

Usability study of word processing applications on different mobile devices

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ABSTRACT

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Educators and learners are making more use of technology in education, however, personal computers (PC's) are still expensive, and many developing countries do not have the resources to implement computer systems in educational institutions. Creating and editing documents is an important component for students to perform in their studies. A preliminary questionnaire showed that students still prefer to use the PC for reading and writing, however, reading and writing is starting to be done more frequently on mobile devices such as mobile phones as these are more readily available.

Technology is being used more frequently to write and existing research shows there are numerous issues regarding the usability of the current mobile tools to achieve this. Therefore, there is a need to study the usability of mobile word processing applications on different mobile devices.

The literature review reveals that usability studies have been performed on health and e-learning applications, however, no study has looked at the usability of reading and writing on word processing applications on mobile devices. Thus, the aim of this study is to investigate usability issues of word processing applications on different mobile devices.

Two usability studies are set up; the first study determines the usability of mobile word processing applications and the second study determines the usability of mobile devices. The applications chosen for the first study include, Google Docs, Microsoft Word and WPS Writer.

Participants were chosen to perform specific tasks on each mobile application and mobile device. The results were measured in terms of usability. The results of the studies were collected using usability test procedures which include quantitative and qualitative measures. The problems experienced by the user found in the studies were mapped to the generic guidelines from literature for verification. The usability issues of different mobile

devices were investigated in terms of creating and editing documents in the word processing applications.

The results from Study 1 showed that the best available word processing application is Google Docs. Google Docs is the best application since the participants could perform the tasks in less time and with fewer errors than Microsoft Word and WPS Writer. This resulted in users rating Google Docs easier to use than Microsoft Word and WPS Writer.

The results from Study 2 showed that the Samsung Galaxy Tab A is the best available mobile device to create and edit documents when seated at a desk. The device has the largest screen size which makes it more user friendly when creating documents, however, due to the large size of the device, it is more practical to use it at a desk. If a user is not at a desk and is therefore mobile, then the Samsung Galaxy S6 Edge is the best device to use since the device has the fastest processor and largest screen size of the smartphone devices tested.

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TABLE OF CONTENTS

ABSTRACT	i
TABLE OF CONTENTS	iv
LIST OF FIGURES	vi
LIST OF TABLES	vii
1. INTRODUCTION	1
1.1 Preamble	1
1.2 Background of technology used in education	1
1.3 Background of word processors used in education.....	7
1.4 Problem statement	8
1.5 Purpose of the study.....	8
1.6 Layout of the study	9
2. LITERATURE REVIEW	11
2.1 Preamble	11
2.2 Comparison of PCs and mobile devices	11
2.3 Text input methods on mobile devices.....	16
2.4 Usability studies	19
2.5 Conclusion	32
3.METHOD	34
3.1 Preamble	34
3.2 Preliminary questionnaire.....	35
3.3 Study 1: Word processing mobile application usability study.....	35
3.4 Study 2: Mobile device usability test	53
3.5 Verification of results	55
3.6 Conclusion	56
4.VALIDATION OF RESULTS	58
4.1 Preamble	58
4.2 Preliminary Questionnaire	58
4.3 Study 1.....	60
4.4 Study 2.....	80

4.5 Conclusion	88
5.CONCLUSION	91
5.1 Preamble	91
5.2 Overview of the study	91
5.3 Validation of the objectives	92
5.4 Limitations of study.....	93
5.5 Recommendations for further studies.....	93
5.6 Closure of study	94
REFERENCES	95
Appendix A: Preliminary questionnaire	102
Appendix B: Method tasks	105
Appendix C: Participant form	108
Appendix D1: SUS scores	111
Appendix D2: Task results	112

LIST OF FIGURES

Figure 1: Mobile devices used in education in 2004.....	5
Figure 2: Mobile device usage for university work in 2015.....	6
Figure 3: Hardware and software components of a PC	12
Figure 4: Hardware and software components of a smartphone	13
Figure 5: Three methods of text input	17
Figure 6: Desktop and mobile devices in use today	28
Figure 7: Hardware components of a mobile device	29
Figure 8: Sequence of tasks to be performed	38
Figure 9: Equipment and test setup	41
Figure 10: Test setup and equipment	44
Figure 11: Study procedure and measuring results.....	45
Figure 12: Flow diagram of data analysis.....	52
Figure 13: Results from preliminary questionnaire	59
Figure 14: Ranking of applications	65
Figure 15: Completion rate	68
Figure 16: Navigational cost	69
Figure 17: Task-level satisfaction	69
Figure 18: Correlation between completion rate and navigational cost.....	71
Figure 19: Study 2 completion time	82
Figure 20: Study 2 navigational cost	82
Figure 21: Mobile devices relative screen size.....	84

LIST OF TABLES

Table 1: Usability measurements	20
Table 2: Participant details	37
Table 3: Minimum completion rate and navigation cost.....	40
Table 4: Difference between laboratory and field testing.....	42
Table 5: Pros and cons of different usability moderating methods	43
Table 6: Word processing mobile applications.....	46
Table 7: Word processing applications mapped to basic functions	47
Table 8: Null hypotheses for demographic data.....	50
Table 9: Null hypotheses for usability metrics	51
Table 10: Mobile device properties	53
Table 11: Results of preliminary questionnaire	58
Table 12: Respondents details.....	59
Table 13: Demographic Welch's t-test results	61
Table 14: ANOVA for Tasks 2 and 3.....	62
Table 15: Study 1 ANOVA of usability data	63
Table 16: Study 1 averages.....	64
Table 17: Errors of completion rate and navigational cost	66
Table 18: Correlation coefficients	70
Table 19: ANOVA.....	73
Table 20: Averages.....	73
Table 21: Mapping of issues found to generic guidelines.....	74
Table 22: Usability results.....	77
Table 23: Completion time and navigational cost of Study 2	81
Table 24: Summary of the questions and preferred devices.....	86
Table 25: Usability measurements of study 2.....	87

Chapter 1: Introduction

This chapter introduces the purpose of the study by providing the necessary background information. Technology is being used more frequently to write and existing research shows there are numerous issues regarding the usability of the current tools to achieve this. As a result, there is a need to study the usability of word processing applications on different mobile devices.

1. INTRODUCTION

1.1 Preamble

Technology and the advantages it can provide are of fundamental importance to advancing education. This chapter aims to provide background to technology that is used in education today and the usability of this technology. This chapter also addresses the problem technology faces in education and what the purpose of the study is.

1.2 Background of technology used in education

1.2.1 Introduction

Education forms a vital part of the future prosperity society. Education is defined as the process of facilitating learning, or the acquisition of knowledge, skills, values and beliefs [1]. This study will focus on the skills of reading and writing.

To be an effective tool for the development and success of students, education must progress with the latest developments in technology [1]. The development of these technologies such as the internet, multimedia systems and in recent years the increased use of mobile technologies, e-learning and mobile learning have improved the quality of education [2].

A review of 219 research articles done by Jay Sivin – Kachala [3], assessed the effect of technology on learning and achievement across all learning domains and ages of students. From his analysis, he reported the following findings:

- Students in technology rich environments experienced positive effects on achievement in all major subject areas.
- Students in technology rich environments showed increased achievement in preschool through higher education for both regular and special needs children.
- Students' attitudes toward learning and their own self-concept improved consistently when computers were used for instruction.
- The level of effectiveness of educational technology is influenced by the specific student population, the software design, the educator's role, and the level of student access to the technology [3].

1.2.2 Importance of reading and writing

Education includes the important skills of reading and writing [4]. Writing is the dominant form of communication in society and is currently the only way of documenting and publishing research [4]. A number of studies have shown that for students to engage in a deeper and more meaningful understanding of the subject, they need to engage in the active process of writing [4]. Writing can lead to a longer retention of the study material and can motivate students to learn. It has been shown that incorporating writing components into science and engineering courses, may have enormous potential for students and teachers [4].

University students' academic success is partly determined by their competence and ability to write [5]. There are many varieties of academic writing to master at university, including reports, essays, reflective pieces, and research projects. Each of these methods requires students to adopt a set of conventions for the format, content, and genres in their work. Writing is a course requirement that is a skill students need to acquire to achieve a pass for the module [5]. Researchers have found that students that make use of word processing software for writing, produce higher quality materials [3]. Word processing tools in conjunction with revision from teachers or lecturers significantly improves the quantity and quality of revisions, drafts, and final products of documents [6].

1.2.3 Technology used for reading and writing

The mode of writing has undergone dramatic change over the past and now digital writing tools associated with the use of personal computers, laptops and mobile devices are increasingly replacing writing by hand [7]. Research has shown that digital devices positively impact the writing process in three ways: increased feedback, connection to authentic audiences, and opportunities for multimodal composing.

The first use of the computer in the education system occurred in 1970 [8]. According to the US Congress, Office of Technology Assessment, the percentage of schools with access to one or more computers grew from 18 percent in 1981 to 95 percent in 1987 [3]. Currently computers are used in educational systems all over the world.

Computers are expensive and previously disadvantaged schools and universities are still struggling to keep up with well-resourced education institutions [9].

There is still a substantial number of students in developing countries who have not used or even seen a computer [10]. Dr Kozma analysed issues relating to the adoption of computers in developing countries educational institutions [11]:

- Financial issues: resources in developing countries are scarce and therefore countries need to prioritise money for food and infrastructure.
- Limited internet access: the limited supply of electricity makes it difficult for developing countries to gain internet access.
- Lack of trained staff: a lack of trained teachers is another challenge and the traditional teachers are sometimes reluctant to accept new technology into the classroom.
- Lack of policy: inappropriate policy and funding decisions hinder equal educational development as some nations tend to focus more on higher education.

The issues faced by developing countries relating to the adoption of computers has allowed the mobile market to grow substantially. Smartphones perform the basic functions of a computer, at a much lower cost [10].

Smartphones outgrew the number of computers in 2011 with a huge increase in developing countries. The Research **ICT** Africa (RIA ICT) survey data in 2012 showed that 84.2% of South Africans own a mobile device [12]. This can probably be attributed to the gradual decline of mobile device prices and a growth in market share [13]. In 2013, Samsung Electronics noted that Nigerians bought 41% of the entire smartphones sold in Africa, surpassing South Africa by 10% and the usage is predominant in youths who are less than 30 years, work full time or attend school [13].

The advantages of using mobile technology for education offers diverse opportunities for educators and learners [14]. It can offer control over learning, mobility in terms of where and when education is taking place and offers interaction between students and educators. These advantages are even more significant in developing countries where mobile technology is more abundant [14].

University students in the USA and South Africa access websites through mobile phones, especially amongst the lower income youth who do not own computers [15]. For low-income students in South Africa, a mobile device constitutes their primary connection to the Internet, with 83% of participants accessing mobile internet [16]. Mobile phones among students are predominantly used for social purposes, however, there is an indication of the potential for it to be used for more academic-related activities. Students should engage in more systematic mobile-learning activities to support learning both cognitively and effectively.

In South Africa, the government has turned to modern technology to strengthen teaching and learning and to redress past inequalities in education. The Department of education through its Information and Communications Technology (ICT) policy, has developed guidelines for the distribution and use of digital resources in schools and universities. Previously disadvantaged schools and universities are still struggling to keep up with well-resourced education institutions [16].

To illustrate how the usage of mobile devices have transformed over the years, a study done in 2004 and a follow-up study done in 2013 is discussed. In 2004, a study was performed among 63 student's studying Applied Computer Science. The objective of the study was to find out which mobile devices the students used in education. The results are shown in Figure 1 [14]. The students used notebooks (laptops), and cellular phones equally with smartphones being used the least. In 2004, smartphones were very expensive compared to cellular phones. The platforms, Android and iOS, did not exist yet [14].

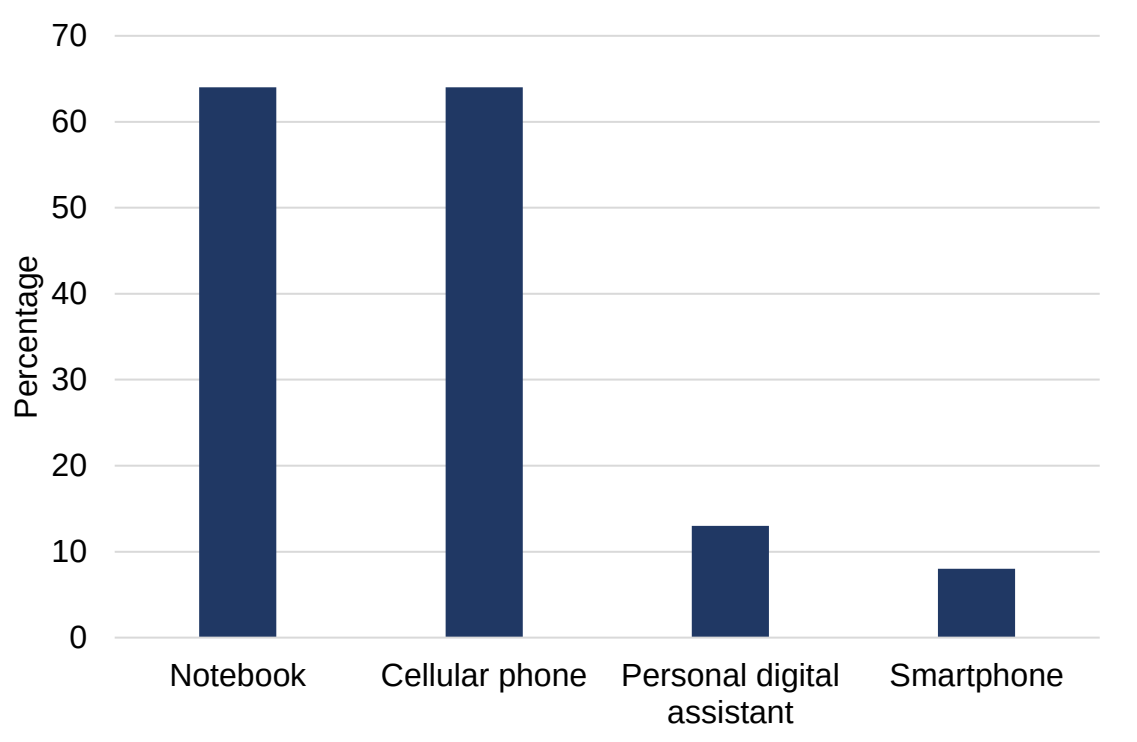


Figure 1: Mobile devices used in education in 2004

The follow-up study was done in 2013 with 113 Applied Computer Science students. The students owning laptops increased from 64% to 89% with only 11% of respondents using a desktop computer [17]. Students therefore preferred using a laptop as opposed to a desktop computer.

Pearson¹ seeks to better understand how university students use technology for learning and their 2015 Student Mobile Device Survey covered the following:

- Current ownership and usage of mobile devices by university students;
- How university students currently use mobile devices for classwork, and how they expect to use them for classwork in the future;
- Students' attitudes towards mobile devices for learning, with a special focus on tablets;
- The devices that students feel they learn best on; and
- Preferences for different types of digital devices when reading, studying, taking notes, and doing other educational-related activities.

¹ <https://www.pearsoned.com/wp-content/uploads/2015-Pearson-Student-Mobile-Device-Survey-College.pdf>

Figure 2 shows the type of mobile devices that students used for their university work in 2015. Laptops are still the most popular used mobile device for classwork as students say they learn best on laptops. More students use smartphones regularly for classwork than tablets and about one in five students uses a hybrid laptop/tablet.

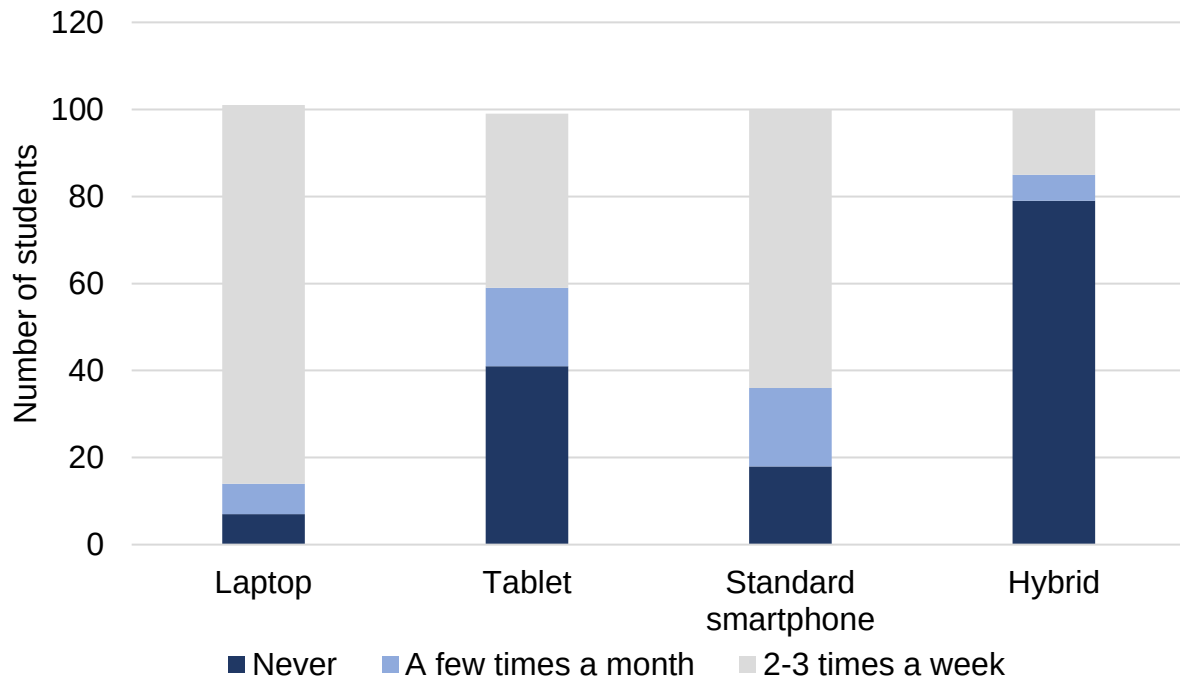


Figure 2: Mobile device usage for university work in 2015

Only 11% say they study more efficiently on a smartphone. One in five students feels that they study more efficiently using a tablet. One in eight students feels that they study the same, no matter which mobile device is utilised

The advantages of using smartphones in education has led to the increase of mobile devices being used in education. The increase in the technology has allowed for developing countries to have access to mobile devices. Even though it has been determined that computers and mobile devices are used extensively in education and in writing, it is important to understand how these devices are being used in terms of reading and writing.

The focus of the study will be on document creation for which reading and writing, especially for research purposes, is a skill and the functionality supporting the skill to read and write needs to be supported by word processing applications and mobile devices in order for document creation and editing to successfully take place.

1.3 Background of word processors used in education

1.3.1 Introduction

The word processing industry has already evolved for more than 30 years. It originally required expensive hardware and software that was only used by big corporate businesses. PC's changed that by allowing households to be able to afford the hardware and software [21]. Before the internet and other PC related applications, PC's were primarily used for word processing and calculations using spreadsheets.

The word processing industry exploded and by 1984, there were over 300 word processing packages for the IBM PC alone [22]. Windows 1.03 was released in 1985 and by early 1989, Windows had sold 2 million copies and was Microsoft's best-selling product [23]. Microsoft Word is considered as one of the most frequently used product of Microsoft's Office Suite.

Today, word processing software allows users to create, edit and print documents. It enables the user to type text that can be displayed electronically on a screen and provides various functions for formatting and editing documents.

The most popular and the world's leading word processing software is Microsoft Word [24] and is used extensively at academic and professional levels [25]. Microsoft offers functions that are superior to the competition, however, Microsoft Word is facing some challenges from Google Docs, WordPerfect and other word processors. The following list is a few basic examples these word processors can perform ²:

1. Create, edit, save and print documents
2. Copy, paste, delete and move text
3. Format text such as bold, underline or italic
4. Create and edit tables and figures
5. Insert images from other software elements

As mobile technology is becoming increasingly common in education, it is important to design educational applications for this purpose. Mobile technology pursues a 'write anywhere' philosophy, encouraging unrestricted typing. This approach is more

² <https://study.com/academy/lesson/what-is-word-processing-software-definition-types-examples.html>

convenient for short documents but is not conducive to the standard editing tools and functions that make word-processors so powerful [19].

While word processing applications have grown in complexity and sophistication since the introduction of computers, usability problems have not disappeared. Most of the mobile user interface designs are based on desktop paradigm, but the desktop designs do not fully fit the mobile context.

1.4 Problem statement

Technology improves the quality of students' reading and writing skills. PCs have been used for reading and writing by students for much longer than mobile devices, however, students now have more access to mobile devices than PCs. Many low-income households do not have access to PCs. Students of these households use mobile devices as their primary source for academic related activities [16].

Many word processing mobile applications are adjusted from their desktop counterparts and are therefore not very usable. Despite the increase in mobile application usage, it is still limited in terms of the educational contribution [22]. Therefore, the need for the study is to analyse the usability of word processing applications on mobile devices.

1.5 Purpose of the study

The main objective of the study is to investigate the usability of word processing applications on different mobile devices.

The sub-objectives of the study include the following:

- To investigate the usability issues of different mobile devices
- To propose the optimal mobile word processing application and device specifications to use to create and edit documents
- To provide suggestions for future word processing mobile application development

1.6 Layout of the study

Chapter 1: Introduction

This chapter introduces you to the purpose of the study by providing the necessary background information.

Chapter 2: Literature Review

This chapter provides an overview of existing research on mobile devices, mobile word processing applications and usability studies.

Chapter 3: Method

This chapter provides the method to address the purpose of the study.

Chapter 4: Validation of results

The results from executing the method is provided in this chapter.

Chapter 5: Conclusion

This chapter concludes the study and provides recommendations for future studies.

The introduction provides insight and background into the role that technology has in education and how computers and mobile devices are currently being integrated into educational institutions. It has been established that there is a need for utilising mobile devices in education in developing countries and that the devices need to be used for creating and editing documents.

Chapter 2: Literature Review

This chapter provides an overview of literature that provides context to the need of the study. This includes analysing the usability of word processing applications on different mobile devices

2. LITERATURE REVIEW

2.1 Preamble

The main objective of the study is to investigate the usability of word processing applications on different mobile devices. Mobile word processing applications are based on PC paradigm and therefore it is important to understand the differences between PCs and mobile devices.

2.2 Comparison of PCs and mobile devices

In Figure 3 and Figure 4, the hardware and software components of a PC and mobile device used for reading and writing are shown respectively. As mobile technology is becoming increasingly common in productivity and education, it is important to design educational applications for this purpose. It is therefore important to understand what makes mobile devices different from the PC.

Different characteristics of PCs and mobile devices are discussed such as power consumption, price, screen size, portability, storage, connectivity, operating systems and data entry. Each device has pros and cons in terms of these characteristics when creating and editing documents and should therefore be considered when choosing a device for this purpose.

Mobile devices include smartphones and tablets.

