A HEURISTIC USABILITY EVALUATION OF ELECTRONIC INPUT DEVICES WITH REGARD TO RECORDING CLASS ATTENDANCE AT UNIVERSITIES:

CASE OF CENTRAL UNIVERSITY OF TECHNOLOGY

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Dissertation submitted in fulfilment of the requirements for the degree

MASTER OF INFORMATION TECHNOLOGY:

in the

Department of Information Technology

Faculty of Engineering and Information Technology

at the

Central University of Technology, Free State

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BLOEMFONTEIN

November 2018

DECLARATION OF INDEPENDENT WORK

DECLARATION WITH REGARD TO INDEPENDENT WORK

I, André Deon van der Walt, identity number and student number , do hereby declare that this research project, submitted for the degree MASTER OF INFORMATION TECHNOLOGY, is my own independent work and has not been submitted before to any institution by me or anyone else as part of any qualification and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State.

30 November 2018

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Student`s Signature Date

ACKNOWLEDGEMENTS

I would like to take this opportunity to acknowledge and extend my gratitude to the following persons who have made the completion of this dissertation possible:

Mr Casper Wessels who supervised my dissertation and tirelessly supporting me. A special mention of thanks is due to Dr Nicolaas Luwes for being my co-supervisor and for his dedicated time to work with me on the dissertation.

My parents, Mr André van der Walt and Mrs Elize van der Walt, who were a constant source of encouragement and motivation during some very difficult personal and professional times over the course of this dissertation. To my sister, Nicolene van der Walt, thank you for your support and love during this journey of my dissertation.

Lastly, but most importantly, I would like to thank God Jesus Christ for giving me the opportunity to start, progress and complete my research.

ABSTRACT

Student attendance is an important aspect at universities. Attending classes also increases a student's interaction with a variety of faculty members. This raises the likelihood of finding mentors and role models who can help guide their academic, career and personal development. The digital strategy of the Faculty of Engineering and Information Technology at the Central University of Technology, Free State, encourages the replacement of manual processes by technological processes, to capture class attendance. The manner in which class attendance is generally captured, relevant to the research setting, is a manual process using pen and paper. With the advent of new technologies it is possible to replace the aforementioned manual system with a custom hardware and software solution, by using electronic input devices (EID's). The question remains, how can a usability study on electronic input devices be used to assess and determine the most suitable device for recording class attendance electronically? The site of this research was restricted to the Central University of Technology, Free State (CUT). A mixed methodology to explore the phenomenon was used. Sixty-three (63) first- year students, currently enrolled for the Diploma in Information Technology, Extended Curriculum Programme (ECP), were identified as a suitable population, with the correct demographics and sample size, to participate in the study. An open-ended questionnaire was developed to determine student perceptions of EID's as well as the traditional method of recording student class attendance. Three different input devices were identified, namely: Barcode Scanner, Fingerprint Scanner, and Radio Frequency Identification Scanner (RFID). The devices were connected to custom software to gather the quantitative data over a period of four (4) weeks for each device. All the data captured was stored in a database. Data mining was implemented to extract data from the database. The objective of the study was to determine which electronic input device performs the best. A Performance Metric was developed that comprises the student's opinions, duration for each individual scan as well as the duration of the total scan time for each device. The data in the Performance Metric was analysed using correlation and standard deviation. Each student was identified using their student number, which is linked to the barcode on the student card. For both the RFID and Fingerprint Scanners, student numbers must be linked to the Fingerprint and the RFID code. At the inception

of the study, it was envisaged that the Barcode Scanner would be the most efficient and take the least time. It was also expected that students would be in favour of the Barcode Scanner, mainly because they are more familiar with it than with the other two devices.

Keywords: Attendance, Attendance Systems, Electronic Input Device, Usability, Scanning Devices.

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LIST OF EQUATIONS

LIST OF ABBREVIATIONS

1D	-	One Dimension
ACB	-	Adjusted cost base
CUT	-	Central University of Technology
DIT	-	Department of Information Technology
ECP	-	Extended Curriculum Programme
EID	-	Electronic Input Device
EIDs	-	Electronic Input Device’s
GSM	-	Global System for Mobile communications
GPA	-	Grade Point Average
GUI	-	Graphical User Interfaces
HTTP	-	Hypertext Transfer Protocol
IDE	-	Integrated Development Environment
IT	-	Information Technology
ITS	-	Integrated Tertiary Software
MHz	-	megahertz
MIS	-	Management Information Systems
M-score	-	Minimum Score
OOP	-	Object-oriented Programming
RFID	-	Radio Frequency Identification Scanner
SDK	-	Software Development Kit
SMS	-	Short Message Service
SOAP	-	Simple Object Access Protocol

SQL	-	Structured Query Language
UE	-	Usability Evaluation
UI	-	User Interface
UoT	-	Universities of Technology
UoTs	-	Universities of Technologies
USB	-	Universal Serial Bus
VS	-	Versus
XML	-	eXtensible Markup Language

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CHAPTER 1

INTRODUCTION

This chapter provides an introduction to this dissertation as well as background information to the project. It includes a definition of the problem and states the scope and aim of this project.

1.1. BACKGROUND

Student attendance is an important aspect at universities. Regular class attendance requires discipline and time management skills. These skills are beneficial no matter what career path one chooses. Attending class could also increase a student's interaction with a variety of faculty members. This raises the likelihood of finding mentors and role models who can help guide their academic career and personal development. (State University.com – U.S. University Directory, 2007).

(Cohall & Skeete, 2012) indicate that attendance registers also provide evidence of a student's class attendance habits and can assist in cases where the university is accused by a student of providing insufficient guidance in lectures.

To date, the Central University of Technology (CUT) utilises a system of a circulated, printed class list where students sign next to their name. This list is circulated in class from student to student to work through the list and find their names to sign for attendance. The signed list is added on the Integrated Tertiary Software (ITS) system, the database system that, among other things, would show all registered students (adapt IT, 2019).

At the end of each academic quarter these lists need to be captured on the university ITS system. This tedious task is done by departmental admin officers. In the past, it was seen that non-registered students add their names at the bottom of the paper class list. This is difficult to control as students that are not registered for a subject must not be allowed in class.

This manually managed class attendance control system, where a printed class list is circulated through the class, is therefore clearly a very tedious, time-consuming and outdated process. When dealing with a large group of 100+ students in a large venue, time is limited, especially if only one or two periods are allocated to this class. When students receive the paper-based attendance list and search for their names, their concentration is interrupted while they focus on signing the list.

There may be a method for improving the above stated manual attendance list by utilising technology. Various forms of research have previously been done in this regard, but mainly on a single scanning device solution. This study proposes a method to identify the most appropriate electronic scanning hardware device to recommend for an attendance checking system.

The three most practical, locally available and affordable input devices identified would be a Barcode Scanner which will scan optically in parallel lines of different widths and spacing as the printed standard on student cards at the CUT, a RFID (Radio Frequency Identification) Scanner that is compatible with the Microsoft Operating System and a Fingerprint Scanner that had a compatible software development kit (SDK) for Visual Studio 2015 available. The scanners identified would have the USB 2.0 connection speed, for the reason of constant speed certification which is USB 2.0 rated for the identified devices will indicate the same transfer rate of data of the identified devices.

Efficient input devices should be thoroughly evaluated and tested to scientifically recommend a device for attendance systems. An evaluation test will be developed to process data so that relevant conclusions can be drawn. The identified electronic scanning device can then be recommended for a fully automated electronic attendance system to be utilised at CUT.

An automated electronic attendance system would be advantageous to the lecturers as well, by providing data on student attendance which may be correlated with a student's academic progress. Attendance recording is an important aspect of tests and exams, where a record must be kept of students writing the paper.

Finally, such a system could provide evidence of a student's class attendance habits in cases where the university is accused by a student of providing insufficient guidance in lectures. In such cases, the university holds no liability if it can be showed that the student was regularly absent from class (van Wyk, 2008).

1.2. PROBLEM DEFINITION

The digital strategy in the Faculty of Engineering and Information Technology at the Central University of Technology encourages the replacement of manual processes by technological processes. This strategy was initiated in 2016 by the Dean of the Faculty at the time (Ngowi, 2016). Class attendance, currently mainly recorded with pen and paper, can be replaced by electronic input devices (EIDs). Simply relying on factors like the recording ability of a device may be insufficient when determining which device is most suited for the task in the relevant environment.

There is a lack of methods in literature to assess and select electronic capturing devices for the purpose of recording class attendance at tertiary institutions, especially concerning the lens that is usability. The usability theorem encapsulates more than a device's ability to capture data by addressing issues such as effectiveness, efficiency, learnability and memorability.

Thus far, the Central University of Technology usability of electronic input devices has not been employed as a metric in the context of electronic class attendance recording to assess and determine the suitability of different devices for the task at hand. There is a need to identify a device to have quantitative and qualitative qualities of scanning for class attendance.

Research question:

The main research question is: How can a usability study on electronic input devices be employed to assess and determine the most suitable input device for recording class attendance electronically, in terms of the usability aspects of efficiency, learn-ability and satisfaction?

Sub-questions:

- What are the usability concerns when selecting input devices for attendance systems in universities in South Africa delineated to the student-user?
- To what extent does heuristic evaluation in terms of usability aid in selecting the most suitable device for use in an attendance system at universities?
- What are the constituents of the usability metrics utilised to assess electronic input devices?

1.3. SCOPE OF THIS RESEARCH

In this research, the Department of Information Technology at the Central University of Technology, Free State, was used as a basis for defining the problem and finding a solution. A solution is given at the end of this dissertation which could be implemented at other educational institutions facing similar challenges.

1.4. RESEARCH OBJECTIVES

- To determine which electronic input device performs the best against a set of pre-determined usability metrics before this objective in the context of the environment and users with the aim to propose the most suitable electronic input device for capturing student attendance electronically. The process of determination would be to identify the research population, location and perform calculations of capture scanning time data. A quantitative approach will be taken.
- To suggest a method of assessing electronic input devices in terms of the usability metrics of such devices. A qualitative approach will be taken.

1.5. METHODOLOGY & RESEARCH DESIGN

Research site and Methodology

The research site is restricted to the Central University of Technology and will involve a mixed data collection approach.

Qualitative and quantitative methods will be employed to gather data in order to understand the research concepts and problem (Creswell & Clark, 2007). Mixed methods also require a researcher to have a broader set of skills that work for both qualitative and quantitative research methods.

The qualitative approach will be to gather scanning time data from scanning input devices for a specific duration and statistical methods like Correlation, Frequency analysis and standard deviation will be used. This will indicate mathematically, and scientifically which scanning input device performed the best against each other.

The quantitative approach will be implemented by using questionnaires where the observation of the research population will be tested, focusing on areas like effectiveness, user-friendliness and security. This method could indicate valuable feedback on the visual perception and opinion of the research population that will participate.

Research Population

To determine the most suitable population, the correct demographic and sample size of students will be identified. Students currently enrolled for Information Technology in the first year Extended Curriculum Programme would participate in this research study. Refer to sub-section 1.5.1.

Research Methods

A qualitative questionnaire will be developed to determine student perceptions on EIDs as well as the traditional method of recording student class attendance. The questionnaire will be deployed as a hard copy to participants. These qualitative questionnaires will be administered after classes for students to determine their perception of EIDs and the traditional method of capturing student class attendance.

Closed-ended questionnaires will be administered as a valid sample for exploratory data (Singhapakdi, et al., 1996) Statistical analysis of the data will be undertaken to determine the most suitable EID.

Open-ended questionnaires will be administered with the aim to identify trends among the students' opinions regarding EID's.

The quantitative methods that will be applied to determine the most suitable EID will be based on standard deviation, correlation and frequency in terms of performance and will include:

- Correlation of "Time scan per student"
- Correlation of "Total time scan per class"
- Standard Deviation of "Participants scan for four weeks for each device"
- Improvements on each of the variables on prolonged use of devices.
- Frequency Analysis of the scanning time recorded all the weeks and all devices for the participants.

Finally, quantitative and qualitative results will be statistically analysed to recommend the most suitable EID for class attendance at a UoT in terms of the pre-determined usability metrics.

1.5.1. Selecting the correct demographical students involved in the study (research population)

In finding the ideal student to participate in the study, the following must be considered:

The group will represent a student that will enter higher education at the CUT for the first time and possible from a previously disadvantaged background. Which has been seen in students enrolled for the extended curriculum programmes. Students must be from various provinces in South Africa and from different ethnic groups. Students might not have the same technical background as a typical engineering student and might have limited exposure to technology.

Information Technology (IT) Extended Curriculum Programme (ECP) students in the Programming Principles subject in the Department of Information Technology (Subject Code: PPC00FP) will be selected for this study. The admission requirements for IT ECP are students with an M-score of between 22 and 27 on the CUT scoring scale, with a minimum mark of 60% in Mathematical Literacy or 40% in either Mathematics or Information Technology.

The biography of IT ECP students involved in this study is from various provinces in South Africa and from different ethical groups. IT ECP students do not have the same technical background as a typical engineering student that qualified for the mainstream courses and most of them have limited exposure to technology. Some of the students come from disadvantaged backgrounds and rural areas. Limited technology was available when these students attended school. This category of student that did not use technology every day will be a good baseline to use to determine the usability and effectiveness of the electronic scanning devices.

1.6. RESEARCH PROCEDURE

The contribution of this study will be developing an method on EIDs for use in an attendance system at a UoT. The Evaluation Experiment should produce results that can be used to discuss factors such as the ability of the demography of students to operate the scanning devices and the performance of the scanning devices.

1.7. ETHICAL CONSIDERATIONS/CHALLENGES

Students participating in this study have complete an indemnity form. This will inform students that they will be part of this study and will confirm their consent.

a. Information obtained will be treated as confidential and no names or personal details will be made available in reporting the results obtained.
b. The questionnaire will be completed anonymously and involve no sensitive information.
c. Participation will be completely voluntary.

1.8. DISSERTATION ORGANIZATION

This dissertation comprises five chapters. The research question, background and problem statement are highlighted in Chapter 1. In the same chapter objectives and methodology are also highlighted with a view to answering the research question and the assessment of electronic scanning devices to be recommended for an automated electronic attendance system that can be utilised at Universities of Technology.

This dissertation has been organised into following chapters:

Chapter 2 – *Literature Review and Current Manual Attendance System*. In this chapter, relevant work and different technologies available to solve the problem pertaining to the most suitable scanning hardware device for an automated electronic attendance system are discussed. The current attendance method used at the Central University of Technology, Free State, and the manner in which student attendance is captured and processed, are also presented.

Chapter 3 – *Research Structure.* The process employed to locate the correct demographical student to participate in the study is explained, and the scanning devices that were selected, as well as pre-written software, are identified. An indication of how these were benchmarked is also provided. In addition, the methods of capturing data to the custom database, the manner in which the devices are connected and used, and the method of capturing qualitative and quantitative data will be discussed.

Chapter 4 – *Results.* The results of the different tests that were conducted during the course of this research project, are presented in this chapter. All the methods that were used to analyse the data captured and to correlate the results of scanning devices are discussed. Statistical methods and the results thereof are explained. Finally, recommendations are made, and the advantages of the results were identified.

Chapter 5 – *Conclusions and Future Work.* The dissertation is concluded by means of an examination of some of the challenges that arose during the research. A normative approach is followed, as the researcher describes an ideal situation for the implementation of an automated electronic attendance system, which situation is highlighted to benefit both students and the institution's staff members. Certain areas that were outside the scope of this research, but that warrant further research, are discussed.

