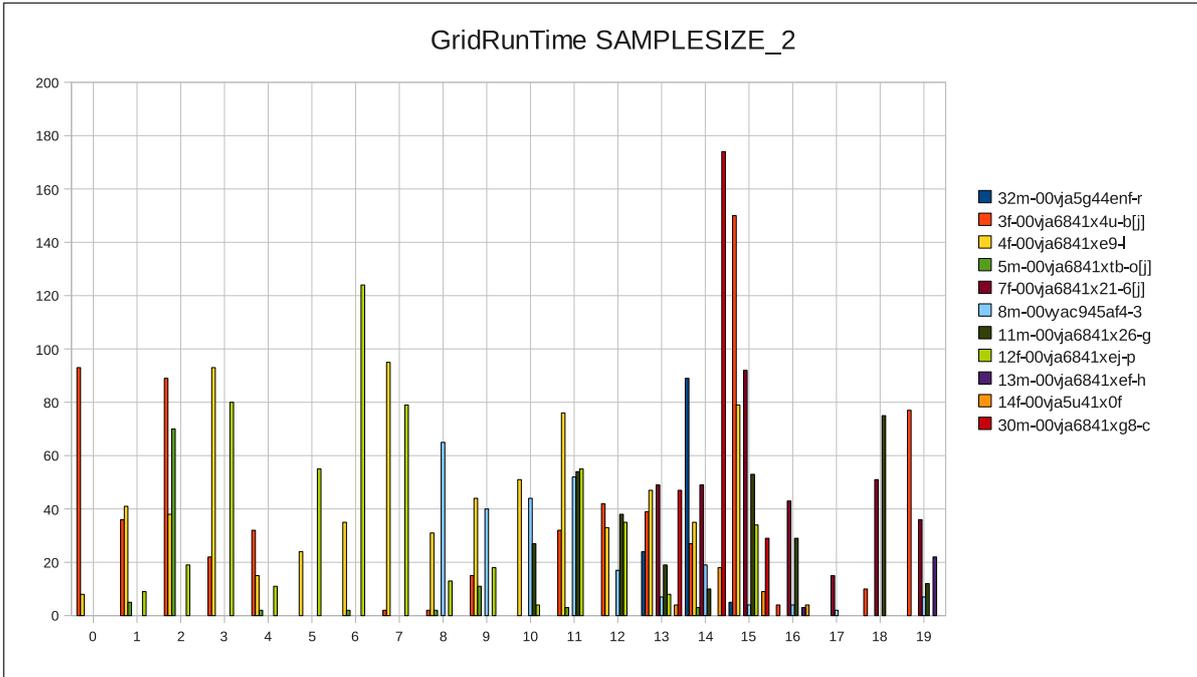


Figure A.43: Graph Runtime Per Slice Phase 4

GridRunTime SAMPLESIZE	ug-10-500-applog	ug-01-500-applog	ug-04-500-applog	ug-05-500-applog	ug-06-500-applog	ug-09-500-applog
0	234	263	63	72		223
1	53	64	11	8	22	119
2	88	13	18	10	14	3
3	36				13	
4	49				15	
5	15				15	
6	26				4	
7	10				6	
8					10	
9					2	
10						
11	21					
12	17					
13	9					
14	9					
15	3					

Figure A.44: Runtime Per Slice Phase 1

GridRunTime SAMPLESIZE	ss-10-500-applog	ss-01-500-applog	ss-03-500-applog	ss-04-500-applog	ss-07-500-applog
0	99	19	7	46	446
1	24		20	2	126
2	42	3	34	17	237
3	7		6	2	116
4	9				70
5					10
6					

Figure A.45: Runtime Per Slice Phase 2

Runs Per Week Tables

GridRunTime SAMPLESIZE	32m-00ja5g44enf-r	3f-00ja6841x4u-b[j]	4f-00ja6841xe9-4	5m-00ja6841xtb-o[j]	7f-00ja6841x21-6[j]	8m-00yac945af4-3	11m-00ja6841x26-g	12f-00ja6841xej-p	13m-00ja6841xef-h
0		93	8						
1		36	41	5					9
2		89	38	70					19
3		22	93						80
4		32	15	2					11
5			24						58
6			35	2					124
7		2	95						79
8		2	31	2		65			13
9		15	44	11		40			18
10			51			44	27		4
11		32	75	3		52	54		55
12		42	23			17	39		35
13	24	39	47		49	7	19		8
14	89	27	35	3	49	19	10		
15	5	150	79		92	4	53	34	
16		4			43	4	29		3
17					15	2			
18		10			51		75		
19		77			36	7	12		22

Figure A.46: Runtime Per Slice Phase 4

A.0.5 Battery Use Graph

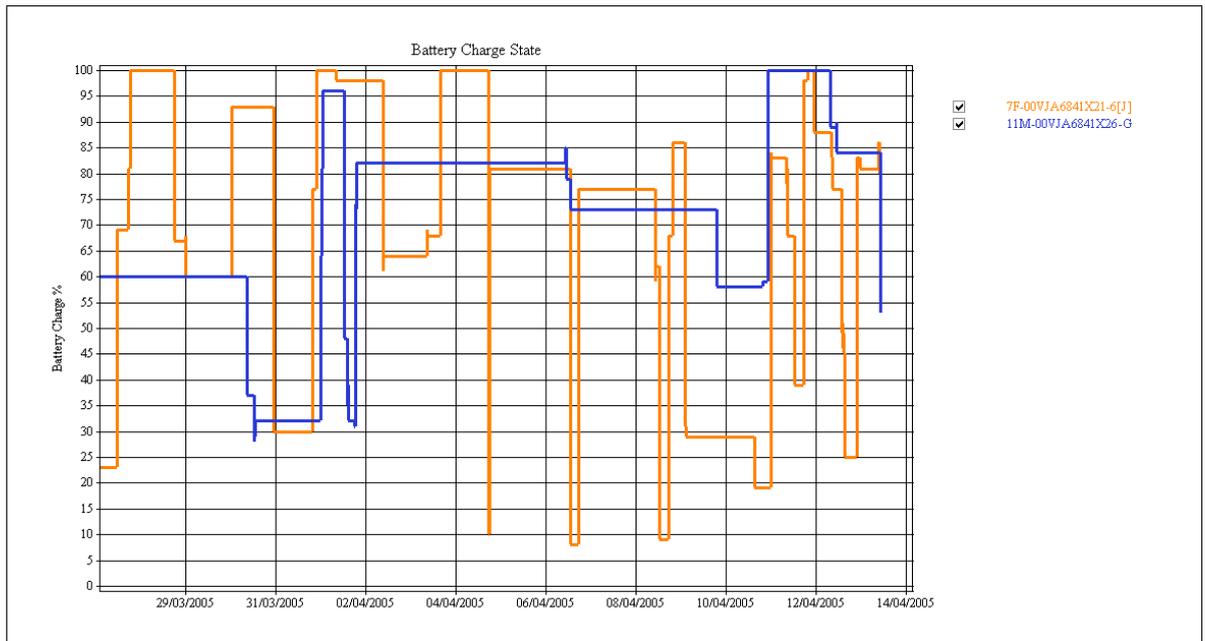


Figure A.47: Battery Use

A.0.6 Day Use Grids

A.0.7 Phase 1

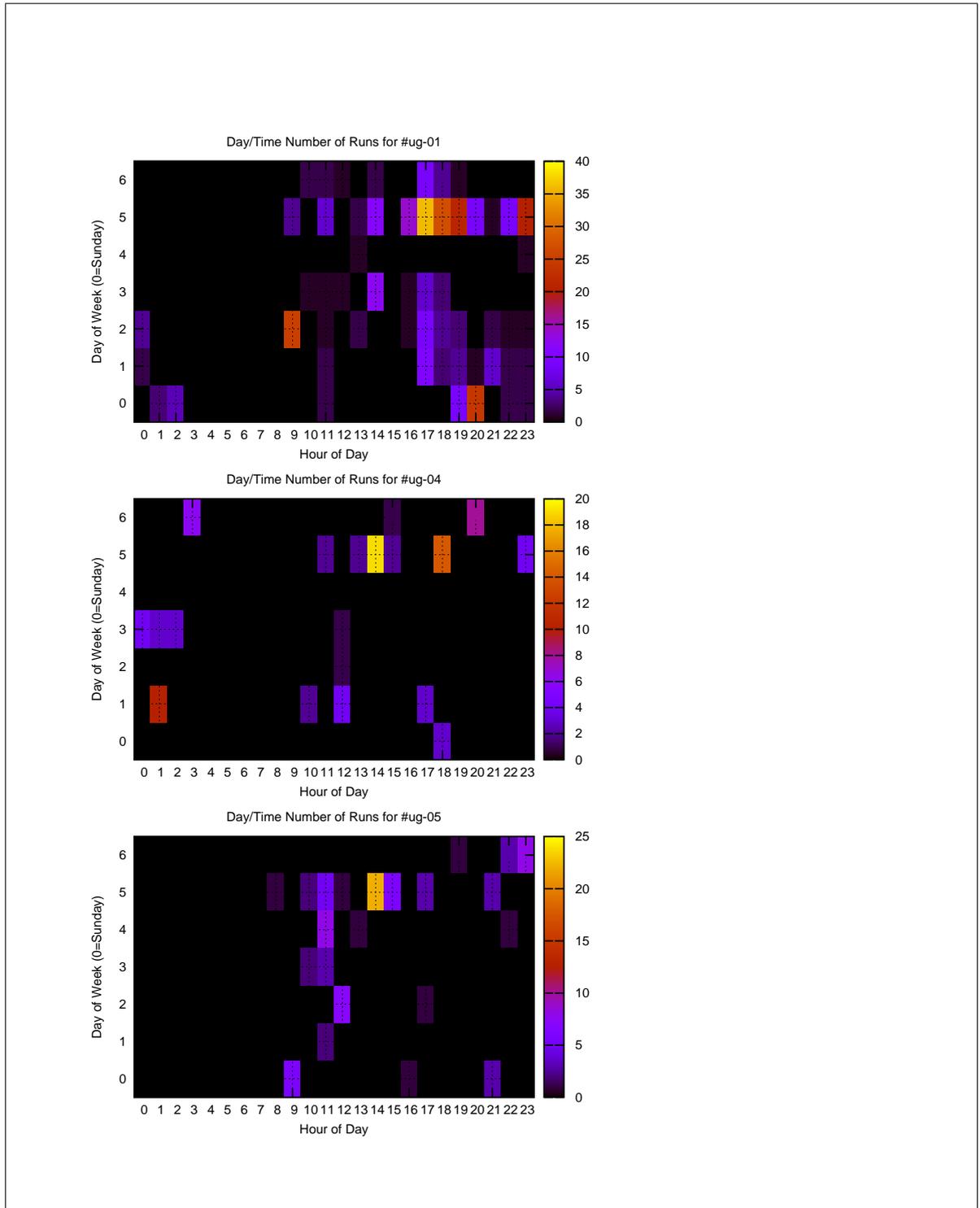


Figure A.48: Day Factor Phase 1 Part 1

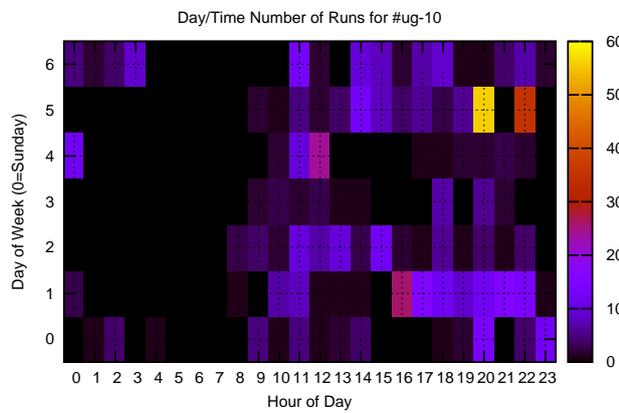
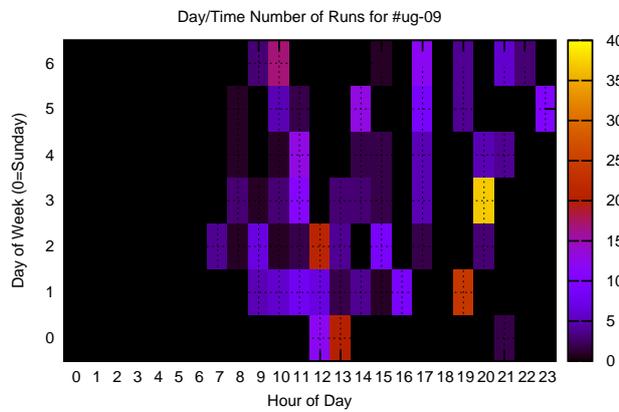
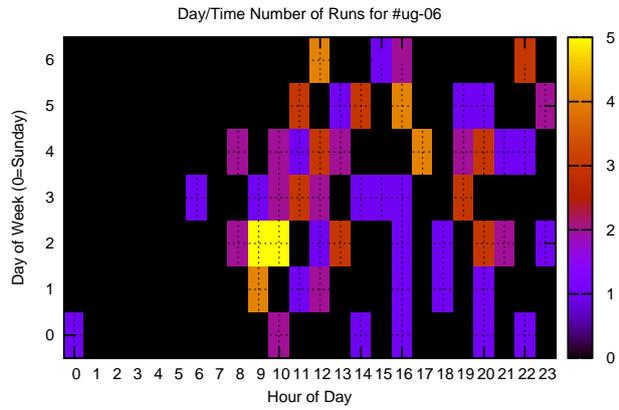