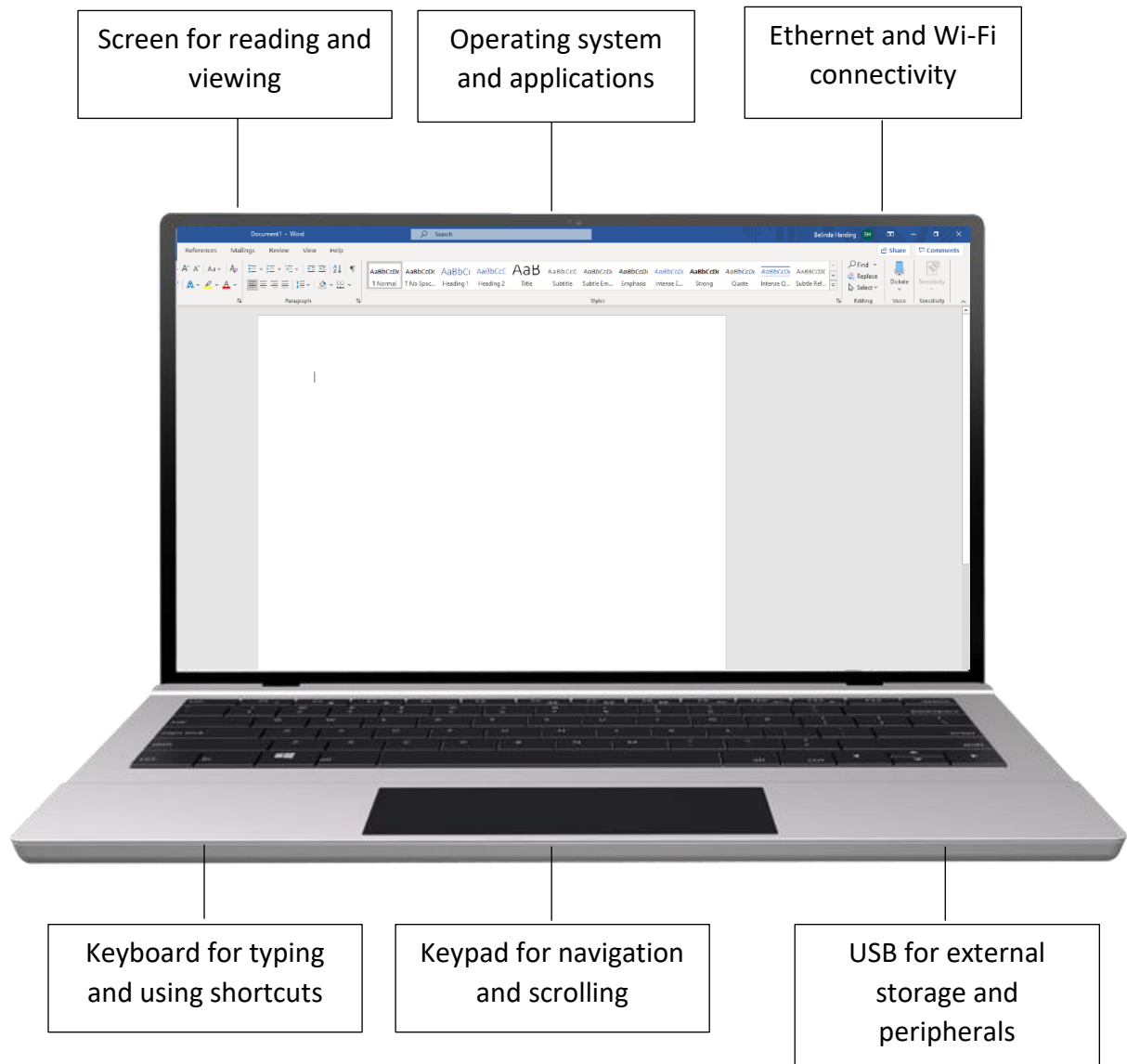


Figure 3: Hardware and software components of a PC

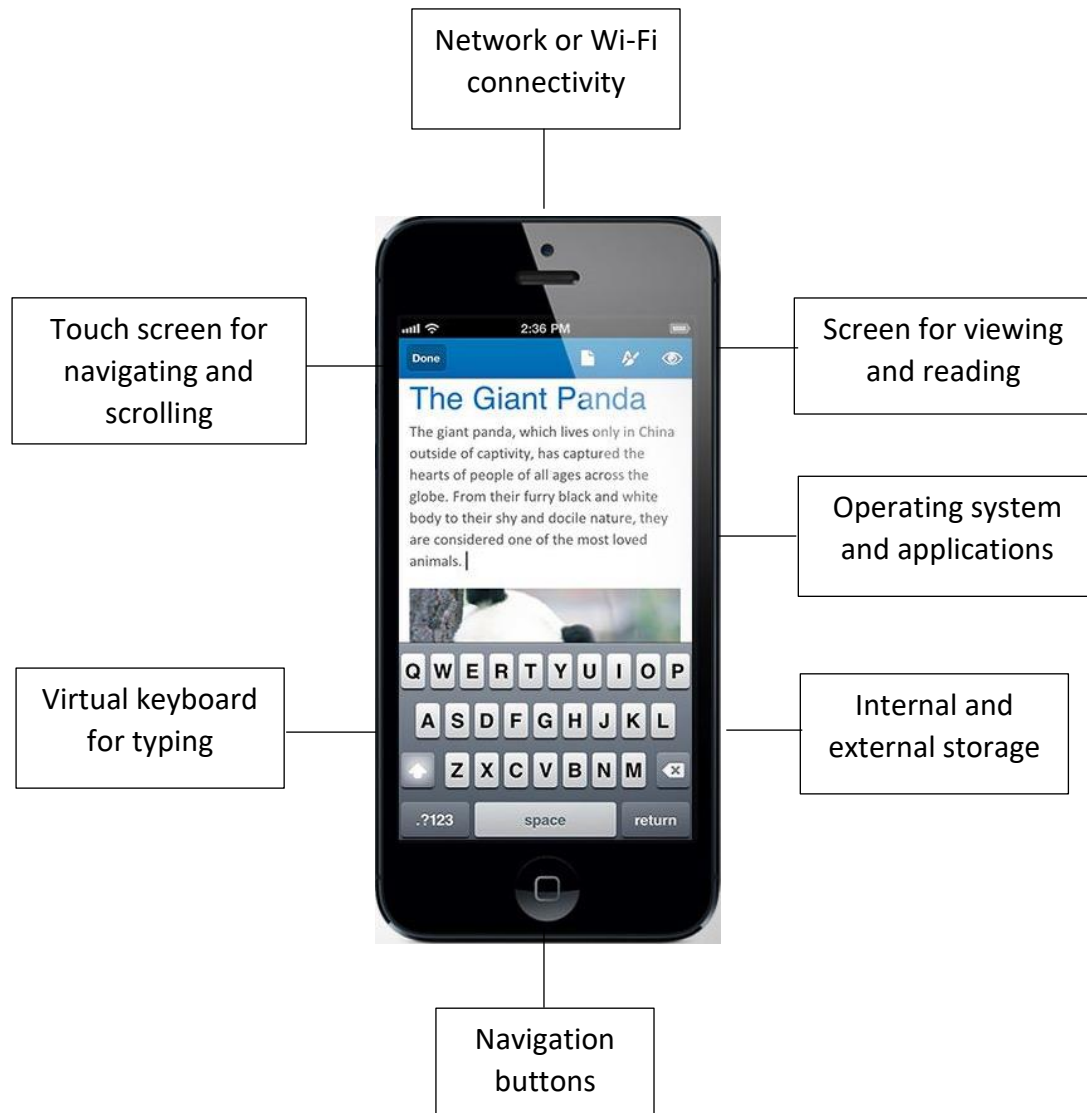


Figure 4: Hardware and software components of a smartphone

Power

The central processing unit (CPU) of a computer requires a lot of power. Desktops need a constant power supply and generate a lot of heat, requiring heat sinks and cooling fans. Mobile devices use batteries for power and therefore do not provide as much CPU power as a desktop or laptop. Smartphones and tablets battery power lasts longer than a laptop because of the power the CPU requires³.

Cost

Computer prices vary, based on their capabilities. A mid-range computer can cost R5000 and a high range can cost R30 000. Smartphones are usually on contract with a service provider. A bottom of the range smartphone can cost R500 while the new Samsung's and iPhones can cost R16 000.

Screen size

Desktops can connect to multiple display monitors. Laptops have screen sizes predominantly in the range from 13" to 17". Mobile devices are much smaller than desktops and laptops. The physical sizes may vary from 3-6 diagonal inches for a phone and 9-12 diagonal inches for a tablet. A smaller device results in having less screen real estate therefore, the user can see less information at once.

Portability

Desktops are not meant to be portable. It requires a large amount of space to set up when compared to mobile devices. Mobile devices are designed to be portable and can fit into a purse or pocket.

Storage

Computer hard drives range from 250 gigabytes (GB) to 1 terabyte (TB) and can even exceed that. They can also have additional internal or external hard drives. Mobile devices have built in storage ranging from 8 GB to 64GB. They offer less storage than desktops and laptops, however, cloud computing can be used to store and manage data and therefore the need for large storage devices is less.

³ <https://www.computerhope.com/issues/ch001398.htm>

Connectivity

Most desktops and laptops include Wi-Fi and Ethernet networking capabilities. Mobile devices can connect to Wi-Fi networks. Alternatively, they may be used on a mobile data network. The advantage of mobile is that they can use a data network when there is no Wi-Fi available.

Operating system

Operating systems on desktops and laptops are fully featured as they take advantage of the processing power of CPUs. Popular mobile operating systems include Android, iOS and Windows Mobile. These OS systems do not offer complete access to system hardware and have stricter hardware requirements.

Data entry and user input

Desktops use external inputs such as a keyboard and mouse. A laptop has a keypad that can be used instead of a mouse. A desktop keyboard is easier to use because the user has access to the keys by using all 10 fingers. Mobile devices use touch-based input, this creates a few implications for designing mobile device applications.

Text entry is one of the most problematic tasks in smartphones due to the screen real estate. Bluetooth keyboards can be used with mobile devices, but this is not common practice and it will add to the cost of the device. Therefore, it is not considered for the purposes of this study.

Using gestures however, enhances the users experience on a mobile device [18]. Word prediction is an assistive tool which aims to reduce the number of keys pressed, based on words previously typed. Word prediction is used in mobile devices to increase accuracy and typing speed [19].

Desktop word processing programs include spell-check, such as in Microsoft Word, that allow the users to correct the misspelt word. Mobile devices have auto-correct which is a much more effective tool than spell –check as it automatically corrects the word for the user.

The background information provided above gives insight into the difference between PC's and mobile devices in terms of reading and writing. The hardware and software properties of PC's make PC's more operational than mobile devices, however. PC's are still expensive, and many developing countries do not have the resources to implement computer systems in educational institutions. Mobile devices are therefore a viable option and thus makes it important to understand what needs to be done to integrate mobile devices into reading and writing environments.

2.3 Text input methods on mobile devices

The functions of word processors require text input from the users and there are currently 3 input methods available, soft keyboard (QWERTY), speech to text and Swype as shown in Figure 5.

Soft keyboard was the first input method; users need to use two hands to type quickly which was found to be difficult whilst 'on the move'. It is the most popular keyboard layout as its functionalities are similar to a desktop. The layout is not feasible as user typing errors often occur [26].

Speech to text and Swype were developed to address this problem with examples given in Figure 5; these input methods allow single-hand text input. Swype allows users to swipe their fingers across the keyboard to form words and the mobile application attempts to predict the word.

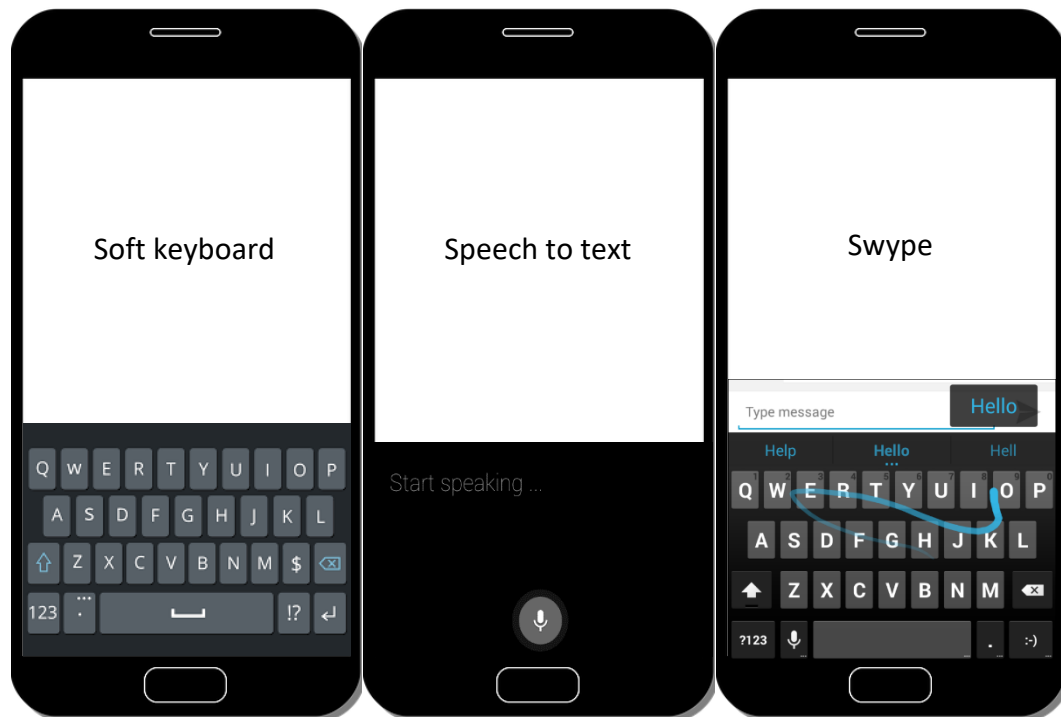


Figure 5: Three methods of text input

Speech to text has taken on new importance in addressing user needs for ubiquitous mobile access. Google is making speech to text their goal to make access to the technology ubiquitously available [29]. Their developers claim that such text input methods improve on text input as the soft keyboard is considered inaccurate on very small smartphone devices [30].

A soft keyboard is the most efficient for typing short pieces of text [27], between 14 – 30 characters, however, speech to text outperforms soft keyboard for longer text. Swype is becoming more popular among users as it enables faster text input than soft keyboard and is more discreet compared to speech to text [27]. The use of word prediction has been found to sometimes decrease the typing speed because it may take longer to select the word from the list [28].

Text editing is not a very common task on mobile devices as it can be difficult due to the size of the screen. Unlike a desktop keyboard, there are no key shortcuts that can be used. Text editing on a touchscreen device is currently performed through a Widget-based method. Users enter text using a soft keyboard and move the cursor by

tapping on the screen at the desired point. A long press makes a menu appear over the text that allows the user to perform editing operations [31].

A new gesture-based editing technique was presented in a study by G. Costagliola, M. De Rosa, and V. Fuccella [31]. Users can perform editing operations such as deleting and moving text more efficiently. The technique was designed by considering the most natural gestures for users. Their results showed a performance improvement of 13 to 24 % for the gesture technique. Positive feedback was also received from the participants and they stated that it can be mastered in a short period of time. Gesture-based editing can be added to any soft keyboard without interfering with the experience of the user that chooses not to use it. The results also show that the gesture-based editing technique produces better results than the traditional one, when the text font size increases [31].

The more an application relies on gesture controls, the less buttons need to be placed on the screen leading to more space for more important content. This makes the application more content focused, however, the biggest disadvantage to gesture controls is the learning curve.

The functions of word processing applications are usable on PC's because of the characteristics of PC hardware and software. It is important to understand how these functions work with mobile specific characteristics in order to ensure that the mobile word processing applications are usable.

2.4 Usability studies

2.4.1 Introduction to usability studies

Usability testing is applied to evaluate the usability of a product by testing it on users. This testing technique is important as it gives direct input on how actual users use the system. Usability testing methods include surveys, questionnaires and observation and heuristic evaluation [34]. Questionnaires and interviews determine users' preferences and how they feel about the product. Observation simply involves the user to perform tasks and then to observe how the user interacts with the product. Heuristic evaluation is a usability engineering method where a set of test facilitators analyse the product and judge its compliance with recognised usability principles.

This section discusses the usability of word processing applications and the usability of mobile devices.

2.4.2 Usability

Word processing software needs to be tested and evaluated, to ensure it can perform the functions as mentioned in section 1.3.1, in a user-friendly environment. Application usability forms an integral part of application uptake and user retention. This section provides insight into how application usability is evaluated.

The demand for quality software applications is rising. Quality software is necessary for satisfying the consumer demands. Researchers have developed many quality models for measuring and assuring quality and these models emphasise usability as the main quality factor [32].

According to the ISO 9241-11 standard, usability is defined as follows: “the extent to which a product can be used by identified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” [35]. In literature, there are other ways of defining usability. Nielsen [36], who is an expert in web usability, provides five dimensions: learnability, efficiency, memorability, errors, and satisfaction. Shackle [37] provides four dimensions, which are effectiveness, learnability, flexibility and attitude. Table 1 shows how the usability dimensions of Nielsen have been categorised into the 3 ISO guidelines [38].

Table 1: Usability measurements

ISO 9241	Nielsen
Effectiveness	• Consistency and Standards • Error prevention
Efficiency	• Flexibility and efficiency of use • Aesthetic and minimalist design • Help users recognize, diagnose, and recover from errors
Satisfaction	• User control and freedom • Visibility of system status Match between system and the real world • Recognition rather than recall Help and documentation

In 2006, Hornbeak [39] evaluated the usability measurements, effectiveness, efficiency and satisfaction by reviewing and categorising 180 studies on usability [39]. Problems were identified with the usability measurements and that increased attention to the problems may strengthen studies of usability. Below are some of the current practices identified in measuring usability.

Effectiveness is measured by whether the user successfully completed a task or not. A user should not spend a lot of time completing a task. Effectiveness can also be measured by accuracy which quantifies the number of errors users make while completing a task. Of the studies evaluated, 22% did not include any measure of effectiveness.

Efficiency is a measure of the time taken to complete the task and the navigational cost (number of steps or taps) required to complete the task. The benchmark navigational cost is the minimum number of steps or taps required to complete a task. Of the studies evaluated, 57% measure time as task completion time.

Measurement of efficiency includes text input rate which measures the average number of texts correctly entered by the user. Time is considered a resource of which successful applications minimise consumption, however, some studies suggest that an increase in completion time is considered to indicate motivation and engagement on the task.

Satisfaction measures the level of satisfaction of the users after completing a task or test. The user satisfaction is measured through standardised satisfaction questionnaires. Task level satisfaction is measured by giving the user a questionnaire directly after each task (post-task). The goal is to provide insight into task difficulty as seen from the user's perspective. Examples of post-task questionnaires are:

- ASQ: After Scenario Questionnaire
- SMEQ: Subjective Mental Effort Questionnaire
- SEQ: Single Ease Question

Test level satisfaction is measured by giving a questionnaire at the end of each test session. The goal is to measure the users' impressions of the overall ease of use of the system being tested. Examples of test-level questionnaires are:

- SUS: System Usability Scale
- QUIS: Questionnaire for user interaction satisfaction
- SUMI: Software Usability measurement inventory

Many of the studies Horbaek [39] evaluated did not give details on the questionnaires used for assessing satisfaction. There are challenges with measuring usability and these challenges are identified as the following [39]:

- Subjective and objective measures of usability:
Both subjective and objective measures need to be considered as they may provide different insights into the usability of the application. The challenge is, to evaluate the relation of subjective and objective measures such as, objective measures of satisfaction versus subjective satisfaction questionnaires.
- Measures of learnability and retention:
Nielsen [36] recommends measuring learnability, efficiency, memorability, errors and satisfaction. Little is known about the usability of applications that are used repeatedly, therefore the measure of retention of the application is important in gaining a more complete measure of usability.

- Measures of usability over time:
Most usability studies are performed within 30 minutes, therefore understanding how usability changes over time, should be considered.
- Extending, validating and standardising measures of satisfaction:
Studies conducting usability tests should use standardised questionnaires and the satisfaction measures should be validated by drawing correlation between the different usability measures.
- Studies of correlations between measures:
Issues may rise with a weak understanding of the correlation between usability measures. Some of the studies reviewed showed interesting correlation between usability measures. A study in the context of web application showed the correlation between mouse clicking and satisfaction; less clicking leads to more watching, therefore engaging in the web experience more.

Designing applications for mobile use as opposed to desktops is popular because of the rapid increase in mobile device usage. The design process has changed for these devices and therefore the usability of mobile devices has become a significant issue [33].

The usability of the word processing mobile applications are an important issue since it helps the mobile applications to be user friendly, increase productivity, reduce the cost for training, and improve the user satisfaction [40]. Usability and functionality are key to the success of mobile applications.

2.4.3 Application Usability

Microsoft and Google Docs are frequently used by students. Microsoft is one of the fundamental word processing tools that most students are accustomed to. However, Google Docs, a web-based platform, is new and may even outperform Microsoft Word.

Web apps is a mobile application that is accessed through a web browser such as Chrome. Example of web apps include Wikipedia and Facebook. A native app is a mobile app programmed for a specific device such as Android or iOS. Hybrid apps are

installed like native apps but are programmed to function like web apps. Examples of hybrid app include Instagram and Evernote⁴.

A study done by S. Dedilva et. al. compared the usability of Microsoft Word and Google Docs on the laptop [41]. After conducting the usability test, it was found that Microsoft Word was the preferred application. However, the authors stated that it may be as a result of users being more accustomed to Microsoft Word, thus users did not have to undergo the discoverability and learnability process.

Discoverability refers to the degree of ease with which users can find features within an application. Learnability refers to the ease with which users can learn to use the features within an application. There are a few factors that affect the execution of learnability in applications⁵:

- Users will put in more effort into learning an application if they know they are going to use it regularly.
- Learnability is sometimes delivered in proportion to the cost of the application. The higher the price, the more time users are willing to spend learning the application.
- Learnability and complexity are relational. The less complex or fewer features an application has, the easier it should be to learn.

Most studies make no attempt to measure learnability as it is very difficult to measure. A study done by B. Sheeshan et. al. assessed learnability by measuring the number of hints, prompts, and errors experienced by users as they completed website tasks [42]. Learnability can also be measured by determining how many times a user performs a task to completion. The need for users to discover features in an application becomes critical on a mobile device as limited screen real estate requires different design approaches when compared to the desktop.

⁴ <https://www.mobiloud.com/blog/native-web-or-hybrid-apps/>

⁵ <https://www.interaction-design.org/literature/article/make-it-easy-on-the-user-designing-for-discoverability-within-mobile-apps>

A usability study of smartphone applications, conducted by Nielsen Norman group in 2009 and reported by Iqbal [43], resulted in a 59% successful completion rate with 3 usability issues identified including efficiency, screen size and text insertion.

The aim of the study done by N. A. Ismail et. al. was to provide a set of usability issues of different genre-specific mobile applications namely, education, health and tourism [44]. The issues relating to educational applications include flexibility, minimal action, affordance, visibility, user-friendly, consistency, aesthetics, intention of use, ease-of-use, convenience, learnability, user satisfaction and task-technology fit.

These studies show that well-established applications built using a contemporary set of guidelines have usability issues. This may be due to the fact that the set of guidelines used to develop mobile applications were not designed specifically for mobile devices [40].