1.9. SUMMARY

This study proposes a solution by means of determining the best suitable scanning device for an automated electronic attendance system. The most affordable, efficient and usable input device will be identified and recommended for an automated attendance system. An evaluation test will be developed to process data so that relevant conclusions can be drawn. At the end of the study, the recommended scanning device can then be used with an automated electronic attendance system at the CUT and other UoT’s.

CHAPTER 2

LITERATURE REVIEW AND CURRENT MANUAL ATTENDANCE SYSTEM

Student attendance is an important aspect at universities. State University indicates that regular class attendance requires discipline and time management skills. It is mentioned that these skills are beneficial no matter what career path is chosen. State University indicates that attending class also increases a student's interaction with a variety of faculty staff members (State University.com – U.S. University Directory, 2007).

It is also mentioned that this could raise the likelihood of finding mentors and role models who can help guide these students' academic, career, and personal development (State University.com – U.S. University Directory, 2007)). (Cohall & Skeete, 2012) indicate that attendance also provides evidence of a student's class attendance habits and can assist in cases where the University is accused by a student of providing insufficient guidance in lectures.

Evidence suggests that the process of recording class attendance is still paper-driven in many tertiary institutions (Kovac, *et al*., 2011). This is also the case for many South African tertiary academic institutions. The process of student attendees signing a paper-based form or the process of a relevant lecturer recording attendance on a paper-based form is not only time-consuming, out-of-date and in many cases frustrating, but, with the introduction and use of integrated tertiary software (ITS) systems that many tertiary institutions employ, also incompatible with such systems (adapt IT, 2019).

Research and technologies are being developed to try and automate this as can be seen in Cupido's research showing the implementation of a Biometric attendance system by using fingerprint access. This research addresses the question of whether the change from a manual attendance register to a biometric time and attendance system would more effectively ensure the availability of municipal employees to improve basic service delivery. His finding for this research was that Stellenbosch Municipality, through its management, has decided that the manual attendance register needs to be replaced with more secure and trustworthy technology. (Cupido, 2011)

Other approaches for automation include that by De Klerk that completed a research project in which a face detection system was used for access control. The face detection system is implemented and integrated into an Access Control system. Face detection systems locate the size and scale of human faces in images and video sequences, if present. De Klerk's results were that the Viola and Jones detector has been most suited for his requirements; consequently they implemented a detector strongly based on the Viola and Jones detector. (De Klerk, 2009) indicates that the detector was a system capable of detection frontal-view faces in real time. This is attributed to the AdaBoost learning algorithm. This algorithm sequentially constructs a classifier as a linear combination of "weak" classifier. The classifiers are combined in a "cascade" which allows background regions to be quickly discarded while spending more computation on more promising object like regions.

Another approach was seen when Kuriakose undertook a research project in an automatic student attendance registration using radio frequency identification (RFID). The main aim of this research was to automate student attendance registration, thereby reducing human involvement in the entire process. This was made possible using RFID technology. The study determines that the read range for student cards of the RFID reader is 3-4 cm. The results findings were that the RFID system used for automating the attendance register in this project can scan a single student card at a time. The findings indicated that this is an inherited limitation of the technology (Kuriakose, 2010).

(Brown, 2012) completed a research project in an SMS-based Student Response System. In this project, the feasibility of creating an SMS-based Student Response

System that is extendable and exposes its functionality over HTTP was investigated. The author indicates that this SMS system was put through load tests where it was hit with a number of simultaneous requests. It is reported that the server handled 20, 40 and 80 simultaneous requests without any issue. A 99.25% success rate was reported when hitting the server with 160 simultaneous. Since the transmission rate of a GSM modem is only 6 to 10 messages per minute, the modem will become the bottleneck on the system. It is however reported that the bottleneck will be resolved if more modems will be added. The conclusion of this research was that a SMS-based system can be recommended for a university environment.

With all these technologies the question arises how to select the best one and how to truly evaluate the correct methods. A literature study will need to be conducted to determine the importance of attendance, methods of gathering data, the importance of the test sample or demographic, methods of evaluating summative data and methods of evaluating quantitative data as well as heuristic evaluation. This would lead to the acceptance of truly and thoroughly electronic input devices with regard to recording class attendance.

2.1. CLASS ATTENDANCE

Plentiful literature exists where the question regarding the effect of class attendance on academic performance of students and whether class attendance should be implemented.

Previous studies have documented the relationship between class attendance and grades. In a study conducted by (Clump, *et al*., 2003), the results revealed a significant relationship between attendance and both immediate test scores and overall class test scores, using a sample of 423 undergraduate students enrolled in two sections of a general Psychology course (Chenneville & Jordan, 2008).

(Park & Kerr, 1990) states in their journal paper that a student's grade, as a measure of performance, is generally determined by effort and intelligence. It is also mentioned that attendance and the student's overall value of the course, could perhaps have some influence, and could be a less crucial factors. These findings are confirmed by (Durden & Ellis, 1995), who conclude that grade-point-average [GPA] and exam-entrance scores are among the most important determining factors in student performance. Despite these findings, much research has been undertaken on the relationship between students' attendance levels and performance in an academic programme (Schmulian, 2014).

Furthermore, students who do not attend classes miss the opportunity of learning from questions asked by fellow students during lectures and the resulting additional explanations provided by the lecturer (Sleigh & Ritzer, 2001). Lecturers sometimes ask questions in class to induce students to think critically about a topic. Absent students are not able to benefit from these critical thinking discussions (Schmulian, 2014).

(Woodfield, *et al*., 2007) aimed to determine what the direct effect is of class attendance on the final marks of 650 undergraduate students. The students were tracked throughout their degree course (i.e. a longitudinal study spanning their entire degree programme). They found that greater levels of absence were associated with lower final scores.

Most research studies suggest that the attendance of classes at a university does indeed influence academic performance. This influence occurs in varying degrees over many years. These studies, while all undertaken at the tertiary level, where not undertaken against the background of an Accounting programme as stated in this research. Studies of students who are enrolled for various subjects and programmes may yield different results (Ylijoki, 2000).

There may be negative effects of students missing classes, for example some lecturers may have made a critical announcement in class that a certain piece of material or topic is very important for the coming test or exam. Missing this important hint could have a disastrous effect on the absent student's course mark. (Lucier, 2014) states an absent student misses out on the opportunity to participate in asking questions in class that could have helped preparation for coming tests or exams. Important announcements, such as due dates for assignments or reminders, could also have been missed during the absence.

An article published by "State University" stated that most students who fail a course did not attend classes regularly. Regular class attendance requires discipline and time management skills. These skills are beneficial no matter what career path one chooses. Skipping class can be a fast track to deficient performance, increased stress and anxiety, lower marks, dropping classes, and even dropping out of university. Students need to realise that going to class is not a decision that needs to be made: students *need* to attend classes (State University.com – U.S. University Directory, 2007).

As stated by (Moore, 2006), class attendance is usually a strong predictor of students' academic success. With this in mind, faculties should monitor students' attendance and use quantitative data about class attendance and course marks to counsel them to avoid missing class. Moreover, faculties should intervene before absenteeism becomes an established pattern. Students who insist on skipping class may need counselling to explore their roles as learners.

Thus, the importance of class attendance is obvious. CUT aims to implement an eighty percent (80%) student class attendance, but this cannot be enforced due to the lack of a valid attendance recording method. At the time of this study, the CUT attendance system required lecturers to create a manual class list where students sign next to their name on a circulated paper class list. When classes reach the end of the academic quarter, these lists are then captured on the university's Integrated Tertiary Software (ITS) system by departmental administrator officers.

In Figure 2.1, below, the ITS administrative system module is shown. This is the structure of the university's management system.

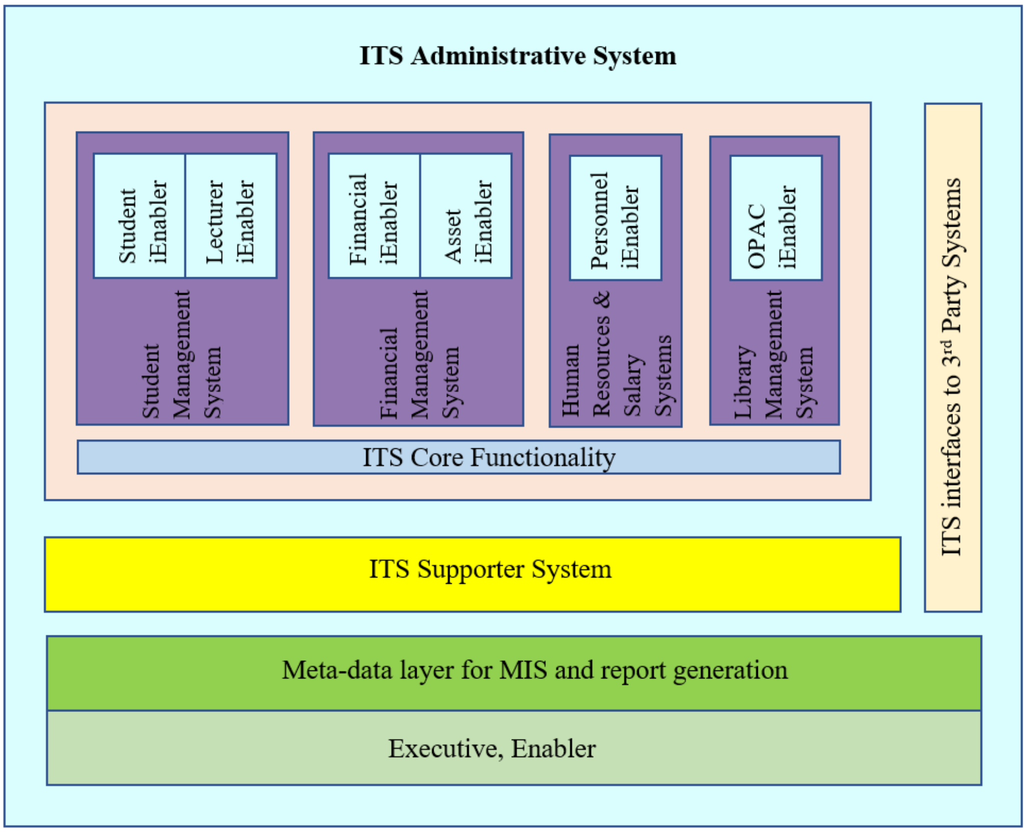


Figure 2.1: The ITS Administrative system module (adapt IT, 2019).

Figure 2.1 illustrates the different system modules available in the ITS system. The ITS Administrative System consists of the following main modules (adapt IT, 2019):

- ITS Core Functionality which consists of:
    - Student Management System, which is used for student applications, Admissions, student registrations, etc.

- Financial Management System, which is used for accounts, budgeting, purchases, etc.
- Human Resources and Salary Systems, which is used for appointments, leave system, etc.
- Library Management System, which is used for short-term loans, online public access catalogue (OPAC), self-service system for searching books available, etc.

- The ITS Supporter System can be used in conjunction with one or more of the ITS Core Functionalities. This system expands functionality, and additional areas can be added to the ITS. For example, printing Costing, Vehicle reservation, Meal booking, etc.
- The Meta-data layer for Management Information System (MIS) and report generation are used to request data in terms of student performance and enrolment data, financial reporting, etc.
- Executive, Enabler is used for project management, design new procedures, etc.
- The ITS Interfaces to 3rd Party Systems allow for electronic banking, Adjusted cost base (ACB) for students and staff payments, etc.

At CUT the Student Management System is used mainly for applications, admissions and student registration. The Financial Management System is used for accounts of the different departments, budgeting, purchases and asset management. The Human Resources and Salary System is currently used for appointments of new staff, a system for staff to apply for leave, and a Salary System to manage salaries and claims that are submitted. The Library Management System is used for short-term loans and the online public access catalogue (OPAC) self-service system for searching books available.

The ITS system is fully Web-enabled, and staff and students access the system on campus through a standard Web browser. Students and staff can access the system via the internal network (Intranet) using standard Web browsers and specially designed self-service (the iEnabler) applications. Implementation of the ITS system can be done in a phased manner with one or more of the mainstream functional areas of Student, Financial, Human Resources or Library Management. Institutions can then select which modules from within each of these areas will support their business requirements (adapt IT, 2019).

Shortcomings of capturing attendance manually on the ITS include:

- It is a very tedious process, taking attendance as well as the capturing of it on ITS, while errors can also play a role; the attendance as well as reports have to be generated.
- It is not secure.
- Where non-registered students add their names at the bottom of the paper class list, this is difficult for lecturers to control.
- Currently using pen-and-paper attendance recording can cause certain issues such as archiving these paper records and keeping records, if students did not sign the lists.

2.2. RESEARCH POPULATION

To determine the most suitable population, the correct demographic and sample size of students could be identified to participate in this research study. (Martínez-Mesa, et al., 2014) define ‘population’ as a group of individuals restricted to a geographical region (neighbourhood, city, state, country, continent, etc.), or certain institutions (hospitals, schools, health centres etc.), that is, a set of individuals that have at least one characteristic in common. The authors of this article indicate that the target population corresponds to a portion of the previously mentioned population about which one intends to draw conclusions.

It is indicated that the research population could be part of the population whose characteristics are an object of interest of the investigator. Martínez-Mesa *et al.* propose that the population which will be part of a study and be evaluated, will enable the researcher to draw conclusions about the target population, as long as it is representative of the latter (Martínez-Mesa, *et al*., 2014).

Research by (Hammer, 2011)indicates that attention has been placed on increasing the diversity of research participants and describing the demographic characteristics of participants when presenting findings in journal articles. This also applies to the importance of collecting and describing the characteristics of research participants when submitting manuscripts. Hammer claims that at a minimum, information needs to be provided about participants' demographic details such as age, gender, race/ethnicity, educational level and languages spoken. The author states that without the inclusion of such information, researchers risk assuming the stance of "absolutism", which assumes that the phenomena of interest are the same regardless of culture, race, ethnicity and socioeconomic status.

2.3. SCANNING INPUT DEVICES

Electronic attendance devices are used in different areas, from taking attendance from employees clocking in and out to students attending classes. These automated time and attendance systems can use barcode cards, RFID cards, biometrics (fingerprint) and other devices (Group, 2014). In the case of an automated electronic attendance system, software would be used to identify and authenticate students. Attendance software authentication would be able to check if a student is registered for a subject and is attending the correct class.

This next sub-section describes the investigated electronic scanning devices available, and the different advantages and disadvantages of each device. With this information, an educated decision can be made about which devices to use for this research. Factors to consider are cost effectiveness, security, and availability, to mention a few.

The following devices were investigated and will be described in detail:

2.3.1. Barcode Scanner

TPGTEX Label Solutions indicates that a barcode reader (or Barcode Scanner) is an electronic device for reading printed barcodes. The scanner reads the barcode and transfers this data to a program on the computer. Most scanners use a USB connection. The barcode characters are then received by the host computer as if coming from its keyboard, decoded and converted to keyboard input within the scanner housing. This makes it easy to interface the barcode reader to any application that is written to accept keyboard input (TPGTEX Label Solutions , 2014).

The ease of use with barcodes is one of their most attractive characteristics. McCathie claims that since the invention of barcodes, the typical barcode printing costs have decreased to less than a cent per barcode. McCathie states further that one of the advantages of using barcodes is that barcodes can also be read manually, and that this holds a distinctive benefit over alternative technologies such as RFID, which is chip-based. Research has shown that Barcode Scanners are a very productive way of scanning. The author also highlighted some disadvantages where barcode scanners is a line-of-sight technology, thus products must have barcode labels that are clearly visible to make scanning easy. The author also emphasised another important disadvantage, where barcodes are susceptible to damage that leads to an inherent hindrance. To prevent damage, barcodes must be relatively clean, be handled gently in abrasion-free environments, and not be exposed to extreme temperatures and harsh surroundings (McCathie, 2004).