Figure A.49: Day Factor Phase 1 Part 2

A.0.8 Phase 2

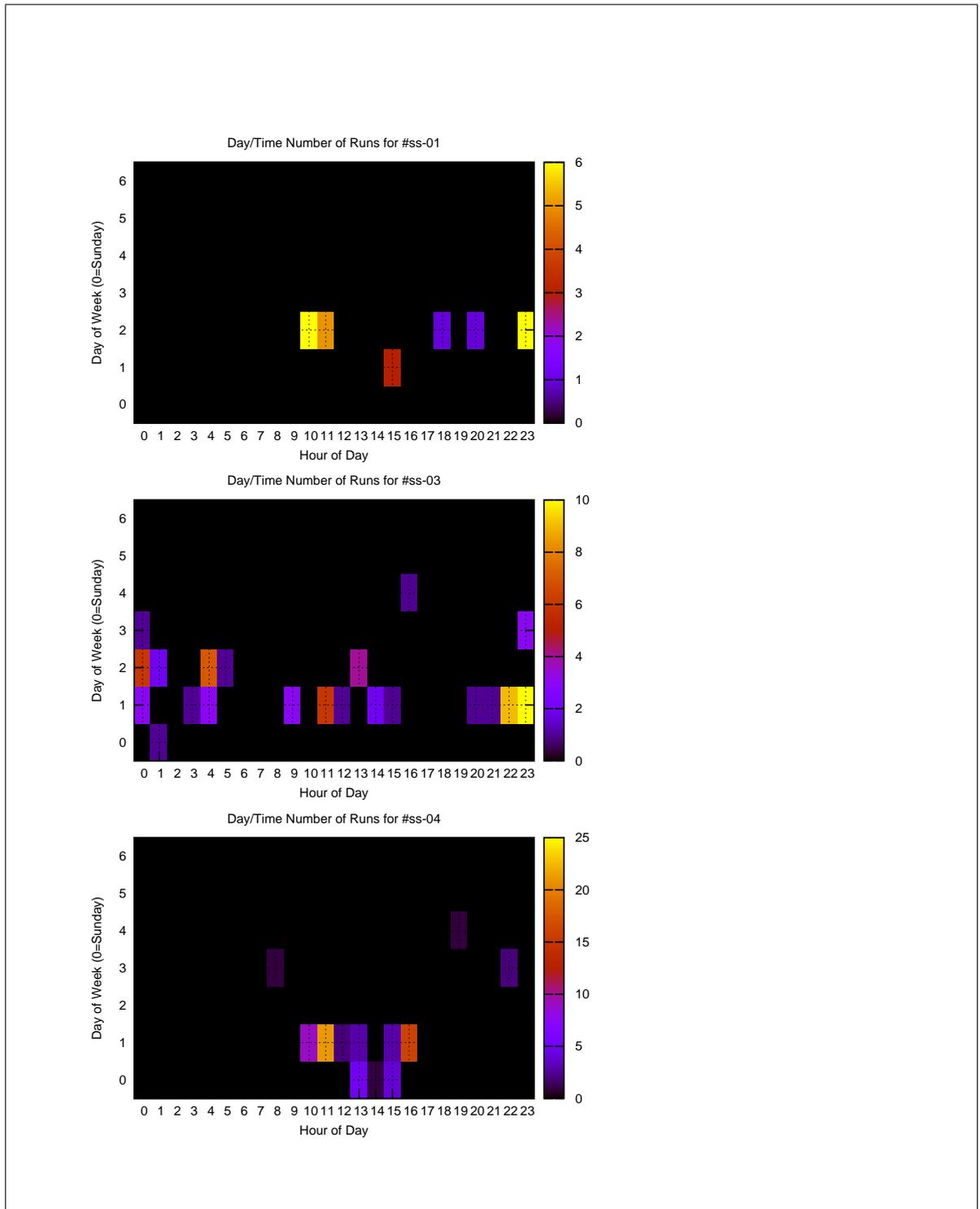


Figure A.50: Day Factor Phase 2 Part 1

A.0.9 Phase 4

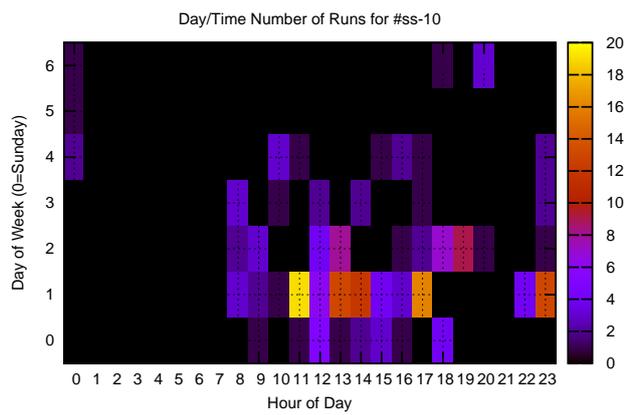
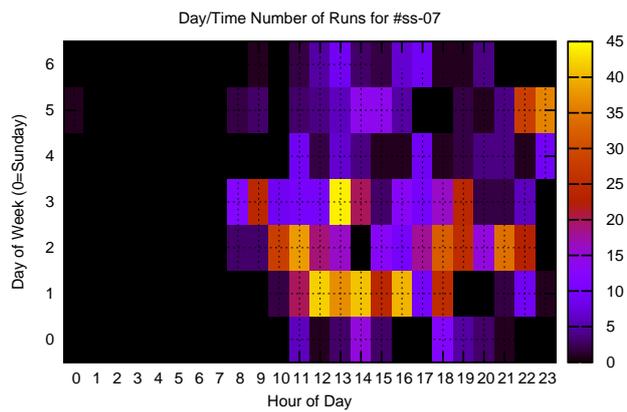


Figure A.51: Day Factor Phase 2 Part 2

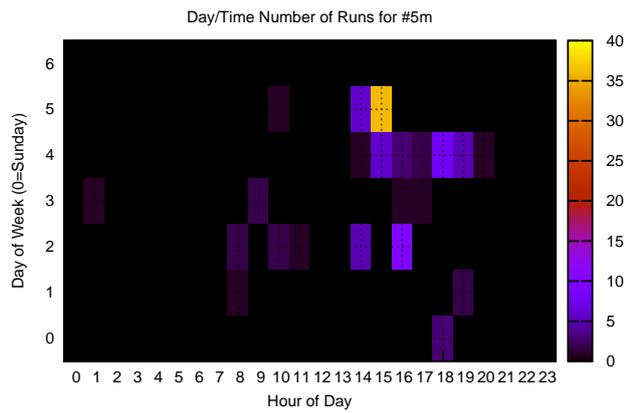
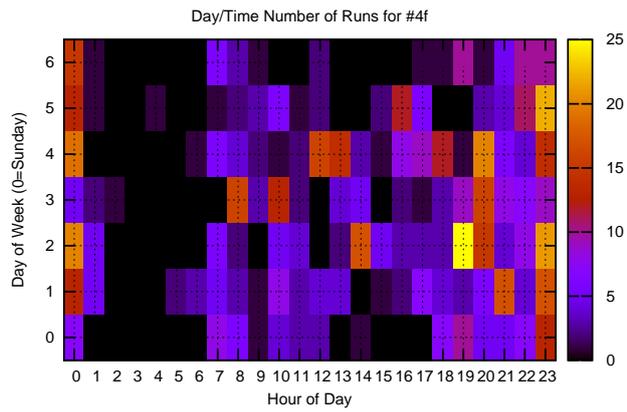
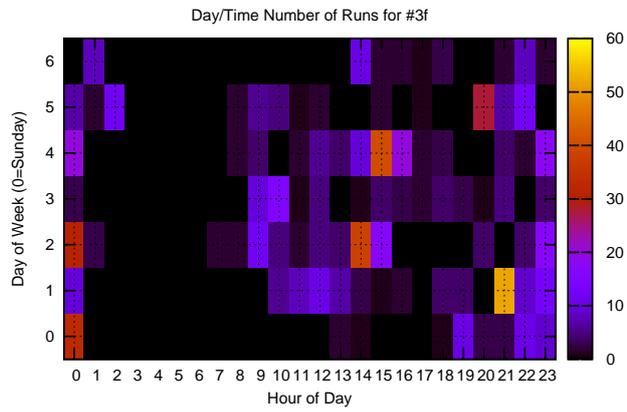


Figure A.52: Day Factor Phase 4 Part 1

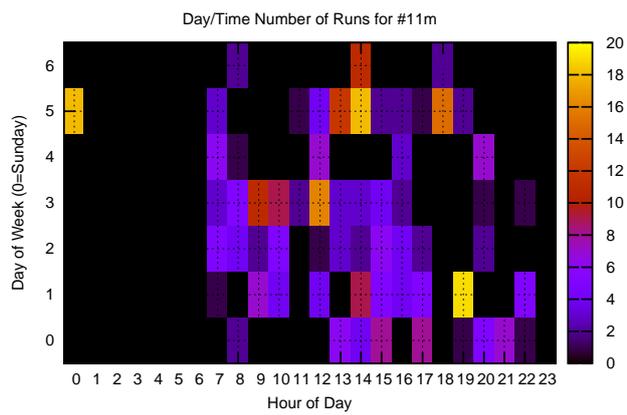
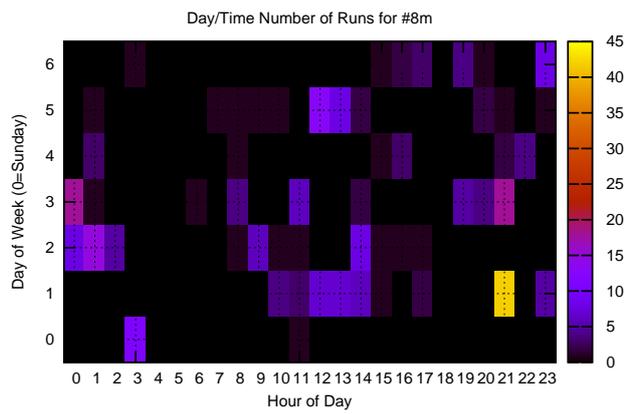
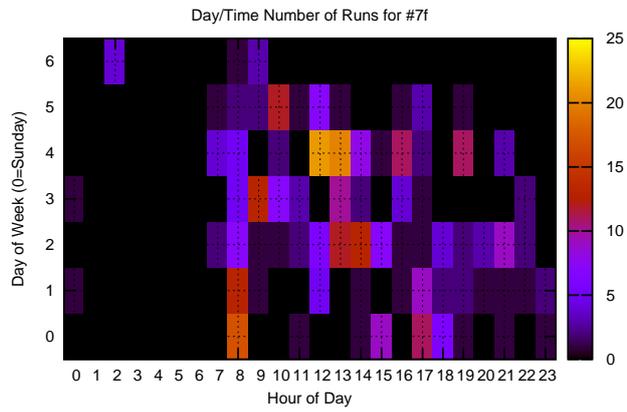


Figure A.53: Day Factor Phase 4 Part 2

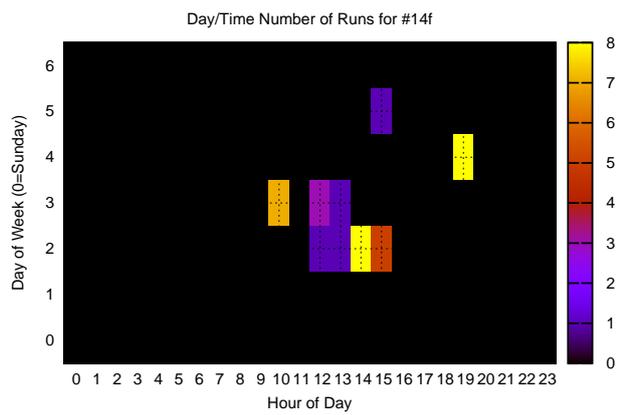
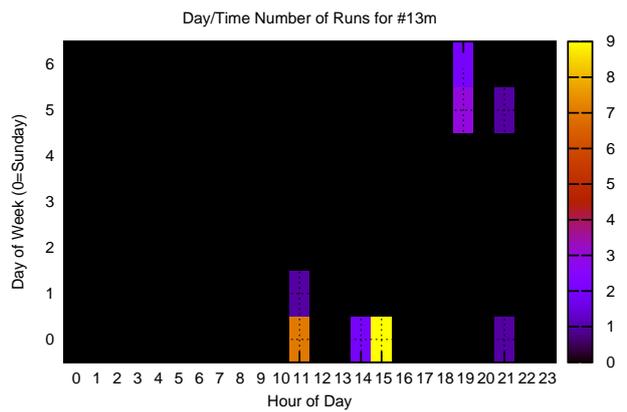
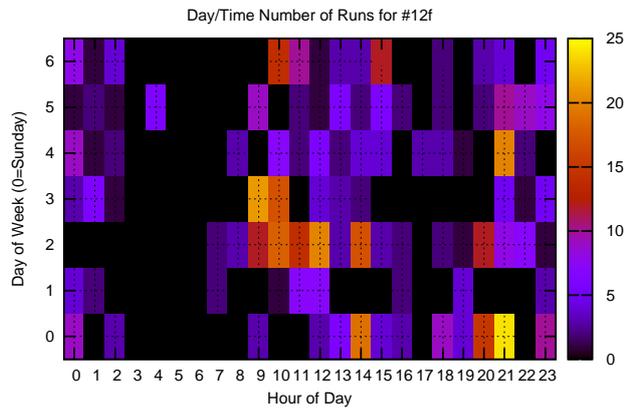


Figure A.54: Day Factor Phase 4 Part 3

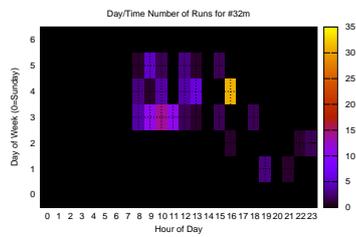


Figure A.55: Day Factor Phase 4 Part 4

Appendix B

AppLog User Guide

AppLog 5

AppLog is an application logging tool for use on PalmOS PDA's. It has been written to assist researchers studying the use of PDA's.

AppLog records the time any application is used on the PDA. Each log entry notes the time, date and application identifier whenever an application is started and how long the application is used for.

When the PDA is synchronised with the desktop application the file is processed to produce a text file indicating:

- Application identifier
- Date and Time the application was started
- How long the application was used

The file produced is in tab-separated format suitable for use with spreadsheet and database programs.

The data collected by AppLog may also be beamed to another PDA that is running the Ninelocks TeksLogs application. TeksLogs processes the files on the Palm and produces a data file the same as the AppLog desktop conduit.

Installation

AppLog consists of a Palm application and a conduit for the Palm hotsync manager on the PC.

- AppLog.prc
- Desktop hotsync conduit.

PalmOS components

Install AppLog.prc using the PalmOS install tool.

(Locate the folder containing the above files and double click one of them and the install tool will be launched. The other files can then be dragged into the installer windows and added to the files to be installed.) Now hotsync your PDA

AppLog Icon



The main form of AppLog shows the number of events recorded (applications started) and amount of memory the logging database is using.



What the numbers mean.

Events

An application starting is an event.