Usability guidelines are used by application developers in developing usable smartphone applications. The usability guidelines range from generic, designed for any genre application, to genre-specific which is designed for specific applications. Generic guidelines were initially developed for desktop applications and then adapted for smartphones. Generic guidelines include: Nielsen's general guidelines; Shneiderman's Eight Golden Rules of Interface Design; Gerhardt-Powel's Cognitive Engineering Principles; and Weinschenk and Barker classification [40].

Genre-specific guidelines address specific categories of applications such as health applications and news applications [40]. The problem with genre-specific guidelines is that it is difficult to apply to other types of applications. N. Ahmad et. al. developed a comprehensive list of usability guidelines suitable for multiple platforms and genres of smartphone applications. It was noted that even popular and established applications have usability issues. The study's systematic literature review resulted in 148 studies that comprised a total of 359 usability guidelines. These guidelines were then condensed into 25 guidelines in 7 categories by removing redundancy, repetition and similarity through a sequential and iterative process.

The list of the generic guidelines is given as follows:

1. Navigation
 - a. Use clear consistent navigation
 - b. Provide visible and well-defined buttons for easy navigation
 - c. Reduce navigation by providing hierarchies and menus
 - d. Minimize scrolling through search button
 - e. Provide complete control to the user so that they can exit or go back at any stage.
2. Content
 - a. Do not use objects which provide different meanings
 - b. Use terms that are related to the real world
 - c. Content should be brief and specific
 - d. Avoid use of fast-moving objects and animations
 - e. Visited items should be distinguishable
 - f. Provide thumbnail at each page.
3. Error handling
 - a. Provide error prevention, by confirming 'before commit' an action
 - b. Error messages should be simple and easy to follow
4. Input method
 - a. Minimise number of keystrokes while doing input.
5. Equitable use
 - a. Provide relevant graphical and voice assistance
 - b. Provide same functionality for different screen orientation and size.
6. Cognitive load
 - a. Provide little and homogenous information in modules to avoid cognitive load
 - b. Similar and minimal steps or actions should be required to complete a task
 - c. System status should be visible through proper feedback.
7. Design
 - a. Design should be attractive but avoid using too many colours and animations

- b. Colour contrast of background and front content should be visible
- c. Avoid fancy font styling
- d. Design should be consistent and should follow conventions
- e. Limit number of screens and provide proper title for each
- f. Direct physical touch enhances user satisfaction.

Other factors, other than usability, affect student's decisions in selecting applications to meet their requirements. Responses from students indicated that the price of the application plays an important role as respondents had either very limited monthly income or no income at all [45].

The mobile device memory is an important factor to consider as it influences the performance of the application, therefore, an important secondary consideration was the size of the actual application. The size of the application and the amount of resources it utilises while in use, consumes too much battery life or memory on mobile devices, which causes frustration about the performance.

Other equally important factors users considered were the number of features the application had to offer, the star user rating of the application on the application stores, and the app's description. It becomes evident that feedback which gives an application a better rating is considered more helpful by users, who then rate these positive reviews as more helpful. The least important factors that users considered when downloading applications were the number of users that have rated the app, and the number of users that have already downloaded the app.

The security risk was an issue raised by respondents. In 2014, 51% of the respondents indicated a concern with security risks that come with downloading applications. The risks associated with downloading mobile applications are factual as a MetaIntell study found that 92% of the top 500 downloadable Android applications carry security or privacy risks [45].

Understanding application usability and how it is measured is important for developing user-friendly word processing software, however, the hardware aspect of mobile devices should also be considered when evaluating usability.

2.4.4 Device Usability

To investigate the usability of word processing applications on mobile devices, device usability needs to be considered. Word processing software can be used on various mobile devices, however, mobile devices differ from one another in hardware and firmware capabilities and this affects the usability of word processing applications. It is important to understand the different types of mobile devices and how their characteristics determine the usability of the device.

The rapid development and adoption of mobile devices gives rise to new usability challenges given their unique design and limitations. The traditional methods of measuring usability needs to be adopted to fit mobile devices [46].

The classification of mobile devices adopted by this research [47], categorises mobile devices according to the following criteria:

- Size and weight
- Input modes
- Output modes
- Performance
- Kind of usage
- Communication capabilities
- Type of operating system
- Expandability

Figure 6 shows different devices that are in use today. The category of mobile devices includes the following devices:

- *Smartphones* are great communication devices and are the most portable of all mobile devices
- *Tablets* are less portable than smartphones but offer a range of advantages such as bigger screen sizes.
- *Personal Digital Assistants* are being phased out and being replaced by smartphones.
- *Laptops* have the most processing power but are the least portable of the mobile device options

- *Netbooks* are more compact than laptops and therefore are less processor intensive. ⁶



Figure 6: Desktop and mobile devices in use today

The market is flooded with mobile devices and it is difficult to know how these devices differ from one another and which device will meet the user's needs. It is important to understand how the hardware components affect the performance of mobile devices and applications. Figure 7 shows the different hardware components of a mobile device.

⁵ <https://rekalltech.com/how-to-get-the-most-out-of-your-website/>

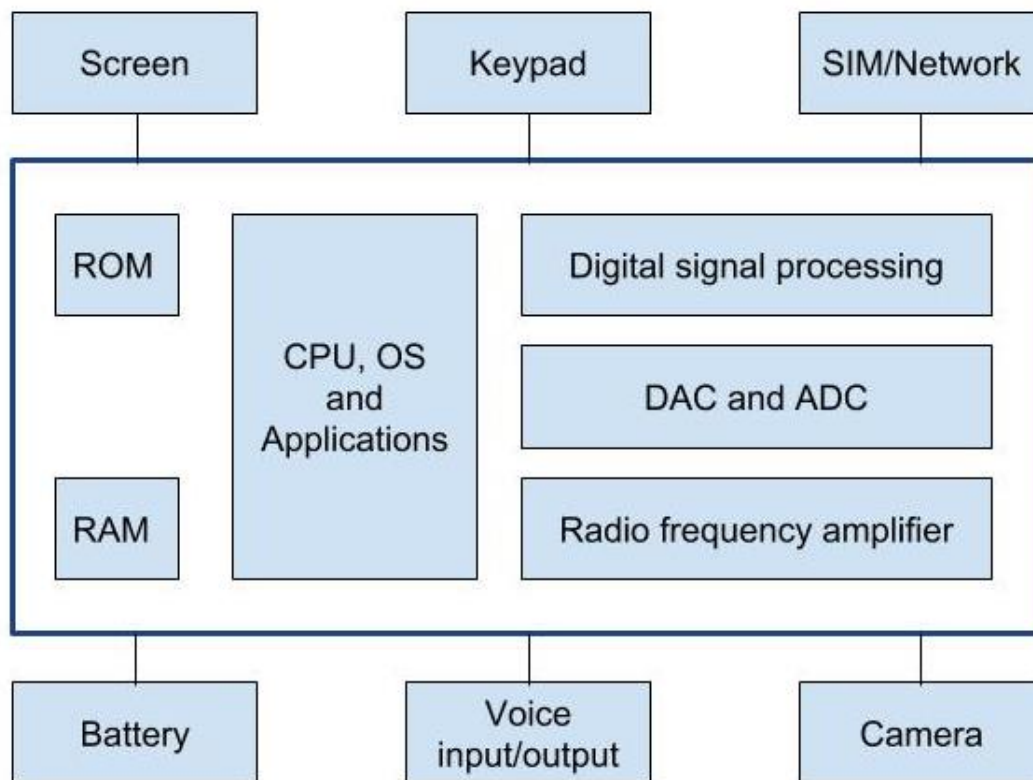


Figure 7: Hardware components of a mobile device

The following points discuss the different hardware features of mobile devices and which features influence the usability of mobile device.

Screens

A study by T. Tsai et. al. focused on testing the usability of gestures on 3 different smartphones. Regarding the display size, the subjects had a faster response time in operating the various gestures on the 5-inch or 6-inch phone. The study suggests that operating gestures on a smartphone display of 5-inch or larger is recommended [48].

A study done by S. Adepu et. al. demonstrated that screen size impacts task performance. The larger the screen size, the higher the task production, however, not all tasks may benefit from larger screen displays. Future work should examine performance and preference across devices in other tasks[49].

An experiment conducted by E. Alghamdi et. al. measured the impact of smartphone screen sizes on user comprehension and retention. The results showed that there was

a significant difference between the screen size and the time taken to read the contents. Reading was found to be the hardest on small screens, however, the organisation of the application's information was better. There was no significant difference on the user comprehension, retention scores, number of errors or effective task completion. The study concluded that screen size is not the main concern in comprehension of the contents or application structure, however, the reading speed does improve with larger screen sizes [46].

CPU

The CPU (central processing unit) is the brain of the device. The CPU receives data input, executes instructions and processes information. It is important for a mobile device to execute instructions quickly for user satisfaction. A study done by M. Halpern showed how mobile CPU design trends have developed over time and enabled more advanced mobile applications to be developed; therefore making users more satisfied over time [50]. When a user taps a button within an application on a mobile device, they expect it to respond immediately. If there is a slight delay due to slow processing speeds, then the user is tempted to press the button again or even to restart the application.

C. Gao et. al. showed that current mobile applications do not effectively use many processing cores. Instead, they suggest that a system that can accommodate both high performance and good energy-efficiency is a more practical choice for current mobile applications [51].

Battery

The battery life of a mobile device is one of the most important features because devices are portable and therefore users are not always at a power point if the battery is low. The major cause of power consumptions is the LCD screen vary between 50% and 80% of the total energy consumption. That is due to the screen usually being turned on as the touch screen is the preferred input/output device [52]. The other major cause of power consumption is network usage.

Random Access Memory (RAM)

RAM is the memory that a mobile device uses whilst in operation. A phone with more RAM has a quicker response time to inputs and outputs and is good with running many applications simultaneously without crashing the software. User satisfaction decreases if there is a mismatch between the requirements of an application and the response time of the RAM [53].

Users require more RAM in the mobile device to load more complex applications and perform better task-switching between applications, manufacturers are required to meet their demand by increasing the RAM of mobile phones.

Network

Mobile devices are typically connected through Wi-Fi or service provider networks. Students typically use a Wi-Fi network to download applications because of the large sizes of applications. Access to Wi-Fi also impacts consumption of video via smartphone; one-third of students indicated that they would never download a video when not connected to Wi-Fi [54]. A general problem for mobile applications is an unreliable network connection with minimum bandwidth [55]

Software

The operating system of a mobile device is software that supports the device's basic functions. A study done in 2014 by K. Bala et. al. described the Android architecture, Android operating system and its main features. They compared Android with different operating systems such as Apple's iOS, Nokia's Symbian & Blackberry's OS. From their study, they concluded that Android is better than the other operating systems. However, due to Android's open source OS, Android has some limitations which leads to malware attacks like virus, worms, spyware, adware and Trojan horse [56].

The study also presented a detail review on the latest and upcoming operating systems for 2014 like iOS 7 (Apple), Android 4.4 KitKat (Google) and Windows 10 (Microsoft). They compared updated features, facilities, performance and verdict surrounding these operating systems. From market share analysis conducted during December 2013, they found that Android got 81.3% and is the best Smartphone OS in the world today [56].

Previous studies on the usability of mobile devices have focused on specific applications and not on the device [42]. B. Sheeshan et. al. examined the usability of 4 commonly used mobile devices for accessing healthcare information. The devices included an iPhone, an Android with touchscreen keyboard, an Android device with built-in keyboard, and an iPad. They compared the effectiveness and efficiency of each device. It was found that the iPhone was the most usable as users made less errors while executing the tasks [42].

A design challenge, is to provide consistent experience to users, therefore regardless of the size of the mobile device, the experience needs to be similar for a good user experience. It is easier for users to interact and engage with different devices if they know what to expect if they have used the application before⁷.

2.5 Conclusion

The main objective of the study is to investigate the usability of mobile word processing applications. A comparison of PCs and mobile devices showed the differences between the devices. Text entry is an important component in mobile devices and has an impact on the usability of word processing applications. The generic guidelines were developed to address the need for a set of guidelines to address all genre applications. These guidelines will be used to validate the results of the usability tests as designed in Chapter 3.

The studies mentioned in Section 2.4.3 and 2.4.4, tested different aspects of software and hardware. Testing different applications require different test setups and usability requirements. A usability test should be designed to test the specific user requirements of the application. This is discussed in Chapter 3.

⁷ <https://www.lollypop.design/blog/2017/july/designing-for-different-screens-and-devices/>

Chapter 3: Methodology

The literature studied in Chapter 2 is used in this chapter to develop a methodology with the aim of investigating the usability of word processing applications on mobile devices. Different usability testing methods are discussed, and two usability studies are setup:

Study 1 investigates the usability of word processing applications on mobile devices

Study 2 investigates the usability of mobile devices.

3. METHOD

3.1 Preamble

In this chapter, the methodology of the study is explained in detail. The aim is to investigate the usability of word processing applications on mobile devices. To this end, the methodology is separated into two studies, Study 1 and Study 2, and each study has its own design, data collection and data analysis procedures. Before executing Study 1 and 2, an online preliminary survey was distributed to university students to determine the preferred device when given specific scenarios. The results of the survey are given in Section 4.2

Study 1 investigates the usability of word processing mobile applications. Qualitative and quantitative methods are used to gather the data. The data is analysed using statistical analysis and the mobile application with the least usability issues will then be used in study 2. The usability issues found are mapped to the generic guidelines to determine whether a word-processing genre-specific set of guidelines is needed.

Study 2 investigates the usability of different mobile devices. The most usable word processing application determined from study 1 will be used to perform the tasks of study 2. Qualitative and quantitative methods are used to gather the data.

The purpose of the study is to find out what the factors are that effect writing in the mobile environment by looking at the different software (Study 1) and hardware (Study 2) options.

3.2 Preliminary questionnaire

An online preliminary questionnaire was distributed to university students. The objective of the questionnaire is to determine the preferred device when given specific scenarios. The scenarios include the following:

1. Which devices do you use the most to read text messages?
2. Which device do you use the most to read emails?
3. Which device do you use the most to read short pieces of text such as a news article?
4. Which device do you use the most to read longer text such as reports?
5. Which device do you use the most to type a text message?
6. Which device do you use the most to type emails?
7. Which device do you use the most to type a single page document?
8. Which device would you use the most to type a large document (More than 2 pages)?

The questionnaire is used to determine which device students prefer to use for reading short pieces of text, reading long pieces of text, typing short pieces of text and typing long pieces of text.

3.3 Study 1: Word processing mobile application usability study

3.3.1 Introduction

Understanding what makes applications and devices usable is important in creating a successful word processing application. Understanding usability requires usability testing. Usability testing is a process that involves participants or users who are representative of the target population to evaluate the degree to which a product meets specific usability criteria [57]. The goal of usability testing is to find as many usability issues as possible during the testing procedure. Factors that affect the mobile application usability include participants, tasks, equipment and the environment.

3.3.2 Participants

Demographic characteristics of participants refer to the personal characteristics such as:

- Age
- Gender
- Study level
- Mobile OS ownership
- Knowledge of device or app
- Amount of time spent on a device

Many studies have shown that gender plays an important role in technology adoption. When males decide to use a mobile device, their decision is often strongly influenced by the perceived usefulness of the device in comparison with others, while ease of use is the major variable influencing females' decisions. Pew Internet (2014), reported that smartphone adoption differed greatly across gender and age groups, and surprisingly, with high diffusion among older age groups [13]. However, the study found no significant differences in terms of demographic characteristics between the respondents and non-respondents [58].

The study found that student device ownership was largely focused on two smartphone platforms, Android-based phones and iPhones, which together represented 83% of the survey responses. Android (43%) was slightly higher than iPhone (40%). It is important to note that while iPhone represents a specific device with iOS as the operating system, Android represents many different devices and manufacturers [54].

The larger the number of participants, the higher the accuracy and number of usability issues found will be. It is however difficult to gather many participants. For such a study A. Kaikkonen et. al., found that a minimum of 95% of the usability issues were found with 20 participants and variation between the groups was small [59].

For this study, the criterion for selecting the participants includes that they should be studying in the EBIT (Engineering, Built environment and IT) field and be familiar with

smartphones. A total of 40 postgraduate engineering students were selected from the North West University and the details of the participants are shown in Table 2.

Forty were selected based on gender, age, which OS they use and whether they had any prior experience working in the word processing application selected for the study. The aim of this is to test whether these factors influence the usability study of the applications and the results are discussed in Chapter 4.

Table 2: Participant details

Category	Frequency	Count	Percentage (%)
Gender	Male	27	67.5
	Female	13	32.5
Age	20 - 24	26	65.0
	25 - 30	14	35.0
OS	Android	29	72.5
	IOS	11	27.5
Experience	Yes	13	32.5
	No	27	67.5

3.3.3 Tasks

The usage of smartphones and desktop computers is dependent on the type of tasks performed, therefore it is important to define the tasks that the user is required to perform to measure usability. The scenario-based task description is a useful approach for building mobile device tasks to simulate certain mobile environments. Text entry is one of the most problematic tasks in mobile devices, and testing the usability of text entry is necessary to improve the performance of this task [18].

Research done on users, revealed that high performances are achieved for reading tasks and lower performance for typing tasks on smartphones. Tasks which were difficult to complete and require scrolling showed significant differences in efficiency. Users expressed frustration at performing search tasks with PDA devices, saying they would not use it in this way [49].

Written research requires a specific process and layout to be followed depending on the field of study and learning institution. The following characteristics of a research study were used to develop 6 tasks to be performed by the participants:

- Conduct research – A research document is based on the work of others.
- Collect and visualise data – Research needs to be valid and verifiable and this can be done by providing data.
- Create a structured report – A systematic approach is used to carry out research and is documented so that the procedure can be replicated.

Each participant performed the sequence of tasks on a smartphone. As shown in Figure 8, Task 1, 4, 5 and 6 were performed in the word processing applications. Task 2 and 3 were performed in Google Chrome. There are 3 variations of the tasks to avoid participants from learning the tasks as they progress through the study. The tasks and the variations are attached in Appendix B.

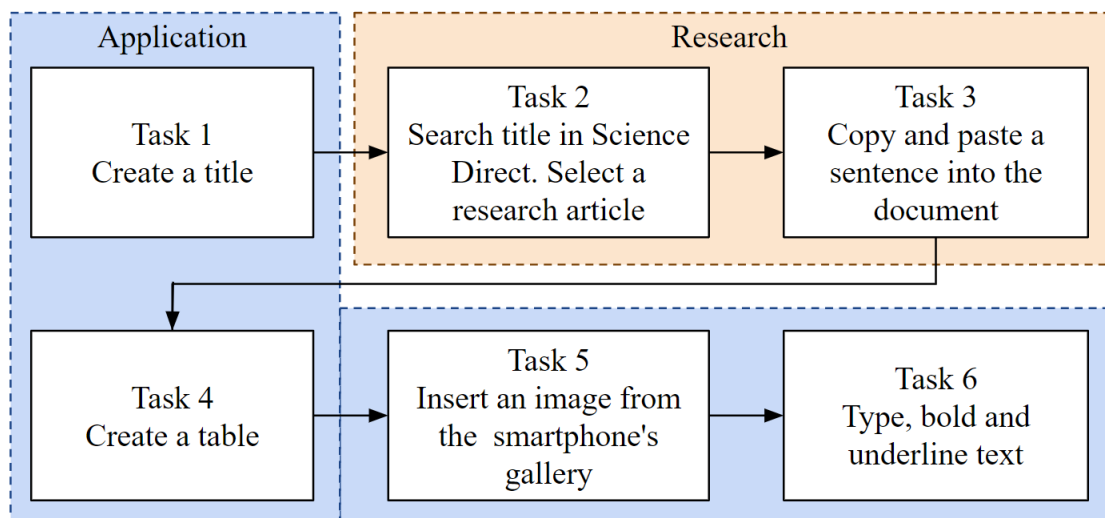


Figure 8: Sequence of tasks to be performed

Task 1

Each research article requires a structure such as titles and headings and therefore Task 1 is to create a title of the document. Each word processing application has a function that allows the user to create a title. This task will test the applications features and the users text input.

Task 2

The task requires the participants to exit the word processing application and open Google Chrome on the mobile device. The Science Direct webpage was already setup for the participant as the purpose of the study is not to test the usability of using the internet on the mobile device. The participant searched for the title created in Task 1 and selected a research article.

This task is setup to test the devices' characteristics such as the CPU and RAM as application switching requires the devices to load a new page. This will also test how users experience application switching with different mobile devices.

Task 3

The participants were required to select a sentence from the research article and copy and paste the sentence into the document under the title created in Task 1. This task will test the native selection of the devices and how usable the copy and paste functions of the editor are. A native mobile application is a smartphone application that is coded in a specific programming language, such as Objective C for iOS or Java for Android operating systems⁸. This study only considers Android devices.

Task 4

A research article requires data to be presented in a visual manner and therefore this task required participants to create a table. Each word processing application has a different way of creating tables and therefore the procedure for creating a table could not be learnt. A table was selected as not all the word processing applications are able to create charts or graphs.

⁸ <https://www.techopedia.com/definition/27568/native-mobile-app>

Task 5

The participants were required to insert an image from the smartphone's gallery. This tests the mobile application's ability to integrate with other smartphone functions such as the gallery. This task also tests the applications ability to insert and display an image.

Task 6

To generate a research article, a researcher is required to convey the method and results in a logical format such as a research document. This task requires making use of basic editing functions. The participants were given 2 to 3 sentences to type. This is usually longer than a simple text message and it tests the applications ability to receive and display long text. The participants were then required to bold and underline certain text. This tested the editing tools of the word-processing applications.

Table 3 shows the minimum completion rate and navigational cost of each task for each application. The completion rate is taken from when the user starts the task to when the user is complete. The Navigational costs is the minimum number of taps required to complete the task. Task 2 and 3 are not included in study 1 as the tasks are not performed on the applications being tested.

Table 3: Minimum completion rate and navigation cost

		Google Docs	Microsoft Word	WPS Writer
Task 1	Completion rate (s)	8.14	12.24	13.09
	Navigational cost (taps)	4	5	5
Task 4	Completion rate (s)	42.88	44.25	35.43
	Navigational cost (taps)	15	15	12
Task 5	Completion rate (s)	12.84	13.14	6.30
	Navigational cost (taps)	4	6	4
Task 6	Completion rate (s)	85.00	85.20	96.70
	Navigational cost (taps)	7	7	13

3.3.4 Equipment

Figure 9 shows the basic equipment used in usability tests. Test facilitators can make use of a fixed camera or a cradle-based camera to record the users' interactions with the mobile device. Any video camera can be used if it stays focused on the participants' hands.

Recording software may be necessary if the test facilitators would like to view the participant's real-time movements and assists the test facilitator not to intrude while the participant is busy with the test. Participants can either keep the device flat on the table or hold the device in the manner they prefer.