2.3.2. RFID Scanner

OMNI-ID defines the term ‘RFID’ refers to Radio Frequency Identification, a technology which uses radio waves to automatically identify items or people that are using a RFID tag. Most commonly, this involves the use of an RFID tag and a reader device (Omni-ID an introduction to RFID, 2009). Van Wyk proposes a system where RFID technology could be used to design an automated class attendance recording system. The author discussed some of the advantages and disadvantages of RFID technology in his research. Some advantages mentioned were the speed of RFID and availability of RFID chips, already used in student cards. The disadvantages mentioned were that students could lose their student cards, and that students could ’lend’ their cards to their friends to scan for them (van Wyk, 2008).

2.3.3. Fingerprint Scanner

Kumar and Walia indicated that fingerprints as patterns of friction ridges and valleys on an individual's fingertips that are unique to that individual. They mentioned that law enforcement has been classifying and determining identity by matching key points of ridge endings and bifurcations. Fingerprints are unique for each finger of a person, including identical twins. It has been reported that as one of the most commercially available biometric technologies, fingerprint recognition devices for desktop and laptop access, are now widely available, users no longer need to type passwords (Kumar & Walia, 2011).

Some advantages that were reported on fingerprint verification was high reliability, proven accuracy, and robust and highly distinctive features. Some of the disadvantages listed were that in a poor environment, injury could have an effect, and dry skin can cause difficulties (Kumar & Walia, 2011).

2.3.4. Bluetooth

The *Science American* journal reports that Bluetooth technology is a short-range wireless communications technology to replace the cables connecting electronic devices, allowing a person to have a phone conversation via a headset, use a wireless mouse and synchronise information from a mobile phone to a PC, all using the same core system (Scientific American, 2007). Bhalla *et al.* propose a student attendance system where data will be sent to the mobile phone using Bluetooth. The authors report that this approach is cost effective and secure and prevents students from misleading an attendance system (Bhalla, *et al*., 2013).

A few downsides were reported by Bhalla *et al,* when using Bluetooth technology, where not all students have the Bluetooth functionality on their phones to participate in this method of taking attendance. Proxy attendance was also mentioned as one of the demerits in this research. It has also been reported that Bluetooth in its most common implementation has a limitation on scanning area of 30 feet or 10 metres (Bhalla, *et al*., 2013).

2.3.5. Facial Recognition

(KAWAGUCHI, *et al*., 2005) describe face detection as a recognition module which detects faces from the image captured by the camera or cameras, and the image of the face is captured and then cropped and stored. They discuss how the mentioned module could recognise the images of a student's face, where the student's details and facial features were preregistered in a database. It has been reported that in some circumstances, facial recognition could be ineffective because of the ambient light factor when scanning, which could result in a rescan.

Research by (Sajid, *et al*., 2014) approaches face recognition as a technique effectively replacing biometrics. The authors describe the use of facial features of a person for identification purposes as the most innovative of all and can be attributed as a technique with minimum flaws. The simple reason is that the facial features of every human being are unique. The authors report that the initial approach of attendance management through biometrics had an awkward cost of extra effort and personal time at the user end. This research paper indicates that after the occurrence of face recognition as a useful method, techniques were evolved to include it in attendance management systems.

2.3.6. Magnetic Stripe Scanner

(encyclopedia.com, 2002) defines a magnetic stripe card as a card that contains a stripe of magnetically encoded data. It is mentioned that magnetic stripe cards are used in most identification, credit, automated teller machine, and membership cards, having a thin magnetic stripe across one side of the card. It is stated that the stripes on the card can also contain encrypted information and information not printed on the card which can be created or read only by specialised computers.

The Smart Card handbook indicates that the main drawback of magnetic-stripe technology is that the stored data can be altered very easily using a standard read/write device (Wolfgang & Wolfgang, 2004). Teach-ICT listed the advantages of magnetic stripe cards as the user needing little or no training to use these cards. The cards are inexpensive to produce, and pin numbers can be added to use these cards. Some disadvantages worth mentioning from Teach-ITC are that these cards have very limited storage capacity for data and this data could easily be destroyed by a strong magnetic field (Teach-ICT, 2016).

2.3.7. Retina Scanner

(Kadry & Smaili, 2010) state that one of the most reliable methods for personal identification is the iris recognition and verification in biometrics. The authors claim that biometric personal authentication uses data taken from actual measurements. The research paper indicates that such data is unique to each individual and remains so during one's life. The authors claim that a typical iris recognition system generally consists of the following basic components: image acquisition, iris location and pre-processing, iris texture feature extraction and signature encoding, and iris signature matching for recognition or verification.

(Khaw, 2002) lists some advantages when using retina iris-scanning technology and indicated that the technology is not very intrusive as there is no direct contact between the user and the camera technology. The author indicates that it is a non-invasive approach, as the iris scanner does not use any laser technology and uses simply video technology. The author further discusses the retina scanner's disadvantages, indicating that the camera used in the method of scanning needs to have the correct amount of illumination. It is stated that without the sufficient lighting, it is very difficult to capture an exact image of the iris.

(Shirke, et al., 2012) indicate another interesting disadvantage, that when death is caused by brain injury and within the period of the somatic death, the deceased person still can be scanned, both the iris and the fingerprints of the subject still match, and a successful scan is possible. They mention that it is obvious that machines cannot identify human physiology.

2.3.8. Palm Vein Scanner

(Wong, *et al*., n.d.) indicate that the palm vein biometric systems function differently from other biometric systems such as the fingerprint and iris scanner systems. These traditional systems compare external physical features of the scanned area, but the palm vein scanning system takes the digitised image of the user's veins and compares it to patterns stored in the system.

(Wong, *et al*., n.d.) further mentions that each person's vascular patterns are unique. With large, robust, stable and hidden biometric features which provide a great benefit to this technology. The authors state that the pattern of blood vessels is hard-wired into the human body since birth and remains relatively unaffected by aging apart from predictable growth as with fingerprints. Wong *et al. state* the only weaknesses with this technology are the different factors that could affect the quality of the captured vein image. Factors such as body temperature, ambient temperature and humidity, uneven distribution of heat, heat radiation, nearness of the vein to the surface, and camera calibration and focus could influence the quality of the scanning system.

Table 2.1 below illustrates the list of scanning devices, each with features, advantages and disadvantages.

Table 2.1: Advantages and disadvantages of the different available scanning devices

Scanning Devices	**Description**	**Features**	**Advantages**	**Disadvantages**
Bluetooth (Mobile)	Attendance can be taken via mobile phone Bluetooth connection	Bluetooth waves typically can only travel 33 feet or less. (Mapleridge, 2019)	Cost Effective Secure and prevents students from misleading attendance (Bhalla, *et al*., 2013)	Not all students have Bluetooth on their phones • Proxy Attendance • Limited scanning area (Bhalla, *et al*., 2013)
RFID Scanner	Attendance can be taken using embedded RFID cards and RFID Scanner.	Tags can be embedded and hidden with no need for line-of-sight. Tag detection not requiring human intervention reduces employment costs and eliminates human errors from data collection	• Accurate • Timely data entry • Inexpensive • Fast scanning (van Wyk, 2008)	• Security issues in terms of buddy scan • Tag read degrading when near electronic devices (van Wyk, 2008)

		(Kaur, et al., 2011)		
Fingerprint Scanner	Attendance taken via fingerprint of student and Fingerprint Scanner.	Automatic finger detection Encryption Supported operating systems (Maltoni, et al., 2003)	• Very Secure • No buddy scans • Reliable • Fair cost (PBWORKS, 2006)	• Incomplete scans possible • Very slow process (PBWORKS, 2006) .
Facial Recognition	Multi cameras are used to do facial recognition to process student attendance.	Universality Distinctiveness Permanence **Issues:** Performance Acceptability Circumvention (Jain, et al., 2004)	• Ability of taking attendance continuously (KAWAGUCHI, *et al*., 2005)	• Ineffective because if ambient light is not correct scanning errors occur • Students entering a venue are not always facing the camera • Expensive (KAWAGUCHI, *et al*., 2005)
Barcode Scanner	Taking attendance via student cards that are printed with barcodes.	Accuracy Speed Low Cost (Evans, 2019)	• Less expensive than RFID tags • Cost Effective • Fast scanning (Adaptalift, 2012)	• Barcode scanners need a direct line of sight to the barcode to be able to read • Barcodes have less security than RFID

				(Adaptalift, 2012)
Magnetic Stripe Scanner	Attendance can be taken via a student card that make use of a magnetic strip and a magnetic scanner.	Magnetic stripe cards have had a well-established position in the marketplace for over 30 years. Magnetic stripe cards have minimal security (Smart Card Alliance, 2012)	• Widely used • Cost-effective • Flexible and practical (van Wyk, 2008)	• Outdated and not secure • Life-span low of card magnetic strip damage • Buddy scan (van Wyk, 2008)
Retina Scanner	Scans veins in the iris of the student. (Kadry & Smaili, 2010)	Retinal Scan technology is based on the blood vessel pattern in the retina of the eye. Users claim discomfort with the fact that they must position their eye very	• Reliable • Secure • Effective System (biometrics pbworks, 2007)	• Slow scan • Low Social acceptability • Expensive (biometrics pbworks, 2007)

		close to the device. (Spinella, 2003)		
Palm Vein Scanner	The palm vein scanner digitizes images of the user's vein and compare with a template in database to scan for attendance. (Wong, *et al*., n.d.)	The vein based system can meet all the accuracy requirements because, with the right illumination conditions. Due to the optical properties of the human skin, near-infrared light cannot penetrate very deep in the human tissues, making the extraction of deep vein patterns a very difficult task. (Neves, 2013)	• Each Person's vascular patterns are unique • Surface of skin change has no effect • Injuries of hand has no effect on scan (Wong, *et al*., n.d.)	• Expensive • Factors like temperature, humidity and vein camera calibration becomes an issue (Wong, *et al*., n.d.)

(Bluetooth (Mobile) (Bhalla, *et al*., 2013), (Mapleridge, 2019), RFID Scanner (van Wyk, 2008), Fingerprint Scanner (PBWORKS, 2006), (Kaur, et al., 2011), (Maltoni, et al., 2003), Facial

Recognition (KAWAGUCHI, *et al*., 2005), (Jain, et al., 2004), Barcode Scanner (Adaptalift, 2012), (Evans, 2019), Magnetic Strip Scanner (van Wyk, 2008), (Smart Card Alliance, 2012), Retina Scanner (Kadry & Smaili, 2010) (biometrics pbworks, 2007), (Spinella, 2003), Vein Scanner (Wong, *et al*., n.d.), (Neves, 2013)).

2.3.9. Choosing the Scanning Devices

As stated, electronic scanning devices will be evaluated and can be utilised in an automated electronic attendance system. The identified three input scanning devices will be evaluated to determine the best input method for an electronic attendance system. The three different scanning devices listed, i.e. the Fingerprint Scanner, the Barcode Scanner and the RFID Scanner, have been identified to be used in this study.

The Fingerprint Scanner has been chosen because of low cost and its secure ability of taking attendance. Another reason for choosing the Fingerprint Scanner is for its popularity in South Africa, where it is been used in Banks, Home Affairs Department and Traffic Department. Thus, this technology is familiar to the targeted audience. With the current development software namely Visual Studio 2015 a compatible software development tool (SDK) is available for fingerprint scanner's.

The Barcode Scanner has been chosen because of low cost and high speed of scanning. Another reason was that the student cards at the CUT already has the printed barcodes that represents the student number, it makes good business sense to utilise this functionality as it is already available. Familiarity is also a benefit as barcode is used in sales, where products has a printed barcode to scan to determine the price. When barcodes are scanned it is transmitted as text which then can be used to easily access a database and do processing.

The RFID Scanner has been chosen as a scanning device and access cards because of low cost, and of the high-speed of scanning. Another reason would be that the CUT students' cards already contains a passive RFID chip and it makes good business sense to utilise this functionality as it is already available. Some stores already use the additional method of payment where a bank card of some user can make use of tap and pay, where their bank cards chip only needs to come close to a scanner to make a purchase.

The scanning devices that was not chosen for this study listed in Table 2.1, were not chosen because of their limited functionality like the magnetic strip scanner that is an outdated technology. The biometric scanners were not chosen because of its specific needs with illumination at certain times as well as the high storage of images for scanning. Lastly not all students have the Bluetooth functionality available on their phones.

The purpose for evaluating these scanning devices is to suggest a method for evaluating input peripherals that can be used for capturing attendance data. Custom software will be used to connect these three scanning devices and time data will be recorded. The time data will then be used to correlate the three devices, to determine which device performs the best scanning time per class and per student. The time data will be recorded with every scan of a class once a week. The three devices will each be tested for a month cycle for the same students in the same class-room. Each device will be used four times per month to complete a month cycle.

As stated, the following input devices would be evaluated:

2.3.1.1. Barcode Scanners:

A barcode reader (or Barcode Scanner) is an electronic device for reading printed barcodes. The scanner reads the barcode and transfers this information to a program on the computer. Most scanners use a USB connection. The barcode characters are then received by the host computer as if they came from its keyboard, decoded and converted to keyboard input within the scanner housing. This makes it easy to interface the barcode reader to any application that is written to accept keyboard input (TPGTEX Label Solutions , 2014).

Figure 2.2 shows an example of a Barcode Scanner scanning a barcode. Laser scanners use a laser beam as the light source and typically employ either a reciprocating mirror or a rotating prism to scan the laser beam back and forth across the bar code (Trait, 2014). A barcode is an optical machine-readable representation of data relating to the object to which it is attached. Originally barcodes systematically represented data by varying the widths and spacings of parallel lines and may be referred to as linear or one-dimensional (1D) (AppAspect, 2013).

Figure 2.2: Trait Barcode Scanner

(Trait, 2014).

Barcodes can allow for the organisation of large amounts of data. Information Technology (IT) is widely used in the healthcare and hospital settings, ranging from patient identification to access patient data, including medical history, drug allergies, etc. IT can also be used to keep track of objects, people, rental cars, airline luggage, nuclear waste, registered mail, express mail and parcels by using barcodes (girian-atas-desa-kelurahan.ptkpt.net, 2014).

Barcoded tickets allow the holder to enter sports arenas, cinemas, theatres, fairgrounds, and transportation, and are used to record the arrival and departure of vehicles from rental facilities, etc. Barcodes are widely used in shop floor control applications software where employees can scan work orders and track the time spent on a job (girian-atas-desa-kelurahan.ptkpt.net, 2014).

Figure 2.3: Zebex Barcode Scanner

(comx-computers, 2014).

The Z-6010, the Zebex Barcode Scanner shown in Figure 2.3, is a compact hands-free omnidirectional laser scanner and becomes a single-line laser scanner by pressing down a button. It is designed to suit requirements for both omnidirectional and single-line scanning. This omnidirectional scanner has no need for the user to hold and push a button to scan, but costs almost five times more than the hand-held scanner (NIVO interactive shopping, 2014). This hands-free Zebex Barcode Scanner will be used for this study, as it has no need for user interaction and is easy to operate.

Another example of a Barcode Scanner is the Champtek SG100 USB shown in Figure 2.4. This Champtek SG100 is a Long-Range CCD Barcode Scanner, Smart Detect Reading Speed up to 500 scans/sec and is very cost-effective and available below R500 per scanner (comx-computers, 2014). This is, however, a manual Barcode Scanner, where a button needs to be pressed to scan each barcode.

Figure 2.4: Champtek Barcode Scanner

(comx-computers, 2014).