Records

There are multiple numbers of events written to each record

DBSize

Total size of the database stored on the Palm, this is the size of the records and any overhead used for database management by the Palm operating system.

Free Ram

The amount of unused memory on the Palm.

LogLimit

A maximum size can be set to limit the amount of memory that is taken up by the application logging. When this limit is reached no more events will be added to the logging database. The default size is 500K. AppLog will also stop recording events if the amount of Palm memory is less than 1Mbyte.

The entry **notify mode** is for compatibility with older versions of AppLog that were used on pre PalmOS 5 machines.

Collecting the Data From AppLog

The AppLog data may be transferred to a desktop machine via hotsyncing or transferred to a PDA that is running the Ninelocks TeksLogs application. TeksLogs processes the files on the Palm and produces a data file in the same format as the AppLog desktop conduit. TeksLogs is described in a separate document that is included in the download from <http://www.ninelocks.com/AppLog>

Desktop Conduit Installation

The data collected by AppLog can be transferred to the PC during a hotsync by a special application known as a Hotsync Conduit. (HotSync functionality is provided by a number of conduits. Conduits are small programs designed to transfer data during HotSync)

To install the conduit run the *AppLogSetup.exe* installer application.

During installation we recommend you use the default options presented.

Configure the conduit

The conduit is enabled by opening the hotsync manager (tap the  Icon in the Windows task bar)

1. Choose custom
2. Select your user name
3. Scroll down the list to “AppLog conduit”
4. Tap the “Change” button.
5. Choose “Handheld overwrites desktop”
6. If you want the conduit enabled everytime you hotsync tick the “Set as default” checkbox.
7. Click the “Done” button.

Test its all working

Now is the time to test if it is all working!

On your palm open a close some applications.

Open AppLog and check that the numbers have changed.

If everything is working, try hotsyncing your Palm.

Now check in your Palm Desktop user folder.

(Normally in c:\Program Files\PalmOne\yourName where your name will be a variation of your hotsync user name).

Inside that folder there should now be a sub folder called AppLog.

Inside the AppLog folder there should be a .txt file called AppLog.txt

The file is a tab separated data file in a format as shown below.

A	B	C	D	E	F
1017064714	bckp	Mon Mar 25 13:58:34 2002	13	58	13
1017064727	lnch	Mon Mar 25 13:58:47 2002	13	58	5
1017064732	trgf	Mon Mar 25 13:58:52 2002	13	58	32
1017064764	lnch	Mon Mar 25 13:59:24 2002	13	59	5
1017064769	bckp	Mon Mar 25 13:59:29 2002	13	59	34
1017064803	lnch	Mon Mar 25 14:00:03 2002	14	00	165
1017064968	sync	Mon Mar 25 14:02:48 2002	14	02	327
1017065295	lnch	Mon Mar 25 14:08:15 2002	14	08	9
1017065304	JTeN	Mon Mar 25 14:08:24 2002	14	08	32
1017065336	lnch	Mon Mar 25 14:08:56 2002	14	08	120

All PalmOS applications have a four character identifier known as a creator code or Creator ID.

Each application should have a unique identifier as the Palm will only recognise unique creator codes. If two applications did have the same creator ID only one would be seen by the Palm.

Some of the data in the log file is produced in more than one format. The start time is shown in two formats. A human readable test string, to make looking through the log easy when you don't want to import it into a spreadsheet and with the start hour and minute in separate fields for use within spreadsheets.

This is the first version of the data file and the format is likely to be changed in response to user feedback. The format of the logfile is controlled by the desktop conduit so changes to the format can be made without requiring updating of the application file on the Palm.

In the log listing a creator code of *ZZZZ indicates that the Palm was switched off or shut itself down.

In the log listing a creator code of *WAKE indicates that the Palm was switched on and is resuming the application that was in use when the device was last used.

Feedback

If you have any comments, have suggestions for new features or alternative log file formats then please contact us. AppLog was written to help anyone who is conducting research into the use of PalmOS PDA's we are always interested to hear how AppLog is being used, so please tell us about your project.

applog@ninelocks.com

Information and updates will be made available at:-
www.ninelocks.com

Thanks

Special thanks to:

The late Bozidor Benc (<http://www.benc.hr/appusage.htm>) for contributing information to aid development.

The installer for this product was created using Installer VISE from MindVision Software. For more information on Installer VISE, contact:

MindVision Software
5901 North 58th Street
Lincoln, NE 68507

Voice: (402) 323-6600
Fax: (402) 323-6611
E-mail: mindvision@mindvision.com
<http://www.mindvision.com>

Appendix C

TeksLogs User Guide

TeksLogs

TeksLogs is a companion program for users of AppLog. AppLog is an application logging tool for use on PalmOS PDA's. AppLog is a tool to assist researchers studying the use of PDA's.

AppLog records the time any application is used on the PDA. Each log entry notes the time, date and application identifier whenever an application is started and how long the application is used for.

The data collected by AppLog may also be beamed to another PDA that is running the Ninelocks TeksLogs application. TeksLogs processes the files on the Palm and produces a data file the same as the AppLog desktop conduit.

TeksLogs also helps with beaming items to other PDAs. Often in an educational environment a tutor may wish to beam a number of files to a student, such as new programs, quizzes etc. TeksLogs can also help this process by sending a batch of files.

Installation

Install TeksLogs.prc using the PalmOS install tool.

(Locate the folder containing the above file and double click one of itthem and the install tool will be launched.) Now hotsync your PDA



TeksLogs can also help to copy files between memory cards. Files on a memory card may be copied to a temporary storage area on the Palm then copied back to a different card. This can help when needing to organise files on a card (such as swapping MP3 files etc).

TeksLogs manages files stored in 3 areas. The different file locations are select by tapping the Icons at the top of the form.



Files on a removable memory card, eg SD/MMCard or memory stick. If you use a communication module such as a Bluetooth card, files can be moved to a temporary area on the PDA, see below.



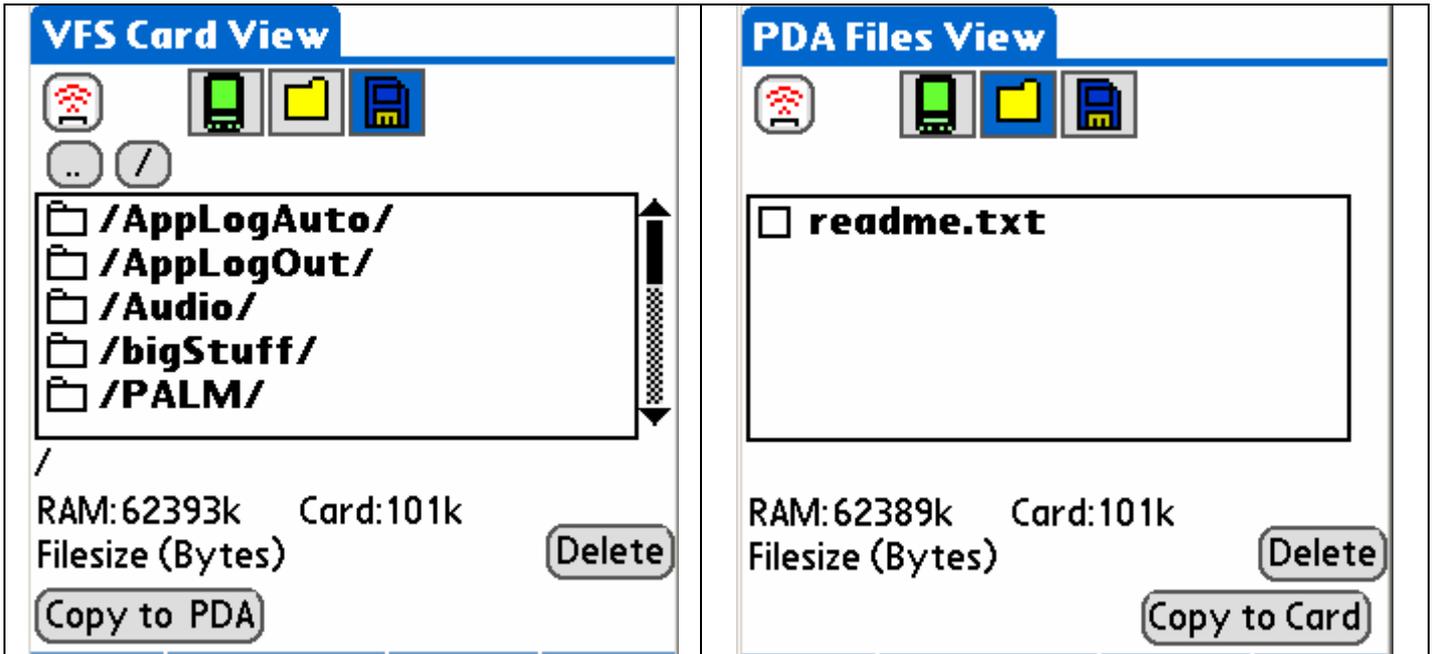
Files stored on the PDA. This area is a temporary area for saving files that you wish to transfer to or from a memory card. This area is useful if you wish to transfer files to or from a removable card when you also use the memory card slot for a communication module, such as a bluetooth.



Palm Application files and databases that are stored in main memory (not the card)

To copy a file, first select the files you wish to copy, by ticking them (tap the checkbox next to its name), then tap the button at the bottom of the form that corresponds to your chosen destination.

The screen captures on the next page show examples of each of the views.



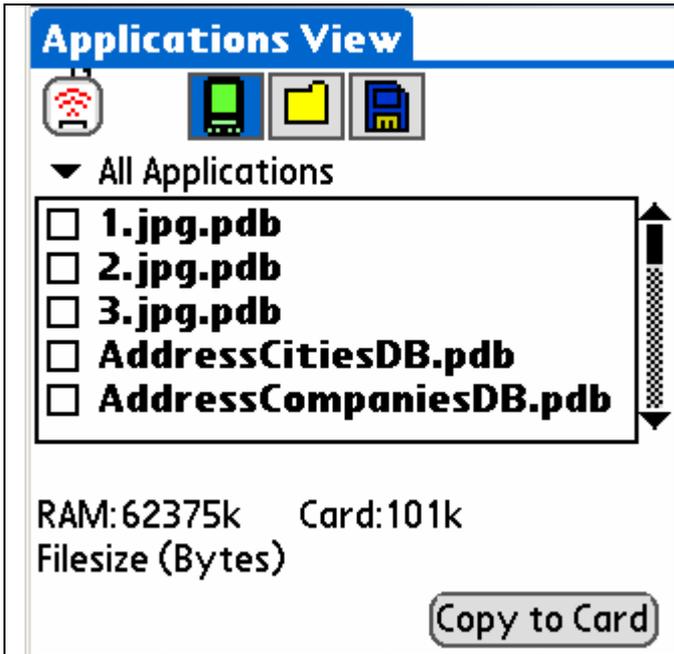
In card view navigate between folder by tapping on the folders name. To move back a folder tap the ".." button, to return to the root of the card tap the "/" button.

To get information about the size of a file, select the file by tapping on its name. The file size will be shown at the bottom of the screen.

PDA Files view shows the files stored in TeksLogs special "holding" area. These files are stored in the main memory of the Palm.

This area is a temporary area for saving files that you wish to transfer to or from a memory card. This area is useful if you wish to transfer files to or from a removable card when you also use the memory card slot for a communication module, such as a bluetooth.

Another use of the temporary area is to move files between different folder of your memory card. Just transfer the files to this area from the card, then change to the destination folder on your card, flip to PDA files view and choose copy to card.

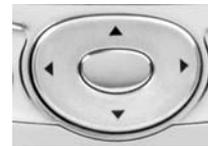


The Applications view shows the Program and data files that are stored in the main memory of the Palm.

To list only items that belong to a particular application use the drop down list box. The association between the data files and applications is reliant on both sharing the same application identifier (Creator code). Some applications have additional data files with a different creator code to the main application, so if you cannot find the file you are looking for, try setting the selection to "All Applications".

The AppLogAuto Folder is a special folder that can be used to assist with the beaming on multiple items to other PDAs.

When the select button (the centre of the 5 way button) is pressed,



TeksLogs checks for files in the AppLog auto folder. If there are any files there then it TeksLogs will attempt to beam them.

To create the folder use the "Create AppLogAuto Folder" option from the menu bar.

To display the menu tap the top of the form

Test its all working

To test out the operation of TeksLogs you need two PDAs. For the purposes of this description we will refer to them as the students PDA and the tutors PDA.

The students PDA should have a copy of AppLog installed. (see the AppLog manual)
The tutor PDA should have TeksLogs installed.

Student PDA

On your palm open a close some applications.
Open AppLog and check that the numbers of events have changed.

Tutor PDA

Open TeksLogs

Now, prepare to beam the logs from the **Student PDA**. From the AppLog page tap the beam button.

The **Tutor PDA** should now indicate that it is receiving files.

The **Student PDA** will send two files. One contains the events recorded by AppLog. The other will contain a list of the Applications and their associated Creator IDs of all applications on the **Student PDA**.

Creator IDS

All PalmOS applications have a four character identifier known as a creator code or Creator ID. Each application should have a unique identifier as the Palm will only recognise unique creator codes. If two applications did have the same creator ID only one would be seen by the Palm.

Eg the creator code for the calculator built into Palms is 'calc'.

The files sent from the Student PDA are called
Username-DateOfBeaming--timeOfBeaming.alo
example:
delph---20050204-2120--.alo

Username--ccd-- DateOfBeaming--timeOfBeaming.ccd
example
delph--ccd-20050204-2120--.ccd

So the above example files were sent from Palm with user name of "delph" at 21:20 on Feb 4th 2005.

TeksLogs saves the incoming files in separate folders of the memory card on the Tutor PDA.

AppLogIn

For files beamed from AppLog (ie file extension .alo)

AppLogOut

For processed AppLog files

AppLogCCD

For files from AppLog that contain application information
(files with extension .ccd)

When TeksLogs processes an AppLog log file (to convert the .alo file to an .alp file) the processed file is stored in the AppLogOut folder on the card and the file extension is changed to .alp (indicating a 'processed' AppLog file)

File Formats

The file is a tab separated data file in a format as shown below.