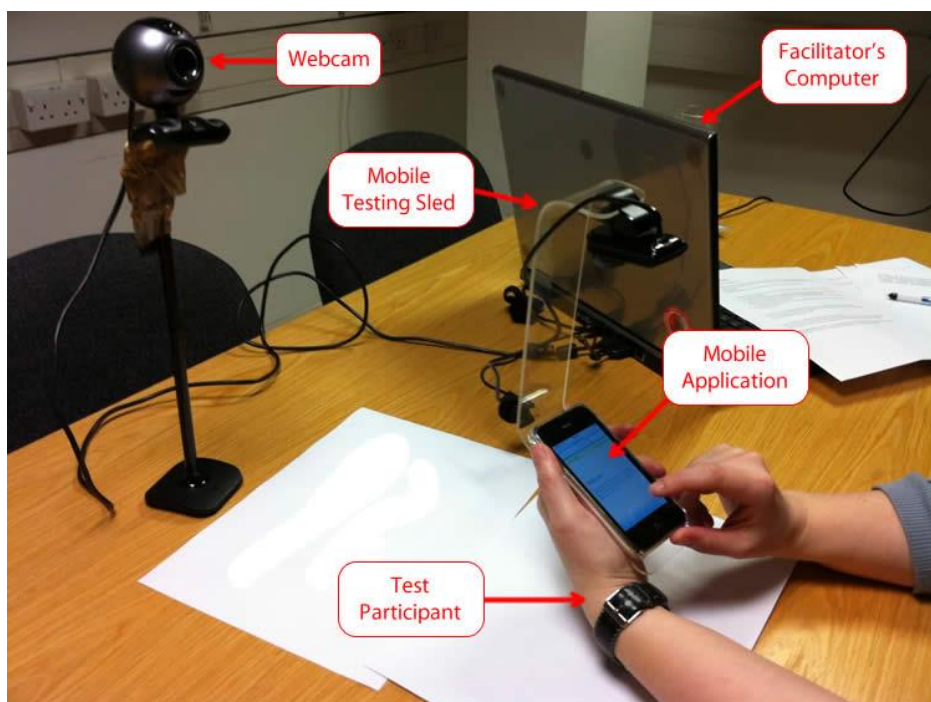


Figure 9: Equipment and test setup⁹

3.3.5 Environment

The purpose of mobile devices is to have a portable computing device and therefore these devices are used in various environments. There are two main methods for conducting usability testing of mobile devices and they include laboratory based testing and remote testing.

⁹ <https://usabilitygeek.com/usability-testing-mobile-applications/>

Remote or field testing allows test facilitators to conduct the usability test with participants in their natural environment by utilising screen-sharing software. This includes; allowing users to walk, stand or sit in any way they would normally, while performing the tasks. Remote testing is not the preferred method because of the costly software needed and the software still needs to be developed to accurately measure the participants' movements on the device.

Usability experts have been concerned that laboratory tests do not accurately simulate the environment and context where mobile devices are used. In the study done by A. Kaikkonen et. al., the usability of mobile devices was tested in the laboratory and in the field with a total of 40 test users [59]. The results, refer to Table 4, show that there was no difference in the number of problems that occurred in both environments. The disadvantage with field testing is that it takes longer to perform a usability test. The usability tests described in this study will be tested in a laboratory environment.

Table 4: Difference between laboratory and field testing

Environment	Testing time (min)	Instruction and preparation (min)	Travel time for test facilitator (min)
Laboratory	35	10	-
Field	45	20	40

The test facilitator will also need to ensure that there are good networking signals in the testing room.

There are different methods of moderating usability tests and four of those methods are discussed and a comparison of the pros and cons of each method is given in Table 5¹⁰.

¹⁰ <https://www.usability.gov/get-involved/blog/2013/04/moderating-usability-tests.html>

- **Concurrent Think Aloud** is used to understand participants' observations and thoughts as they interact with the mobile device and the application. The goal is to encourage participants to verbalise their thoughts as they perform the test.
- In **Retrospective Think Aloud**, the test facilitator asks participants to retrace their steps when the usability test is complete. Often participants watch a video replay of their actions and are then asked to recall what they were experiencing.
- **Concurrent Probing** requires that as participants perform the tasks, they say what they are thinking or experiencing and then the test-facilitator will ask follow-up questions.
- **Retrospective Probing** requires waiting until the testing session is complete and then asking questions about the participant's thoughts and actions.

Table 5: Pros and cons of different usability moderating methods

Techniques	Pros	Cons
Concurrent Think Aloud	Understand participants' thoughts and experiences as they occur giving real-time feedback and emotional responses	Can interfere with the usability test and therefore may have inaccurate measures.
Retrospective Think Aloud	Does not interfere with usability measurements	Overall test length increases, and it is difficult for participants to remember everything.
Concurrent Probing	Understand participants' thoughts as they attempt to work through a task	Interferes with the participants natural thought process as they are getting interrupted
Retrospective Probing	Does not interfere with usability measurements	Difficult to remember everything which leads to poor usability results.

The concurrent think aloud technique and the retrospective technique are used in this study. This allows the test facilitator to understand what the user is experiencing during the usability test and what their thoughts and experiences were after the usability test.

3.3.6 Test setup and procedure

The test setup and equipment used, is shown in Figure 10. A smartphone is mounted onto a tripod and positioned to be able to record the user's hands. All participants used the same mobile device. The device could be held in any way the participant desired with the only requirement being the participants needed to keep the device within the space of the white paper. The footage of each participant was then analysed on a PC.

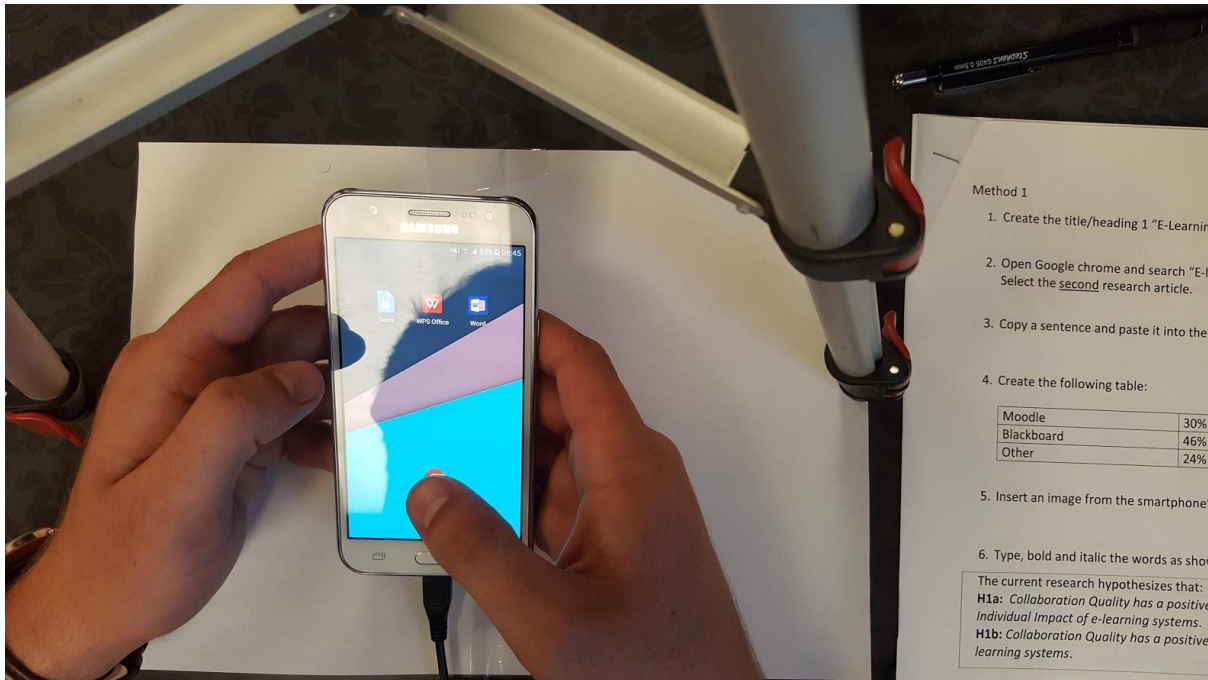


Figure 10: Test setup and equipment

The role of the test facilitator included the following:

- Brief the participant of the experiment and tasks to be performed
- Ensure that the recording was taking place
- Ensure that the participants kept the device within the space of the white paper
- Take note of what the participants comments and reactions are during the test and where they made mistakes
- Help the participant if needed

The order of events of the experiment and the quantitative and qualitative data that was collected for each participant is shown in Figure 11. The order of the word processing applications were rotated for each participant, however, the task sequence remained the same.

The participants performed Task sequence 1 on the first mobile application, Task sequence 2 on the second mobile application and Task sequence 3 on the third mobile application. After each task sequence was complete the participants answered the task-level and test-level questionnaires respectively.

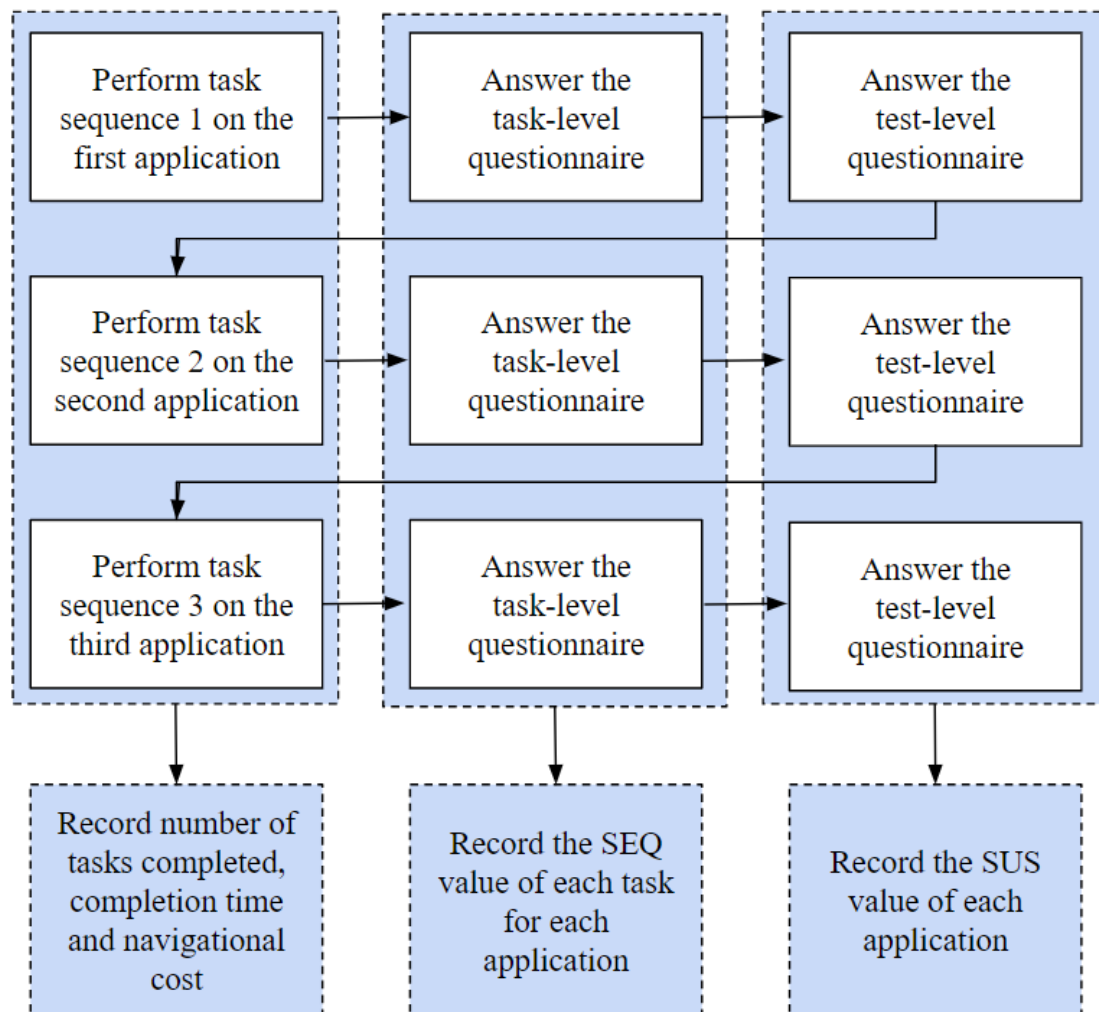


Figure 11: Study procedure and measuring results

3.3.7 Mobile application selection criteria

A list of word processing mobile applications is given in Table 6 as well as the operating system, number of downloads and their user ratings of the applications. Free versions of these applications are available on Google Play and Apple's store, however, if the user requires added or special features then they will have to purchase those packages. There are many more word processing software applications available, however, they are not as popular as the ones given in Table 6.

Table 6: Word processing mobile applications

Application	Platform	Number of downloads	User rating (/5)
Google Docs	Android and IOS	100,000,000+	4.3
Zoho writer	Android	100,000+	3.7
WPS Writer	Android	100,000,000+	4.5
iA writer	Android and IOS	600 000+	4.3
Notebooks	IOS	100,000,000+	4.4
Microsoft Word	Android	100,000,000+	4.5
Evernote	Android and IOS	100,000,000+	4.6
Pages	IOS	100,000,000+	3.2
Polaris Office	Android	50,000,000+	4.3
Quip	Android	100,000+	4.2

These applications are available on mobile and desktop. The desktop versions have more functions and more information can be displayed to the user on a single screen. Table 7 shows the functions, as mentioned in Chapter 1 and listed below, that word processing applications should have, and whether these applications can perform these functions.

1. Create, edit, save and print documents
2. Copy, paste, delete and move text
3. Format text such as bold, underline or italic
4. Create and edit tables and figures
5. Insert images from other software elements.

Table 7: Word processing applications mapped to basic functions

Application	Function				
	1	2	3	4	5
Google Docs	✓	✓	✓	X*	✓
Zoho writer	✓	✓	✓	X*	✓
WPS Writer	✓	✓	✓	X*	✓
iA writer	✓	✓	X	X	X
Notebooks	✓	✓	✓	✓	✓
Microsoft Word	✓	✓	✓	X*	✓
Evernote	✓	✓	✓	X*	✓
Pages	✓	✓	✓	✓	✓
Polaris Office	✓	✓	✓	✓	✓
Quip	✓	✓	X	X*	✓

*Application does not support graphs

The word processing applications chosen for the study include Google Docs, Microsoft Word and WPS writer. The criteria used for selecting these three word processing applications include:

1. Must have more than 100 million downloads. This shows that the application is popular and is therefore a more user-friendly application than those with fewer downloads.
2. Must be available for free on Android devices. Applications with paid features may perform better and the features will vary too much across applications. For validity, free applications were chosen for this study.
3. Must be able to work on various mobile devices. The applications need to be tested on different mobile devices such as smartphones and tablets and different makes.
4. Must have an editor that can perform the functions of a word processor. There are many applications that perform the functions of reading and writing such as note-taking applications, however, they do not perform editing functions. An example is Evernote.

3.3.8 Data collection procedure

Study 1 uses both quantitative and qualitative methods for data collection. For the quantitative data, user testing tools are used to map the participants' user experience of each task for the three applications. The tools included the number of completed tasks, completion rate, navigational cost, SEQ and SUS.

The completion rate was recorded by noting the participants' ability to complete the task. The task was incomplete if the user asked for assistance to complete the task. The task duration and navigational costs were recorded from the video footage taken during the study. The test facilitator watched the recordings and used a stopwatch to calculate the task duration. The navigational costs were calculated by counting the number of gestures the participant performed to complete a task. Gestures include tapping the screen, scrolling, swiping and pinching to zoom in or out. Gestures did not include typing on the keyboard which was performed in task 1 and 6 because the device was kept the same and the keyboard is the same across all the applications.

The SEQ was recorded once a participant completed all the tasks for an application. They were asked to rate each task on a scale from 1 to 7, with 1 representing very difficult and 7 representing very easy. The participants then filled out the SUS questionnaire and the SUS score was calculated. This was performed for each application.

For the qualitative data, Concurrent Think Aloud method was used in the study. Participants thoughts and experiences were recorded while they were performing the tasks. The recordings were viewed again to observe where participants hesitated and which paths they took to find a function to complete a task. Errors were identified when a participant executed an incorrect action when trying to complete a task. The form that was filled out by the test facilitator for each participant is attached in Appendix C.

3.3.9 Data analysis

Statistical analysis is a process that involves data collection, data interpretation and data validation [60]. Hypothesis testing assesses if a certain premise is true for the set of data. The null hypothesis assumes that the data occurred by chance, so the null would be that there is no difference between the data sets. The alternative hypothesis is that the data is a result of a real effect. Welch's t-test and Analysis of Variance (ANOVA) were used to analyse the data. The quantitative data from all 40 participants, including the demographic data, were recorded in Microsoft Excel and the built-in Data Analysis tool was used to analyse the data.

Analysis of Variance (ANOVA) is a statistical technique for testing if three or more populations means are all equal [60]. The null hypothesis for an ANOVA test is that there is no significant difference between the mean values of the groups. The alternative hypothesis assumes that there is at least one statistically significant difference among the groups. The F-ratio is then calculated and the corresponding probability value (p -value) is determined. The significant level is taken as 0.05.

If the p -value associated with the F is smaller than 0.05, then the null hypothesis is rejected. If the p -value is greater than 0.05, then the null hypothesis fails to be rejected.

Welch's t-test for unequal variances was used to compare scores across the demographic categories. The test is used to test if two sample means are significantly different. Welch's t-test is used as it performs better than Student's t-test when data sets sizes and variances are unequal [60].

The categories include gender, the smartphone operating system that the participant currently uses and if the participant had any experience working with Google Docs, Microsoft Word or WPS Writer on a mobile device.

The following set of null hypotheses were tested to determine the statistical significance of the demographic data of the participants. The term usability here encompasses task completion status, completion rate and SEQ. The SUS is kept separate as the questionnaire was filled in after each application and it is based more on the over-all feelings towards the application.

Table 8: Null hypotheses for demographic data

	Hypothesis
<i>H0</i>	There is no statistical significance between males and females with regards to Usability
<i>H1</i>	There is no statistical significance between males and females with respect to SUS.
<i>H2</i>	There is no statistical significance between Android and iOS users with respect to Usability.
<i>H3</i>	There is no statistical significance between Android and iOS users with respect to SUS.
<i>H4</i>	There is no statistical significance between experienced and non-experienced users with respect to Usability.
<i>H5</i>	There is no statistical significance between experienced and non-experienced users with respect to SUS.

The ANOVA is based on the same assumptions as Welch's t-test and is used when comparing more than two groups means. Therefore, this test is used to compare the usability of Google Docs, Microsoft Word and WPS Writer. The set of null hypotheses used to analyse the data is given in Table 8. Task 2 and 3 were not tested using ANOVA as these tasks are not performed in the applications. The flow diagram of testing the null hypotheses are shown in Figure 12.

The H_A hypothesis determines if there is statistical difference between Google Docs, Microsoft Word and WPS using the results from effectiveness, efficiency and satisfaction together. Fail to reject H_A means that there is no statistical significance and there is no difference in terms of usability between the applications. If H_A is rejected then there is statistical significance and the usability results are then separated into effectiveness, efficiency and satisfaction. The rest of the null hypothesis listed in Table 9 are used to determine which mobile application ranks the highest in each of the usability metrics.

Table 9: Null hypotheses for usability metrics

	Hypothesis
H_A	There is no statistical significance between Google Docs, Microsoft Word and WPS Writer in terms of usability for all 6 tasks.
H_{B_1}	There is no statistical significance between Google Docs, Microsoft Word and WPS Writer in terms of efficiency.
H_{B_2}	There is no statistical significance between Google Docs, Microsoft Word and WPS Writer in terms of completion rate.
H_{B_3}	There is no statistical significance between Google Docs, Microsoft Word and WPS Writer in terms of navigational cost.
H_C	There is no statistical significance between Google Docs, Microsoft Word and WPS Writer in terms of task-level satisfaction.
H_D	There is no statistical significance between Google Docs, Microsoft Word and WPS Writer in terms of test-level satisfaction.

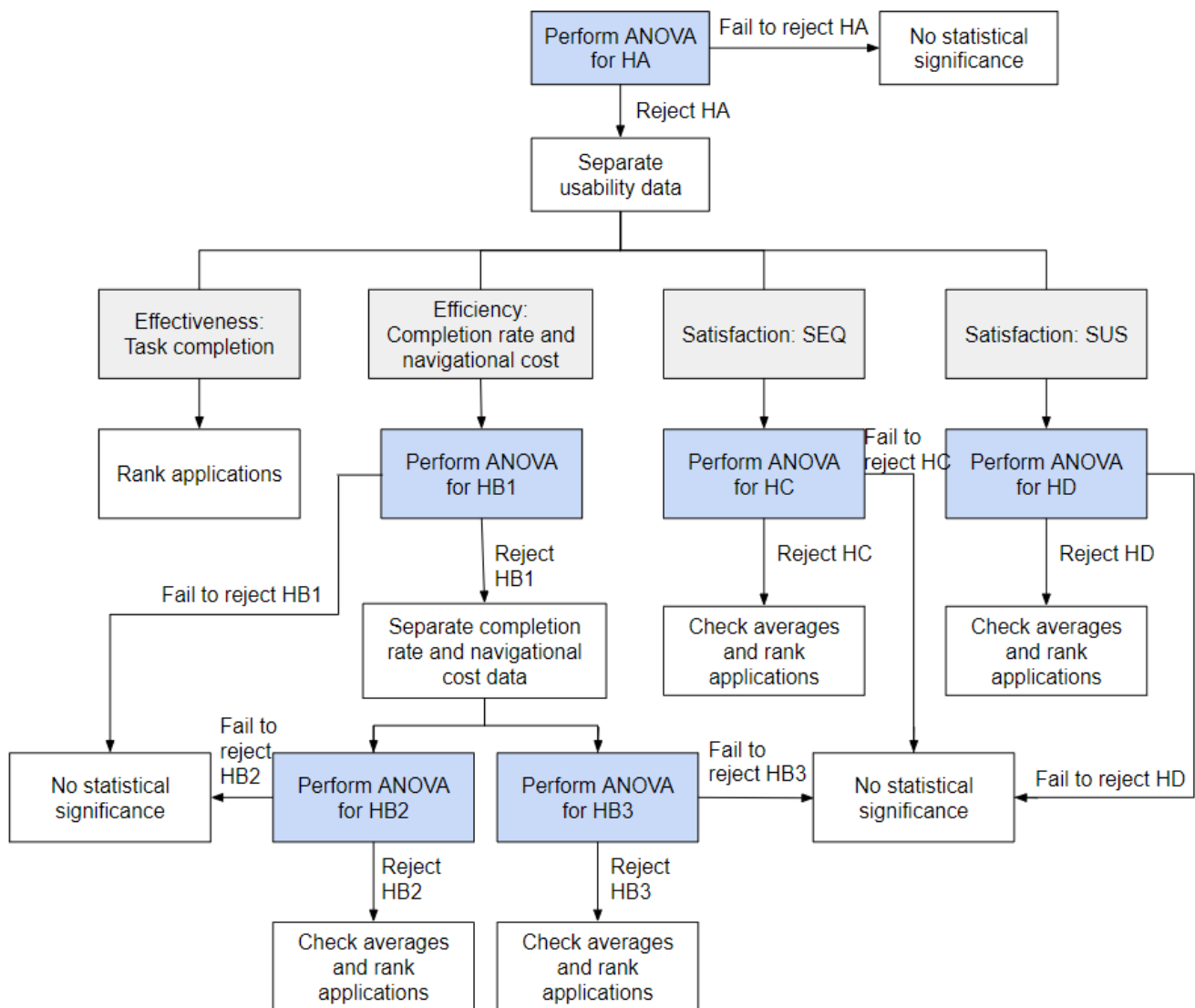


Figure 12: Flow diagram of data analysis

Usability testing is needed for this study to analyse the usability of word processing applications of mobile devices. The goal of the usability testing is to find as many usability issues as possible with current word processing applications. The participants, equipment, tasks and environment are factors that need to be carefully considered when setting up a usability test. The following section discusses the usability of mobile devices.