2.3.1.2. RFID Scanners:

The term 'RFID' refers to Radio Frequency Identification, a technology which uses radio waves to automatically identify items or people using a RFID tag. Most commonly this involves the use of an RFID tag and a reader device. When the RFID tag receives the message from the reader, it responds with its identification and other information. In general terms, Radio Frequency Identification systems consist of an RFID tag (typically many tags) and an interrogator or reader. The interrogator emits a field of electromagnetic waves from an antenna, which are absorbed by the RFID tag. The absorbed energy is used to power the tag's microchip and a signal that includes the tag unique identification number is sent back to the interrogator (Omni-ID an introduction to RFID, 2009).

In Figure 2.5 below an example of an RFID smart card is shown. There are two RFID Scanner types, namely Mifare and EM4100. In Figure 2.5 below the RFID (Mifare) Card is shown. Student cards at CUT are currently using the RFID Mifare chip.

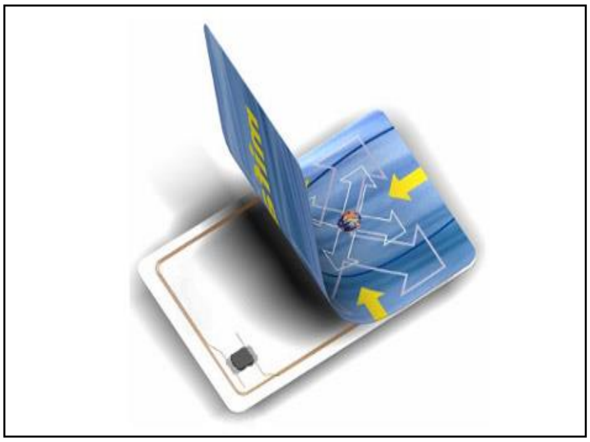


Figure 2.5: Smart Card with RFID chip inside (all4-FP Green Power, 2009).

The USB Mifare contactless smart 13.56mhz RFID ID Card Reader Writer IC01 is shown in Figure 2.6. It is more expensive than the RFID reader that will be used. This scanner uses custom software not automatically installed by Microsoft products (EBAY Card Encoders & Readers, 2014).

Figure 2.6: Mifare RFID Card Reader Writer (EBAY Card Encoders & Readers, 2014).

The RFID device chosen for this study is the USB HF RFID ID Mifare Card Reader 13.56MHz RC522 RF Windows arduino, shown in Figure 2.7. This device was chosen because it is affordable and available, below R300.00 (EBAY, 2014). It is also easy to use as no extra software needs to be installed. The device interfaces directly with the Microsoft platform which complies with plug and play compatibility.

Figure 2.7: USB HF RFID ID Mifare Card Reader

(EBAY, 2014).

2.3.1.3. Fingerprint Scanners:

Mohan and Kumar state that fingerprint recognition or fingerprint authentication refers to the automated method of verifying a match between two human fingerprints. Fingerprints are one of many forms of biometrics used to identify individuals and verify their identity (Mohan & Kumar, 2013).

Patterns that exist in fingerprints (Mohan & Kumar, 2013):

The three basic patterns of fingerprint ridges are the arch, loop, and whorl: (Figure 2.8)

- arch: The ridges enter from one side of the finger, rise in the centre forming an arc, and then exit the other side of the finger.
- loop: The ridges enter from one side of a finger, form a curve, and then exit on that same side.
- whorl: Ridges form circularly around a central point on the finger

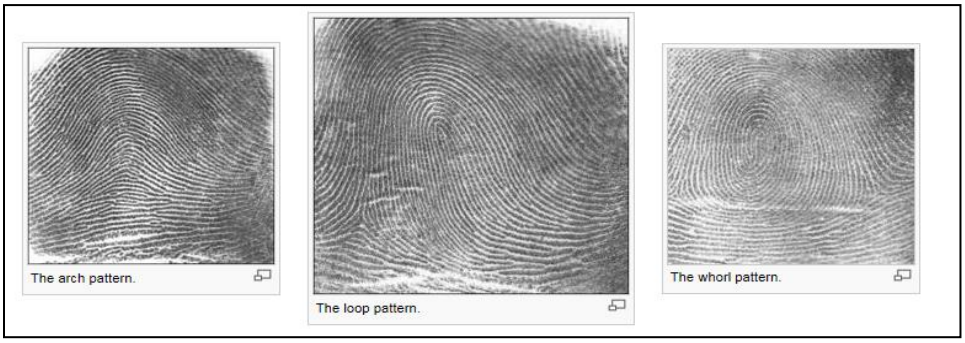


Figure 2.8: Different fingerprint patterns

(Mohan & Kumar, 2013).

A fingerprint sensor is an electronic device (Figure 2.9) used to capture a digital image of the fingerprint pattern. The captured image is called a live scan. This live scan is digitally processed to create a biometric template (a collection of extracted features) which is stored and used for matching.

Figure 2.9: Fingerprint Scanner

(Shoewu & Idowu, 2012).

Another example of a Fingerprint Scanner is shown in Figure 2.10 (the Mecer FS80 Fingerprint Scanner).

Figure 2.10: Mercer Fingerprint Scanner

(comx-computers, 2014).

The fingerprint scanning device used in this study is the Digital Persona Uareu Dp500 4500, as shown in Figure 2.11. This device was chosen because of its compactness and user-friendliness. The fingerprint device shown falls in the same price range as the other chosen devices and therefore this device is used.

Figure 2.11: Digital Persona Fingerprint Scanner

(B-Technology, 2014).

2.4. PROGRAMMING AND C#

C# is a powerful and flexible programming language. Like all programming languages, it can be used to create a variety of applications. One's potential with C# is limited only by imagination. The language does not place constraints on what one can do. C# has already been used for projects as diverse as dynamic Web sites, development tools, and even compilers (Jones, 2009).

The programming language C# could be used to compile custom software that could be compatible with the chosen scanning hardware devices in the previous section. Data could then be recorded such as specific timing data for each scanning device, for example to record the duration of a scan for each participant and the total scan time of each class.

2.5. RELATIONAL DATABASES

Many organizations use a database to organise the information in these files. A database holds a group of files that an organisation needs to support its applications. In a database, the files often are called tables because their contents can be arranged in rows and columns. Creating a useful database requires planning and analysis. The database designer must decide what data will be stored, how that data will be divided between tables, and how the tables will interrelate (Farrell, 2011).

In most database tables created, the database designer wants to identify a column, or possibly a combination of columns, as the table's key column or field, also called the primary key. The primary key in a table is the column that makes each record different from all others (Farrell, 2011). In this research, the custom pre-written C#

programming was used, connecting a MS Access 2016 database for all data storage and retrieval.

2.6. QUANTITATIVE CALCULATIONS

Siddharth states that a correlational study determines whether or not two variables are correlated. This means to study whether an increase or decrease in one variable corresponds to an increase or decrease in the other variable. *Positive correlation* between two variables is when an increase in one variable leads to an increase in the other and a decrease in one leads to a decrease in the other. *Negative correlation* is when an increase in one variable leads to a decrease in another and vice versa. *No correlation* is when two variables are uncorrelated when a change in one does not lead to a change in the other and vice versa (Siddharth, 2011).

2.6.1. Pearson Correlation Coefficient

When looking for correlations, a researcher will look for patterns -- what they see happening again and again. A simple pattern known to every educator, but unfortunately not every student, is the link between studying and grades. Research by Kowalczyk states the studious students who study is more likely to score a higher score on their tests. Students who do not study much are less likely to score as high as those who do (Kowalczyk, 2014).

Correlation will be used to graphically represent captured data from the identified electronic scanning devices. Data will be analysed after a three-month cycle has been concluded and will then be compared against each other. Correlation refers to any of a broad class of statistical relationships involving dependence (Boundless, 2014) .

Correlation, according to Boundless, means that familiar examples of dependent phenomena include the correlation between the physical stature of parents and their offspring, and the correlation between the demand for a product and its price. Correlations are useful because they can indicate a predictive relationship that can be exploited in practice. For example, an electrical utility may produce less power on a mild day based on the correlation between electricity demand and weather (Boundless, 2014). In this study, three scanners' time data will be compared with four different scans per month cycle by using correlation.

Formally, dependence refers to any situation in which random variables do not satisfy a mathematical condition of probabilistic independence. In loose usage, correlation can refer to any departure of two or more random variables from independence, but technically it refers to any of several more specialised types of relationship between mean values. There are several correlation coefficients, often-denoted ρ or r, measuring the degree of correlation (Boundless, 2014).

In this study, correlation is used to compare time data for each scanning device and the total and average time for each month cycle where class attendance was taken. This will be done for all three devices and at the end analysed together to see the correlation for all three devices. Results of the correlation between devices can indicate which device was difficult to use and which device performed the best time base (easier to use).

The University of the West of England states that correlation is a technique for investigating the relationship between two quantitative continuous variables. The Pearson Correlation Coefficient (r) is a measure of the strength of the association between the two variables. The first step in studying the relationship between two continuous variables is to draw a scatter plot of the variables to check for linearity. The correlation coefficient should not be calculated if the relationship is not linear. For correlation-only purposes, it does not really matter on which axis the variables are plotted. However, conventionally, the independent (or explanatory) variable is plotted on the x-axis (horizontally) and the dependent (or response) variable is plotted on the y-axis (vertically) (University of theWest of England, 2015).

Figure 2.12 below shows four sets of data with the same correlation of 0.816.

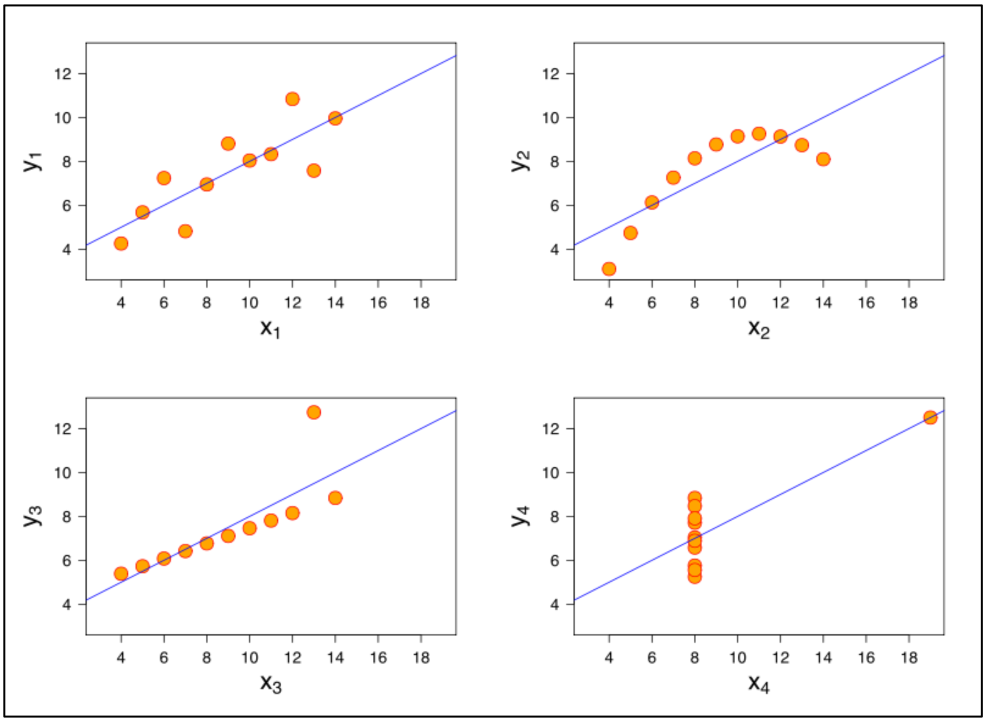


Figure 2.12: Anscombe's Quartet -- Sets of data with the same correlation (Ngobi, *et al*., 2007).

The image above shows scatter plots of Anscombe's Quartet, a set of four different pairs of variables created by Francis Anscombe. The four y variables have the same mean (7.5), variance (4.12), correlation (0.816) and regression line (y = 0.5x + 3) (Anscombe, 1973). However, as can be seen on the plots, the distribution of the variables is very different (Ngobi, *et al*., 2007). With this method data can be plotted and Pearson/Spearman correlation can be done per scanning device. With the three correlations, a comparison can be done against the three devices to determine speed and accuracy of scans. Each dot that is represented on the plots will be a scan per student per week.

The Anscombe's Quartet illustrated in Figure 2.12 shows how four sets of data with identical simple summary statistics can vary considerably when graphed. Each data set consists of eleven (x, y) pairs as listed in Table 2.2 (Anscombe, 1973):

Table 2.2: Anscombe's 4 Regression data sets

I		II		III		IV	
x	y	x	y	x	y	x	y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

(Anscombe, 1973).

Each quartet will be repeated for each week to have four quartets (month cycle) to compare per device. When all three devices' quarters are completed the three devices can each be compared with its own quartet per device to create a comparison. In this study, the quartets are designed as follows: the x axis represents *the student number* (15 students) and the y axis (Seconds) represents *time elapsed*. This creates plots to determine the scan time for the whole class per device.

Correlation is calculated using the CORREL function in Excel. Where Excel returns the correlation coefficient of the Array1 and Array2 cell ranges. Where Excel use the correlation coefficient to determine the relationship between two properties (Microsoft Support, 2014).

The Syntax in Excel will be =Correl (Array1, Array2) (Microsoft Support, 2014)

- Array1 Required. A cell range of values.
- Array2 Required. A second cell range of values.

The equation used for Correlation coefficient is: (Microsoft Support, 2014):

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

Equation 1: Correlation Coefficient

(Microsoft Support, 2014).

where $\bar{x}$ and $\bar{y}$ are the sample means AVERAGE(array1) and AVERAGE(array2) (Microsoft Support, 2014).

Using Excel's Correlation data analysis toolkit, it is possible to compute the pairwise correlation coefficients for the various variables (Zaiontz, 2014)

2.6.2. Standard Deviation

The Economic Times define standard deviation is the measure of dispersion of a set of data from its mean. Standard Deviation measures the absolute variability of a distribution; the higher the dispersion or variability, the greater is the standard deviation and greater will be the magnitude of the deviation of the value from their mean. The concept of Standard Deviation was introduced by Karl Pearson in 1893 and it is by far the most important and widely used measure of dispersion. Standard Deviation is also known as root-mean square deviation as it is the square root of means of the squared deviations from the arithmetic mean (The Economic Times, 1999).

Niles states that standard deviation is kind of the "mean of the mean," and often can help one find the story behind the data. A normal distribution of data means that most of the examples in a set of data are close to the "average," while relatively few examples tend to one extreme or the other. The standard deviation is a statistic that tells one how strongly all the numerous examples are clustered around the mean in a set of data. When the examples are tightly bunched together and the bell-shaped curve is steep, the standard deviation is small. When the examples are spread apart and the bell curve is relatively flat, that tells one there is a relatively large standard deviation (Niles, 2012).

The symbol for Standard Deviation is **σ** (the Greek letter *sigma*). The equation used for Standard Deviation is the following (Maths is Fun, 2017):

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

Equation 2: Standard Deviation Formula

(Maths is Fun, 2017).

In the formula above μ (the Greek letter *mu*) is the mean of all the values.

Example: 9, 2, 5, 4, 12, 7, 8, 11, 9, 3, 7, 4, 12, 5, 4, 10, 9, 6, 9, 4

STEP 1: Work out the mean

The mean is:

$$\frac{9+2+5+4+12+7+8+11+9+3+7+4+12+5+4+10+9+6+9+4}{20}$$

$$=\frac{140}{20}=7$$

The answer:

μ = 7

STEP 2: Then for each number: subtract the mean and square the result

This is the part of the **Equation 2** (Maths is Fun, 2017) formula that states:

$$(x_i - \mu)^2$$

So, what is xi? These are the individual x values 9, 2, 5, 4, 12, 7, etc...