A	B	C	D	E	F
1017064714	bckp	Mon Mar 25 13:58:34 2002	13	58	13
1017064727	lnch	Mon Mar 25 13:58:47 2002	13	58	5
1017064732	trgf	Mon Mar 25 13:58:52 2002	13	58	32
1017064764	lnch	Mon Mar 25 13:59:24 2002	13	59	5
1017064769	bckp	Mon Mar 25 13:59:29 2002	13	59	34
1017064803	lnch	Mon Mar 25 14:00:03 2002	14	00	165
1017064968	sync	Mon Mar 25 14:02:48 2002	14	02	327
1017065295	lnch	Mon Mar 25 14:08:15 2002	14	08	9
1017065304	JTeN	Mon Mar 25 14:08:24 2002	14	08	32
1017065336	lnch	Mon Mar 25 14:08:56 2002	14	08	120

All PalmOS applications have a four character identifier known as a creator code or Creator ID.

Each application should have a unique identifier as the Palm will only recognise unique creator codes. If two applications did have the same creator ID only one would be seen by the Palm.

Palm provide a publicly accessible database of registered creator codes where it is possible to find the name of an application, if you have its creator ID.

<http://www.palmos.com/dev/support/creatorid/>

Some of the data in the log file is produced in more than one format. The start time is shown in two formats. A human readable test string, to make looking through the log easy when you don't want to import it into a spreadsheet and with the start hour and minute in separate fields for use within spreadsheets.

This is the first version of the data file and the format is likely to be changed in response to user feedback. The format of the logfile is controlled by the desktop conduit so changes to the format can be made without requiring updating of the application file on the Palm.

In the log listing a creator code of *ZZZZ indicates that the Palm was switched off or shut itself down.

In the log listing a creator code of *WAKE indicates that the Palm was switched on and is resuming the application that was in use when the device was last used.

Registration

Registration of TeksLogs is free, just send us your hotsync name and we'll send you a registration code.

Feedback

If you have any comments, have suggestions for new features or alternative log file formats then please contact us. AppLog was written to help anyone who is conducting research into the use of PalmOS PDA's we are always interested to hear how AppLog is being used, so please tell us about your project.

applog@ninelocks.com

Information and updates will be made available at:-
www.ninelocks.com

Thanks

Special thanks to:

The late and greatly missed Bozidor Benc (<http://www.benc.hr/appusage.htm>) for contributing information to aid development. Checkout Benc Softwares Application Usage application .

The installer for this product was created using Installer VISE from MindVision Software. For more information on Installer VISE, contact:

MindVision Software
5901 North 58th Street
Lincoln, NE 68507

Voice: (402) 323-6600
Fax: (402) 323-6611

E-mail: mindvision@mindvision.com
<http://www.mindvision.com>

Appendix 1 The AppLog .ccd file, containing the list of applications and associated creator codes on the device.

AppLog .cc file

```
[NineLocksAppCCD]
[USER]ninelocks
4JMS, Timesheet
6JMS, Symbols
ADBE, Adobe Reader
Algf, Algebraf
AwBM, BigMoney
AwBW, Book Worm
AwJC, Bejeweled!
AwSC, Seven Seas!
BTMr, BtManager
BoMr, MarkMyScriptures
CHMT, ChemTable
CNvt, Converter
DDIR, DynDevInfo-DDIR
DGcl, Calcul-8!
DTGB, SheetToGo
DTGP, DocsToGo
DTGR, WordView+
EERF, EE REF
EPms, MMSLib Library-EPms
EPpm, Messages
Filz, Filez
```

Appendix 2

TeksLogs AppLog Processed File .alp

Main body is the same as that produced by the AppLog desktop conduit, but with the addition of a header section

```
[UserName]ninelocks
[BeamDate]Tue Feb 15 10:10:49 2005
[LastSync]Mon Feb 14 10:28:19 2005
[GoodSync]Mon Feb 14 10:28:19 2005
[DEVID_SOURCE]Zi72
[MAKE_SOURCE]Palm
[SERIAL_SOURCE]00VJA5G42FYY-P
[APPROG_VER]5.0.3
[DEVID_TEKSLOGS]Zi72
[MAKE_TEKSLOGS]Palm
[SERIAL_TEKSLOGS ]00VJA5G42F9P-E
[TEKSLOGS_VER]1.0.0
1101815377 lneh Tue Nov 30 11:49:31 2004 11 49 6
1101815386 nlAL Tue Nov 30 11:49:37 2004 11 49 9
1101815387 lneh Tue Nov 30 11:49:46 2004 11 49 1
1101815399 nlAL Tue Nov 30 11:49:47 2004 11 49 12
```

Explanation of Header fields

[UserName]Username of the machine that the AppLog data is from

[BeamDate]When the file was beamed from AppLog to TeksLogs

[LastSync]Time when the sending PDA was last hotsynced

[GoodSync] Time when the sending PDA was last hotsynced

[DEVID_SOURCE] The hardware device ID of the sending PDA

[MAKE_SOURCE] The manufacturer id of the sending device

[SERIAL_SOURCE]The serial number of the sending device
(not all Palm devices have a serial number in ROM so in those cases
the serial number field is set to "No-Serial Number")

[APPROG_VER]The Version number of Applog

[DEVID_TEKSLOGS] Hardware ID of the PDA that produced this file

[MAKE_TEKSLOGS]Palm

[SERIAL_TEKSLOGS]The serial number of the device on which TeksLogs
that produced this file was running

[TEKSLOGS_VER] TeksLog version

The body of the file is a tab separated data file in a format as shown below.

A	B	C	D	E	F
1017064714	bckp	Mon Mar 25 13:58:34 2002	13	58	13
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1017065295	lnch	Mon Mar 25 14:08:15 2002	14	08	9
1017065304	JTeN	Mon Mar 25 14:08:24 2002	14	08	32
1017065336	lnch	Mon Mar 25 14:08:56 2002	14	08	120

Logfile format

Col	Data
A	Seconds in Palm time format (seconds since Jan 1904)
B	Creator ID (see explanation below)
C	Start date and time in human readable form
D	Application Start time (Hours)
E	Application Start time (Minutes)
F	Amount of time application was used (Seconds)

TeksLogs

TeksLogs is a companion program for users of AppLog. AppLog is an application logging tool for use on PalmOS PDA's. AppLog is a tool to assist researchers studying the use of PDA's.

AppLog records the time any application is used on the PDA. Each log entry notes the time, date and application identifier whenever an application is started and how long the application is used for.

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TeksLogs also helps with beaming items to other PDAs. Often in an educational environment a tutor may wish to beam a number of files to a student, such as new programs, quizzes etc. TeksLogs can also help this process by sending a batch of files.

Installation

Install TeksLogs.prc using the PalmOS install tool.

(Locate the folder containing the above file and double click one of itthem and the install tool will be launched.) Now hotsync your PDA



TeksLogs can also help to copy files between memory cards. Files on a memory card may be copied to a temporary storage area on the Palm then copied back to a different card. This can help when needing to organise files on a card (such as swapping MP3 files etc).

TeksLogs manages files stored in 3 areas. The different file locations are select by tapping the Icons at the top of the form.



Files on a removable memory card, eg SD/MMCard or memory stick. If you use a communication module such as a Bluetooth card, files can be moved to a temporary area on the PDA, see below.



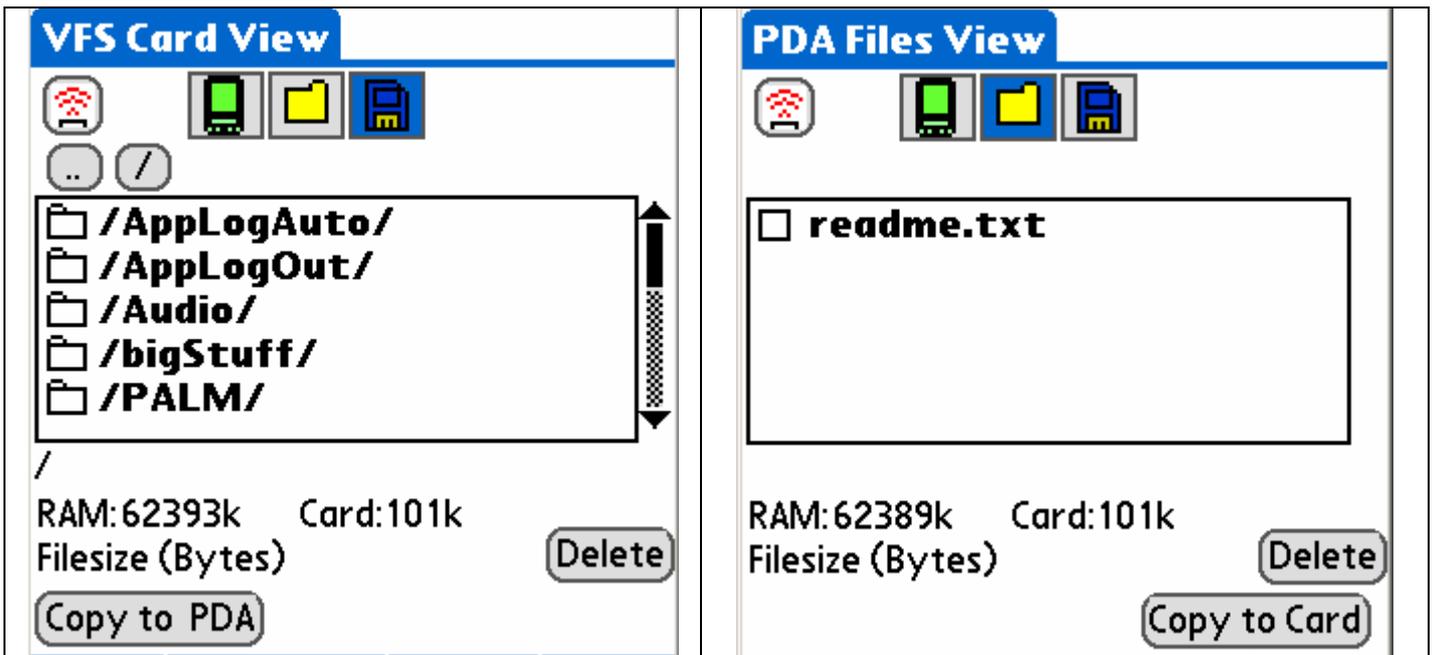
Files stored on the PDA. This area is a temporary area for saving files that you wish to transfer to or from a memory card. This area is useful if you wish to transfer files to or from a removable card when you also use the memory card slot for a communication module, such as a bluetooth.



Palm Application files and databases that are stored in main memory (not the card)

To copy a file, first select the files you wish to copy, by ticking them (tap the checkbox next to its name), then tap the button at the bottom of the form that corresponds to your chosen destination.

The screen captures on the next page show examples of each of the views.



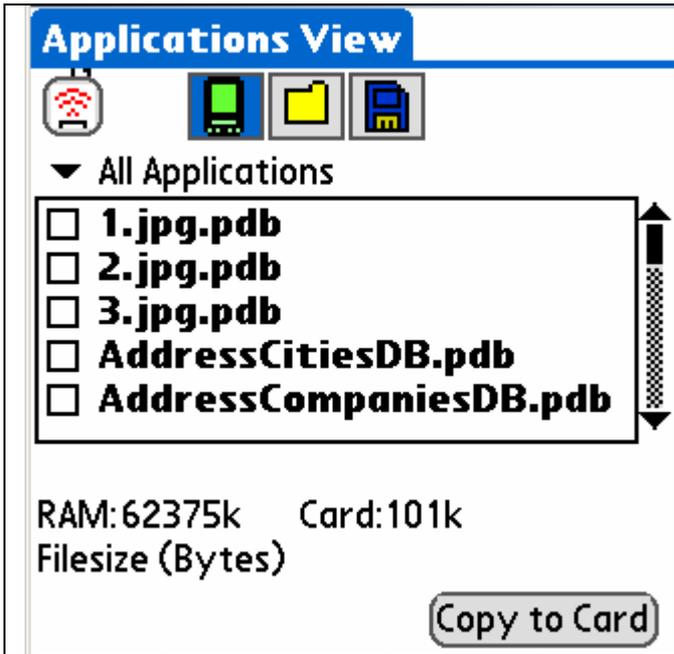
In card view navigate between folder by tapping on the folders name. To move back a folder tap the ".." button, to return to the root of the card tap the "/" button.

To get information about the size of a file, select the file by tapping on its name. The file size will be shown at the bottom of the screen.

PDA Files view shows the files stored in TeksLogs special "holding" area. These files are stored in the main memory of the Palm.

This area is a temporary area for saving files that you wish to transfer to or from a memory card. This area is useful if you wish to transfer files to or from a removable card when you also use the memory card slot for a communication module, such as a bluetooth.

Another use of the temporary area is to move files between different folder of your memory card. Just transfer the files to this area from the card, then change to the destination folder on your card, flip to PDA files view and choose copy to card.



The Applications view shows the Program and data files that are stored in the main memory of the Palm.

To list only items that belong to a particular application use the drop down list box. The association between the data files and applications is reliant on both sharing the same application identifier (Creator code). Some applications have additional data files with a different creator code to the main application, so if you cannot find the file you are looking for, try setting the selection to "All Applications".

The AppLogAuto Folder is a special folder that can be used to assist with the beaming on multiple items to other PDAs.

When the select button (the centre of the 5 way button) is pressed,



TeksLogs checks for files in the AppLog auto folder. If there are any files there then it TeksLogs will attempt to beam them.

To create the folder use the "Create AppLogAuto Folder" option from the menu bar.

To display the menu tap the top of the form

Test its all working

To test out the operation of TeksLogs you need two PDAs. For the purposes of this description we will refer to them as the students PDA and the tutors PDA.

The students PDA should have a copy of AppLog installed. (see the AppLog manual)
The tutor PDA should have TeksLogs installed.

Student PDA

On your palm open a close some applications.

Open AppLog and check that the numbers of events have changed.

Tutor PDA

Open TeksLogs

Now, prepare to beam the logs from the **Student PDA**. From the AppLog page tap the beam button.

The **Tutor PDA** should now indicate that it is receiving files.

The **Student PDA** will send two files. One contains the events recorded by AppLog. The other will contain a list of the Applications and their associated Creator IDs of all applications on the **Student PDA**.

Creator IDS

All PalmOS applications have a four character identifier known as a creator code or Creator ID. Each application should have a unique identifier as the Palm will only recognise unique creator codes. If two applications did have the same creator ID only one would be seen by the Palm.

Eg the creator code for the calculator built into Palms is 'calc'.