3.4 Study 2: Mobile device usability test

The objective of Study 2 is to determine which mobile device is the most usable for performing the tasks on the most usable word processing application determined from Study 1.

3.4.1 Mobile device selection process

Five mobile devices were selected based on their different properties as shown in Table 10. The mobile devices include 3 smartphones and 2 tablets. The smartphones and tablets were selected for their different screen sizes, processors, memory and prices. All the devices selected are Android devices.

Table 10: Mobile device properties

Device type	Device model	Screen size (inches)	Price (R)	Operating system	Processor	Memory
Smartphone	Vodafone VFD 200	3.5	399	Android 5.1	1.3GHz quad-core	512MB RAM
	Samsung J500F	5.0	2 999	Android 5.1.1	1.2 GHz Quad-core	1.5GB RAM
	Samsung Galaxy S6 Edge	5.1	7 999	Android 7.0	Octa-core 4x2.1 GHz 4x1.5 GHz	3GB RAM
Tablet	Vodafone VFD 1100	7.0	999	Android 6.0	1.3GHz quad-core	1GB RAM
	Samsung Galaxy Tab A 2016	10.1	6 849	Android 7.0	Octa-core 4x1.6 GHz 4x1.0 GHz	3GB RAM

The devices were ranked from best to worst according to each property, except price, given in Table 10. The mean ranking per devices was calculated and the devices are ranked from the best to worst as follows:

1. Samsung Galaxy Tab A 2016
2. Samsung Galaxy S6 Edge
3. Vodafone VFD 1100
4. Samsung J500F
5. Vodafone VFD 200

3.4.2 Data collection and analysis

Quantitative and qualitative data was collected and analysed to determine the most usable mobile device. The quantitative data which includes the minimum completion rate and minimum navigational cost, was recorded. The processing times between tasks were also recorded. The completion rates were performed three times and the averages were subsequently recorded.

The qualitative data was recorded during the test procedure using the think-aloud method. Ten participants from Study 1 were selected to participate in collecting the qualitative data. Participants were chosen from Study 1 because they have already performed the test and the learnability and discoverability factor is not considered in Study 2.

The participants performed the tasks on the different devices and the test facilitator recorded any comments or observations made by the participant. The test facilitator also records any difficulties that the participant faced while executing a task. Five questions were then asked after the test to determine the participants' preferences:

1. Which device was easier to handle?
2. Which device had the best layout of the best word processing application?
3. Which device was easier to type with?
4. Which device would you prefer to use to create documents?
5. Would you use this device in any environment?

3.5 Verification of results

The issues that were found during Study 1 were mapped to the generic guidelines. The mapping of these issues serves as verification that the applications have usability issues and that these issues can be addressed by using the guidelines.

The issues were grouped according to each application. A description of how a certain guideline addresses a certain issue found was given. A summary of the generic guidelines is given below:

Navigation

Navigation refers to the process of moving from one screen to another to complete a set of tasks. Navigations includes the usage of buttons, tabs and links [40]. Ensuring effective navigation is challenging because of the limited displays of mobile devices.

Content

Content refers to the information displayed to the user. Content includes various forms of text and multimedia such as images. Some applications do not require much content, however, word processing applications are content specific applications because of all the features it needs to provide the user to complete a task.

Error handling

Mistakes from users need to be addressed in the application by means of confirmation messages or undo options. This is very important for word processing applications as users are required to perform input tasks and they may make mistakes [40].

Input method

The small keyboards of mobile devices make it difficult for the user to provide accurate input. This problem increases the rate of errors made by the user. Other forms of input such as drop-down menus and lists can be used to reduce the number of keystrokes.

Equitable use

An application needs to be equally usable for all types of users [40]. This could refer to the users themselves or the different mobile devices the users use. An application should cater for these differences.

Cognitive load

Cognitive load refers to the total amount of mental energy in working memory [40]. Working memory is the system responsible for processing information. In simpler terms, the application should not be complicated to use. This means that an application should provide accurate information in small quantities and allow for minimal keystrokes to complete a task.

Threats to validity of the usability experiment were handled by taking the following measures [50]:

- Ordering effect: The word processing applications were reordered with each participant to counter the effect of ordering.
- Learnability: There were three variations of the tasks to be performed to counter the effect of learnability. The participants performed each variation on a different application.
- All the participants performed the tasks at the same location with the same mobile device.
- All the participants were briefed on the tasks to perform and the testing procedure.
- The test facilitator was neutral about all 3 applications as there is no association with any of the applications.
- The participants could ask any questions during the test.
- All the participants use smartphones and are familiar with research and writing.

3.6 Conclusion

The purpose of the study highlighted in Chapter 1 is to investigate the usability of word processing applications on mobile devices. In this Chapter, Study 1 and Study 2 were designed to investigate the usability of word processing mobile applications and to investigate the usability of different mobile devices respectively. The data collection procedures were discussed, and the results are analysed in Chapter 4.

Chapter 4: Validation of results

The results of study 1: usability of word processing applications, the results of study 2: usability of devices and the preliminary questionnaire results are provided in this chapter. The results of each study are put into context in terms of the purpose of the study.

4. VALIDATION OF RESULTS

4.1 Preamble

In this chapter, the validation of results of the study is explained in detail. The results from the preliminary questionnaire, Study 1: usability of word processing applications and the results of Study 2: usability of devices is provided. The results from Study 1 are interpreted and discussed and verified by mapping the usability issues found to the guidelines discussed in Section 2.4.3.

4.2 Preliminary Questionnaire

The online questionnaire received 180 responses. Of the respondents, 115 were undergraduate engineering students from the University of Pretoria and 65 were postgraduate engineering students from the North-West University. The results of the scenario-based questionnaire is given in Table 11 and a visual representation of the data is shown in Figure 13.

Table 11: Results of preliminary questionnaire

Questions	Computer (%)	Mobile device (%)	Both equally (%)
Which devices do you use the most to read text messages?	5.6	83.3	11.1
Which device do you use the most to read emails?	50	23.9	26.1
Which device do you use the most to read short pieces of text such as a news article?	19.4	61.2	19.4
Which device so you use the most to read longer text such as reports?	91.1	2.8	6.1
Which device do you use the most to type a text message?	6.1	85	8.9
Which device do you use the most to type emails?	80	11.1	8.9
Which device do you use the most to type a single page document?	94.4	4.4	1.2
Which device would you use the most to type a large document (More than 2 pages)?	100	0	0

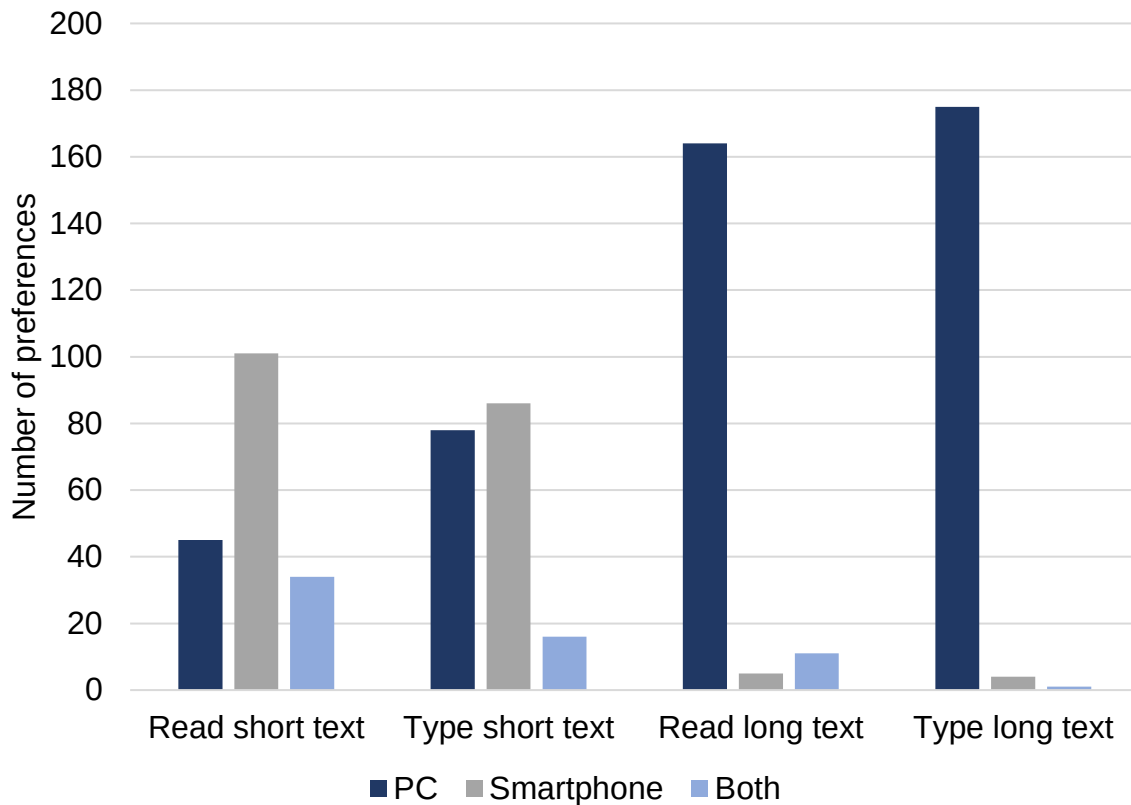


Figure 13: Results from preliminary questionnaire

The questionnaire was conducted as a preliminary analysis and consisted of 11 multiple choice questions. The number of choices per question were kept to a minimum in order to make the extractions of the results easier. The questionnaire is attached in Appendix A. Table 12 shows the ages of the respondents and the percentage of the day that respondents have access to a computer.

Table 12: Respondents details

Category	Frequency	Percentage (%)
Age	17 - 20	35.7
	21 - 30	63.4
	31 – 40	0.0
	41+	0.9
Percentage of the day that respondents have access to a computer	0 – 50	91
	51 – 100	9

The results from the questionnaire demonstrates that students prefer to read, and type short text using a smartphone and read and type long text using a PC. This is due to the different designs, hardware and software, of smartphones and PC's. For example, if a student wants to quickly check an email and reply, then the student will use a smartphone as it is easily accessible, the information on the screen is short and brief and typing is kept to a minimum. If the student needs to finish an assignment, then the student will use a laptop or PC as the student will be spending more time on the device and the device makes it easier to read and type long text as the screen is larger and has an external input such as a keyboard and mouse.

4.3 Study 1

4.3.1 Introduction

Investigating the usability of Google Docs, Microsoft Word and WPS Office in terms of effectiveness, efficiency and satisfaction was performed in Study 1. The aim of the study is to determine the most usable word processing application for creating and editing documents on mobile devices.

The tasks as shown in Figure 8 are as follows:

1. Create a title
2. Search the given title in Science Direct and select a research article
3. Copy and paste a sentence from the article into the document
4. Create a table
5. Insert an image from the smartphone's gallery
6. Type, bold and underline the given text.

4.3.2 Welch's T-test: Demographic Data

Welch's t-test was performed in Microsoft Excel on the demographic data. The hypotheses were tested and Table 13 shows the p value, T-value, T-critical and the result of whether the null hypotheses were rejected or failed to be rejected. The term usability includes task completion, completion rate, navigational cost and task-level satisfaction.

Table 13: Demographic Welch's t-test results

Category	p	T-value	T-critical	Result
Gender Usability	0.57	0.57	1.97	Fail to reject H0
Gender SUS	0.00	3.18	1.99	Reject H1
Smartphone usability	0.41	0.84	1.97	Fail to reject H2
Smartphone SUS	0.21	1.27	2.01	Fail to reject H3
Experience Usability	0.04	2.09	1.97	Reject H4
Experience SUS	0.30	1.04	2.00	Fail to reject H5

It was found that females tend to give higher SUS scores than males, even though there is no statistical significance in their usability data. The average SUS score for females was 65.2 and the average SUS score for males was 59.2.

It was found that users with experience in Google Docs, Microsoft Word or WPS Writer on a mobile device performed better in the usability test than those without any experience. Of the 40 participants, 13 had experience in either Google Docs, Microsoft Word, WPS Writer or a combination of the three applications. They, however, did not give significantly higher SUS scores. This shows that even though users have been exposed to the applications before, giving them the advantages of discoverability and learnability, they still did not rate the applications any better than the users that have had no exposure.

The users with experience may have used the application for a different purpose and therefore performed the tasks described in this study for the first time. This may be why they did not give higher SUS scores.

This data is relevant for testing how demographics influence the usability results, however, the results obtained in this study focuses on the usability of word processing applications and issues were discovered regardless of the demographic data. It is thus possible to interpret the results without considering the demographics and therefore the following section provides the results from the usability tests.

4.3.3 Usability: Results of ANOVA

The results from testing the null hypothesis as shown in Figure 12 are given in this section. The ANOVA was done using Microsoft Excel. Task 2 and 3 data are not considered in the hypothesis testing as their data is not statistically significant as shown in Table 14. The results of the SUS scores is attached in Appendix D1 and the effectiveness, completion rate, number of navigational cost and SEQ of each task is attached in Appendix D2.

Table 14: ANOVA for Tasks 2 and 3

	p	F-value	F-critical	Result
Task 2 and 3 ANOVA	0.3	1.2	1.8	No statistical difference

The p value, F-value and F-critical values determined from the ANOVA are shown in Table 15. The results of each ANOVA performed show that all the null hypotheses are rejected. This means that there is a statistical difference between the data, therefore there is a difference in usability between the 3 applications in terms of efficiency, effectiveness and satisfaction. Users found various issues in each application and rated them accordingly. The task was then to determine where the issues lie and how these issues can be corrected by mapping the issues to the generic guidelines.

Table 15: Study 1 ANOVA of usability data

	p-value	F-value	F-critical	Result
HA: Overall ANOVA	0.01<	13.7	1.4	Reject HA
HB₁: Efficiency ANOVA	0.01<	15.7	1.7	Reject HB1
HB₂: Completion time ANOVA	0.01<	16.5	2.1	Reject HB2
HB₃: Navigational cost ANOVA	0.01<	39.4	2.1	Reject HB3
HC: Task-level satisfaction ANOVA	0.01<	5.4	2.1	Reject HC
HD: Test -level satisfaction ANOVA	0.05	3.2	3.0	Reject HD

The averages of the data determined from study 1 are shown in Table 16. The null hypotheses are all rejected, meaning there is a significant difference between the results. The averages are used to determine where the statistical differences lie.

Task completion shows the percentage of students that were able to complete the tasks. The higher the task completion, SEQ and SUS and the lower the completion rate and navigational cost the more usable the application is.

Table 16: Study 1 averages

		Google Docs	Microsoft Word	WPS Writer
Task completion (%)	Task 1	75	83	88
	Task 4	100	85	100
	Task 5	100	100	100
	Task 6	100	93	93
	Average	94	90	95
Completion rate (s)	Task 1	49.6	50.1	47.5
	Task 4	75.3	105.0	65.7
	Task 5	23.6	24.8	16.6
	Task 6	158.1	174.2	226.5
	Average	76.6	88.5	89.1
Navigational cost (taps)	Task 1	15.6	17.6	15.4
	Task 4	24.3	31.3	21.4
	Task 5	9.3	8.1	6.6
	Task 6	14.2	18.9	42.9
	Average	15.8	18.9	21.6
Task-level satisfaction (SEQ)	Task 1	4.0	4.3	4.1
	Task 4	5.5	4.4	5.4
	Task 5	5.9	5.6	5.7
	Task 6	5.4	5.2	3.8
	Average	5.3	4.9	4.8
Test-level satisfaction (SUS)	Average	67.7	60.9	54.9

The main objective of the study is to investigate the usability of word processing applications on mobile devices. The averages of each usability measure are used to rank the applications from the best performing to the worst-performing application. The purpose of this is to determine which application is the most usable.

The rankings are shown in Figure 14. Google Docs is first in 4 out of the 5 usability measures; Microsoft is second in 4 out of the 5 usability measures and WPS Writer is last in 4 out of the 5 usability measures and first in effectiveness. This shows that Google Docs is the most user friendly word processing application, therefore, if students want to use a mobile application to create documents then Google Docs would be the best application to do so according to this study. Microsoft Word is second and WPS Writer is third. Google Docs will therefore be used as the application on the various devices that are tested in Study 2.

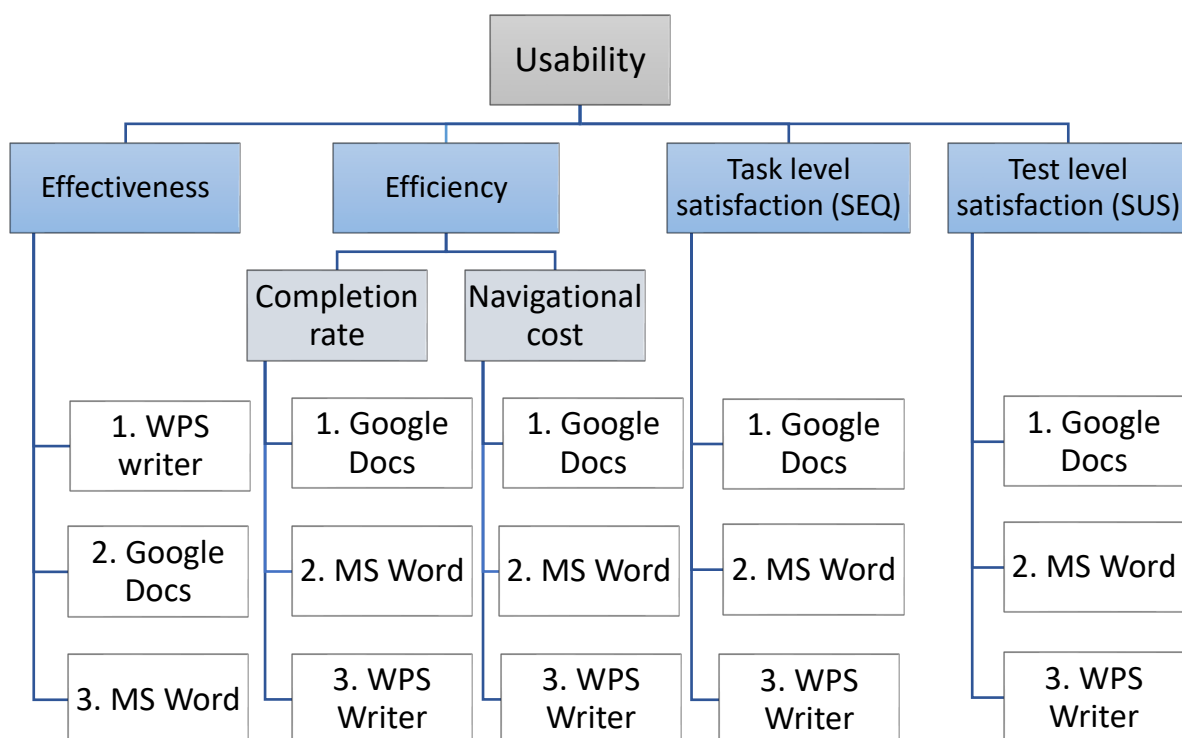


Figure 14: Ranking of applications

To achieve the sub-objective of providing suggestions for future word processing mobile application development; details of where the usability data differs for each application is discussed by evaluating the task averages. This will show which tasks students struggled with the most, this information can be used by mobile application developers in developing usable word processing applications.

The ranking of the applications was determined by comparing the usability measures, completion rate and navigational cost, against each other. However, this does not take into consideration how the applications were designed to be used. To determine how difficult students found each task, the average number of errors the participants incurred are calculated and subtracted from the minimum completion rate and navigational cost required to perform the task without incurring any errors. The results are given in Table 17.

The minimum data is the minimum completion rate and navigational cost that an application requires to complete a task. Refer to Section 2.3.3, Table 3 for the minimum data. This calculation gives insight into which tasks participants made the most errors in and an explanation is given as to why they made these errors.

Table 17: Errors of completion rate and navigational cost

		Google	Microsoft Word	WPS Writer
Completion rate (s)	Task 1	41.4	37.9	34.4
	Task 4	32.4	60.7	30.2
	Task 5	10.7	11.6	10.3
	Task 6	73.1	89.0	129.75
Navigational cost (number of taps)	Task 1	11.6	12.6	10.4
	Task 4	9.3	16.3	9.4
	Task 5	5.3	2.1	2.6
	Task 6	7.2	11.9	29.9

Task 1

The errors for task 1 are very high compared to the other tasks. This may be due to the discoverability and learnability that is required when using an application for the first time. Thirty eight percent of participants struggled to locate the function that creates a title. Google Docs had the highest error for this task with 67% of the 38% of participants that made errors. The reason for this is Google Docs used an unfamiliar symbol to represent the edit functions of the app.

Task 4

Microsoft Word had the highest error percentage for task 4 with 15% of participants that struggled to locate where to insert a table. It is not clear that the home button is a drop-down menu for other functions of the application.

Participants also struggled to select the number of rows and columns when creating a table; the application automatically generates a 3 by 3 table. They therefore had to delete a column which caused an increase in completion time and navigational cost.

Task 5

The function for inserting an image is found in the same location as inserting a table. The participants knew where to find the insert image function due to completing the table in the previous step. None of the participants struggled with inserting the image, however, the participants struggled to get the cursor under the image to start task 6. The applications don't allow users to scroll through a blank page as one would on a computer, therefore many participants couldn't begin task 6 underneath the image.

Task 6

Participants were not familiar with typing or editing using a mobile application. The applications' edit functions are designed to work by first selecting the edit function, such as bold, then to start typing the word that is to be in bold, unselect bold and select underline, to then type the rest of the sentence.

Participants began by first typing out the sentences and then tried to select the text to bold and underline. This caused an increase in completion time and navigational cost

as selecting text creates a lot of errors. Only 12% of participants used the editing functions properly.

Figure 15, Figure 16 and Figure 17 show that participants spent the most time and navigational cost executing task 6. WPS Writer performed the worst in this task as participants struggled to locate the underline function. When this function was selected, it did not always work, resulting in them having to go back to check if it was selected.