In other words, x_1 = 9, x_2 = 2, x_3 = 5, etc.

So, it says "for each value, subtract the mean and square the result", as follows:

$(9 - 7)^2 = (2)^2 =$ **4**

$(2 - 7)^2 = (-5)^2 =$ **25**

$(5 - 7)^2 = (-2)^2 =$ **4**

$(4 - 7)^2 = (-3)^2 =$ **9**

$(12 - 7)^2 = (5)^2 =$ **25**

$(7 - 7)^2 = (0)^2 =$ **0**

$(8 - 7)^2 = (1)^2 = \mathbf{1}$

... etc ...

These are the results:

4, 25, 4, 9, 25, 0, 1, 16, 4, 16, 0, 9, 25, 4, 9, 9, 4, 1, 4, 9

STEP 3: Then work out the mean of those squared differences.

First add up all the values from the previous step.

Now add up all the values from 1 to N, where N=20 in our case because there are 20 values:

This is the part of the **Equation 2** (Maths is Fun, 2017) formula that states:

$$\sum_{i=1}^{N}(x_i - \mu)^2$$

which means: Sum all values from $(x_1-7)^2$ to $(x_N-7)^2$

We have already calculated (x1-7)2 = 4 etc. in the previous step, so just sum them up:

4 + 25 + 4 + 9 + 25 + 0 + 1 + 16 + 4 +1 6 + 0 + 9 + 25 + 4 + 9 + 9 + 4 + 1 + 4 + 9 = **178**

But that is not yet the mean: we need to divide by *how many*, which is simply done by multiplying by "1/N":

This is the part of the **Equation 2** (Maths is Fun, 2017) formula that states:

$$\frac{1}{N}\sum_{i=1}^{N}(x_i-\mu)^2$$

Mean of squared differences = (1/20) × 178 = **8.9**

STEP 4: Take the square root of that:

This is the part of the **Equation 2** (Maths is Fun, 2017) formula that states:

$$\sigma=\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i-\mu)^2}$$

σ = √ (8.9) = **2.983...**

Investopedia indicates that standard deviation is a measure of the dispersion of a set of data from its mean. It is calculated as the square root of variance by determining the variation between each data point relative to the mean. If the data points are further from the mean, there is higher deviation within the data set (INVESTOPEDIA, 2018).

Microsoft Excel provides a more practical way to compute the standard deviation. In Microsoft Excel, type the following code into the cell where you want the Standard Deviation result, using the "unbiased," or "n-1" method:

=STDEV(A1:Z99) (substitute the cell name of the first value in your data set for A1, and the cell name of the last value for Z99) (Niles, 2012).

When making use of the above formula in excel the standard deviation will be calculated for a range of values and provide the standard deviation result for the range of data selected. When this answer of the standard deviation needs to be calculated as a percentage, the following calculation must be done as follows: the calculated standard deviation answer is divided by the average of the data range that was used and multiplied by 100. This method of calculating the percentage of standard deviation is called Percentage Relative Standard Deviation (%RSD) (HelpComputerGuides.com, 2010).

= (STDEV(Data Range) / AVERAGE(Data Range))*100

2.6.3. Frequency Analysis

Descriptive statistics are the study of quantitatively describing the characteristics of a set of data. Frequency Analysis is a part of this descriptive statistics. In statistics, frequency is the number of times an event occurs. Frequency Analysis is a key area of statistics that deals with the number of frequency events and analyses the measures of central tendency, dispersion, percentiles, etc., as reported by (Research Optimus, 2017).

Research Optimus states Frequency Analysis usually deals with three types of measures:

Measures of Central Tendency - this is a single measure that tries to describe the set of data through a value that represents the central position within that data set. Most popular measures of central tendency used for frequency analysis are Mean, Median and Mode. While the mean is the average value of the data set, the median is the middle observation (observation which has an equal number of values lying above and below it) in the data set. Mode is the value that occurs the most number of times in a data set (Research Optimus, 2017).

Measures of Dispersion - these reflect the spread or variability of data within a data set. Most popular measures of dispersion used for frequency analysis are Standard Deviation, Variance and Range (Research Optimus, 2017).

Percentile Values - a percentile value shows what percent of values in a data set fall below a certain percent. Frequency Analysis commonly uses percentile values like Quartiles, Deciles, Percentiles, etc. While the 10th percentile value shows that 10% of the observations fall below it in a data set, it is also called the 1st Decile (where the data set is divided into 10 Deciles at intervals of 10% each). Similarly, the 25th, 50th and 75th percentiles are also called the 1st, 2nd and 3rd Quartile respectively (where the data set is divided into four Quartiles at intervals of 25% each) (Research Optimus, 2017).

Frequency Tables in Microsoft Excel:

The data that needs to be analysed is presented in the form of a frequency table, as seen in Figure 2.13 below. For example, the data in range A4:A11 can be expressed by the frequency table in range C4:D7 (Real Statistics Using Excel, 2015).

	A	B	C	D
3	data		x	freq
4	2		2	4
5	2		3	1
6	2		4	2
7	2		5	1
8	3			
9	4			
10	4			
11	5			

Figure 2.13: Frequency Example Table

(Real Statistics Using Excel, 2015).

Microsoft Excel's FREQUENCY formula counts how often values occur in a set of data. Excel's FREQUENCY function can be used to create a frequency distribution. A summary table that shows the frequency (count) of each value in a range will be displayed. It returns a vertical array of numbers that represent frequencies and must be entered as an array formula with the combination of Control + Shift + Enter on the keyboard (Exceljet, 2012-2018).

The syntax of the frequency formula in MS Excel is =FREQUENCY (data_array, bins_array), where data_array is an array of values (data) for which you want to get frequencies and the bins_array is an array of intervals ("bins") for grouping the values (Exceljet, 2012-2018).

2.7. OUTLIERS

The Engineering Statistics Handbook states that an outlier is an observation that lies an abnormal distance from other values in a random sample from a population. The definition leaves it up to the analyst (or a consensus process) to decide what will be considered abnormal. Before abnormal observations can be singled out, it is necessary to characterise normal observations (Engineering Statistics Handbook, 2014). An example of outliers is shown in Figure 2.14.

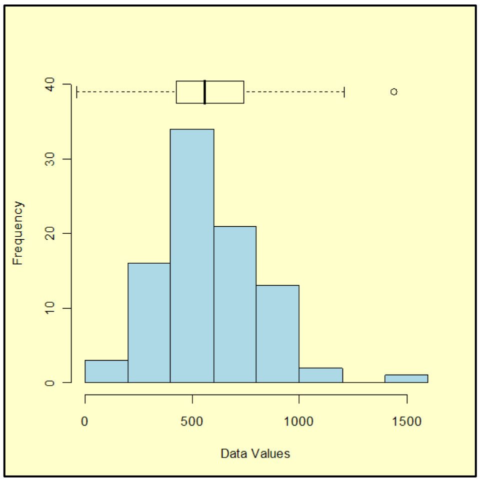


Figure 2.14: Example of outlier data

(Engineering Statistics Handbook, 2014).

Outliers are data values that differ greatly from most of a set of data. These values fall outside of an overall trend that is present in the data. Sometimes outliers are caused by error. Other times outliers indicate the presence of a previously unknown phenomenon. Another could be because of all the descriptive statistics that are sensitive to outliers. The mean, standard deviation and correlation coefficient for paired data are just a few of these types of statistics mentioned (about education, 2014).

2.8. SCATTER PLOTS

The University of Illinois specifies that scatter plots are similar to line graphs in that they use horizontal and vertical axes to plot data points. However, they have a very specific purpose: scatter plots show how much one variable is affected by another. The relationship between two variables is called their correlation. Scatter plots usually consist of a large body of data. The closer the data points come when plotted to making a straight line, the higher the correlation between the two variables, or the stronger the relationship (University of Illinois, 2014).

If the data points make a straight line going from the origin out to high x- and y-values, these variables are said to have a positive correlation. If the line goes from a high-value on the y-axis down to a high-value on the x-axis, the variables then have a negative correlation (University of Illinois, 2014)). Figure 2.14 demonstrates a perfect positive and perfect negative correlation.

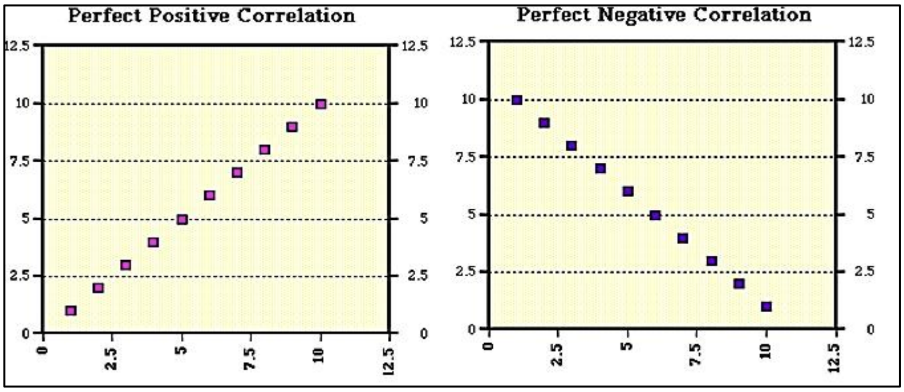


Figure 2.15: Perfect Positive and Perfect Negative correlation in Scatter Plots (University of Illinois, 2014).

In the figure above a perfect positive correlation is given the value of 1. A perfect negative correlation is given the value of -1. If there is absolutely no correlation present, the value given is 0. The closer the number is to 1 or -1, the stronger the correlation, or the stronger the relationship between the variables. The closer the number is to 0, the weaker the correlation. So, something that seems to roughly correlate in a positive direction might have a value of 0.67, whereas something with an extremely weak negative correlation might have the value -.21 (University of Illinois, 2014).

Pearson’s Correlation Coefficient has been chosen above outliers and scatter plots because correlation provides a better graphical representation per scanning device.

2.9. QUALITATIVE QUESTIONNAIRES

(StatPac Inc., 1993) indicates that questionnaires are one of the most popular methods of conducting scholarly research. Questionnaires provide a convenient way of gathering information from a target research population. It is claimed that written questionnaires reduce interviewer bias for the reason that there is a uniform question presentation. Unlike in-person interviewing, there are no verbal or visual clues to influence a respondent to answer in a particular way. Questionnaires should leave adequate space for respondents to make comments. One criticism of questionnaires is the inability to retain the "flavour" of a response. If respondents of a questionnaire have adequate space for comments, it could provide valuable information not captured by the response categories. StatPac Inc. specifies that well-designed questionnaires should include clear and concise instructions on how they should be completed. These must be very easy to understand, so short sentences and basic vocabulary must be used .

(Akaeze & Akaeza, 2016) suggest that qualitative questionnaires could be used to gather facts about people's beliefs, feelings, experiences in certain jobs, service offered, activities, and more. Researchers who gather data in this way could find it helpful to understand how people (research population) feel about certain issues. The literature of Akaeze and Akaeze provides a few examples for collecting qualitative questionnaires data in this way, such as to collect data about the user's experiences in using certain products, feelings about service offered by surgeries, hospitals, and restaurants, and so on. This type of research method could be useful for companies who seek to understand the experiences and feelings of consumers who use certain products.

(Brennan, 1997) highlights that open-ended questions are used in survey research where it is considered important to allow respondents to answer in their own words and are frequently used to generate ideas that will form the basis of checklists or closed questions in subsequent surveys. Brennan claims that despite that open-ended questionnaires being in wide-spread use, relatively little attention has been paid to the effects that research design and question wording could have on the responses to open-ended questions. The author explains that the purpose of using an open-ended question is to generate as many ideas as possible, then it would be useful to know how to design a questionnaire and formulate questions appropriately to achieve this objective.

(Nair & Mertova, 2011) indicate that the adoption of student feedback was initially a contested topic, where it was mainly used as a performance management tool, but with on-going educational research, it has grown in recognition as a tool to enhance teaching and learning. When feedback questions are designed, care must be taken to create suitable questions that would generate relevant data for analysis. When analysing the data, one should focus attention on the use of the results rather than on the results themselves.

2.10. USABILITY

Nielsen describes usability where users can use a computer system or interactive device to achieve specified goals effectively and efficiently while promoting feelings of satisfaction in a given context of use. Usability evaluation (UE) consists of methodologies for measuring the usability features of a system's user interface (UI) and identifying specific problems (Dix, *et al*., 1998); Nielsen 1993). Usability evaluation is itself a process that entails many activities depending on the methodology employed.

(Karampelas, 2012) states common activities include the following:

- Capture: collecting usability data, such as task completion time, errors, guideline violations, and subjective ratings;
- Analysis: interpreting usability data to identify problems in the interface; and

- Critique: suggesting solutions or improvements to mitigate problems.

Usability also refers to ensuring that interactive products enhance the interaction the users have with products to enable them to carry out certain activities. (Preece, *et al*., 2002) broke down these "usability goals" into the following:

- the effectiveness of the device
- the efficiency of the device
- the safety/security of the device
- the utility of the device
- the learnability of the device
- the memorability of the device

Which goals to address and how to operationalise these goals listed above will depend on the interactive devices in question, the environment and the purpose of a study/investigation Kwang and Grice indicate that studies have also proven that usability can influence device or system adoption and usage directly and that usability has an influence on productivity (Kwang & Grice, 2004).

(HarperCollins Publishers, 2019) defines efficiency as the quality of being able to do a task successfully, without wasting time or energy. It is also stated that in physics and engineering, efficiency is the ratio between the amount of energy a machine needs to make it work, and the amount it produces.

The U.S Department of Health and Human Services states that when reporting results from a usability test, one should focus primarily on the findings and recommendations that are differentiated by levels of severity. This includes the pertinent information from the test plan and presents just enough detail so that the method is identifiable. The reporting sections must be short and use tables to display the metrics and use visual examples to demonstrate problem areas if possible (usability.gov, 2015).

2.11. HEURISTIC EVALUATION

(Moustakas, 1990) defines heuristics as a way of engaging in scientific search through methods and processes aimed at discovery, a way of self-inquiry and dialogue with others aimed at finding the underlying meanings of important human experiences, where the deepest currents of meaning and knowledge take place within the individual through one's senses, perceptions, beliefs, and judgments. Moustakas claims this process requires a passionate, disciplined commitment to remain with a question intensely and continuously until it is illuminated or answered, having presented the basic nature of heuristics in its origins and meanings and having outlined its conceptual foundations as well as its core processes and phases.

(Kleining & Witt, 2000) indicate that qualitative heuristics are applicable to all topics within psychology and the human and social sciences which are open to empirical research, where qualitative data is especially suitable to discover qualitative relations such as structure or patterns and structural changes, as reported by Kleining and Witt. The goal of qualitative heuristics will at the end be to try to bring back the qualities of exploration and discovery into psychological and sociological academic research .

(Nielsen, 1995) indicates that in general, heuristic evaluation is difficult for a single individual to carry out because one person will never be able to find all the usability problems in an interface. Nielsen also states that experience from many different projects has shown that different people find different usability problems. It is, therefore, possible to improve the effectiveness of the method significantly by involving multiple evaluators.

Heuristic evaluation (Nielsen & Molich, 1990) (Nielsen, 1992) is a usability engineering method for finding the usability problems in an interactive product or system design so that they can be attended to as part of an iterative process. Heuristic evaluation is one of the main discount usability engineering methods. It is easy (can be taught in a half-day seminar); it is fast (about a day for most evaluations); and it is as affordable.