The files sent from the Student PDA are called
Username-DateOfBeaming--timeOfBeaming.alo
example:
delph---20050204-2120--.alo

Username--ccd-- DateOfBeaming--timeOfBeaming.ccd
example
delph--ccd-20050204-2120--.ccd

So the above example files were sent from Palm with user name of "delph" at 21:20 on Feb 4th 2005.

TeksLogs saves the incoming files in separate folders of the memory card on the Tutor PDA.

AppLogIn

For files beamed from AppLog (ie file extension .alo)

AppLogOut

For processed AppLog files

AppLogCCD

For files from AppLog that contain application information
(files with extension .ccd)

When TeksLogs processes an AppLog log file (to convert the .alo file to an .alp file) the processed file is stored in the AppLogOut folder on the card and the file extension is changed to .alp (indicating a 'processed' AppLog file)

File Formats

The file is a tab separated data file in a format as shown below.

A	B	C	D	E	F
1017064714	bckp	Mon Mar 25 13:58:34 2002	13	58	13
1017064727	lnch	Mon Mar 25 13:58:47 2002	13	58	5
1017064732	trgf	Mon Mar 25 13:58:52 2002	13	58	32
1017064764	lnch	Mon Mar 25 13:59:24 2002	13	59	5
1017064769	bckp	Mon Mar 25 13:59:29 2002	13	59	34
1017064803	lnch	Mon Mar 25 14:00:03 2002	14	00	165
1017064968	sync	Mon Mar 25 14:02:48 2002	14	02	327
1017065295	lnch	Mon Mar 25 14:08:15 2002	14	08	9
1017065304	JTeN	Mon Mar 25 14:08:24 2002	14	08	32
1017065336	lnch	Mon Mar 25 14:08:56 2002	14	08	120

All PalmOS applications have a four character identifier known as a creator code or Creator ID.

Each application should have a unique identifier as the Palm will only recognise unique creator codes. If two applications did have the same creator ID only one would be seen by the Palm.

Palm provide a publicly accessible database of registered creator codes where it is possible to find the name of an application, if you have its creator ID.

<http://www.palmos.com/dev/support/creatorid/>

Some of the data in the log file is produced in more than one format. The start time is shown in two formats. A human readable test string, to make looking through the log easy when you don't want to import it into a spreadsheet and with the start hour and minute in separate fields for use within spreadsheets.

This is the first version of the data file and the format is likely to be changed in response to user feedback. The format of the logfile is controlled by the desktop conduit so changes to the format can be made without requiring updating of the application file on the Palm.

In the log listing a creator code of *ZZZZ indicates that the Palm was switched off or shut itself down.

In the log listing a creator code of *WAKE indicates that the Palm was switched on and is resuming the application that was in use when the device was last used.

Registration

Registration of TeksLogs is free, just send us your hotsync name and we'll send you a registration code.

Feedback

If you have any comments, have suggestions for new features or alternative log file formats then please contact us. AppLog was written to help anyone who is conducting research into the use of PalmOS PDA's we are always interested to hear how AppLog is being used, so please tell us about your project.

applog@ninelocks.com

Information and updates will be made available at:-
www.ninelocks.com

Thanks

Special thanks to:

The late and greatly missed Bozidor Benc (<http://www.benc.hr/appusage.htm>) for contributing information to aid development. Checkout Benc Softwares Application Usage application .

The installer for this product was created using Installer VISE from MindVision Software. For more information on Installer VISE, contact:

MindVision Software
5901 North 58th Street
Lincoln, NE 68507

Voice: (402) 323-6600
Fax: (402) 323-6611

E-mail: mindvision@mindvision.com
<http://www.mindvision.com>

Appendix 1 The AppLog .ccd file, containing the list of applications and associated creator codes on the device.

AppLog .cc file

```
[NineLocksAppCCD]
[USER]ninelocks
4JMS, Timesheet
6JMS, Symbols
ADBE, Adobe Reader
Algf, Algebraf
AwBM, BigMoney
AwBW, Book Worm
AwJC, Bejeweled!
AwSC, Seven Seas!
BTMr, BtManager
BoMr, MarkMyScriptures
CHMT, ChemTable
CNvt, Converter
DDIR, DynDevInfo-DDIR
DGcl, Calcul-8!
DTGB, SheetToGo
DTGP, DocsToGo
DTGR, WordView+
EERF, EE REF
EPms, MMSLib Library-EPms
EPpm, Messages
Filz, Filez
```

Appendix 2

TeksLogs AppLog Processed File .alp

Main body is the same as that produced by the AppLog desktop conduit, but with the addition of a header section

```
[UserName]ninelocks
[BeamDate]Tue Feb 15 10:10:49 2005
[LastSync]Mon Feb 14 10:28:19 2005
[GoodSync]Mon Feb 14 10:28:19 2005
[DEVID_SOURCE]Zi72
[MAKE_SOURCE]Palm
[SERIAL_SOURCE]00VJA5G42FYY-P
[APPROG_VER]5.0.3
[DEVID_TEKSLOGS]Zi72
[MAKE_TEKSLOGS]Palm
[SERIAL_TEKSLOGS ]00VJA5G42F9P-E
[TEKSLOGS_VER]1.0.0
1101815377 lnc Tue Nov 30 11:49:31 2004 11 49 6
1101815386 nlAL Tue Nov 30 11:49:37 2004 11 49 9
1101815387 lnc Tue Nov 30 11:49:46 2004 11 49 1
1101815399 nlAL Tue Nov 30 11:49:47 2004 11 49 12
```

Explanation of Header fields

[UserName]Username of the machine that the AppLog data is from

[BeamDate]When the file was beamed from AppLog to TeksLogs

[LastSync]Time when the sending PDA was last hotsynced

[GoodSync] Time when the sending PDA was last hotsynced

[DEVID_SOURCE] The hardware device ID of the sending PDA

[MAKE_SOURCE] The manufacturer id of the sending device

[SERIAL_SOURCE]The serial number of the sending device
(not all Palm devices have a serial number in ROM so in those cases
the serial number field is set to "No-Serial Number")

[APPROG_VER]The Version number of Applog

[DEVID_TEKSLOGS] Hardware ID of the PDA that produced this file

[MAKE_TEKSLOGS]Palm

[SERIAL_TEKSLOGS]The serial number of the device on which TeksLogs
that produced this file was running

[TEKSLOGS_VER] TeksLog version

The body of the file is a tab separated data file in a format as shown below.

A	B	C	D	E	F
1017064714	bckp	Mon Mar 25 13:58:34 2002	13	58	13
1017064727	lnch	Mon Mar 25 13:58:47 2002	13	58	5
1017064732	trgf	Mon Mar 25 13:58:52 2002	13	58	32
1017064764	lnch	Mon Mar 25 13:59:24 2002	13	59	5
1017064769	bckp	Mon Mar 25 13:59:29 2002	13	59	34
1017064803	lnch	Mon Mar 25 14:00:03 2002	14	00	165
1017064968	sync	Mon Mar 25 14:02:48 2002	14	02	327
1017065295	lnch	Mon Mar 25 14:08:15 2002	14	08	9
1017065304	JTeN	Mon Mar 25 14:08:24 2002	14	08	32
1017065336	lnch	Mon Mar 25 14:08:56 2002	14	08	120

Logfile format

Col	Data
A	Seconds in Palm time format (seconds since Jan 1904)
B	Creator ID (see explanation below)
C	Start date and time in human readable form
D	Application Start time (Hours)
E	Application Start time (Minutes)
F	Amount of time application was used (Seconds)

Appendix D

AppLog Main Code

D.1 AppLog Write Entry

```
#include <PalmOS.h>
#include <PalmCompatibility.h>
#include "FtrDef.H"
#include "WriteAppLog.h"
#include <DLserver.h>
Boolean CanWeWrite(void);
Boolean CreateJournalDB(void);
/*=====*/
/*=====*/

Boolean CanWeWrite(void)
{
#ifdef DEBUG_JON
char debugL[50];
#endif
//char tempBuffer[12];
//char creatorString[8];
//UInt32 timeStamp;
DmOpenRef s_dbJRec = 0;
MemHandle s_hRec = 0;
//this for sussing creatr of the dbase
//UInt32 * creatorP;
//UInt32 theCreator;
//Int n; //used for offset into record
MemHandle hJRec = 0;
//Err err;
Char zero = 0;
UInt16 uIndex = 0;
// start of size limite vars
UInt32 freeRam;
UInt32 numRecs;
UInt32 dbSize;
UInt32 maxLogSize; //for reading from features
```

```

//end of size limit vars
LocalID dbIDHere = 0;
s_dbJRec = 0;
//ram info log info etc

MemCardInfo (0,0,0,0,0,0,0,&freeRam);
//must have managed to read it ok
if (FtrGet(ajHIDent,ajFtrLimit,&maxLogSize) != 0)
{
//feature didnt exist!
//therefor invalid so set iyt oursleves
maxLogSize = 500000; //100K!
}
dbIDHere = DmFindDatabase(0,APPLLOG_DB_NAME );
if (dbIDHere != 0)
{
#ifdef DEBUG_JON
    StrCopy(debugL,"DBID was not 0\n");
    DlkSetLogEntry(debugL, StrLen(debugL), true);
#endif
s_dbJRec = DmOpenDatabase (0, dbIDHere, dmModeReadOnly);
    if (s_dbJRec)
    {

if ( DmDatabaseSize (0, //UInt16 cardNo,
    dbIDHere, //LocalID dbID,
&numRecs, //UInt32 *numRecordsP,
&dbSize, //UInt32 *totalBytesP,
0 //UInt32 *dataBytesP)
) != errNone)
{
numRecs = 0;
dbSize = 0;
}
if ( s_dbJRec )
{
DmCloseDatabase ( s_dbJRec );
s_dbJRec = 0;
}
if ( (dbSize >= maxLogSize) || (freeRam <1000000))
return false;
    }

}
else
{
//no db found so check available ram
    if ( freeRam <1000000)
return false;
}

```

```

return true;
}
return true;

}

/*=====*/
/*=====*/
Boolean CreateJournalDB(void)
{
LocalID dbIDHere = 0;
DmOpenRef s_dbRef = 0; //DBRef
UInt16 s_recordNum; //used when searching for record
MemHandle s_hLogRec = 0; //record handle
MemPtr s_pLogRec; //for when we lock it down
Err err;
    // not there - create it now
    err = DmCreateDatabase ( 0,
                            APPLOG_DB_NAME,
                            APPLOG_FILE_CREATOR,
                            APPLOG_DB_TYPE,
                            false);
        // handle unexpected err

if (err)
return false;

dbIDHere = DmFindDatabase(0,APPLOG_DB_NAME );
if (dbIDHere == 0)
return false;
//there dbID != 0 then!
s_dbRef = DmOpenDatabase (0, dbIDHere, dmModeReadWrite);
// handle unexpected err
if ( 0 == s_dbRef)
{
return false;// ErrFatalDisplayIf ( true, "Could not open new database.");
}

//If we dont creat and initialise one
//uIndex = 0;
s_recordNum = dmMaxRecordIndex;
s_hLogRec = DmNewRecord ( s_dbRef, &s_recordNum, APPLOG_REC_LENGTH);
if ( s_hLogRec )
{
s_pLogRec = MemHandleLock(s_hLogRec);
DmSet(s_pLogRec,0,APPLOG_REC_LENGTH,0x00);
MemPtrUnlock(s_pLogRec);
DmReleaseRecord(s_dbRef,s_recordNum,true);
DmCloseDatabase (s_dbRef);
return true;
}

```

```

        }
        else
        {

DmCloseDatabase (s_dbRef);
s_dbRef = 0;
    return false;
    }
}
/*=====*/
/*=====*/
Boolean WriteEventToApplog(char *stringToWrite )
{
#ifdef DEBUG_JON
char debugL[50];
#endif
//char tempBuffer[12];
//char creatorString[8];

DmOpenRef s_dbLogRec = 0; //DBRef
MemHandle s_hLogRec = 0; //record handle
MemPtr s_pLogRec; //for when we lock it down
UInt16 s_recordNum; //used when searching for record
Err err;
Char zero = 0;
UInt16 uIndex = 0;
//Int n; //used for offset into record
// start of size limite vars
//UInt32 freeRam;
UInt32 numRecs;
UInt32 dbSize;
//UInt32 maxLogSize; //for reading from features
//end of size limit vars
struct_AppLogEntry anEntryRecord;
//this is the one UInt16 recEntryCount;
//first entry in a real record indicating insertion point
    UInt32 recEntryCount;
//first entry in a real record indicating insertion point
UInt32 recSize; //how much of the block we've used!
UInt16 offsetToEntry;
LocalID dbIDHere = 0;
s_dbLogRec = 0;
if (CanWeWrite() == false)
return false;
dbIDHere = DmFindDatabase(0,APPLLOG_DB_NAME );
if (dbIDHere != 0)
{
s_dbLogRec = DmOpenDatabase (0, dbIDHere, dmModeReadWrite);
}

```

```

if ( 0 == s_dbLogRec )
{
if (CreateJournalDB() == true)
{
dbIDHere = DmFindDatabase(0,APPLLOG_DB_NAME );
if (dbIDHere == 0)
return false;
//there dbID != 0 then!
s_dbLogRec = DmOpenDatabase (0, dbIDHere, dmModeReadWrite);
// handle unexpected err
if ( 0 == s_dbLogRec )
{
return false;// ErrFatalDisplayIf ( true, "Could not open new database.");
}
}
else
return false; //coz we didnt write anything
}

if ( DmDatabaseSize (0, //UInt16 cardNo,
dbIDHere, //LocalID dbID,
&numRecs, //UInt32 *numRecordsP,
&dbSize, //UInt32 *totalBytesP,
0 //UInt32 *dataBytesP)
!= errNone)
{
numRecs = 0;
dbSize = 0;
}
//now find record (should be last one!
s_recordNum = 0;
if (numRecs >0)
uIndex = numRecs - 1 ;

if ( s_dbLogRec )
{
err = DmSeekRecordInCategory ( s_dbLogRec,
&s_recordNum, // start at 0
uIndex,
dmSeekForward, // seek forward
dmAllCategories); // all categories

// get the record
if (!err)
{
s_hLogRec = (MemHandle)DmGetRecord ( s_dbLogRec, s_recordNum );
if ( s_hLogRec )
{