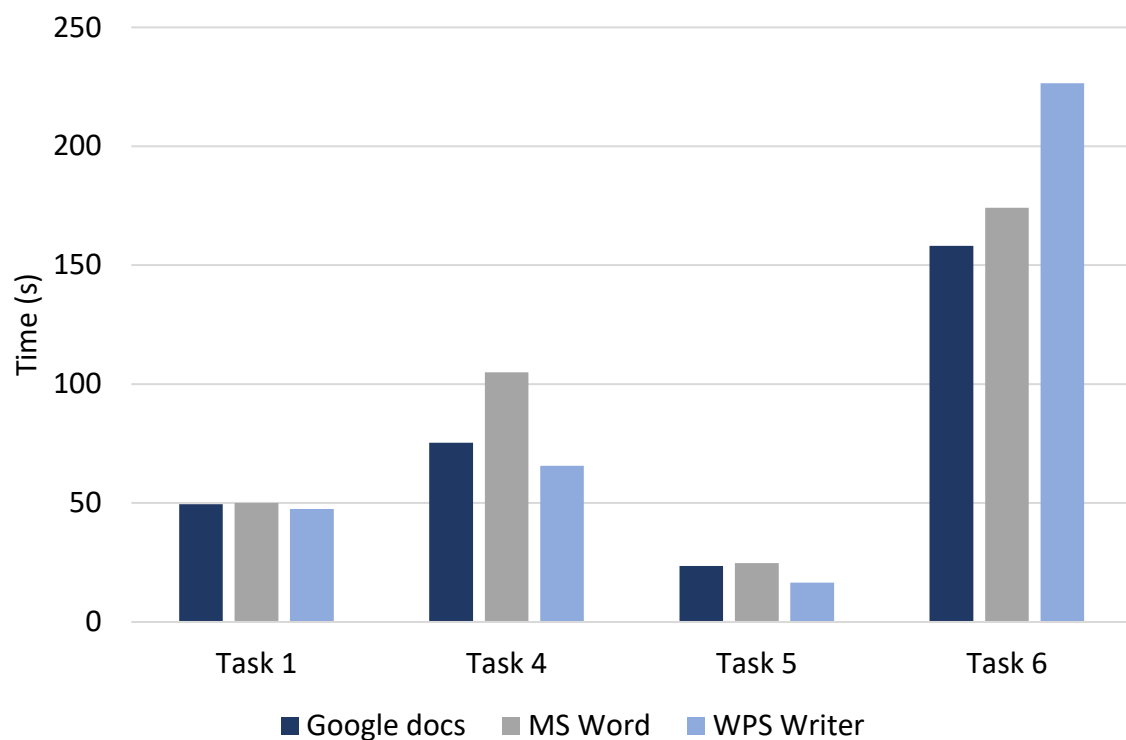


Figure 15: Completion rate

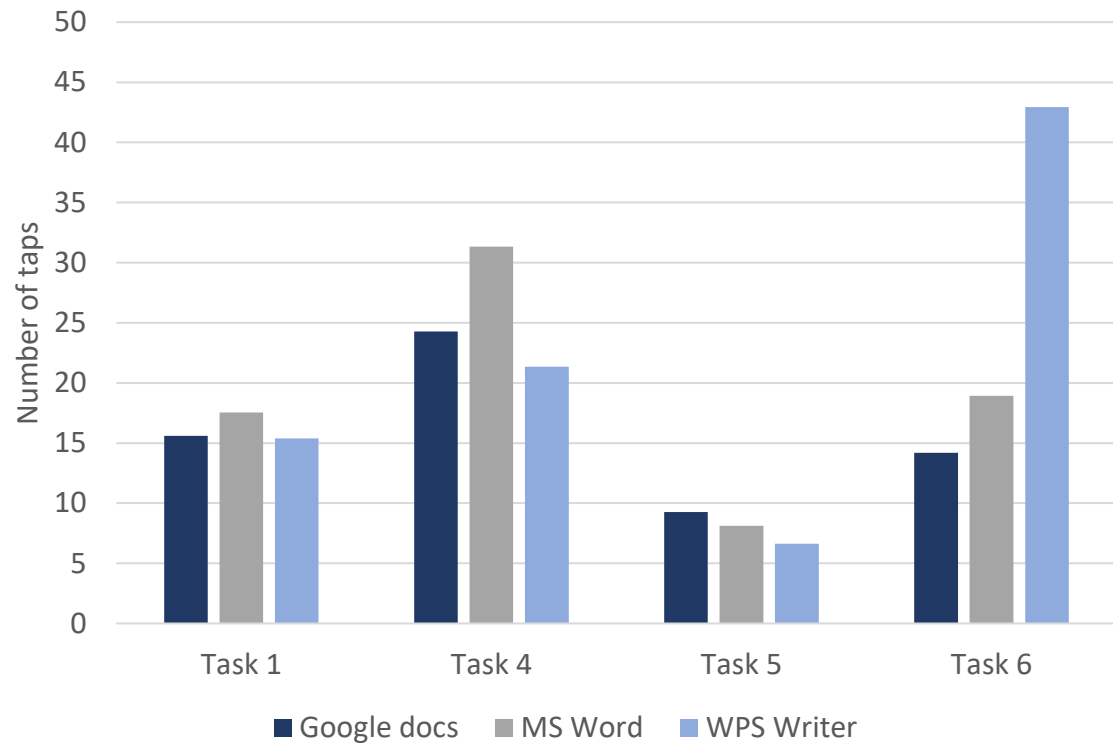


Figure 16: Navigational cost

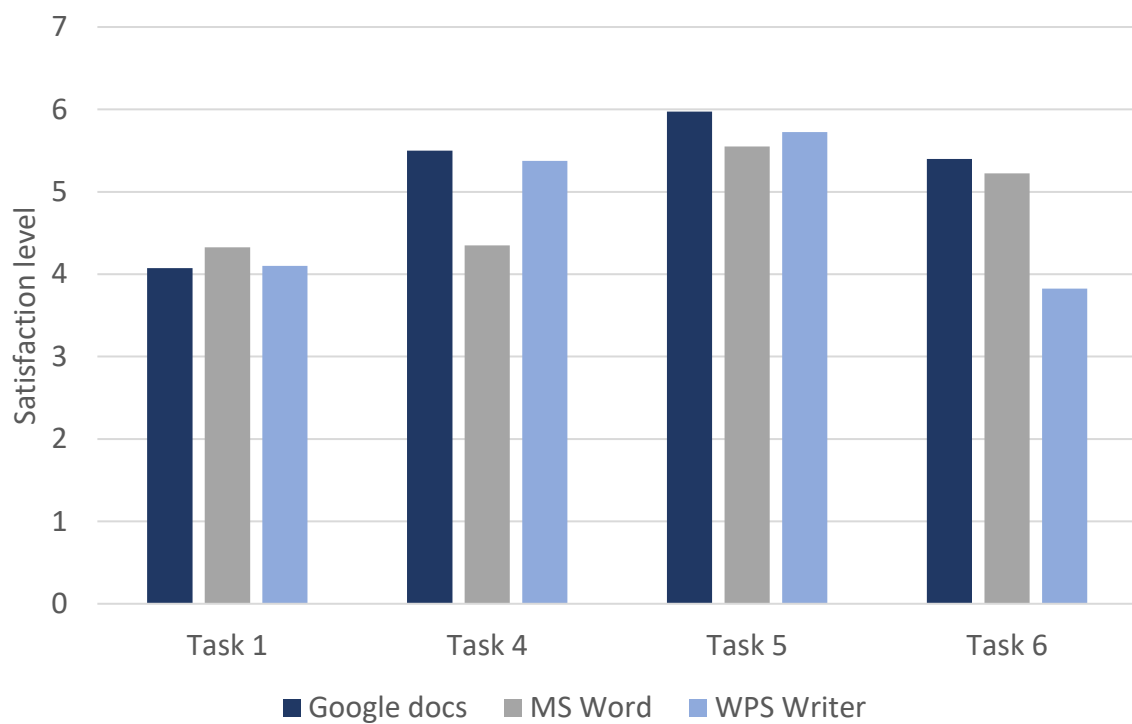


Figure 17: Task-level satisfaction

Figure 15, Figure 16 and Figure 17 seem to show some correlation from a visual aspect. The higher the bars of completion rate and navigational cost, the lower the bars are for task-level satisfaction. To test if there is a correlation, the correlation coefficients are calculated and represented as scatter plots.

Figure 18 shows the scatter plots and regression lines for tasks 1, 4, 5 and 6 shows the relation between completion rate, navigational costs and task-level satisfaction. Time is on the x-axis, navigational cost on the y-axis and task-level satisfaction is the colour of the points.

The plots were plotted using Python and the correlation coefficient was calculated. The larger the magnitude of the coefficient (closer to 1), the stronger the correlation. The correlation coefficient is a measure of how strong the relationship is between the two variables. The correlation coefficient for the tasks are given in Table 18:

Table 18: Correlation coefficients

Task	Correlation coefficient
Task 1: Create a title	0.63
Task 4: Create a table	0.81
Task 5: Insert an image	0.58
Task 6: Type, bold and underline text	0.65

Task 4 has a strong correlation while tasks 1, 5 and 6 have moderate correlations. This means that there is a relation between the completion rate and the navigational cost. The calculation did not exclude outliers and therefore the correlation may be stronger. The correlation coefficients will be closer to 1 by testing the applications with more participants.

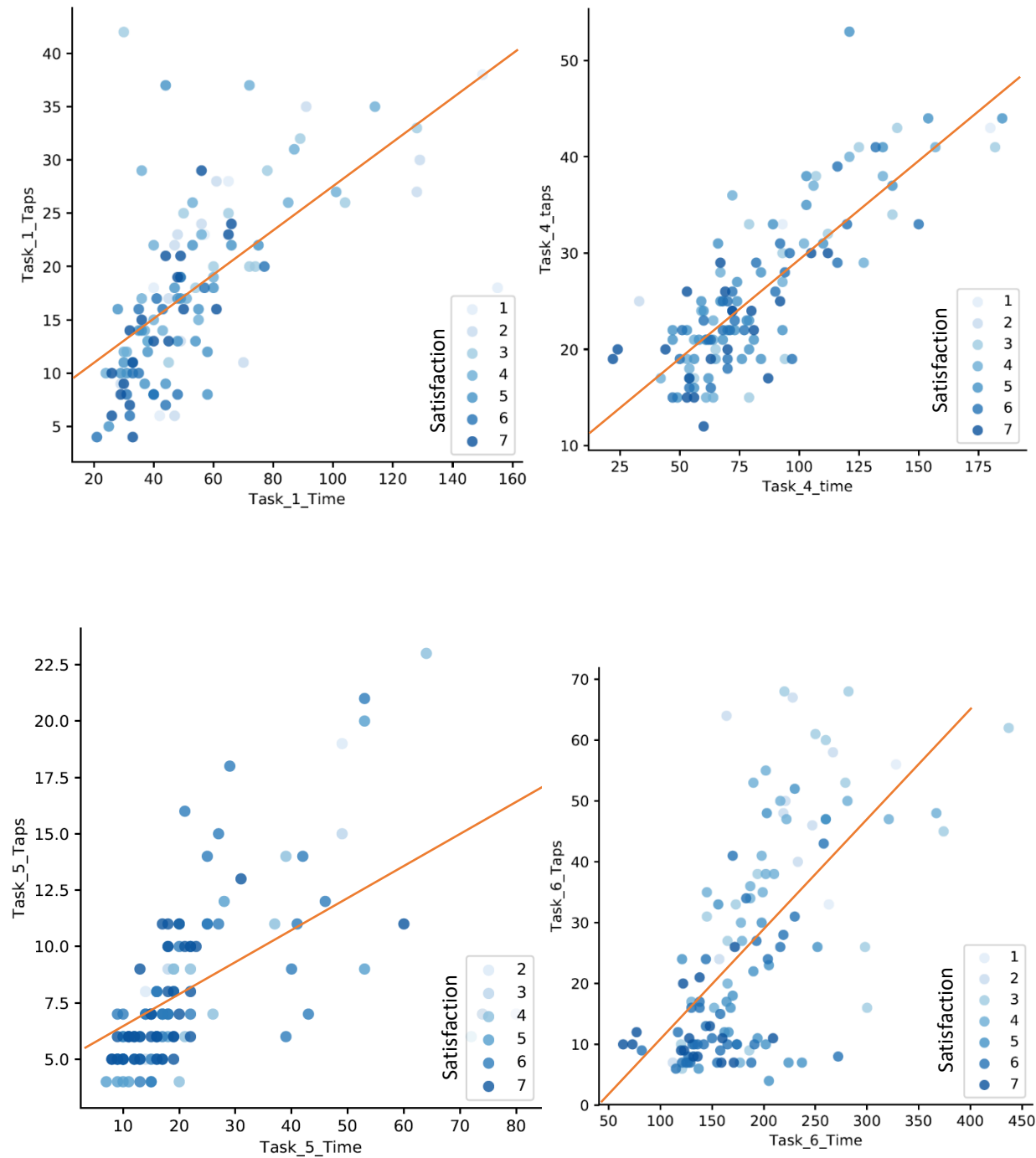


Figure 18: Correlation between completion rate and navigational cost

The graphs in Figure 18 indicate that if usability experts and application developers want to test their application without spending too much time creating a usability test, they can simply perform a completion rate test as navigational cost and task-level satisfaction is related. This will save time on testing applications, therefore increasing time for development, thus improving the usability of applications. However, discoverability and learning of an application should still be considered. The next section shows that although a task may take longer to perform, the level of satisfaction may not necessarily be related to the completion rate of the task.

4.3.4 Discoverability and learnability

Task 6's completion rate and task-level satisfaction is used to test learnability since it was the biggest contributing factor to the usability test, completion rate and navigational cost are directly proportional. The following null hypotheses were tested using ANOVA.

H0: There is no significant statistical difference for task 6 completion rate.

H1: There is no statistical significance for task 6 task-level satisfaction (SEQ).

The results of the ANOVA are shown in Table 19 and the total averages of the data are shown in Table 20. There is no statistical difference between the SEQ data, however, there is a statistical difference between the completion rates. This shows that participants who performed the worst for the first application, did not rate the first application significantly more difficult than applications two and three.

Even though the participants performed better, they still felt that the applications were difficult to use. This means that although some applications may take longer to complete tasks, users may still prefer using the application because of the user-friendliness. The user-friendliness is therefore not based on how quickly and efficiently a user can perform a task, but how easy it is to navigate through the application without the user getting stuck, not knowing how to complete the task.

Table 19: ANOVA

	p-value	F-value	F-critical	Result
ANOVA completion rate	0.02	4.0	3.1	Reject H0
ANOVA SEQ	0.2	1.6	3.1	Fail to reject H1

Table 20: Averages

Application	Completion rate	SEQ
First app	208.4	4.5
Second app	172.6	5.1
Third app	177.6	4.9

It is therefore important for developers to design applications that perform tasks in a manner that users are accustomed to, ensuring that performing these tasks is not time consuming. There may be trade-offs between these two concepts when designing applications. According to the users, Google Docs performed both concepts the best, however, this does not make the application usable as there are still usability issues found with the application that are discussed in the next section.

4.3.5 Verification of results

The issues described in this section were issues that participants voiced while executing the tasks and issues that the videos showed where participants struggled to execute tasks. The issues are mapped to a guideline that addresses that issue and some issues are addressed by more than one guideline. The purpose of this section is to verify that each issue is addressed by a generic guideline which is important for developers. This shows that if developers use these guidelines when designing and developing word processing applications; the application should be more usable.

There are currently no genre specific guidelines for word processing applications. All the issues relating to the word processing mobile applications were able to be mapped to at least one generic guideline which means that there is no need for genre specific guidelines. Developers of word processing applications can therefore use the generic

guidelines to ensure their applications have minimal usability issues. Table 21 maps the issues discovered during the methodology to the guidelines, refer to section 1.4.3 in the text. The list of the generic guidelines is given as follows:

Table 21: Mapping of issues found to generic guidelines

Issues found in Google Docs	Guidelines
Participants struggled to find where to create a title. The button is an unconventional symbol.	1b: Provide visible and well-defined buttons for easy navigation 2b: Use terms that are related to the real world
Participants did not know that headings and titles is found under styles.	2b: Use terms that are related to the real world
Participants checked if the title created was indeed a title as the text did not change.	1e: Provide complete control to the use so that they can exit or back at any stage 6c: System status should be visible through proper feedback
The insert function is found in the top bar and this bar disappears when participants are typing. Participants had to scroll to the top of the document for the bar to reappear.	1c: Reduce navigation by providing hierarchies and menu
The table inserted is bigger than the screen and therefore the participants find it difficult to navigate the table.	1a: Use clear consistent navigation 5b: Provide same functionality for different screen orientation and size 6b: Similar and minimal steps or actions should be required to complete a task
Each new cell in the table must be double tapped to input text. This increases time and navigational costs.	1a: Use clear consistent navigation 4a: Minimise number of keystrokes while taking input
The image takes a while to display once inserted. Participants start inserting the image again thinking that it did not work the first time.	6a: Provide little and homogenous information in modules to avoid cognitive load. 6c: System status should be visible through proper feedback
Issues found in Microsoft Word	Guidelines
To create a title, participants need to scroll to the bottom of the Home page. There are too many options that by the time participants get to the bottom they do not read all the options available and therefore miss the Styles option that allows one to create a title.	1b: Provide visible and well-defined buttons for easy navigation 1c: Reduce navigation by providing hierarchies and menu 2b: Use terms that are related to the real world

Participants need to enter too many layers to create a title.	2c: Content should be brief and specific
Once the style is selected, the participant wants to type however, the keyboard needs to be called up by a small arrow on the right side of the screen. This is unconventional, and participants struggle to get the keyboard.	6c: System status should be visible through proper feedback
To insert an image or table, the participants need to select the Home button which is a drop-down list. Participants are unaware of this function and it adds layers.	1a: Use clear consistent navigation 7d: Design should be consistent and should follow conventions
There are no options for inserting a custom table. A generic 3 by 3 table is inserted and participants must manually delete and add rows and columns	1e: Provide complete control to the use so that they can exit or back at any stage 6b: Similar and minimal steps or actions should be required to complete a task
The table is very small, and participants must pinch to zoom in and out to insert text	6b: Similar and minimal steps or actions should be required to complete a task
There are two means of deleting rows and columns. This adds unnecessary functions.	4a: Minimise number of keystrokes while taking input 6b: Similar and minimal steps or actions should be required to complete a task
The inserted image takes up an entire page and participants had to try make the image smaller before moving onto the next task.	6a: Provide little and homogenous information in modules to avoid cognitive load 6b: Similar and minimal steps or actions should be required to complete a task
The text is too small to read and therefore participants must zoom in and out and this makes navigating the document difficult. There is an option to change the view however, participants are unaware of this.	7d: Design should be consistent and should follow conventions 7e: Limit number of screens and prove title for each
Issues found in WPS Writer	Guidelines
Participants struggle to find the button used for creating a title. Unconventional icon is used	2b: Use terms that are related to the real world
Participants created a heading instead of a title as to create a title, the participant must enter another layer and they are unaware of this layer as it not very clear and visible.	2a: Do not use objects which provide different meanings 4a: Minimise number of keystrokes while taking input

The table visuals confused participants as they want to select the table by dragging on the displayed figure instead of using the small scrolls found to the side and bottom of the table.	7a: Design should be attractive but avoid using too many colours and animations 7d: Design should be consistent and should follow conventions 7f: Direct physical touch enhances user satisfaction
Participants struggle to find underline as they can bold using the top bar but not underline.	4a: Minimise number of keystrokes while taking input 6b: Similar and minimal steps or actions should be required to complete a task 7d: Design should be consistent and should follow conventions
Once underline is selected, it does not always underline, and participants must go back to the underline function to select it again.	6c: System status should be visible through proper feedback
If participants make a mistake when typing at the beginning and remove the text using backspace, the editing tools revert to the previous settings as participants must reselect the tools that they require.	6c: System status should be visible through proper feedback 1e: Provide complete control to the use so that they can exit or back at any stage
The participants tap on the page to place the cursor however; the cursor does not change position. Participants must press enter to get to the desired place.	1a: Use clear consistent navigation 7d: Design should be consistent and should follow conventions

The only problem that was not addressed by any of the guidelines and was experienced in all three word processing applications, is selecting text. This was performed in Task 3 when participants had to select text from the research article. Participants also used this tool in Task 6 although it was unnecessary. The applications were designed to select the edit function such as bold and underline, before the user begins to type to avoid having to select text.

In this section, the most usable word processing application was found to be Google Docs and all the issues were addressed by a guideline. The need for the study is to analyse the usability of word processing applications on mobile devices, therefore this leads to understanding how Google Docs performed on the different mobile devices.

The statistical ANOVA results showed that there was statistical significance between each applications' results. Therefore, it can be concluded that Google Docs is the most

usable word processing application, Microsoft Word is second and WPS Writer is third. Table 22 gives a summary of the ranking of each application in terms of the usability measurements.

Table 22: Usability results

Usability measurement	Effectiveness	Efficiency	Satisfaction
1st Application	WPS Writer	Google Docs	Google Docs
2nd Application	Microsoft Word	Microsoft Word	Microsoft Word
3rd Application	Google Docs	Microsoft Word	WPS Writer

The tasks that the participants had to perform were comprised of the basic functions that word processors are expected to have. The task that participants struggled the most with was Task 6. This task asked participants to type certain text and then to bold and underline certain words. Typing text should be the main objective of a word processor, however, participants found this the most difficult task to perform. This is due to a few factors that are discussed below.

Text input

Participants used a soft keyboard which is the most common method of text input yet; 87% of participants found the task difficult as the text was longer than what the participants are used to typing. There are features on mobile devices that allow for easier typing such as text prediction; this was not used in the test as some of the older mobile devices were unable to perform these features. Typing text without using any of the features designed to make typing easier is not recommended as the screen size and keyboard is too small. Using Swype is the most efficient form of text input, however, it requires the most learning.

Correcting errors

Seventy five percent of participants made spelling errors or missed keystrokes. Fixing an error on a mobile device is more difficult than on a desktop. Users are required to either tap on the incorrect word exactly where the mistake is and correct it, or to tap behind the word, press backspace and retype the word. This is very tedious and frustrated many participants. Using a Swype keyboard or SwiftKey will minimise errors. It is suggested that word processing software makes use of auto-correct or spell check.

Selecting text

Participants rarely selected the correct text the first time. The small screen size makes it difficult for users to select a sentence from beginning to end. The text is smaller than a finger contact area as well as visually obstructed by a finger while pressing. Text selection is determined by the method of application development such as native or web and therefore the application itself does not determine how selection is carried out. An easier method of selecting text should be developed such as a single swipe gesture which highlights and selects text. The algorithm for the text selection should be accurate to minimise correcting errors. A suggestion is to develop a better selecting method and to perform the usability tests again and compare the results with the results of this study to see which method is more usable and what the learnability will be with the new method.

Discoverability

Google Docs came third in effectiveness and this can be explained using the concept of discoverability. As explained in Section 2.4.3, discoverability refers to the degree of ease with which users can find features within an application. Participants needed assistance with the first task in Google Docs because of the unconventional icon the application uses to display the editing features. Therefore, the discoverability of Google Docs was the most difficult of the 3 applications, however, once participants discovered what the icon meant, they were able to complete the rest of the tasks with ease.

The features within WPS Writer were the easiest to discover, however, when performing the tasks, the features were difficult to implement and therefore WPS Writer performed the worst in efficiency and satisfaction. Users are more satisfied with applications that take time to learn to navigate and locate features and then use these features with ease, than with applications that do not take long to find features, but the features are difficult to use. This can be seen by the satisfaction ratings of the participants; Google Docs performed the worst in effectiveness and the best in efficiency and therefore users rated the application more usable.

Upon first use of an application, the application could have an introductory setup to the user through all the functionality of the application. Some users may find this frustrating and skip the introduction. Another suggestion would be to limit the number of levels a user has to enter to perform a function, however, this will influence the amount of screen real estate available to the user.