2.12. SUMMARY

The literature in this chapter provides an overview of previous research that was done on evaluating electronic input devices, with regard to recording class attendance at universities. An overview was given of how to choose the research population by looking at demographics. The different available hardware scanning devices suitable for this research were listed and compared, each with its pros and cons. Table 2.2 below illustrates the list of scanning devices, each with advantages and disadvantages.

The Fingerprint Scanner has been chosen because of low cost and its secure ability of taking attendance. Another reason for choosing the Fingerprint Scanner is for its popularity in South Africa and compatible with the SDK to develop software for the scanner. The Barcode Scanner has been chosen because of low cost and high speed of scanning. Another reason is that the student cards at the CUT already has the printed barcodes that represents the student number. It makes good business sense to utilise this functionality as it is already available. The RFID Scanner has been chosen as a scanning device because of the low cost of the access cards and because of the high-speed of scanning. Another reason is that the CUT students' cards already contains a passive RFID chip and it makes good business sense to utilise this functionality as it is already available.

Three of these hardware scanners were recommended and investigated in depth. Custom-written C# software that could enable the capture of research data from these scanning devices was mentioned. The importance of class attendance, consequences of students not attending class, the current manual attendance system at the CUT and the ITS were discussed.

The central student database (ITS) at CUT was examined and how it is used to capture student attendance. Relational databases were investigated that could cater for custom-written software to capture data from the different scanning devices. The different calculations' correlation methods were listed and methods of comparing data and creating statistics. The Pearson Correlation Coefficient, standard deviation equations and frequency analysis were discussed. Outliers and scatter plots were investigated as possible methods to display calculated data that could be collected from the scanning devices.

Qualitative questionnaires were discussed, and the literature referred to the importance of open-ended questionnaires and which data could be collected by using this method. Usability methods were discussed and how usability evaluation can be used in this research.

Lastly heuristic evaluation was investigated and how to implement it in this research when collecting data. The next chapter will discuss all methods how data will be captured from scanning devices and correlated. Procedures that will be used in a classroom to capture data will be mentioned and how each scanning device performance will be calculated and be discussed. Questionnaires will also be discussed and how it was compiled and analysed.

CHAPTER 3

RESEARCH STRUCTURE

This chapter describes the research methodology of this study. It aims to practically implement all the topics discussed in Chapter 2. A step-by-step approach is used to bring together all the components discussed in the previous sections to test the different scanning devices to recommend for an electronic attendance system.

This chapter discusses the experiment performed to test for the best electronic scanning device for an electronic attendance system. The hardware section examines all the hardware selected for this experiment, followed by experiment sub-sections. These experiments will test the performance of each identified scanning device, using the custom C# software. An important scientific factor to investigate was to perceive how hardware combined with the human factors would perform for a specific electronic scanning device. A qualitative questionnaire will be developed with multiple sections testing the participant's perception regarding their demographics, course enrolment, device-usability, -security, -efficiency, device recommendation and feedback questions.

3.1. DEMOGRAPHICS OF STUDENTS (Research Population)

Students with specific characteristics were required for this study. The following were the desired requirements for students to participate:

- Preferably technological disadvantaged students: students that possibly attended public schools coming from rural areas. Students of all genders, ethnic groups and different provinces in South Africa were targeted for this research population.

- The Grade 12 M-Score (Matric, Grade 12 level score total) target range should be between 22 and 27 points.
- Students in this M-Score range qualified for the extended curriculum programme (ECP) at the Central University of Technology (CUT).
- Students should have written the selection test to be accepted for the ECP.

Research participants were identified for the data-capturing process of the EIDs for this study with the above guidelines. These participants completed an indemnity form and were informed that the information obtained in this research would be treated as confidential and no names or personal details would be made available in the reporting of the results obtained. The participants would form part of a group whose attendance would be checked using the three different scanning devices. The participants were informed that one scan would be performed per week for four weeks for each device.

3.2. QUANTITATIVE DATA GATHERING

As mentioned in Table 2.2 in the Chapter 2, summary there were eight scanning devices listed, of which three were identified for this study. Advantages and disadvantages were identified and explained in Chapter 2, explaining how these three devices were chosen and why.

Scanners would be connected via USB ports to the pre-written custom C# software to scan students' fingerprints, barcodes and RFID with their student cards. Step-by-step descriptions of different experiments follow in the next section, detailing the three different scanning hardware devices used in these experiments.

The Fingerprint Scanner detects when a human finger presses down on the scanner and scan the fingerprint when touched. When a fingerprint has been successfully scanned, the fingerprint scanner indicates with a brief "beep" sound that the scan was successful. This Fingerprint Scanner then transmits the fingerprint data to the computer as an image.

The barcode code scanner, the second scanning device, scans a surface of an object with a laser and transmits the barcode's numeric value with a successful scan, followed by a “beep” sound.

The third and final scanning device is the RFID Scanner which scans the unique RFID number in the contained chip inside the card and transmits the numeric value with a successful scan, followed by a “beep” sound.

3.2.1. Experiment Setup

The next section details how experiments are carried out by using the identified electronic scanning devices, custom written C# software, and a custom-designed Microsoft Access database to store scanning data, and finally the human interaction.

3.2.1.1. Choosing the three scanning devices:

In Chapter 2, Table 2.2, different electronic scanning devices were listed, and three devices were identified to be used in this study. Numerous factors were investigated, and advantages/disadvantages were measured up between the listed devices. The costs of the devices were an important factor for considering the three identified devices.

Referring to Table 2.2, the reasons for selecting the three scanning devices to be used in this study were the following:

- Fingerprint Scanner

  - Reason: The fingerprint Scanner has been chosen because of low cost and a secure method of taking attendance.
- Barcode Scanner
  - Reason: The barcode Scanner has been chosen because of low device cost and the high speed of scanning. Student cards at the CUT have printed barcodes which represent the student number of the student.
- RFID Scanner
  - Reason: The RFID Scanner has been chosen because of low device cost, and access cards with a passive RFID chip are also of low cost and have a high scanning speed. Student cards at the CUT are compatible with the RFID Scanner used in this research study.

3.2.1.2. Research participants attendance card

The current enrolled student cards used in this case study have a printed barcode that represents the participant's student number. Embedded inside the student card there is a passive RFID tag, each with its own unique number. The research participants will use their current student card to scan their attendance register and participate in the capture of electronic attendance in this research study.

3.2.1.3. Data communication

All three identified electronic scanning devices communicate through the Universal Serial Bus (USB) port of a given computer which directly communicates with the custom-written C# software. When the barcode and RFID Scanner are activated, the data scanned is in a numeric data value format. This data is then sent to the custom-written C# software to identify a student in the custom database and record the class attendance. The custom attendance software will be discussed in the SAMPLING SOFTWARE section.

The third scanner, which is the Fingerprint Scanner, scans a person's fingerprint and send the data scanned in the format of an image value in encrypted numerical values to the custom-written software. When a fingerprint has been enrolled or scanned, it is analysed for very specific features. This data is converted to an algorithm and changed into a unique numeric code. When a fingerprint is scanned these fingerprints are converted into numeric values and then the computer compares the unique values in the database to the scanned fingerprint numeric values.

In the CUSTOM MICROSOFT DATABASE section 3.2.1.5, the data values captured from electronic scanning devices will be discussed. This section will explain how these values are captured in the custom-written software and how the time data per device and for each student is recorded.

3.2.1.4. Sampling Software

A custom-written C# attendance system software has been developed to ensure that all three the above-mentioned scanning devices could be connected to the same identical software platform, ensuring that the data captured will be recorded in the same custom database. This also ensures consistency and that the performance of the software is the same for all three scanning devices. Making use of the custom-written C# software allows areas for customization where the need may arise. In this case there will be a need to record specific timing data for each scanning device, for example allowing recording of the duration of a scan for each participant and the total scan time of each class. The user interface of the custom-written C# software can be seen in ANNEXURE D

3.2.1.5. Custom Microsoft Access Database

A class list of the identified voluntary research participants is retrieved, and a Microsoft Access Database designed for the custom-written C# software populated with the participants' information. A special contact session is arranged with the research participants, who multiple fingerprints each on the custom-written attendance software as well as recording their unique Radio-frequency identification (RFID) number.

The Custom Microsoft Access database has been installed on a standard laptop and the research participants' information below was captured for this experiment on the Custom Microsoft Access Database. The following information is captured:

- Student number
- Initials
- Surname
- RFID unique code of student card
- Fingerprint of participant (converted to unique numeric code by software)
- A unique number allocated to each participant (protecting participants anonymity)

With this information captured in the custom database, it allows for more organised data collection when the electronic attendance commenced. The Custom Microsoft Access Database relationships design can be seen in ANNEXURE A.

Fingerprints of the participants were pre-enrolled, and the thumb and index finger were enrolled. The system scanned each mentioned finger three times before storing it in the database. This was done to increase accuracy, if the fingers are aligned differently with scans. With multiple fingerprints of the participants recorded and stored in the custom-designed database, each student number is connected to a unique number to be identified throughout the database.

This would also be become useful if data mining were done to create statistics to protect participants anonymity. Other information contained within the custom-designed database would be the time and date recorded during scans for each participant and the total scan times of each schedule session. This information was recorded for each mentioned scanning device. Pre-enrolment of participants can be seen in ANNEXURE B.

3.2.2. Qualitative Data Gathering

The experiment involves connecting the three scanning devices to custom- written C# software to scan participants' attendance. A laptop with pre-written C# software is connected to a specific scanning device and the research participants in a scheduled class each scans their attendance electronically, once a week for the scheduled class. This action was repeated for a month cycle or four weeks. With each month cycle a different scanning device was used.

Before any data could be recorded with the pre-written C# software, participants needed to be enrolled for each device before the experiment commenced. The participants' relevant information was captured in the custom-designed Microsoft Access Database to ensure that when the data capturing process for class attendance started there were no delays. The aim was to have the hardware and software ready when the participants arrived at the scheduled attendance data- capturing sessions. The system would not recognise a non-pre-enrolled participant and would not include these students in captured data.

This would ensure that when the scheduled data-capturing session occurred, the participants needed only to scan their attendance and no other factors for example late-enrolling students could influence time data that to be recorded. For this reason, the time data recorded and device accuracy were the most fundamental purpose for this experiment, so that other factors had to be avoided. The purpose of this experiment was to connect a specific scanning device to a computer for a four-week cycle and scan attendance of the class using a specific scanning device.

When each participant scans their attendance, the recorded data contains time in seconds, where a specific time is recorded for each unique participant's scan and a total scan for the attendance session for that specific class or session of the week.

The captured data in the custom database comprises time scanned per participant for a specific device for a specific week. For example: John scanned 4 seconds for Week

1’s class using the Barcode Scanner and the total time scanned for the class in Week 1 for the Barcode Scanner was 32 seconds.

The purpose of the experiment was to capture the attendance in a class with a specific scanning device for four weeks, completing a month cycle for each scanning device. One class for the identified subject was scheduled once a week and one class attendance check taken per week. The Barcode Scanner was used for the first month cycle of four weeks, then the RFID Scanner for the next four weeks and lastly the Fingerprint Scanner for the last four weeks. This completed the three-month cycle for collecting time data from the three scanning devices.

The data captured in this experiment consisted of the total scan time for each class, starting when the first participant scanned until the last participant scan their attendance class list, using a specific electronic scanner. The scanning duration for each participant was also be captured during each recorded class attendance for each scanning device. At the end, the time data captured consisted of twelve weeks’ recorded attendance time data with four weeks’ scan data for each specific scanning device stored in the custom database.

One class attendance scan consists of the total time it took to scan all participants present in the specific class for the week and this time data was recorded in a custom database, as well as the unique scanning time for each participant. This will be done every week for four-week intervals, changing the scanning device in each four-week cycle.

The reason for recording the specific scanning duration for each participant each week for a specific device was to determine scientifically if the participant’s scanning time (performance) changed with repeated scans as the scanning weeks progressed for a specific scanning device. This determined if the participants started to understand the technology better or experienced challenges with the specific scanning technology.

Using each of the scanning devices once a week for a four-week period completed one cycle for a specific scanning device. which ensured four recorded sets of data for the three different scanning devices. After participants scanned their attendance with a specific scanning device for four weeks, in week five they started with the second device, followed by the third device for last four weeks.

Each week's electronic attendance scanning procedure was the same except when devices were changed in the three cycles. A common electronic class scan would commence as follows: A computer placed centrally and loaded with the custom-written C# software was connected to the custom-designed Microsoft Access Database for the electronic attendance system, set up with a specific EID. Participants queued for attendance scanning for the specific week number and device scanning, passing laptop and scanning their attendance electronically on the specific EID for the current scheduled week.

The Barcode Scanner was connected first with the custom-written C# software on a standard laptop for the first four weeks. The RFID Scanner followed in weeks five to eight. The last scanning device, the Fingerprint Scanner was used in the last four weeks of data- gathering, i.e. weeks nine to twelve. As each cycle changed, each different device was connected to custom-written C# software on a laptop.

As each class commenced each week of data capturing, participants passed the laptop with the custom-written C# software scanning either their barcode on their student card or tapping their student card with the embedded RFID chip, or verified their fingerprint to register their attendance, depending on the cycle of data capturing: four times for each device and each device for four weeks.

One of the advantages of using custom-written software is compatibility with all three scanning EIDs; if the need arises, extra features could be developed and added to the software. One such critical feature to be added before data collection would be the functionality of enabling the software to record time elapsed between first participants to last participants scanning. This will ensure that a total time can be recorded for a complete class scan. With this information different class attendance scan times can be compared. An additional functionality of custom software is recording this information for a specific device each week to the custom-designed Microsoft Access Database.

Another feature added to the custom software was recording the duration it takes to scan for a specific participant for each week for each device. This data could possibly prove useful if a participant's time data is compared for a specific device over f a four-week cycle. Different assumptions could be concluded in the area of improvement or challenges in that specific scanning technology, such as familiarity with technology and adjusting to the specific scanning device over the period of exposure.

With the custom-written C# software installed on a laptop and all participants enrolled on the software's custom database, the laptop can be set up in a class environment with the different scanning devices connected via a USB port. Participants queue in the scheduled class to capture their attendance electronically for every scheduled class for the specific electronic scanner. They scan their attendance electronically with the current scanning device for each separate scheduled four-week electronic attendance session cycle. A total of twelve weeks of data would be collected in this way. Figures 3.1, 3.2 and 3.3 below illustrate how attendance data is recorded for the three-scanning devices.

BARCODE SCANNER DATA						
Week	Student Number	Student Unique Number	Student Scan Date & Time	Student Scan Duration	Start of Scan Time	Stud Count
1						1
1						2
1						3
1						4
1						5
BARCODE Scanning WEEK 1 Class TOTAL:						**5**
2						1
2						2
2						3
2						4
2						5
BARCODE Scanning WEEK 2 Class TOTAL:						**5**
3						1
3						2
3						3
3						4
3						5
BARCODE Scanning WEEK 3 Class TOTAL:						**5**
4						1
4						2
4						3
4						4
4						5
BARCODE Scanning WEEK 4 Class TOTAL:						**5**

Figure 3.1: Barcode Scanner -- Time Data

Figure 3.1 above illustrates how the data is recorded when scanning with the Barcode Scanner. The first column indicates the week number where multiple participants information can be recorded depending on the sample size of the participants. The above figure has space for five participants for demonstration purposes. Column 2 records the student number of the participant.

The third column records the unique number assigned to each participant. The fourth column records the date and time the participant scanned their attendance. The fifth column records the scan duration of each participant calculated via the custom-written C# software. The scan duration is calculated from where the previous participant scanned till the next participant. The sixth column records the specific time of day the scan was recorded.