```

```

        // lock it down and get a ptr to the RECORD
        //s_pText = (CharPtr)MemHandleLock ( s_hRec );
        s_pLogRec = MemHandleLock(s_hLogRec);

    }
}
else
{
}

}

//Read first 4 bytes as a UInt32
MemMove(&recEntryCount, s_pLogRec, 4);
anEntryRecord.timeStamp = TimGetSeconds();
StrNCopy(anEntryRecord.szApp,stringToWrite,6);
offsetToEntry = ((UInt16 )recEntryCount * sizeof(struct_AppLogEntry));
offsetToEntry += 4; //to offset from the recEntry 4bytes at start
err = DmWrite ( s_pLogRec, offsetToEntry, &anEntryRecord,sizeof(struct_AppLogEntry) );
recEntryCount++;
DmWrite(s_pLogRec,0,&recEntryCount,4);
// Release the record, not dirty.

//release and unlock the record
if ( s_hLogRec )
{
    MemHandleUnlock ( s_hLogRec );
}
DmReleaseRecord ( s_dbLogRec, s_recordNum, false);
    // reset the current record number

//now see if that record is now full
recSize = (UInt16 )recEntryCount * sizeof(struct_AppLogEntry);

//see if near end of block size, allow a marging
if (recSize >= ( APPLLOG_REC_LENGTH - APPLLOG_MARGIN) )
{
    //need another record in the db so
    s_recordNum = dmMaxRecordIndex;
    s_hLogRec = DmNewRecord ( s_dbLogRec, &s_recordNum, APPLLOG_REC_LENGTH);
    if ( s_hLogRec )
    {
        s_pLogRec = MemHandleLock(s_hLogRec);
        DmSet(s_pLogRec,0,APPLLOG_REC_LENGTH,0x00);
        if ( s_hLogRec )
        {
            MemHandleUnlock ( s_hLogRec );
        }
    }
    DmReleaseRecord ( s_dbLogRec, s_recordNum, false);

```

```

        }
        //need an error handler in here
        else
        {
if ( s_dbLogRec )
{
DmCloseDatabase ( s_dbLogRec );
s_dbLogRec = 0;
return false;
}
}
}

if ( s_dbLogRec )
{
DmCloseDatabase ( s_dbLogRec );
//StrCopy(debugL,"Nice Close\n");
//DlkSetLogEntry(debugL, StrLen(debugL), true);
s_dbLogRec = 0;
}

return false;
}

```

D.2 AppLog Conduit Code.

AppLogPcMgr.cpp

```

/*****
*
* Generic Conduit CAppLogPcMgr Src File
*
*****/
#define ASSERT(f) ((void)0)
#define TRACE0(sz)
#define TRACE(sz)
#include <windows.h>
#include <string.h>
#include <stdio.h>
#ifdef METROWERKS_WIN
#include <wmem.h>
#else
#include <memory.h>
#endif
#include <sys/stat.h>

```

```

#include <TCHAR.H>
#include <syncmgr.h>
#include "AppLogPcMgr.h"
#include "resource.h"
#ifdef NO_HSLLOG
extern HANDLE hLangInstance;
#endif
/* time and date additions */
#include <time.h>
//#include <stdio.h>
#include <sys/types.h>
#include <sys/timeb.h>
#include <string.h>
struct AppJournal {
    AppJournal() { timeStamp = 0;}
    ~AppJournal() {delete [] appID; };
    long timeStamp;

    char *appID;

};
// on the Palm, the items array starts at offset 6. Natural alignment on
// windows would start it at offset 8
#pragma pack(2)
struct PackedAppJournal{
    long timeStamp;
    char appID[6];
};
struct PackedAppJournalVersion2{ //2005 version with battery info
    long timeStamp;
    char appID[6];
char batPercentage; //at offset 7 :-)
char spare;
char spare2;
char spare3;
char spare4;
    char spare5; //that make its 16 bytes long
};
#pragma pack()
//this is all our events packed into one Palm record
#pragma pack(2)
struct PackedAppRecordBlock{
    long recCount;
    char dataBlock[1];
};
#pragma pack()
//we dont seem to use this function!
AppJournal *RawRecordToAppJournal(void *rec) //place 3

```

```

{
    AppJournal *c = new AppJournal;
    PackedAppJournal *pc = (PackedAppJournal *) rec;
    c->timeStamp = SyncHHToHostDWord(pc->timeStamp);
    char * p = (char *) pc->appID;
    c->appID = new char[strlen(p)+1];
    strcpy(c->appID, p);

    return c;
}
/*****
*
* Class:    CAppLogPcMgr
*
* Method:   Constructor
*
* Description: This method initializes the class object.
*
* Parameter(s): szDbName - a pointer to a character buffer specifying the
*                   name of the database being synced.
*                   pFileName - a pointer to a character buffer specifying the
*                   filename of the database.
*                   pDirName - a pointer to a character buffer specifying the
*                   directory where the database is stored.
*                   syncType - an enum value specifying the sync type to be performed.
*
* Return Value(s): None.
*
* Revision History:
*
* Date          Name          Description
* -----
* 03/25/98      KRM           initial revision
*
*****/
CAppLogPcMgr::CAppLogPcMgr(CPLogging *pLogging, DWORD dwGenericFlags, char *szDbName, TC
: CPcMgr(pLogging, dwGenericFlags, szDbName, pFileName, pDirName, syncType)
{
// TODO - Put your own class initalization here
useLog = doLog; //switch on our debug log
strncpy(dirName,pDirName,80);
InitDebugLog("PcMgr Start\n");
}
CAppLogPcMgr::~CAppLogPcMgr()
{
    TRACE0("CAppLogPcMgr Destructor\n");
}
/*
////////////////////////////////////

```

```

    */
long CAppLogPcMgr::WriteDebugLog(char* entryForLog)
{

//char theDBName[25]; //so we can just copy without keeping object around
int length;
FILE *fp = NULL;
    // BYTE rHandle;
    int err;
    bool dbOpen = false;
    char    buffer[BIG_PATH *2];
    strncpy(buffer, dirName,200);
    strcat(buffer, "AppLogDebug.txt");
    if ((fp = fopen(buffer, "a")) == NULL) {
        err = 1;
        LogAddFormattedEntry(slWarning, false, "fopen(%s) failed",
            buffer);
        //goto exit;
    }
else
{
length = strlen(entryForLog);
fwrite(entryForLog,1,length,fp);
fclose(fp);
}
return 0;
}
long CAppLogPcMgr::InitDebugLog(char* entryForLog)
{

//char theDBName[25]; //so we can just copy without keeping object around
int length;
FILE *fp = NULL;
    // BYTE rHandle;
    int err;
    bool dbOpen = false;
    char    buffer[BIG_PATH *2];
    strcpy(buffer, dirName);
    strcat(buffer, "AppLogDebug.txt");
    if ((fp = fopen(buffer, "w")) == NULL) {
        err = 1;
        LogAddFormattedEntry(slWarning, false, "fopen(%s) failed",
            buffer);
        //goto exit;
    }
else
{
length = strlen(entryForLog);
fwrite(entryForLog,1,length,fp);
}
}

```

```

fclose(fp);
}
return 0;
}
/*****
*
* Class:   CAppLogPcMgr
*
* Method:  RetrieveDB()
*
* Description: This method loads the database from file.
*
* Parameter(s): None.
*
* Return Value(s): 0 - no error
*                  <0 - error code.
*
* Revision History:
*
* Date      Name      Description
* -----
* 03/25/98  KRM      initial revision
*
*****/
long CAppLogPcMgr::RetrieveDB(void)
{
// TODO - Put your own file format reading method here
return CPcMgr::RetrieveDB();
}
/*****
*
* Class:   CAppLogPcMgr
*
* Method:  StoreDB()
*
* Description: This method is called to store changes back into the
*             storage meduim.
*
* Parameter(s): None.
*
* Return Value(s): 0 - no error
*                  <0 - error code.
*
* Revision History:
*
* Date      Name      Description
* -----
* 03/25/98  KRM      initial revision
*
*****/

```

```

*****/
long CAppLogPcMgr::StoreDB(void)
{
// TODO - Put your own file format writing method here
char jon[400];
long rawSize = 0; //we use record size to work out which version of Applog
//512 for early 1024 for V6 with battery info
//for data decode
/* some global data for processing outgoing record */
//stuff for help decoding data
timeA = 0;
timeB = 0;
strcpy(appIDA, "");
strcpy(appIDB, "");
sprintf(jon,"AppLog StoreDB");
LogAddEntry(jon, slText,true);
sprintf(debugLog,"Conduit AppLog Build %s %s\n",__DATE__, __TIME__);
WriteDebugLog(debugLog);
// TODO - Put your own file format writing method here
if (!m_bNeedToSave) { // if no changes, don't waste time saving
return 0;
}
long err = Open();
if (err)
return GEN_ERR_UNABLE_TO_SAVE;
sprintf(debugLog,"StoreDB m_dwMaxRecordCount =%d\n",m_dwMaxRecordCount);
WriteDebugLog(debugLog);
sprintf(jon,"Number of Palm Records = %d",m_dwMaxRecordCount);
LogAddEntry(jon, slText,true);
for (DWORD dwIndex = 0; (dwIndex < m_dwMaxRecordCount) && (!err);
dwIndex++){
if (!m_pRecordList[dwIndex]) // if there is no record, skip ahead
continue;
//useful debugg info
//write out the record as decoded hex!

sprintf(debugLog,"\n\n====StoreDB dwIndex =%d =====\n",dwIndex);
WriteDebugLog(debugLog);
rawSize =m_pRecordList[dwIndex]->GetRawDataSize();
if (rawSize == 1024)
{
err = WriteRecordWithTimeVersion2(m_pRecordList[dwIndex]);
}
else
{
err = WriteRecordWithTime(m_pRecordList[dwIndex]);
}
//Could we now delete the handheld record?????
// m_pRecordList[dwIndex]->SetDeleted(true); //zzz

```

```

//zzz
// DeleteRec(m_pRecordList[dwIndex]);
}
Close();
if (err == 0) {
    m_bNeedToSave = FALSE;
sprintf(debugLog, "StoreDB End m_bNeedToSave = FALSE\n");
WriteDebugLog(debugLog);

///Attem
/*
for (DWORD dwIndex = 0; (dwIndex < m_dwMaxRecordCount) && (!err);
    dwIndex++){

DeleteRec(m_pRecordList[dwIndex]);
}
*/
/////end of delete experiment
return 0;
} else
sprintf(debugLog, "StoreDB End GEN_ERR_UNABLE_TO_SAVE \n");
WriteDebugLog(debugLog);
return GEN_ERR_UNABLE_TO_SAVE;
//return CPcMgr::StoreDB(); //WEDS
}
long CAppLogPcMgr::WriteRecord(CPalmRecord *pPalmRec)
{
long recordsInBlock;
PackedAppJournal * entryRec;
unsigned long len;
    const int    kMaxRecordSize = 16000;
    char        buf[kMaxRecordSize];
    char        rawRecord[kMaxRecordSize];
    DWORD      recordSize = kMaxRecordSize;
    long        retval;
    long offsetToEntryRec;
char timeString[40];
long nCount;
// stuff for time conversion
time_t ltime;

_tzset();
    retval = pPalmRec->GetRawData((unsigned char *) rawRecord, &recordSize);
    if (retval)
        return retval;
PackedAppRecordBlock *pc = (PackedAppRecordBlock *) rawRecord;
recordsInBlock = SyncHHToHostDWord(pc->recCount);
//bug waiting to happen what if this block has zero records
//then we have nCount < 0 as the condition, hangup time!

```

```

for (nCount = 0; nCount < recordsInBlock; nCount++)
{
SyncYieldCycles(1);
offsetToEntryRec = (nCount * sizeof(PackedAppJournal) + 4);
    entryRec = (PackedAppJournal *) (rawRecord + offsetToEntryRec);
ltime = SyncHHToHostDWord(entryRec->timeStamp);
ltime -= 2082844800LU;
sprintf( timeString,"%s", ctime( &ltime ) );
    _snprintf(
buf, kMaxRecordSize,
"%lu\t%s\t%s\t\r\n",
ltime ,
entryRec->appID ,
timeString
);
    len = strlen(buf);
    retval = WriteOutData(buf, strlen(buf));
}
//now we need to extract each event record and eff it about to get tme
//out of it etc etc
//AppJournal *aAppJournal = RawRecordToAppJournal(rawRecord);
// Write the record to the file as (if private):
// <customerID>\t<name>\t<address>\t<city>\t<phone>\tP\t<recID>\t
// or, if not private:
// <customerID>\t<name>\t<address>\t<city>\t<phone>\t\t<recID>\t
// delete aCustomer;

    return retval;
}
long CAppLogPcMgr::WriteRecordWithTime(CPalmRecord *pPalmRec)
{
long recordsInBlock;
PackedAppJournal * entryRec;
unsigned long len;
    const int    kMaxRecordSize = 1000;
    char        buf[kMaxRecordSize];
    char        rawRecord[kMaxRecordSize];
    DWORD      recordSize = kMaxRecordSize;
    long        retval;
    long        rawSize;
char timeString[40];
struct tm *timeAsFields;
//unsigned long thisTime;
long offsetToEntryRec;
long nCount;
unsigned char theByte;
// stuff for time conversion
time_t ltime;
struct tm *newtime;

```

```

_tzset();
WriteDebugLog("WriteRecordWithTime\n");
    retval = pPalmRec->GetRawData((unsigned char *) rawRecord, &recordSize);
    if (retval)
        return retval;
/*now to decide what we are doing, ie if we are calculating or storing
stuff for next record output
*/
PackedAppRecordBlock *pc = (PackedAppRecordBlock *) rawRecord;
recordsInBlock = SyncHHToHostDWord(pc->recCount);
sprintf(debugLog,"Number of log entries in Block =%d\n",recordsInBlock);
WriteDebugLog(debugLog);
char jon[400];
//useful message to write into log
//sprintf(jon,"NumbRecs In Block %d",recordsInBlock);
// LogAddEntry(jon, slText,true);
rawSize =pPalmRec->GetRawDataSize();
sprintf(debugLog,"Record Raw Size=%d\n",rawSize);
WriteDebugLog(debugLog);
int colCount = 0;
int lineCount= 0;
strcpy(debugLog,"RecordDump\n");
strcat(debugLog,"Header ");
//printer the header, should be number of entries in block
for (int i=0; i <4; i++)
{
theByte = rawRecord[i];
sprintf(jon,"%02x ", theByte);
strncat(debugLog,jon,DEBUGLOG_SIZE);
}
for(int n= 4; n <rawSize; n++)
{
if ((colCount == 10) || (colCount ==0))
{
colCount = 0;
lineCount++;
sprintf(jon,"\nEntry %03d ",lineCount);
strcat(debugLog,jon);
}
theByte = rawRecord[n];
sprintf(jon,"%02x ", theByte);
colCount++;
strncat(debugLog,jon,DEBUGLOG_SIZE);
}
strncat(debugLog,"\n",DEBUGLOG_SIZE);
WriteDebugLog(debugLog);
    //bug waiting to happen what if this block has zero records
//then we have nCount < 0 as the condition, hangup time!