Learnability

Word processing users are familiar with how applications like Microsoft Word and Google Docs work on a PC. Users tend to type out a document first and then edit it according to how they want it. Users can do this because text selection is easy when using a mouse and a large screen, however, these peripherals are not available for mobile devices, therefore users need to learn to perform editing techniques in a different way. The application developers intended the users not to use selection methods to edit a document as it is very difficult to do. Instead, they intended users to first select the editing feature and then begin typing. This allows users to avoid having to select text.

Some participants did perform editing this way and those that did had lower navigational cost and completion rate for Task 6 than those that did not. They also rated Task 6 easier than those who selected text instead. This shows that users would have performed better in Task 6 if they were able to learn how to perform editing the way it was intended to be used. Word processing applications should demonstrate this technique to users when using the application.

4.4 Study 2

4.4.1 Introduction

Investigating the usability of mobile devices in terms of effectiveness, efficiency and satisfaction was performed in Study 2. The aim of the study is to determine the most usable mobile devices using Google Docs to create and edit documents. A statistical analysis was not performed as the minimum possible completion time and navigational cost of the tasks were recorded to show the efficiency of the devices. All the tasks could be performed on the devices and therefore effectiveness was not considered. The satisfaction was determined by asking the participants which device they preferred to use.

4.4.2 Quantitative results

The quantitative results test the performance of the different devices. The results include the completion time and navigational cost of each task and the processing time taken to open the application, switching between tasks, and loading the article and image.

The results are given in Table 23. The lowest completion rate, navigational cost and values within 5% of the lowest value for each task are highlighted. Figure 19 and Figure 20 show the total completion time and navigational cost for each device. The totals were used to rank the performance of the devices from the best performing to the least performing device:

1. Samsung Galaxy Tab A 2016
2. Samsung Galaxy S6 Edge
3. Samsung J500F
4. Vodafone VFD 1100
5. Vodafone VFD 200

Table 23: Completion time and navigational cost of Study 2

	Vodafone VFD 200	Samsung J500F	Samsung Galaxy S6 Edge	Vodafone VFD 1100	Samsung Galaxy Tab A
Completion time					
Open application (s)	8.7	9.6	6.2	9.9	8.1
Task 1 (s)	9.9	8.2	9.1	10.8	9.2
Switch to google (s)	4.7	3.5	2.3	3.1	2.9
Task 2 (s)	17.9	18.2	14.5	12.6	10.5
Load article (s)	6.3	10.8	3.4	8.2	4.3
Task 3 (s)	19.4	12.6	15.9	13.3	11.4
Switch to application (s)	5.8	2.5	2.5	2.8	2.5
Task 4 (s)	66.3	39.9	36.9	43.2	30.3
Task 5 (s)	12.1	12.8	6.6	9.5	5.1
Load image (s)	2.8	6.8	2.5	2.9	2.2
Task 6 (s)	153	85	88	96	95
Total	306.9	209.9	187.9	212.3	181.6
Navigational cost					
Task 1 (taps)	4	4	4	5	5
Task 2 (taps)	6	5	4	4	4
Task 3 (taps)	8	7	6	6	5
Task 4 (taps)	15	15	15	14	9
Task 5 (taps)	6	4	4	4	4
Task 6 (taps)	7	7	7	7	7
Total	46	42	40	40	34

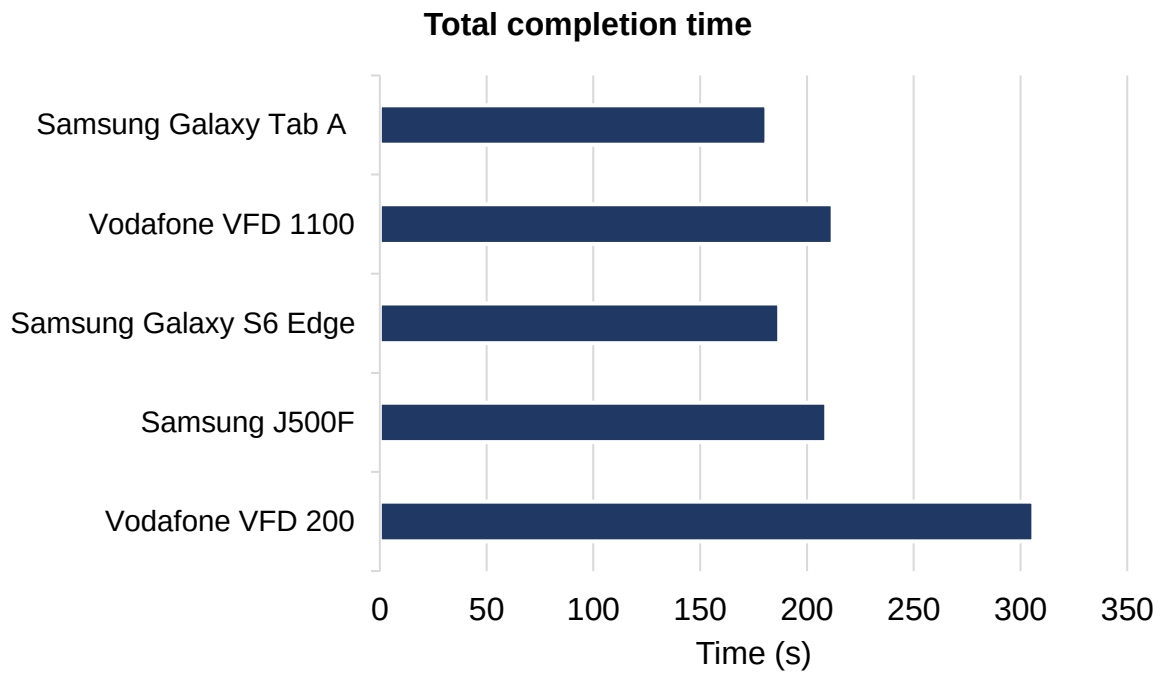


Figure 19: Study 2 completion time

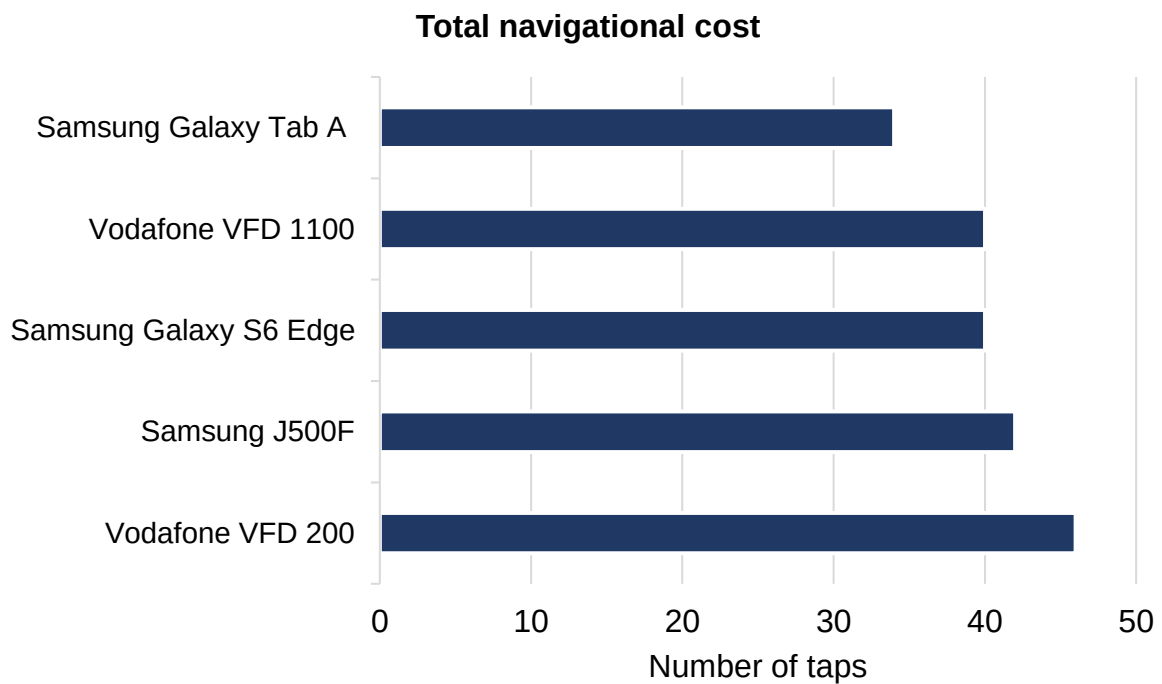
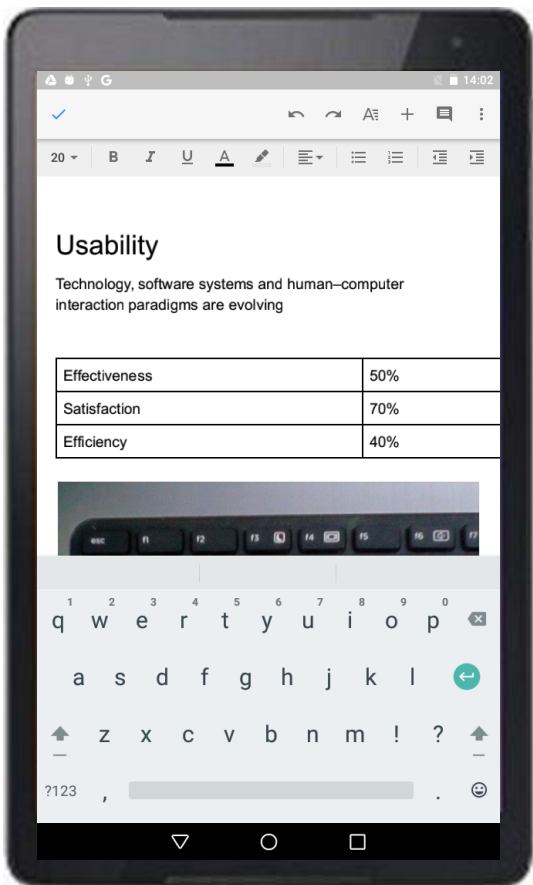


Figure 20: Study 2 navigational cost

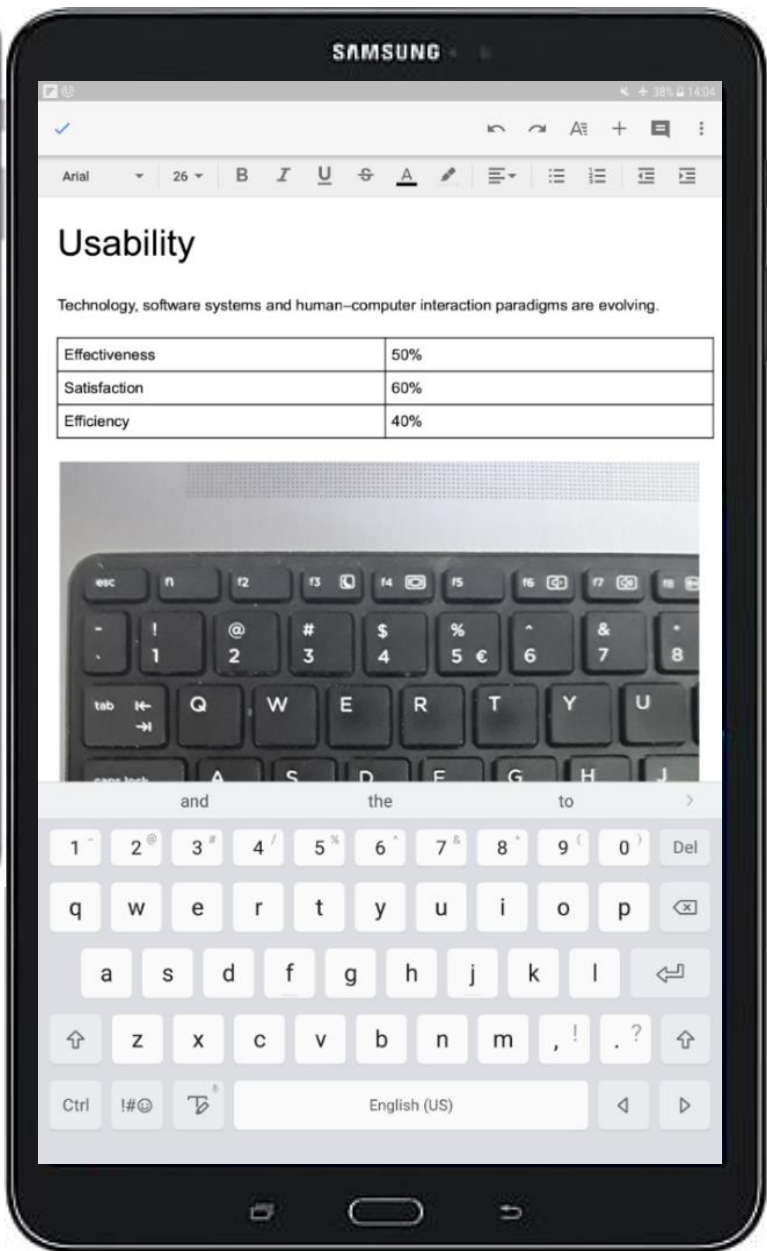
One of the biggest challenges that mobile application developers face is screen real estate. Google Docs has adjusted its application based on the screen size of the device. The images shown below show the different layouts of Google Docs. Vodafone VFD 200 is only able to display the title of the document as the keyboard occupies most of the screen. It is impractical to create a document using this device. The Samsung Galaxy S6 edge has a slightly larger display than the Samsung J500F. The two tablet devices display the edit bar at the top of the application which is different from the smartphone devices. The Samsung Galaxy Tab A is the only device capable of displaying the entire table. The keyboards increase in size as the screen size increases.

Figure 21 shows the mobile device screen real estate and their relative sizes to the other devices.





Vodafone VFD 1100



Samsung Galaxy Tab A

Figure 21: Mobile devices relative screen size

The quantitative results show that the Samsung Galaxy Tab A is the most usable device because of its fast processing time and large screen real estate. A large screen allows users to navigate easier and have more information displayed on the screen.

4.4.3 Qualitative results

Many other factors need to be considered when using a mobile device. The performance of the devices is important but because the devices are mobile, factors such as environment, portability, integration and other functionality needs to be considered when selecting a device.

The following questions were asked to the ten participants and their responses were recorded and are discussed.

Which device was easier to handle?

The aim of this question is to determine how the participants handle the different mobile devices and which device they preferred to handle. Nine out of the ten participants preferred using either the Samsung Galaxy S6 Edge or the Samsung J500F. The two devices are very similar in size.

The Vodafone VFD 1100 was used on the table and in both hands. This device is too small to be used as effectively as the Samsung Galaxy Tab A on the desk but too large to be held in both hands and have the functions of the application within reach.

Which device had the best layout of Google Docs application?

All the participants preferred the layout of Google Docs on the Samsung Galaxy Tab A. The screen is big enough to display all the edit functions and the entire table. It is also the only device that doesn't require the user to double tap in a table cell to input text.

The Vodafone VFD 200 is unable to handle the table function properly which made it difficult for the participants to complete the tasks. This device is not suitable for creating documents.

The participants hesitated slightly when editing text as the edit bar is found at the bottom in the smartphone devices and at the top on the tablets. This also shows that participants grew accustomed to the layout on the smartphone devices. Some

participants noted that the edit bar is easier to use if it is at the bottom of the display as it is within reach of the thumbs.

Which device was easier to type with?

Participants preferred the Samsung J500F and Samsung Galaxy S6 Edge smartphones to type. The tablet keyboards are bigger which creates less errors during typing, however, participants could only use the index fingers to type and this is inefficient as they are not accustomed to typing in this manner and the keys are further apart.

Which device would you prefer to use to create documents?

The test was done at a desk and 8 out of the 10 participants would prefer using the Samsung Galaxy Tab A to create documents. The application and document are displayed the best on the tablet. Participants would prefer to use this device for longer periods of time than the other devices.

Would you use this device in any environment?

The environment plays an important role in selecting a device. Participants would prefer using the Samsung Galaxy Tab A if they were seated at a desk. If the environment included moving around, then the participants would prefer using a smartphone. To answer the question, the participants would use the Samsung Galaxy Tab A if they were seated at a desk or table. Table 24 Gives a summary of the questions and the corresponding preferred device.

Table 24: Summary of the questions and preferred devices

Question	Device
Which device was easier to handle?	Samsung Galaxy S6 Edge Samsung J500F
Which device had the best layout of Google Docs application?	Samsung Galaxy Tab A
Which device was easier to type with?	Samsung Galaxy s6 Edge Samsung J500F
Which device would you prefer to use to create documents?	Samsung Galaxy Tab A
Would you use this device in any environment?	No, only in seated environments

Table 25 gives a summary of the efficiency and satisfaction of the mobile devices.

Table 25: Usability measurements of study 2

Ranking	Efficiency	Satisfaction
1 st mobile device	Samsung Galaxy Tab A 2016	Samsung Galaxy Tab A 2016 Samsung Galaxy S6 Edge Samsung J500F
2 nd mobile device	Samsung Galaxy S6 Edge	
3 rd mobile device	Samsung J500F	
4 th mobile device	Vodafone VFD 1100	Vodafone VFD 1100
5 th mobile device	Vodafone VFD 200	Vodafone VFD 200

The efficiency of the devices is directly related to the hardware and software specifications of the devices. The latest operating system, better CPU and increased RAM make devices more efficient. The most important feature is an octa-core CPU as it processes the fastest. The participants however, preferred using the tablets due to the size of the screen.

There are many factors that need to be considered when selecting a mobile device for creating documents. It is up to the user to decide, based on their needs what they require. The following factors that are discussed should be considered when selecting a mobile device.

Environment

If the user will use the device in office type environments that include a desk or table and chair, then the Samsung Galaxy Tab A device will work the best. If the user is going to use the device while being mobile, then a smaller device such as the Samsung smartphones will work best.

It should be noted that the study was performed while participants were seated at a desk. When the participants asked if they would use the Samsung Galaxy Tab A in any environment, they stated that if the environment did not involve being seated and rather being on the move, they would prefer to use the Samsung Galaxy S6 Edge. This is due to the portable size of the device.

Time

The amount of time a user is going to spend on the device will determine which device they should use. Users are more willing to use a tablet with a large screen if they know they are going to spend hours using the device to create and edit documents. If users are going to use the device for a short period of time such as between lectures or while on the move, then a smartphone device with a screen size of at least 5.0" will suffice.

Task complexity

Complex tasks, such as creating tables and navigating large documents, will be easier to perform on tablets as they are able to display more information. However, typing long pieces of text is easier on smartphone devices due to the ease of handling the device in both hands and typing with the thumbs.

4.5 Conclusion

Usability tests have been performed on various genres of mobile applications, however, very few tests have been done on educational and productivity applications such as word processing applications. This dissertation expands on usability testing and specifically focuses on the usability of reading and writing on mobile devices.

The main objective of the study is to investigate the usability of word processing applications on mobile devices. Chapter 3 and 4 provided the methodology and validation of results respectively. To achieve the main objective, study 1 and study 2 were developed. Study 1 results showed that Google Docs is the most usable word processing application and provided insight into the usability of all the applications tested. Study 2 results showed that the Samsung Galaxy Tab A 2016 is the best performing device, however; this is dependent on the environment it is being used in.

The generic guidelines discussed in the literature review were mapped to issues found during the usability tests of the applications. It was found that all the usability issues could be mapped to a guideline and therefore the generic guidelines are enough in addressing usability issues. The study done by N. Ahmad et. al., suggests using the generic guidelines to develop an application and then test the usability of an application developed, with and without the guidelines, to see if the application developed using the guidelines is more usable [40].

Google Docs is the best application because the participants could perform the tasks in less time and with fewer errors than Microsoft Word or WPS Writer. This led to users rating Google Docs easier to use than Microsoft Word and WPS Writer.

From the list of mobile device tested in study 2, the Samsung Galaxy Tab A is the optimal mobile device to create documents when seated at a desk. The device has the largest screen size which makes it more usable when creating documents, however, due to the large size of the device, it is more practical to use it at a desk. If a user is not at a desk and is therefore mobile, then the Samsung Galaxy S6 Edge is the best devices to use because the device has the fastest processor and largest screen size of the smartphone devices tested.

University students will be able to use Google Docs on their mobile devices for reading and typing documents and reports. Students can use the application in conjunction with the desktop application to review and edit documents while not seated at a table or while on-the-move. This study also gives significant suggestions for future development of word processing applications and developers can use the suggestions made to improve existing applications or develop new applications.

A usability evaluation of word processing applications has not been done prior to this dissertation and therefore usability experts can use this dissertation to further study the usability of word processing applications on mobile devices. Usability experts can use the findings to test other mobile device applications with similar functionality.

Chapter 5: Conclusion

This chapter serves as a conclusion to the study. The research objectives are evaluated and recommendations for future work is provided.

5. CONCLUSION

5.1 Preamble

This study was conducted to address the main objective, which was to investigate the need for, and usability of word processing applications on mobile devices. Chapter 1 highlights the need for this study along with the objectives and Chapter 2 provided the literature review needed to design and implement a method to address the need for the study

In Chapter 3 the knowledge obtained from Chapter 2 was used to develop usability tests to test the usability of word processing applications (Study 1), and the usability of mobile devices (Study 2). The results of Study 1 and Study 2 were discussed in Chapter 4.

A conclusion drawn of the study, in the above mentioned results is given in this chapter. Section 5.2 and 5.3 will provide an overview of the study and demonstrate how the required objectives were respectively met. The study's limitations are listed in Section 5.4 and recommendations for further studies is listed in Section 5.5.

5.2 Overview of the study

It was established in the introduction that there is an increase in mobile device usage in education and there is a need for usable word processing applications for students. Students still prefer to use desktops for reading and writing, however, there is a desire for the use of mobile devices because of the low prices of the devices and the mobility of the devices. Developing countries benefit greatly from using mobile devices in education due to the low cost of the devices and the limited resources available for computers. To address these issues, this study investigated the usability of word processing applications and the usability of different mobile devices for creating and editing documents.

In Study 1, a usability test was done to investigate the effectiveness, efficiency and satisfaction index of Google Docs, Microsoft Word and WPS Writer. Google Docs was found to be the most user friendly word processing application by the 40 participants in this study. These participants found typing and using basic editing tools, such as bold and underline, was the easiest to use in Google Docs.

In Study 2, Google Docs was used on five different mobile devices to test the usability of the mobile devices. From the selected devices, it was found that Samsung Galaxy Tab A 2016 and Samsung Galaxy S6 Edge were the most user friendly. The Samsung Galaxy Tab A 2016 is user friendly because of its large screen and the Samsung Galaxy S6 edge is user friendly because of its speed. The larger the device's screen the more usable it is for creating and editing documents. The users stated that they will only use the tablet if seated at a desk or table as the device is too big to hold and operate at the same time. The participants indicated they would rather use the Samsung Galaxy S6 Edge device if they were on the move or not seated at a desk. In this study it is the users experience or sentiment which determines which factors and functions are important to meet their required needs.

5.3 Validation of the objectives

The main objective of the study was to investigate the usability of word processing applications on mobile devices.

The sub-objectives of the study include the following:

- To investigate and document the usability issues of different mobile devices
- To propose the most usable currently available mobile word processing application and device to use to create documents
- To provide suggestions for future word processing mobile application development.