RFID SCANNER DATA

Week	Student Number	Student Unique Number	Student Scan Date & Time	Student Scan Duration	Start of Scan Time	Stud Count
1						1
1						2
1						3
1						4
1						5
			RFID Scanning WEEK 1 Class TOTAL:			**5**
2						1
2						2
2						3
2						4
2						5
			RFID Scanning WEEK 2 Class TOTAL:			**5**
3						1
3						2
3						3
3						4
3						5
			RFID Scanning WEEK 2 Class TOTAL:			**5**
4						1
4						2
4						3
4						4
4						5
			RFID Scanning WEEK 2 Class TOTAL:			**5**

Figure 3.2: RFID Scanner -- Time Data

Figure 3.2 above illustrates how the data is recorded when scanning with the RFID Scanner. The first column indicates the week number where multiple participants' information can be recorded, depending on the sample size of the participants. The above figure has space for five participants for demonstration purposes. Column 2 records the student number of the participant.

The third column records the unique number assigned to each participant. The fourth column records the date and time the participant scanned their attendance. The fifth column records the scan duration of each participant calculated via the custom-written C# software. The scan duration is calculated from where the previous participant scanned till the next participant. The sixth column records the specific time of day the scan was recorded.

Fingerprint SCANNER DATA						
Week	Student Number	Student Unique Number	Student Scan Date & Time	Student Scan Duration	Start of Scan Time	Stud Count
1						1
1						2
1						3
1						4
1						5
			FingerPrint Scanning WEEK 1 Class TOTAL:			5
2						1
2						2
2						3
2						4
2						5
			FingerPrint Scanning WEEK 2 Class TOTAL:			5
3						1
3						2
3						3
3						4
3						5
			FingerPrint Scanning WEEK 3 Class TOTAL:			5
4						1
4						2
4						3
4						4
4						5
			FingerPrint Scanning WEEK 4 Class TOTAL:			5

Figure 3.3: Fingerprint Scanner -- Time Data

Figure 3.3 above illustrates how the data is recorded when scanning with the fingerprint scanner. The first column indicates the week number where multiple participants' information is recorded depending on the sample size of the participants. The above figure has space for five participants for demonstration purposes. Column 2 records the student number of the participant. The third column records the unique number assigned to each participant.

The fourth column records the date and time the participant scanned attendance. The fifth column records the scan duration of each participant calculated via the custom-written C# software. The scan duration is calculated from where the previous participant scanned till the next participant. The sixth column records the specific time of day the scan was recorded.

When the above data has been recorded for each device, the data can be sorted into weeks and total and average scans can be calculated for each scanning device. Table 3.1 illustrates how this could be done with sample data.

Table 3.1: Scan times of each participant for a specific device, with sample data

BARCODE SCANNER DATA - SCAN TIME PER STUDENT				
Student Number	**Week 1** (Scan Time in Secs)	**Week 2** (Scan Time in Secs)	**Week 3** (Scan Time in Secs)	**Week 4** (Scan Time in Secs)
1	3	2	2	2
2	1	1	1	1
3	2	1	2	1
4	4	1	1	1
5	2	1	2	1
6	3	3	1	1
Average	**2.50**	**1.50**	**1.50**	**1.16**
Total	**15**	**9**	**9**	**7**

In Table 3.1 above it can be seen how Figure 3.1's data could be sorted with sample data, which enabling for effective data mining and performing calculations on this data. Table 3.1 is repeated for each scanning device and can be repeated unlimited times depending on the number of scanning devices investigated. The same is done for adding rows for participants.

3.2.3. Quantitative Data Calculations and Formulas

Correlation, Standard Deviation and Frequency Analysis were discussed in Chapter 2's literature. It was shown that correlation could indicate the statistical relationship between observed data used in the formula. The standard deviation calculation results, of a set of data values, indicate variations or dispersions between the set of data used in the formula. The Frequency analysis enables the researcher to describe the characteristics of the quantitative data captured.

The calculations in the next sub-sections will indicate how this captured data could be processed and then be statistically presented to discuss the outcome for each of the different quantitative data calculation methods. The literature in Chapter 2 explains the theoretical definitions and equations on how to interpret the answers of a correlation (equation 1) calculation, standard deviation (equation 2) and frequency analysis (Excel Frequency Table).

The quantitative methods that applied to determine the most suitable EID, are based on standard deviation, correlation and frequency in terms of performance and include:

- Correlation of “Time scan per student”
- Correlation of “Total time scan per class”
- Standard Deviation of “Participants scan for four weeks for each device“
- Improvements on each of the variables on prolonged use of devices.
- Frequency Analysis of the scanning time recorded all the weeks and all devices for the participants.

3.2.3.1. Correlation Calculations

When this time data is captured in the custom database, a time correlation can be done between total scan times against each scanning device that illustrates the quantitative positive or negative correlated relationship between scanning devices. Making use of multiple correlation the correlative findings can produce great insights and are useful in exploring relationships between scanning devices. As indicated in literature Microsoft Excel can process data captured by making use of a Correlation Matrix if there are more than two variables.

With the knowledge in the literature discussed in Chapter 2, the correlation Equation 1 can be used to calculate the captured time data from the participants. Table 3.2 illustrates an example how the captured data will be populated. In this table the Week numbers are listed in the first column followed by the different scanning devices in the next columns. The total scan time for each week's class is populated below each scanning device.

Table 3.2: Correlation Coefficient -- Total Scan Time with sample data

TOTAL SCAN Time PER WEEK - Devices Compared - in minutes			
WEEK	**BARCODE**	**RFID**	**Fingerprint**
1	00:01:40	00:01:10	00:03:20
2	00:01:30	00:01:00	00:03:00
3	00:01:20	00:00:50	00:02:40
4	00:01:10	00:00:40	00:02:10
CORRELATION CALCULATION: - Excel Data Analysis			
	BARCODE	*RFID*	*Fingerprint*
BARCODE	*1*		
RFID	1	*1*	
Fingerprint	0.994376713	0.994376713	*1*

When the time data is populated for each scanning device in Table 3.2 above, the correlation coefficient calculations can be done next. These calculations can be done by making use of the Equation 1 formula discussed in Chapter 2 or by making use of the Microsoft Excel's Analysis Toolpak add-in and using the correlation function in the Data Analysis tool in Microsoft Excel.

When making use of this analysis tool the necessary headings and correlation calculations would be populated automatically. The first row populates each scanning device's name and in the first column also lists the scanning devices, which would be populated in the same order for both the column and rows. The analysis tool can now be used to perform the correlation calculations on the time data that was provided for each device.

The correlation calculation would use the data provided and provide a value between -1 and +1. This will indicate how strongly the variables or devices in this case are related to each other. The literature in Chapter 2 explains the meaning of the possible answers when performing the correlation calculations. The importance of a positive or negative correlation between variables or in this research, scanning devices were indicated. Table 3.2 above makes use of the total scan times of the participants for each week and performs the Correlation Calculations. Table 3.3 below makes use of the average scan time of the participants in each week for each scanning device. The setup of Table 3.2 and Table 3.3 is identical except for the data that captured in these figures.

The following data is for illustration purposes and random time has been used in combination with observation when testing devices before chapter 4. The times captured in the table below indicates how data will be populated with real world experiment.

Table 3.3: **Correlation Coefficient -- Average Scan Time with sample data**

Average SCAN Time Per Student - Devices Compared - Seconds			
WEEK	**BARCODE**	**RFID**	**Fingerprint**
1	2.50	2.30	3.50
2	2.40	2.00	3.30
3	2.30	1.90	3.10
4	2.40	1.80	3.50
CORRELATION CALCULATION: - Excel Data Analysis			
	BARCODE	**RFID**	**Fingerprint**
BARCODE	*1*		
RFID	0.755928946	*1*	
Fingerprint	0.852802865	0.322329186	*1*

It is important to note that Table 3.2's data is populated in the format of hh:mm:ss (Hours:Minutes:Seconds) and Table 3.3's data in the format of ss:ms (Seconds:Milliseconds). With the above figures, charts could be created to discuss the data, as shown in sub-section 3.2.3.4. below.

3.2.3.2. Standard Deviation Calculations

The standard deviation could be calculated next by making use of data recorded in the database when scanning commences. Once again, the participant's total scan time per device for each week and the average scan time for each week could be used to calculate the standard deviation. When calculating the standard deviation by making use of the scanning data captured in the database, the results could be used to draw conclusions and could indicate how the students adjust to the scanning technology.

To prevent any unnecessary deviations when recording scanning data, the custom attendance software and scanning devices were connected on one computer only in this case a laptop with medium specifications and all the chosen scanning devices were connected to the USB 2.0 port, where there is a standard transfer speed. Before any scanning commence, the scanning devices were connected to the laptop and the custom software started. The software was idle waiting for the first input from the scanning device. Thus, all scanning started with software that is active and ready for scanning, as well as a scanning device ready to scan and record scanning data.

A small standard deviation value would indicate that all students took more or less the same to scan with the specific scanner, indicating all students' ability to use the scanning technology and adjusting well. A high standard deviation value of the total scan times of a device would indicate that the scanning device has certain challenges and further investigation would need to be done.

When the data captured in Figures 3.1, 3.2 and 3.3 are recorded, the average total scan time of each week can be calculated as well as the average scan time for all students per week. Table 3.4 below is used to calculate and record the standard deviation for each scanning device for the four-week period. The first row in Table 3.4 serves as the heading and the second row lists the week and the scanning devices.

The columns below these headings provide the week numbers, the average (which would be the average time recorded with scanning data), the standard deviation and then the deviation in percentage. Below the scanning devices listed in Column 2 to 4, the total scanning time (Total scan time – per week figure) or average scanning time (Average scan time – per student figure) could be captured.

Table 3.4: Total and average scan time per week for a specific device with sample data

TOTAL SCAN TIME EACH WEEK Compared in seconds					**AVERAGE SCAN TIME EACH WEEK Compared in Seconds**			
WEEK	**Bar-code**	**RFID**	**Finger-print**		**WEEK**	**Bar-code**	**RFID**	**Finger-print**
1	100	70	200		**1**	2.50	2.30	3.50
2	90	60	180		**2**	2.40	2.00	3.30
3	80	50	160		**3**	2.30	1.90	3.10
4	70	40	130		**4**	2.40	1.80	3.50
Average	**85.00**	**55.00**	**167.50**		**Average**	**2.40**	**2.00**	**3.35**
Standard Deviation	**12.910**	**12.910**	**29.861**		**Standard Deviation**	**0.082**	**0.216**	**0.191**
Percen-tage:	**15.19%**	**23.47%**	**17.83%**		**Percen-tage:**	**3.40%**	**10.80%**	**5.72%**

The time data recorded in the Total scan time each week, would be in seconds. Thus, 1 minute and 30 seconds would be populated as 90. The average scan time per student, would be populated in the format of seconds and milliseconds. When all the scanning device's data has been populated as discussed, then the Standard Deviation can be calculated and converted to percentage. When all the calculations have been completed, the results can then be charted.

With the knowledge in the literature In Chapter 2, the Standard Deviation Equation 2 could be used to calculate the standard deviation with the data populated in Table 3.4. It is also worth mentioning that the formula for standard deviation is a built-in formula function in the Microsoft Excel software package as indicated in the literature chapter. Thus, if values or data are populated in Figure 3.4, it could also then be used to calculate the standard deviation by making use of Microsoft Excel formula functionality. Also, in this chapter it is discussed how to calculate the percentage of a standard deviation results.

The answers of this standard deviation calculations could indicate the absolute variability of a distribution. The higher the variability, the greater the standard deviation and greater the magnitude of the deviation of the value from their mean as discussed in the literature. When converting the standard deviation calculation answers to percentage, the standard deviation's answer would be divided by the average time for each device, as shown in Table 3.4.

When the standard deviation and deviation percentages have been calculated, each device's answers could also be compared in a chart. Conclusions could then be drawn on each device's usability and efficiency. The standard deviation indicates how a participant adjusted to a certain scanning technology.

High or low standard deviations will indicate different challenges that can be investigated for the device in question. The standard deviation could also be calculated for each participant. This could provide information on the participants individual performance for each week of every scanning device as shown in Table 3.5.

Table 3.5: Standard deviation for individual participant for a specific device with sample data

BARCODE SCANNER DATA - Scan time per student					Barcode Scanner	
Student Number	**Week 1** Scan Time in Secs	**Week 2** Scan Time in Secs	**Week 3** Scan Time in Secs	**Week 4** Scan Time in Secs	**Standard Deviation**	
1	3	2	2	2	0.433	19%
2	1	1	1	1	0.000	0%

Table 3.5 would indicate the unique number of each participant and the recorded scan times for each week's attendance. The standard deviation can be calculated next on the individual's scanning times. The standard deviation percentage could be calculated by using the standard deviation answer and dividing the standard deviation by the average scanning time for this individual participant.

With this information, conclusions could be made about the performance of the participant for the specific device. Table 3.5 can be repeated for all the scanning devices that were mentioned in this chapter. Table 3.6 will be used to summarise all the standard deviation calculations for the total scan times.

Table 3.6: Standard deviation summary for total scan times -- sample data

STANDARD DEVIATION - BETWEEN DEVICES FOR TOTAL 4 WEEK SCAN		
Device:	**Deviation in four weeks**	**Deviation Percentage:**
Barcode	12.910	15.19%
RFID	12.910	23.47%
Finger Print	29.861	17.83%

Table 3.7: Standard deviation summary for average scan times -- sample data

STANDARD DEVIATION - AVERAGE SCAN TIME PER STUDENT		
Device:	**Deviation in four weeks**	**Deviation Percentage:**
Barcode	0.082	3.40%
RFID	0.216	10.80%
Fingerprint	0.191	5.72%

Table 3.7 above will be used to summarise all the standard deviation calculation for the average scan times with sample data populated. With the above tables, charts could be created to discuss the data as indicated in sub-section 3.2.3.4 below.

3.2.3.3. Frequency analysis

The frequency analysis can be calculated next, which could assist describing the characteristics of a set of data as discussed in the literature chapter. A sheet of each participant's recorded scanning times for each device would be populated and the Microsoft Excel frequency formula could be used to calculate how many participants falls in different ranges. For example, if ten students scanned 5 seconds in week 1 for a specific device and five students scanned 3 seconds for this scanning device. the frequency will indicate that in the range from 1 to 5 seconds, there were five students who scanned in 3 seconds and ten students who scanned in 5 seconds.

This information is presented in a table format. This table can be repeated for an unlimited number of participants' information and scanning devices. When this table has been calculated by making use of the frequency formula, the answers could also be converted to percentages. which could indicate how many participants fall in a specific range for a specific week and scanning device. Charts could be created with this information, where the results could be discussed. Table 3.8 below indicates sample data for a specific device and lists each participant's unique number and scanning times. The first two rows in Table 3.8 have the headings, where the participants' information could be populated in the first five columns.

The last five columns will be calculated by making use of the excel frequency formula. It is important to note that in the last five columns where the frequency would be calculated, the headings, including the seconds, must be listed. It is recommended to list all the seconds to the maximum seconds for each of the participants. Thus, where the participant that scanned the longest is 25 seconds, the frequency table's seconds will be listed till 25. Now the frequency formula could be used and will populate the information as show in Table 3.8.

Table 3.8: Frequency Analysis of a specific scanning device with sample data

BARCODE SCANNER DATA – Scan time per student						BARCODE Frequency:				
Student Number	**Week 1** Scan Time in Secs	**Week 2** Scan Time in Secs	**Week 3** Scan Time in Secs	**Week 4** Scan Time in Secs		**Seconds**	**Week 1**	**Week 2**	**Week 3**	**Week 4**
01	3	2	2	2		**1**	1	4	3	5
02	1	1	1	1		**2**	2	1	3	1
03	2	1	2	1		**3**	2	1	0	0
04	4	1	1	1		**4**	1	0	0	0
05	2	1	2	1		**5**	0	0	0	0
06	3	3	1	1		**6**	0	0	0	0

It can be seen in the demo data in Table 3.8 above there are six participants, with each of their scanning times recorded below the weeks for the specific device. The above table's frequency data on the right can now be used to convert it to percentages.