```

```

//it will drop through loop .

retval = -1;
/*next line added Jan2003. If 0 records in block
then it was returning a -1 to caller so we got an error
message in the hotsync log! So now return 0 as all went ok
its just that we were on the boundry of a new record!!
*/
if (recordsInBlock == 0)
return 0;
for (nCount = 0; nCount < recordsInBlock; nCount++)
{
//only write this lot if we are debugging
// sprintf(jon,"nCount is %d",nCount);
// LogAddEntry(jon, slCustomLabel,true);
SyncYieldCycles(1);
sprintf(debugLog,"Process logEntry =%d\n",nCount +1);
WriteDebugLog(debugLog);
offsetToEntryRec = (nCount * sizeof(PackedAppJournal) + 4);
entryRec = (PackedAppJournal *) (rawRecord + offsetToEntryRec);
ltime = SyncHHToHostDWord(entryRec->timeStamp);
ltime -= 2082844800LU; //oops were a couple of minutes out
//better use strncpy for safety!!!!
//
if (timeA == 0)
{
//must be first run then
timeA = ltime;
strncpy(appIDA,entryRec->appID ,10 );
continue;
//return 0; //as we didnt crash or anything!
}
//on second run A will have something but be wont!

timeB = ltime;
strncpy(appIDB,entryRec->appID ,610);
//now we can do the time calc
appLastedTime = timeB - timeA;

//now write out PREVIOUS ie A appName with the time we just calculated as the appTime
//but the previous time as the time it started
// sprintf( timeString,"%s", ctime( &timeA ) );

//may 2003 changed as using ctime gave + 1hour?
newtime = gmtime( &timeA );
/* printf( "Coordinated universal time is %s\n",
asctime( newtime ) );
*/
sprintf( timeString,"%s", asctime( newtime ) );

```

```

//this has a \n at the end so kill it
timeString[strlen(timeString)-1] = 0x00;
//
timeAsFields = gmtime( &timeA );
sprintf(
buf,
"%lu\t%s\t%s\t%02i\t%02i\t%lu\r\n",
timeA , //time app started as unix time
appIDA , //the creator string
timeString, //the time it started as man readable string
timeAsFields->tm_hour,
timeAsFields->tm_min,
appLastedTime //how long app was run for
);
len = strlen(buf);
retval = WriteOutData(buf, strlen(buf));
//now swap the times
timeA = timeB;
strncpy(appIDA, appIDB,10);
}
//delete aAppJournal;

return retval;

}
long CAppLogPcMgr::WriteRecordWithTimeVersion2(CPalmRecord *pPalmRec)
{
long recordsInBlock;
PackedAppJournalVersion2 * entryRec;
unsigned long len;
const int kMaxRecordSize = 2048; //actually 1024
char buf[kMaxRecordSize];
char rawRecord[kMaxRecordSize];
DWORD recordSize = kMaxRecordSize;
long retval;
long rawSize;
char timeString[40];
struct tm *timeAsFields;
//unsigned long thisTime;
long offsetToEntryRec;
long nCount;
unsigned char theByte;
// stuff for time conversion
time_t ltime;
struct tm *newtime;

_tzset();
WriteDebugLog("WriteRecordWithTimeV2\n");
retval = pPalmRec->GetRawData((unsigned char *) rawRecord, &recordSize);

```

```

    if (retval)
        return retval;
    /*now to decide what we are doing, ie if we are calculating or storing
    stuff for next record output
    */
    PackedAppRecordBlock *pc = (PackedAppRecordBlock *) rawRecord;
    recordsInBlock = SyncHHToHostDWord(pc->recCount);
    sprintf(debugLog,"Number of log entries in V6 Block =%d\n",recordsInBlock);
    WriteDebugLog(debugLog);
    char jon[DEBUGLOG_SIZE];
    //useful message to write into log
    //sprintf(jon,"NumbRecs In Block %d",recordsInBlock);
    // LogAddEntry(jon, slText,true);
    rawSize =pPalmRec->GetRawDataSize();
    sprintf(debugLog,"Record Raw Size=%d So AppLog V6\n",rawSize);
    WriteDebugLog(debugLog);
    int colCount = 0;
    int lineCount= 0;
    strcpy(debugLog,"RecordDump\n");
    strcat(debugLog,"Header \n");
    //WriteDebugLog(debugLog);
    //printer the header, should be number of entries in block
    for (int i=0; i <4; i++)
    {
        theByte = rawRecord[i];
        sprintf(jon,"%02x ", theByte);
        strncat(debugLog,jon,DEBUGLOG_SIZE);
    }
    //was rawSize
    for(int n= 4; n <rawSize; n++)
    {
        if ((colCount == 16) || (colCount ==0))
        {
            colCount = 0;
            lineCount++;
            sprintf(jon,"\nEntry %03d ",lineCount);
            strncat(debugLog,jon,DEBUGLOG_SIZE);
        }
        theByte = rawRecord[n];
        sprintf(jon,"%02x ", theByte);
        colCount++;
        strncat(debugLog,jon,DEBUGLOG_SIZE);
    }
    strncat(debugLog,"\n",DEBUGLOG_SIZE);
    WriteDebugLog(debugLog);
    //bug waiting to happen what if this block has zero records
    //then we have nCount < 0 as the condition, hangup time!
    //it will drop through loop .

```

```

retval = -1;
/*next line added Jan2003. If 0 records in block
   then it was returning a -1 to caller so we got an error
   message in the hotsync log! So now return 0 as all went ok
   its just that we were on the boundry of a new record!!
*/
if (recordsInBlock == 0)
return 0;
   for (nCount = 0; nCount < recordsInBlock; nCount++)
{
   //only write this lot if we are debugging
   // sprintf(jon,"nCount is %d",nCount);
   // LogAddEntry(jon, slCustomLabel,true);
   SyncYieldCycles(1);
   sprintf(debugLog,"Process logEntry =%d\n",nCount +1);
   WriteDebugLog(debugLog);
   offsetToEntryRec = (nCount * sizeof(PackedAppJournalVersion2) + 4);
       entryRec = (PackedAppJournalVersion2 *) (rawRecord + offsetToEntryRec);
   ltime = SyncHHToHostDWord(entryRec->timeStamp);
   ltime -= 2082844800LU; //oops were a couple of minutes out
   //better use strncpy for safety!!!!
   //
   if (timeA == 0)
   {
   //must be first run then
   timeA = ltime;
   strncpy(appIDA,entryRec->appID ,10 );
   continue;
   //return 0; //as we didnt crash or anything!
   }
   //on second run A will have something but be wont!

   timeB = ltime;
   strncpy(appIDB,entryRec->appID ,10);
   //now we can do the time calc
   appLastedTime = timeB - timeA;

   //now write out PREVIOUS ie A appName with the time we just calculated as the appTime
   //but the previous time as the time it started
   // sprintf( timeString,"%s", ctime( &timeA) );

   //may 2003 changed as using ctime gave + 1hour?
       newtime = gmtime( &timeA );
   /* printf( "Coordinated universal time is %s\n",
               asctime( newtime ) );
*/
   sprintf( timeString,"%s", asctime( newtime ) );
   //this has a \n at the end so kill it
   timeString[strlen(timeString)-1] = 0x00;

```

```

//
timeAsFields = gmtime( &timeA );
sprintf(
buf,
"%lu\t%s\t%s\t%02i\t%02i\t%lu\t %03d\r\n",
timeA , //time app started as unix time
appIDA , //the creator string
timeString, //the time it started as man readable string
timeAsFields->tm_hour,
timeAsFields->tm_min,
appLastedTime, //how long app was run for
entryRec->batPercentage
);
len = strlen(buf);
retval = WriteOutData(buf, strlen(buf));
//now swap the times
timeA = timeB;
strncpy(appIDA, appIDB,10);
}
//delete aAppJournal;

return retval;

}

```

Appendix E

Graaf Screenshots

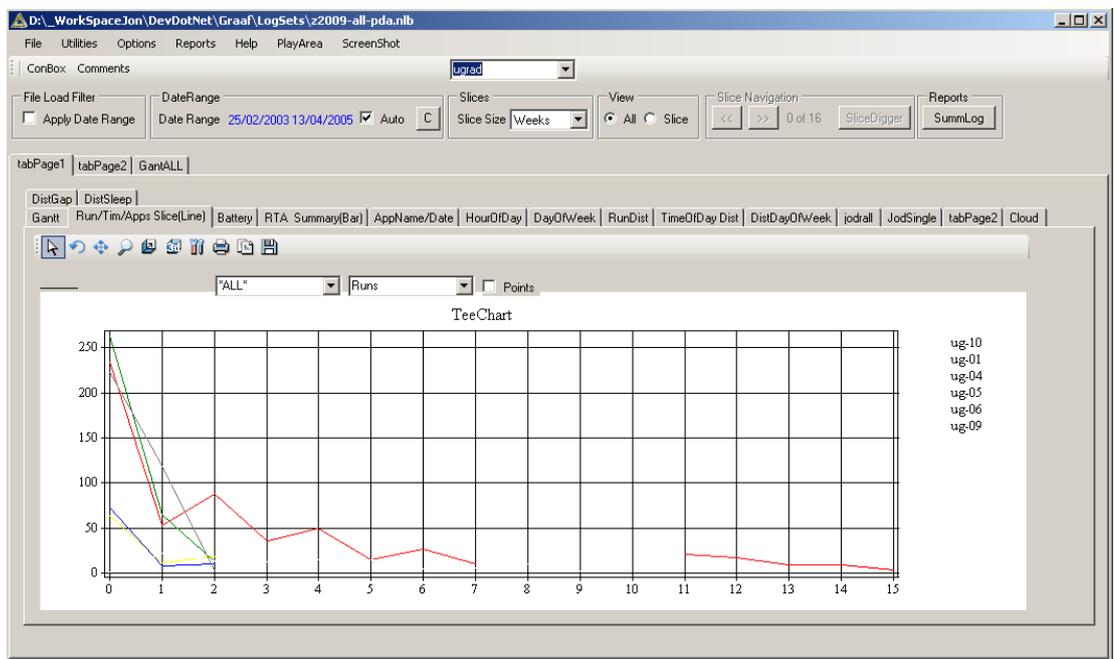


Figure E.1: Graaf Main Screen

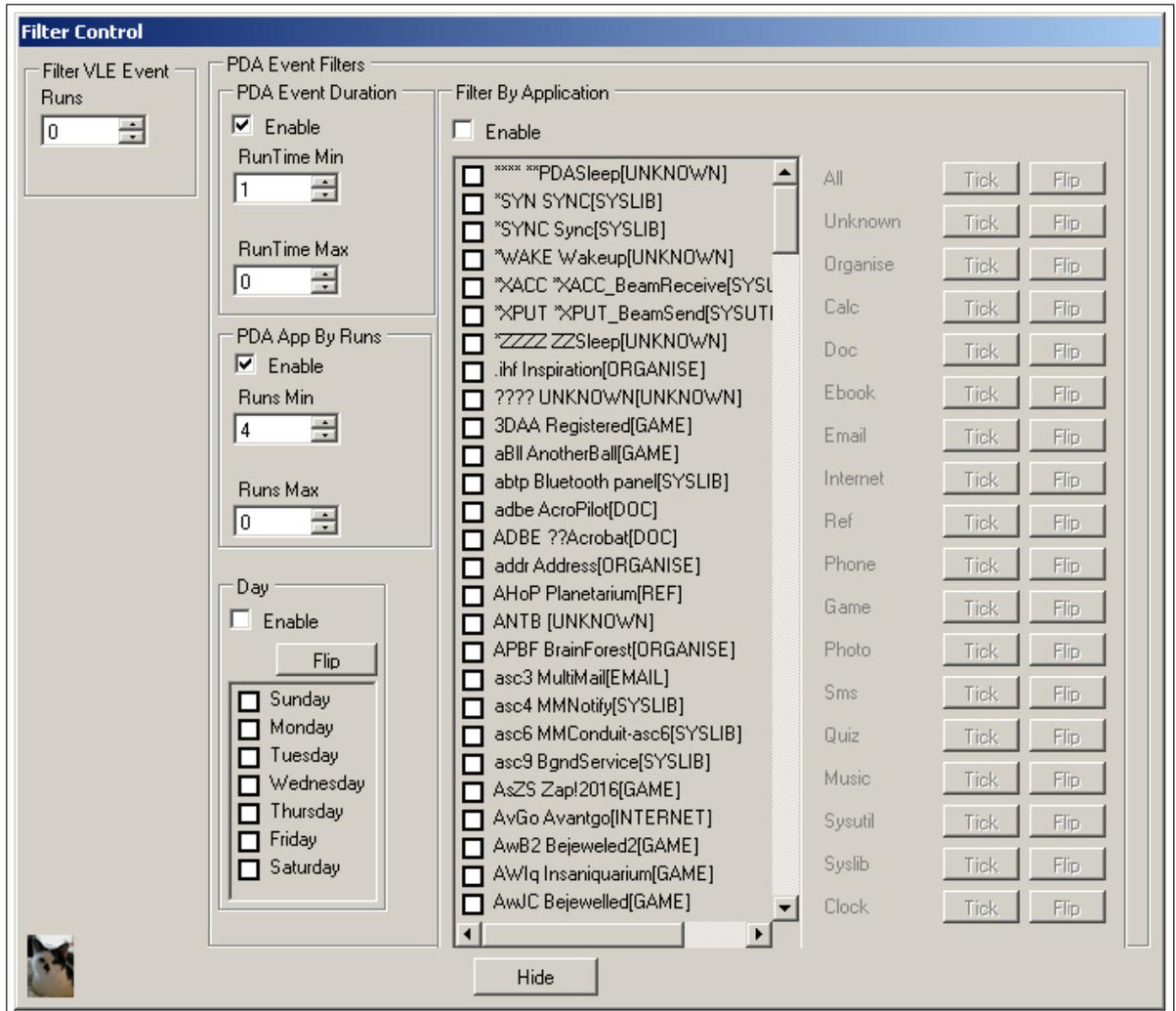


Figure E.2: Graaf Filter Dialog

Appendix F

Palm Creator Codes

Palm application creator identification codes. These codes are seen in the AppLog data files. Those starting with an asterisk were pseudo events inserted into the system logs as part of the operation of AppLog.