Literature was reviewed in Chapter 2 which gave insight into usability testing of applications and mobile devices. Therefore, in order to achieve the main objective, two usability tests were set up to test the usability of word processing applications and mobile devices. The usability tests were performed by 40 students and the results were recorded and evaluated. Thus, the main objective of the study was achieved.

Usability issues of different mobile devices were investigated in terms of creating and editing documents. The results showed that the most usable word processing application is Google Docs and the Samsung Tab A 2016 is the most usable mobile device to create and edit documents. Suggestions for mobile application developers

are given in Chapter 4 and recommendations for further studies are given in the next section and therefore all the sub-objectives have been met.

5.4 Limitations of study

The usability tests performed in this study has inherent limitations due to a limited number of sample resources and that of the small statistical sample sizes available at the time. The limitations that are unique to each study is listed below.

Study 1

1. The applications chosen for evaluation in Study 1 were limited to three of the most popular mobile word processing applications. There is a possibility that a more usable application is available on the application store and was not selected as part of this study.
2. The tests were designed to test certain identified features and functions of the selected applications and does not represent a full user functional test of the application in its ability to edit and create documents such as creating graphs.

Study 2

1. The devices chosen for this study were all Android devices (due to their large market share in Africa) and therefore do not represent the population of users that are accustomed to other platforms such as Windows or iOS.
2. The number of devices was limited to five devices due to financial resource constraints.

5.5 Recommendations for further studies

For future studies, a usability test should be performed on a word processing application that was developed using generic guidelines. Between the three applications chosen in this study, Google Docs was identified as the most user friendly, however, it will be necessary to test all the other word processing applications available. This will give a true indication of which one is the most user friendly.

The tasks given to the participants should include large document tests in order to test the capabilities of the application and mobile device when dealing with large

documents. Other forms of text input should also be tested in document generation test for example: Swype and speech to text.

The demand for usable word processing applications and mobile devices has been established and it is important for application developers to utilise specific mobile device features to optimise document generation. Students will thus have the ability to use mobile devices for document creation and editing, however, this study reiterates the fact that students who have access to computers will still prefer to use them above mobile devices.

5.6 Closure of study

In this study usability tests were performed to test the usability of word processing applications and mobile devices. This was done by establishing the need for the study and reviewing the relevant literature for insights. Thereafter, the problem statement and objectives of the study were defined. The knowledge obtained from literature was then used to develop the usability tests. The results were verified by mapping them to usability guidelines.

This chapter concluded the document by providing an overview of this study. Furthermore, the limitations of the study were discussed, and it was stated how the objectives of the study were met. Recommendations for further studies were provided.

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Appendix A: Preliminary questionnaire

Questionnaire 1

What is your age?

- ☐ 10 - 20 years
- ☐ 21 - 30 years
- ☐ 31 - 40 years
- ☐ 41 + years

What percentage of your day do you have access to a computer?

- ☐ 0% - 50%
- ☐ 50% - 100%

Which device do you use the most to read text messages?

- ☐ Computer
- ☐ Mobile device
- ☐ Both equally

Which device do you use the most to read emails?

- ☐ Computer
- ☐ Mobile device
- ☐ Both equally

Which device do you use the most to read short pieces of text such as a news article?

- ☐ Computer
- ☐ Mobile device
- ☐ Both equally

Which device do you use the most to read longer text such as reports?

- ☐ Computer
- ☐ Mobile device
- ☐ Both equally

Which device do you use the most to type a text message?

- ☐ Computer
- ☐ Mobile device
- ☐ Both equally

Which device do you use the most to type emails?

- ☐ Computer
- ☐ Mobile device
- ☐ Both equally

Which device do you use the most to type a single page document?

- ☐ Computer
- ☐ Mobile device
- ☐ Both equally

Which device would you use the most to type a large document (more than 2 pages)?

- ☐ Computer
- ☐ Mobile device
- ☐ Both equally

When typing something, at what point would you prefer using a computer than a mobile device?

- ☐ 0 - 50 words
- ☐ 50 - 200 words
- ☐ 200 - 1000 words
- ☐ more than 1000 words

Appendix B: Method tasks

Method 1

1. Create the title "E-Learning"
2. Open Google chrome and search "E-learning" on Science Direct. Select the second research article.
3. Copy a sentence and paste it into the document under the title.
4. Create the following table:

Moodle	30%
Blackboard	46%
Other	24%

5. Insert an image from the smartphone's gallery
6. Type, bold and underline the words as shown below:

The current research hypothesizes that:

H1a: Collaboration quality has a positive influence on the individual Impact of e-learning systems.

H1b: Collaboration quality has a positive influence on the use of e-learning systems.

Very difficult

Very easy

1

2

3

4

5

6

7

--	--	--	--	--	--	--

Method 2

1. Create the title “Smartphone usage”
2. Open Google chrome and search “Smartphone usage” on Science Direct. Select the third research article.
3. Copy a paragraph and paste it into the document under the title.
4. Create the following table

Samsung	21%
iPhone	15%
Other	62%

5. Insert an image from the smartphone’s gallery
6. Type, bold and underline the words as shown below:

The percentage of individuals using their smartphones is increasing.

Usability: is the ease of use and learnability of a human-made object such as a device.

Visual design: aims to shape and improve the user experience

Very difficult

Very easy

1

2

3

4

5

6

7

--	--	--	--	--	--	--

Method 3

1. Create the title “Usability”
2. Open Google chrome and search “Usability” on Science Direct. Select the first research article.
3. Copy a sentence and paste it into the document under the title.
4. Create the following table

Effectiveness	70%
Efficiency	56%
Satisfaction	42%

5. Insert an image from the smartphone’s gallery
6. Type, bold and underline the words as shown below:

Heuristic evaluation is performed based on a set of usability heuristics. The set of Nielsen's heuristics:

Heuristic 1: Visibility of system status

Heuristic 2: Match between system and the real world

Very difficult

Very easy

1

2

3

4

5

6

7

--	--	--	--	--	--	--

Appendix C: Participant form

Participant form: U__

Name and surname	
Gender	
Age	
Degree	
Phone type	
IOS/Android	
Any experience in 3 applications	

Application order:

Google 1	WPS 2	Microsoft Word 3	Microsoft Word 1	WPS 2	Google 3
Google 1	Microsoft Word 2	WPS 3	WPS 1	Microsoft Word 2	Google 3
Microsoft Word 1	Google 2	WPS 3	WPS 1	Google MS 2	Word 3

Task number	Effectiveness	Efficiently: Time (s)	Efficiency: Number of taps	Satisfaction	Problems
1					
2					
3					
4					
5					
6					

Strongly

Strongly

disagree

agree

1. I think that I would like to use this application frequently

1	2	3	4	5

2. I found the application unnecessarily complex

1	2	3	4	5

3. I thought the application was easy to use

1	2	3	4	5

4. I think that I would need the support of a technical person to be able to use this app

1	2	3	4	5

5. I found the various functions in

1	2	3	4	5

this application were well integrated

6. I thought there was too much
inconsistency in this app

1	2	3	4	5

7. I would imagine that most people
would learn to use this app
very quickly

1	2	3	4	5

8. I found the application very
cumbersome to use

1	2	3	4	5

9. I felt very confident using the
app

1	2	3	4	5

10. I needed to learn a lot of
things before I could get going
with this application

1	2	3	4	5

SUS Score: ____

Appendix D1: SUS scores

	Gender	Google Docs	Microsoft Word	WPS Writer
U0	M	70	85	55
U1	M	67.5	70	60
U2	M	27.5	30	27.5
U3	M	62.5	47.5	52.5
U4	M	65	35	72.5
U5	M	90	47.5	75
U6	M	50	80	87.5
U7	F	77.5	37.5	47.5
U8	M	92.5	65	67.5
U9	F	100	82.5	40
U10	F	100	92.5	90
U11	F	40	37.5	65
U12	M	30	67.5	30
U13	F	85	87.5	60
U14	F	97.5	77.5	65
U15	M	60	80	85
U16	F	80	70	62.5
U17	F	87.5	45	52.5
U18	F	97.5	87.5	82.5
U19	F	80	55	57.5
U20	M	57.5	42.5	40
U21	M	65	37.5	22.5
U22	F	15	50	42.5
U23	M	87.5	70	55
U24	M	70	40	50
U25	M	57.5	70	47.5
U26	M	82.5	57.5	67.5
U27	M	67.5	47.5	25

U28	M	77.5	87.5	32.5
U29	M	67.5	12.5	47.5
U30	M	87.5	80	72.5
U31	M	32.5	100	0
U32	M	95	70	95
U33	F	90	27.5	72.5
U34	M	72.5	52.5	52.5
U35	M	95	60	82.5
U36	M	32.5	82.5	7.5
U37	M	30	47.5	62.5
U38	M	40	87.5	37.5
U39	F	25	32.5	47.5

Appendix D2: Task results

Task 1

	Google Docs				Microsoft Word				WPS Writer			
	Effect	Time	Tap	Sati	Effect	Time	Taps	Satis	Effect	Time	Taps	Satis
U0	X	104	26	3		72	37	4		40	8	6
U1	X	91	35	2		36	17	4		24	10	4
U2		33	11	5		89	32	3		30	12	4
U3		29	9	2		61	28	2		48	23	2
U4		44	37	5		45	17	2		78	29	3
U5		43	16	6		28	16	5		35	14	5
U6		101	27	4		33	11	7		30	9	7
U7	X	65	28	1		38	12	5		49	13	2
U8		26	6	7	X	87	31	4		48	17	5
U9		48	19	7		50	16	7		56	29	7
U10		26	10	7		40	8	4		114	35	4
U11		47	18	5		53	22	5		32	6	6
U12		53	26	4		49	19	4		45	11	3
U13		60	18	5		57	18	6		54	13	5

U14	X				X				X			
U15		43	14	4		55	16	5		56	23	4
U16		36	29	4		54	18	3		65	25	3
U17		128	33	3	X	150	38	1		129	30	2
U18	X	58	12	5		41	17	6		31	8	6
U19		58	8	5		55	15	4	X	56	24	2
U20		25	5	5		51	17	4		40	22	4
U21		65	23	7		66	24	7		60	20	3
U22		40	18	1		44	21	7	X	70	11	2
U23		48	13	5		31	12	4		44	7	6
U24	X				X				X			
U25	X	74	20	3	X	75	22	5		44	9	5
U26		33	4	7		45	13	7		61	16	7
U27	X				X				X			
U28		50	25	3		29	10	5		30	42	3
U29	X	155	18	1		72	20	3		128	27	2
U30		21	4	6		35	16	6		37	9	5
U31	X	40	8	5		49	21	7		36	15	7
U32		32	7	7		38	13	4		32	14	7
U33		38	13	4	X	85	26	4		29	8	7
U34		35	10	6		66	22	5		60	19	4
U35		40	13	7		77	20	6		48	8	6
U36		47	6	2		33	10	6		42	6	1
U37		40	15	4		47	22	2		37	14	4
U38		49	17	5		30	11	5		49	19	6
U39		57	23	1		36	14	5		31	10	5

Task2

	Google Docs				Microsoft Word				WPS Writer			
	Effect	Time	Tap	Sati	Effect	Time	Taps	Satis	Effect	Time	Taps	Satis
U0		22	8	7		15	5	6		19	13	7
U1		25	7	6		41	11	6		21	6	6

U2		11	4	5		32	12	5		16	6	5
U3		14	6	4		11	7	4		23	9	5
U4		24	7	6		23	6	6		26	7	7
U5		16	8	7		15	7	6		23	8	7
U6		20	6	7		19	6	7		33	8	7
U7		26	7	7		18	5	7		23	6	7
U8		21	8	7		24	7	6		18	7	6
U9		15	6	7		17	6	6		22	9	7
U10		18	8	7		35	17	6		64	5	6
U11		15	7	7		21	5	7		38	5	7
U12		37	12	5		29	8	5		173	41	5
U13		20	6	6		24	8	7		17	5	6
U14		19	9	6		24	10	7		17	5	6
U15		16	5	6		28	7	6		53	15	6
U16		19	8	7		26	8	7		24	8	7
U17		39	13	5		17	5	6		31	9	2
U18		29	8	7		20	6	7		23	9	7
U19		22	6	7		32	8	7		17	6	7
U20		14	8	6		25	9	6		15	7	6
U21		6	5	7		24	8	7		16	7	7
U22		20	8	7		19	7	6		42	8	6
U23		12	8	6		30	9	6		35	10	6
U24		27	6	6		15	6	6		20	7	6
U25		27	7	6		22	6	6		17	6	6
U26		25	6	7		27	7	7		25	5	7
U27		15	6	6		46	7	7		20	7	7
U28		15	5	7		16	10	7		16	7	6
U29		14	7	6		23	7	6		22	10	6
U30		22	6	6		14	5	6		22	8	6
U31		31	11	7		23	7	7		16	5	7
U32		21	99	7		19	8	6		42	7	6

U33		16	6	6		25	6	6		25	6	7
U34		19	6	6		22	11	6		26	10	6
U35		6	9	7		17	5	7		29	6	7
U36		34	7	7		20	5	7		18	9	7
U37		39	10	6		20	5	6		33	10	6
U38		31	8	7		28	8	7		33	5	7
U39		47	15	5		26	6	7		20	8	7

Task 3

	Google Docs				Microsoft Word				WPS Writer			
	Effect	Time	Tap	Sati	Effect	Time	Taps	Satis	Effect	Time	Taps	Satis
U0		20	11	7		29	18	7		38	12	7
U1		63	18	5		94	31	6		10	17	6
U2		27	13	4		38	16	6		30	17	5
U3		18	7	4		39	16	5		35	15	5
U4		35	12	5		23	11	6		30	18	6
U5		20	11	6		20	11	6		34	16	6
U6		36	17	7		27	16	7		19	7	7
U7		26	11	7		34	12	7		26	7	7
U8		33	15	7		78	23	7		23	11	6
U9		26	14	7		33	12	7		23	9	7
U10		21	42	7		33	19	6		29	17	7
U11		20	9	6		29	19	4		52	15	5
U12		63	16	6		45	9	5		32	14	5
U13		46	15	6		39	18	5		25	11	6
U14		26	14	7		43	15	7		18	9	6
U15		59	17	6		37	19	7		33	14	7
U16		42	15	7		32	17	7		56	21	6
U17		55	11	6		48	15	6		93	56	5
U18		25	14	6		20	6	7		26	17	6
U19		31	12	6		39	11	5		38	8	6

U20		27	13	6		47	25	6		32	12	6
U21		26	7	7		37	6	5		13	8	7
U22		28	14	6		19	18	6		62	10	6
U23		37	9	6		25	2	6		37	16	5
U24		27	10	5		25	11	6		35	11	6
U25		29	8	7		35	8	6		27	10	6
U26		32	8	7		64	12	7		44	5	7
U27		66	29	6		35	13	5		21	9	6
U28		26	12	7		27	15	7		26	16	7
U29		32	16	4		30	13	4		43	15	6
U30		28	15	6		23	10	6		35	15	6
U31		30	11	6		32	15	7		36	13	7
U32		26	7	7		35	12	5		33	15	7
U33		20	8	6		26	12	6		23	8	6
U34		27	14	5		35	19	6		31	17	5
U35		31	11	7		44	19	7		39	18	7
U36		48	16	4		43	17	6		55	22	6
U37		26	10	6		42	19	6		25	12	6
U38		22	9	7		19	8	7		23	13	7
U39		27	15	7		26	9	5		21	10	7

Task 4

	Google Docs				Microsoft Word				WPS Writer			
	Effect	Time	Tap	Sati	Effect	Time	Taps	Satis	Effect	Time	Taps	Satis
U0		01:03	21	6		01:11	22	6		01:09	26	7
U1		01:16	19	5		01:33	27	4		01:33	22	5
U2		00:53	22	5		01:12	36	4		00:56	16	5
U3		00:56	17	3		01:37	30	3		01:04	21	4
U4		02:19	37	5		01:18	23	2		01:13	23	6
U5		01:10	19	6		01:43	35	5		01:07	28	4
U6		03:05	44	5		02:12	41	6		00:44	20	7

Usability study of word processing applications on different mobile devices

U7		01:52	30	7		01:37	19	6		01:10	18	6
U8		00:56	15	7		01:45	30	7		01:21	22	7
U9		01:03	19	7		02:01	53	5		01:01	21	5
U10		01:20	24	7		02:05	41	3		00:53	15	7
U11		01:19	33	3		00:33	25	2		01:05	19	4
U12		01:22	29	6		02:37	41	4		01:34	19	3
U13		01:34	28	6		01:32	31	6		01:03	16	6
U14		00:57	17	7		02:15	41	5		00:54	17	7
U15		01:30	26	6	X	02:44	44	5		01:04	23	4
U16		01:06	31	5	X	02:01	40	4		01:07	25	5
U17		01:56	39	6	X	04:02	41	3		01:56	29	6
U18		01:12	26	6		01:19	20	5		00:50	19	6
U19		01:02	21	6		02:19	34	3		01:08	21	5
U20		00:47	21	5	X	01:46	37	4		00:49	15	5
U21		01:00	24	5		01:21	21	5		00:47	22	5
U22		00:54	17	4		02:07	29	4		01:10	22	5
U23		01:29	33	5		01:42	31	4		01:12	24	6
U24		01:01	15	4		01:24	19	5		01:02	17	5
U25		01:08	25	6		01:10	25	6		00:54	16	6
U26		01:32	25	7		02:00	33	6		01:00	12	7
U27		01:00	23	6		01:52	32	3		01:18	23	5
U28		01:01	21	5		01:19	15	3		00:59	24	4
U29		00:53	19	4		03:18	43	1		00:56	21	4
U30		01:07	29	7		00:58	21	5		00:51	22	6
U31		01:24	28	5		00:22	19	7		00:59	25	5
U32		00:53	26	7		02:21	43	3		01:10	20	7
U33		01:17	22	6	X	02:15	38	4		01:08	22	6
U34		01:14	27	5		01:19	23	5		01:14	25	5
U35		01:12	24	7		02:30	33	6		00:24	20	7
U36		01:05	20	3		01:50	31	5		01:47	38	3
U37		01:13	22	5	X	01:33	33	1		00:42	17	4

U38		00:47	15	6		01:43	38	5		01:36	30	6
U39		00:54	18	4		01:04	15	4		00:56	19	5

Task5

	Google Docs				Microsoft Word				WPS Writer			
	Effect	Time	Tap	Sati	Effect	Time	Taps	Satis	Effect	Time	Taps	Satis
U0		19	8	7		19	9	4		20	7	7
U1		43	7	6		22	10	6		53	9	5
U2		49	15	3		53	20	5		19	8	4
U3		21	6	4		41	11	6		16	8	4
U4		15	4	6		180	7	3		16	5	6
U5		21	16	6		15	7	6		10	5	6
U6		25	11	6		16	8	6		9	5	6
U7		60	11	7		22	9	4		13	4	6
U8		21	10	7		19	6	7		10	5	7
U9		23	10	7		22	10	7		13	9	7
U10		16	6	7		16	8	6		20	11	7
U11		18	9	3		19	9	4		13	6	6
U12		17	5	6		15	4	5		14	8	2
U13		22	7	6		12	6	7		10	5	6
U14		16	6	7		53	21	6		10	5	6
U15		9	5	7		42	14	6		27	15	6
U16		11	6	7		46	12	6		12	6	5
U17		18	8	7		39	14	4		18	7	6
U18		22	8	7		15	5	6		10	6	6
U19		27	11	6		17	7	6		28	12	5
U20		11	6	7		22	6	7		7	4	5
U21		18	11	7		15	6	7		9	6	7
U22		19	8	4		18	6	5		20	4	4
U23		25	11	6		25	14	6		14	7	6
U24		17	7	6		10	4	5		9	4	5

U25		18	7	5		18	7	6		11	4	5
U26		15	7	7		17	5	7		8	5	7
U27		29	18	6		39	6	6		11	6	7
U28		18	10	6		15	6	2		12	5	6
U29		14	7	6		16	6	5		20	11	5
U30		31	13	7		72	6	4		13	6	7
U31		40	9	6		16	5	7		18	10	7
U32		17	11	7		9	7	6		74	7	7
U33		15	7	6		37	11	4		10	5	6
U34		17	7	5		16	6	4		10	7	6
U35		13	5	7		12	5	7		19	5	7
U36		64	23	4		13	5	6		14	5	3
U37		49	19	2		17	6	6		26	7	4
U38		19	6	7		12	6	7		8	5	7
U39		20	10	6		9	5	5		10	6	5

Task 6

	Google Docs				Microsoft Word				WPS Writer			
	Effect	Time	Tap	Sati	Effect	Time	Taps	Satis	Effect	Time	Taps	Satis
U0		03:25	23	5		02:08	11	7		02:28	13	7
U1		04:25	4	5		04:20	47	5		04:41	50	4
U2		02:00	10	3		03:53	40	2		03:41	50	2
U3		02:11	10	6		02:45	27	3		03:14	38	3
U4		03:14	11	5		02:22	10	6		04:20	60	3
U5		02:18	16	6		02:17	6	5		03:39	48	2
U6		02:18	17	6		02:02	20	7		03:03	34	6
U7		02:24	13	6		02:52	26	7		04:10	61	3
U8		02:12	8	7		03:29	11	7		03:13	27	6
U9		01:17	12	7		03:10	53	4		02:44	64	2
U10		02:51	7	7		03:26	26	6		05:21	47	4
U11		02:05	7	6		02:13	10	6		04:42	68	3

Usability study of word processing applications on different mobile devices

U12		03:57	7	5		03:11	10	6		04:27	58	2
U13		03:18	30	5		02:07	8	6		03:42	47	4
U14		02:18	21	7		03:50	31	6	X	03:36	50	4
U15		03:18	41	4		04:18	43	6		02:20	11	7
U16		02:45	10	6		03:39	28	6		03:22	55	4
U17		04:32	8	6		05:00	16	3		07:17	62	3
U18		02:28	15	6		02:16	10	6		02:57	7	4
U19		02:45	20	4		02:59	27	4		04:39	53	3
U20		01:32	9	6		01:57	12	6		03:48	67	2
U21		02:10	17	4		02:50	18	5	X	03:40	68	3
U22		01:52	7	2		02:01	6	3		02:37	24	2
U23		02:16	8	7		02:48	16	5		06:14	45	3
U24		03:10	22	5		02:10	16	6		02:36	33	5
U25		02:06	7	5		02:07	7	5		03:07	34	4
U26		02:30	11	6		04:12	26	5		04:20	47	5
U27		03:22	10	5		04:58	26	3		06:07	48	4
U28		02:53	33	3		03:07	36	4		03:50	52	5
U29		03:34	7	5		02:42	12	5		04:23	33	1
U30		02:39	7	7		02:35	7	6		02:50	41	6
U31		03:06	9	3		02:54	10	6		04:07	46	2
U32		01:13	10	7	X	01:52	6	6	X	01:04	10	7
U33		02:01	7	6		02:44	17	5		03:23	48	5
U34		02:46	12	5		02:55	10	5		03:22	38	4
U35		02:00	9	7		02:09	7	6		03:24	24	6
U36		03:08	7	6		02:38	9	6		05:28	56	1
U37		02:24	24	6		02:32	16	4		02:58	30	4
U38		03:30	38	4		02:03	9	7		03:19	35	4
U39		02:01	24	5		02:25	31	3		02:25	35	4