[Creators Code] [Application Name] [Description] [Family]

```
.ihf Inspiration ORGANISE
**** **PDASleep Old Sleep System
*SYN SYNC We detected sync SYSLIB
*SYNC Sync SYSLIB
*WAKE Wakeup Palm Woke up
*XACC *XACC_BeamReceive ??? SYSUTIL
*XPUT *XPUT_BeamSend ??? SYSUTIL
*ZZZZ ZZSleep PDA Went to sleep
3DAA Registered 3DStarFighterPilot GAME
aB11 AnotherBall GAME
abtp Bluetooth panel SYSLIB
adbe AcroPilot DOC
ADBE ??Acrobat ??? DOC
addr Address Address Book www.palm.com ORGANISE ROM
AHoP Planetarium ??? REF
ANTB
APBF BrainForest BrainForest ORGANISE
asc3 MultiMail EMAIL
asc4 MMNotify SYSLIB
asc6 MMConduit-asc6 SYSLIB
asc9 BgndService SYSLIB
AsZS Zap!2016 GAME
AvGo Avantgo Avantgo Site reader www.avantgo.com INTERNET
AwB2 Bejeweled2 GAME
AWIq Insaniquarium GAME
AwJC Bejewelled ??? GAME
```

AwVD Bejeweled VE! GAME
Bcam Batcam Treo Camera PHOTO
BCFG PrintManager Part of PrintBoy SYSUTIL
bckp Palm?? Unlisted but probably backup for TRG www.palm.com
BfBf Getstarted_ie
BkmN BackupMan SYSTUTIL
BLKS blocks GAME
Bloc 3DBlockout GAME
BLrd Billiards Billiards GAME
bltp Unregistered Maybe Bluetooth control Panel SYSLIB
BLZ5 Blazer INTERNET
Bmsy Addit INTERNET
BPBM Unknown
BPDO PrintBoy Docs PrintBoy Docs SYSUTIL
BPSH PrintBoy Shell PrintBoy Shell SYSUTIL
brtP Brightness-brtP SYSUTIL
BTMr BtManager SYSUTIL
bttN PrefsButtons Buttons Prefs Panel www.palm.com SYSUTIL
BUBL BubblesOS5 GAME
calc Calculator a Calculator www.palm.com CALC
CERI RepliGo DOC
CESW Week view WeekView www.pimlicosoftware.com? ORGANISE
CFB9 Pong GAME
CHMT ChemTable Freeware Periodic Table REF
ChsG ChessGenius World Champion Chess Program GAME
CiAa Mac City GAME
cinf Cardinfo The Memory card info www.palm.com SYSUTIL
CLie CLIE Demo ??? SYSUTIL
clpr
CNRN Chain Reaction ??? GAME
CNvt Converter Unit conversion application
COCO PalmPix kodak PalmPix camera www.kodak.com PHOTO
CRbh BatteryLogHack SYSUTIL
CRbl BatteryLog ??? SYSUTIL
Crsh Crash SYSUTIL
CTx1 CompressedReader Textfile DOC
Curl Cool Curling GAME
date DateBook The Palm Diary App www.palm.com ORGANISE
DCTG DocumentsToGo www.dataviz.com DOC
DDIR DynDevInfo-DDIR
DGcl Calcul-8! Scientific Calc CALC

DGET DXTGAttachmentPlugin SYSLIB
DGFY PicsToGo PHOTO
dial Dial PHONE
DIDB DiddleBug ORGANISE
DIDL Diddle Doodling Program ORGANISE
digi Digitizer Digitizer Panel www.palm.com SYSUTIL
dilP Dialer-dilP PHONE
DOwd Dash Off Word DOC and Memo Word Processor DOC
DrDw Darts Deluxe II GAME
dsD2 dsD2.DotDotTwo SYSUTIL
dsEB ExgDemoB
DTGB SheetToGo Docs To Go Spreadsheet DOC
DTGP DocsToGo Docs to Go DOC
DTGR WordView(DTG) Docs to Go Wordviewer DOC
dttm Date/Time Date/Time,PalmOS Date/Time Panel SYSUTIL
DWMH DopeWars GAME
EPc2 CarKit SYSUTIL
EPms MMSLib Library-EPms SYSUTIL
EPp4 Pixier4 DOC
EPpm Messages ORGANISE
ERac E-Racer GAME
exps Expenses The Expenses application www.palm.com ORGANISE
ExtM Ext_Manager Hackmaster replacement SYSUTIL
Filz Filez SYSUTIL
FNMt FanMATE Display a running fan GAME
Foto Photos-Foto PHOTO
FOXH hunting GAME
frmt Formats Formats Panel SYSUTIL
FTMa ?? FineTypeManager
gdem Graffiti Demo Graphiti Demo www.palm.com SYSUTIL
gnrl Gen Prefs The Preferences Panel www.palm.com SYSUTIL
Gtkr GNU Keyring ??? SYSUTIL
HAZL Palmasaurus SYSUTIL
HBAL HardBall Unregistered creator! GAME
HCTB Checkers GAME
HHTB hangman GAME
hjH2 unlisted
HLTB lines GAME
HmMn Monopoly GAME
HmVC MagicDogs Launcher
hoPM PacMan GAME

HsCh Texter SMS
HsDm EMail EMAIL
HsGA GSMActivation PHONE
HsMp IMTAppDB SYSUTIL
HsNC CarrierConfigurator SYSUTIL
HsPB SimPhoneBook ORGANISE
HsPh Phone PHONE
HsPr Calculator CALC
HsSS SimServices PHONE
HsTM Tutorial SYSUTIL
HZLt HandZipper Zip Compression Utility SYSUTIL
IM11 Jewels GAME
IMVS PGPocket ??? PHOTO
INE3 Registered ???
IPn2 IR-Pong 2 GAME
IRBS IRBattleship GAME
IrRm ??RemoteControl ???
isnk IMR Snake GAME
JckL JackFlash Flash ROM Tool Brayder Technologies SYSUTIL
JFi5 JFile JFile Database www.land-j.com
JHSU PToolboxLib SYSLIB
JLTD Today Today ORGANISE
JSP SearchLight Unregistered creator!
JTC0 Quizzler QUIZ
JTcm NineColors
JTkg Unknown
JTsi SysInfo ??? SYSUTIL
JTut JTutor Quiz Application
JWLt JpegWatchLite PHOTO
Kcpt Capture-Kcpt PHOTO
KeYs TestFiveWay SYSUTIL
Kim7 Electronics Electronics reference and calculator REF
kis2 unregistered JON GAME
KLON Klondike GAME
Kndk Solitaire by Handmark GAME
KNMA Kinoma PHOTO
K001 StoKeybd Keyboard Apps SYSUTIL
LEMM Lemmings Lemmings Game GAME
lh12 mh06ePRC
LIBI LibInstall SYSUTIL
lnch Launcher The App Launcher SYSUTIL

lpkr Language Picker SYSUTIL
 MA10 PalmVMFontLibrary SYSLIB
 mail Mail Mail EMAIL
 mdLA Little Angel GAME
 mdPM PortaMonkey GAME
 memo MemoPad Simple memo application www.palm.com ORGANISE
 mine MineSweeper PalmOS Minesweeper www.palm.com GAME
 mJav JAVAHq
 MjUh Application Use Hack Bencs Application use monitor ??? SYSUTIL
 MkCF MonkeyCard SMS Image Tool SMS
 MkSM MonkeyMessenger SMS Tool SMS
 modm Modem Panel Modem Panel www.palm.com SYSUTIL
 MSAr Registered ??? MFapplMSArChineseGB
 MSbK MemoryStickBackup ??? SYSUTIL
 mscm Unregistered MSCam Memory Stick Cam? PHOTO
 MsCt Registered ???
 msG7 MiniGolf GAME
 MSGt MSGate Memory Stick Tool in ROM SYSUTIL
 MTCH Match Card Matching Game GAME
 MxBk Bucky GAME
 NDNz DayNotez DayNotez www.natara.com ORGANISE
 NEKJ Neko Neko the Cat www.ninelocks.com GAME
 netw Network Palm Network Prefs www.palm.com SYSUTIL
 nlAL Applog Applog www.ninelocks.com SYSUTIL
 nlBl ListApps SYSUTIL
 nlCS NineColours Colour Chooser www.ninelocks.com
 nlJB JPWBeam PHOTO
 nlNK NekoAndFriends GAME
 nlPG NinelocksPictreGear PHOTO
 nlSP StikMailLite SnapperPlugIn for StikMail www.ninelocks.com PHOTO
 nlTf TeksFiles SYSUTIL
 nlTl TeksLogs SYSUTIL
 nlTP TeksPhotos PHOTO
 nlUT Unknown
 nlVF VFSFTP INTERNET
 NOtl Bonsai Outliner www.natara.com ORGANISE
 NOVR WebProV INTERNET
 npad Note Pad ORGANISE
 ONLN On-Line Terminal emulator www.mark-space.com INTERNET
 OpCl EasyCalc Scientific Calculator www CALC
 oRem OmniRemote Change your PDA into a remote

ownr OwnerPanel Owner Panel www.palm.com SYSUTIL
 PAdd Contacts-PAdd ORGANISE
 PAJ1 Registered Gobble GAME
 PcLK Clock-PcLK CLOCK
 PDat Calendar-PDat ORGANISE
 pdmE HiddenPIMsSupport-pdmE SYSUTIL
 PFfr Froggy GAME
 PGPD Registered ??????Picture Gear? PHOTO
 Phnx Phoinix Emulator for Nintendo Gameboy GAME
 PIMO Registered Listed but No info on creator databasePuzzles-In-Motion
 GAME
 PktC PocketC
 PMel wwpointscal Weight Watchers Points Calculator or PrintMe wifi printing

 PMem Memos-PMem ORGANISE
 PMGX PMGX
 pnps SlotDrvrPnpsApp-pnps SYSUTIL
 PP2P PP_P2P DocsToGo7 DOC
 PPlx GraphicsLibrary Unregistered creator! ??? SYSLIB
 PPon 22Pong GAME
 PPrs Peanut Reader Palm eBook reader www.palm.com EBOOK
 PQUZ PalmQuiz Quiz Application www.quizapp.com QUIZ
 Prag RadioTimes RadioTimes TV Guide ??? REF
 pref prefs Palm Prefs Panel www.palm.com SYSUTIL
 PrgW RadioTimeSetup RadioTimes TV Guide Setup SYSUTIL
 Prns Parens Scientif Calculator www? CALC
 Prsn Prison GAME
 PSIF PSLaunch
 PSPG PhotoStand PGPocket PhotoStand PHOTO
 PTod Tasks-PTod ORGANISE
 puzl Puzzle GAME
 pwr1 powerOne_Personal CALC
 pXd2 Defender2 Defender Game GAME
 pXsp Spy GAME
 pXtc Tetris GAME
 PZGT GTS Racing GAME
 QCwb EudoraWeb Web Browser INTERNET
 QKTR Quick Tour SYSUTIL
 QRYS QueriesApp
 Reem ResetEmu SYSUTIL
 RNGZ Ringz PUZZLE BAPSOFT.COM GAME

RNWK RealOne AUDIO PLAYER MUSIC
 RScf Crazyfaces GAME
 SdUt SoundUtility Sound Utility In ROM SYSUTIL
 secr Security Palm security www.palm.com SYSUTIL
 setp Setup App Palm Setup www.palm.com SYSUTIL
 SFCv Palm SFCave GAME
 shct Shortcuts Panel Shortcuts Panel www.palm.com SYSUTIL
 SiEd SiEd DOC
 Silo iSilo iSilo Doc Viewer www.isilo.com DOC
 SJLO Strip Encrypted password manager
 skAD ArtilleryDuel GAME
 SmBa SmallBASIC BASIC interpeter for PalmOS
 SMng SoundsApp_SMng
 SnHp Registered Poss part of snappermail
 SnJp Registered Poss part of snappermail
 Snpm SnapperMail Poss part of snappermail EMAIL
 Soc1 Connect4 ??? GAME
 SP2P SS_P2P DocumentsToGo native Excel spreadsheet support add-in DOC
 SpId SplashID
 splZ Splash-splZ
 Spme Snapper-LibExgApp-Spme SYSLIB
 SpMn SplashMoney
 SpSh SplashShopper
 SSTG SlideShowToGo DogToGoPowerPoint www.dataviz.com DOC
 STra Space Trader Space trading strategy game GAME
 sW03 ??SolFree Solitaire Unregistered at Palm GAME
 sW05 Tangrams Tangram Puzzle GAME
 SWAC WorldAlarm ??? CLOCK
 swmr unregistered SpaceWar,StarTrek game GAME
 sync HotSync The hotsync process www.palm.com SYSUTIL
 TANK Tank Attack An exciting game where you drive a tank around ??? GAME

 TB!D cardhouse GAME
 TBMC memory Great memory puzzle GAME
 TBSW SeaWar SeaWar Game GAME
 TetC TetriCrisis-TetC GAME
 TNpt PocketTunes MUSIC
 todo ToDo ToDo www.palm.com ORGANISE
 TstD DAWGShow Dict viewer or Game? GAME
 tt3d TicTacToe_3d TicTacToe Unregistered at Palm ??? GAME
 TT00 TattooArtist

View FireViewer PHOTO
VM00 PocketPoems REF
Vpad VoicePad-Vpad
WCAM Palm Webcam
wclp PalmOS Web Clipping Panel www.palm.com INTERNET
WFFI WifFi SYSUTIL
WP2P WP_P2P DocumentsToGo native Word document support DOC
WrdS Wordsmith DOC
xpuD gMovie PHOTO
XWc4 XWConfig4
Xwr4 Crosswords GAME

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