The frequency value in this table will be divided by the total number of participants. Table 3.9 below indicates the percentage of participants that scanned a certain amount of time in a certain week for this specific device.

Table 3.9: Frequency Analysis for a specific device converted to percentage with sample data

BARCODE Frequency:				
Seconds	**Week 1**	**Week 2**	**Week 3**	**Week 4**
1	17%	66%	50%	83%
2	33%	17%	50%	17%
3	33%	17%	0%	0%
4	17%	0%	0%	0%
5	0%	0%	0%	0%
6	0%	0%	0%	0%

The above Tables 3.8 and 3.9 could be repeated for unlimited participants and scanning devices. In this case it would be repeated for each scanning device mentioned in this chapter. With the above tables charts could be created to discuss the data as indicated in sub-section 3.2.3.4 below.

3.2.3.4. How charts will be created of the results

With the tables in the previous sub-sections the calculations of the Correlation Coefficient, Standard Deviation and Frequency Analysis in sections 3.2.3.1 to 3.2.3.3 can be graphically represented by making use of MS Excel charts functionality. With this visual representation of the answers calculated, conclusions could be drawn and discussed. The figures below cater for one device only, namely the Barcode Scanner, and need to be repeated for each scanning device.

Charts could also be created to indicate the total scan times and standard deviation with the sample data populated in Table 3.4. Below are such charts, created to illustrate visually what the data represents. Chart 3.1 illustrates the total scan times with the different scanning devices by making use of the sample data discussed earlier.

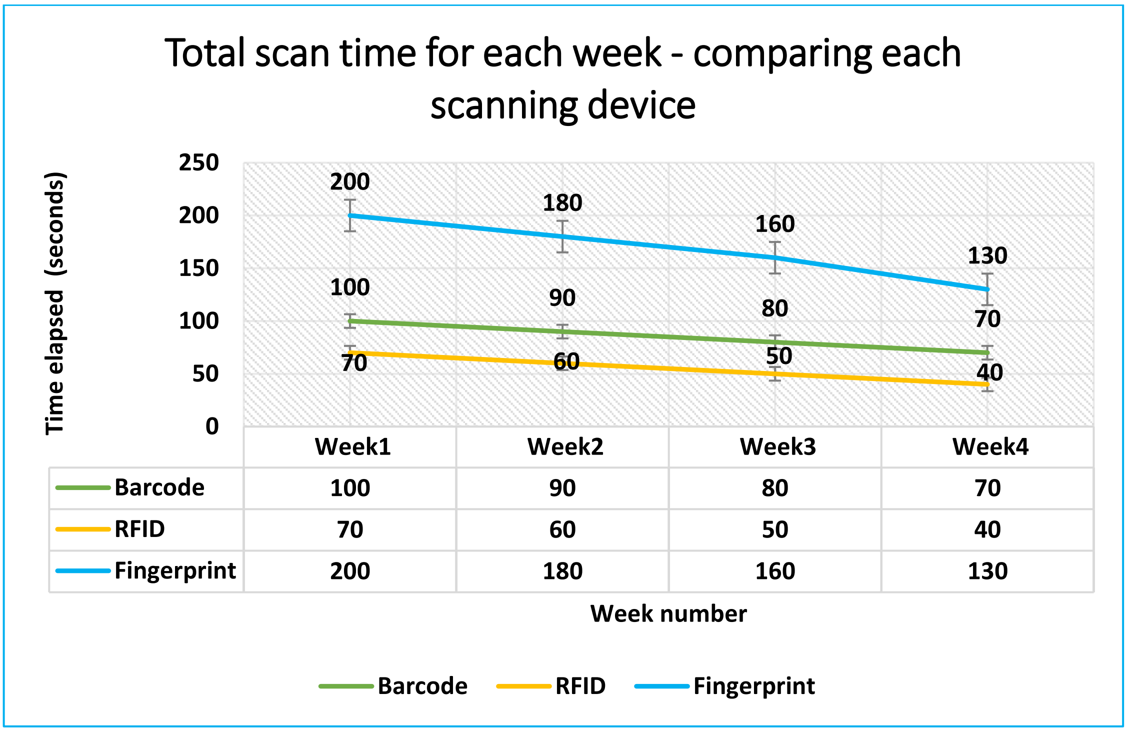


Chart 3.1: Sample (Demo) data for scanning devices. Comparison of Total Time scan per Week

With the above Chart 3.1 created, conclusions can be made about the devices' performance, participants' interaction with the technology and how the participants become accustomed to scanning devices, for example the device that took the longest to scan was the fingerprint Scanner and the scanner that took the least time to scan was the RFID Scanner. This sample data indicates that the fingerprint was the slowest device and the participants could have experienced challenges with this specific scanner.

The average scan times with sample data populated on the right in Table 3.4 will be charted as indicated in Chart 3.2

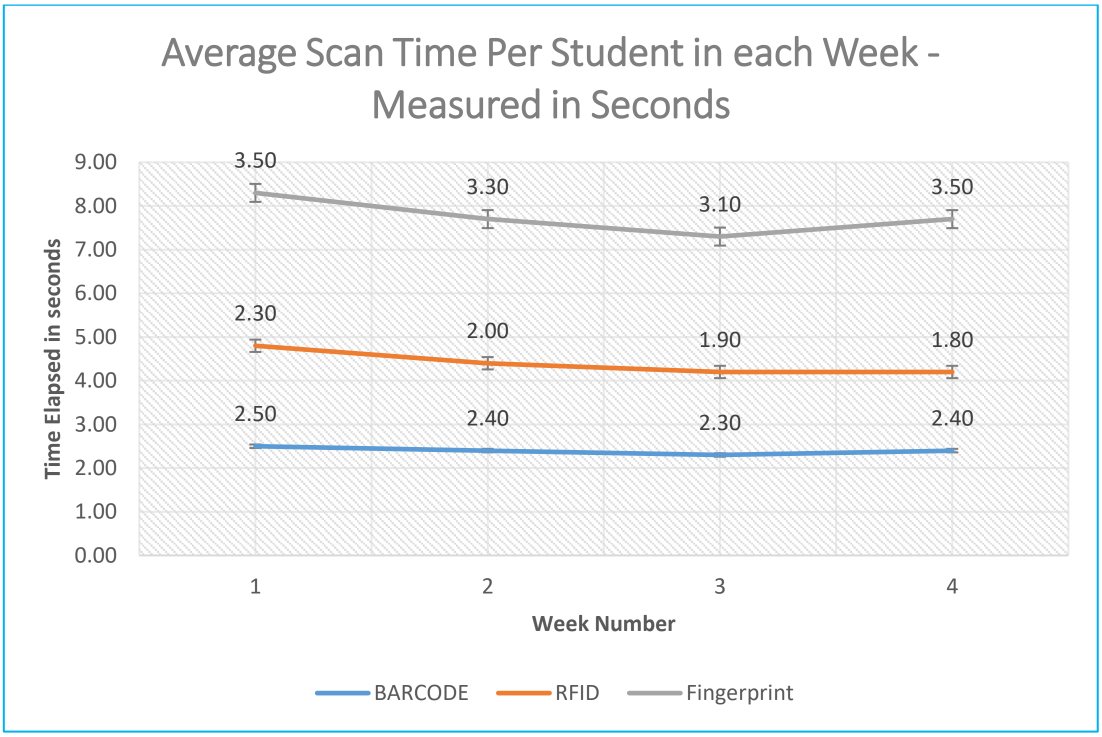


Chart 3.2: Sample (Demo) data for scanning devices. Comparison of Average Scan Time per Week

With the above chart 3.2 created, conclusions can be made about the devices' performance, participants' interaction with the technology. The sample data in sub-sections 3.2.3.1 to 3.2.3.3 -- the correlation coefficient, standard deviation and frequency calculations -- can be presented visually in charts for conclusions. Chart 3.3 illustrates the standard deviation for the total scanning times of the sample data for each scanning devices in Table 3.6.

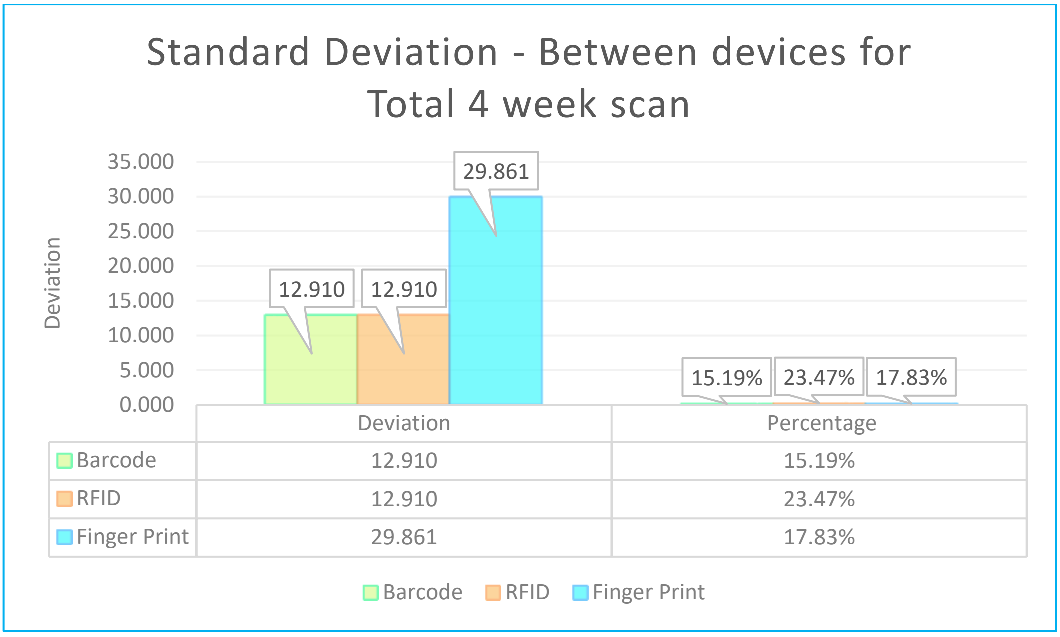


Chart 3.3: Standard Deviation of total scan times per week (Sample Data)

Chart 3.4 below illustrates the standard deviation for the average scanning times of the sample data for each scanning devices in table 3.7. As stated earlier, the method of calculating the percentage value of the standard deviation was discussed in Chapter 2.

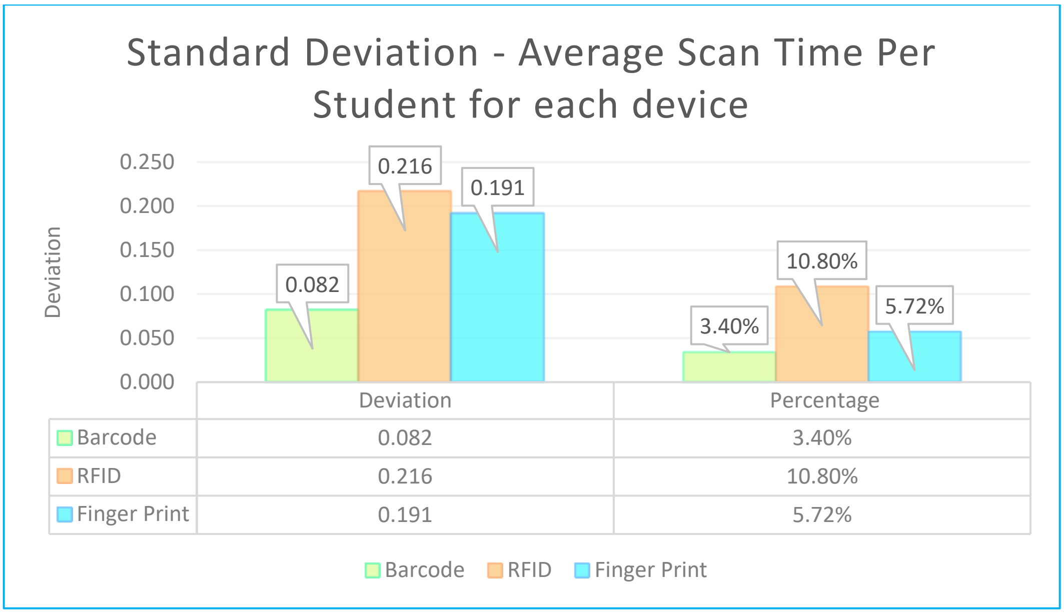


Chart 3.4: Standard Deviation of average scan times per week (Sample Data)

Chart 3.4 indicates the answers of calculating the standard deviation on the sample data of the average scan times per week for each device. With this information conclusions could be drawn on participants' performance on each device.

By making use of the same total and average scan sample times provided in Tables 3.2 and 3.3 the correlation coefficient can be calculated as shown in Charts 3.5 and 3.6 below. By using the correlation coefficient calculations indicated by making use of equation 1 (or Excel's Data Analysis function) as discussed in the literature chapter, this data can be plotted on graphs.

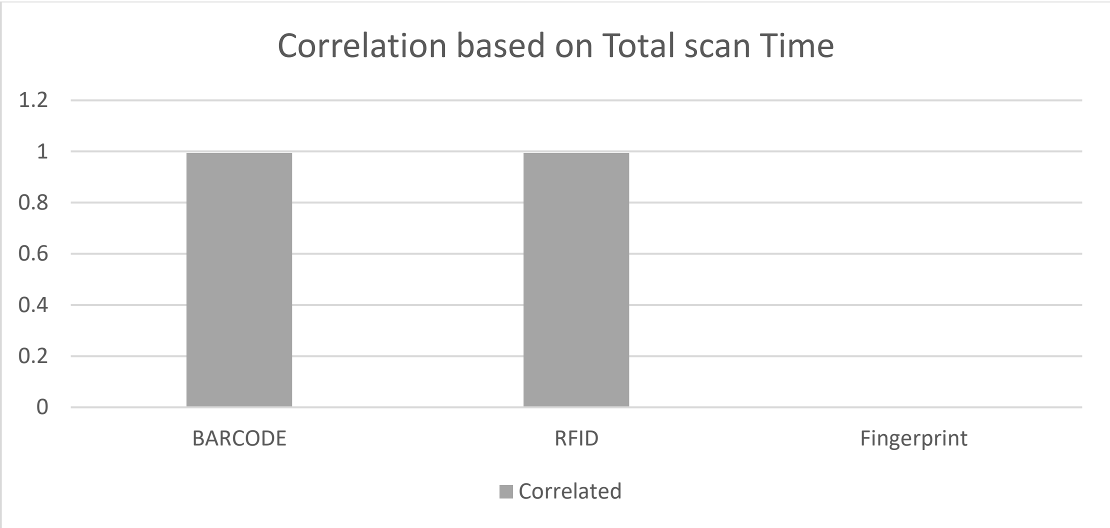


Chart 3.5: Correlation of Total Scan times (Sample data)

With the correlation results by making use of the total scan times of the sample data provided in Chart 3.5 conclusions can be drawn. For example, in this chart above it would indicate how close or not each EID's are related is to one another. As discussed in the literature chapter, this positive 1(+1), which could indicate that the two EID's (Barcode Scanner and RFID Scanner) have a good correlation. Where the Fingerprint Scanner had a bad correlation to the other two EIDs and this indicates that this scanning device should be eliminated and have poor scan times that indicate this device is a under achiever.

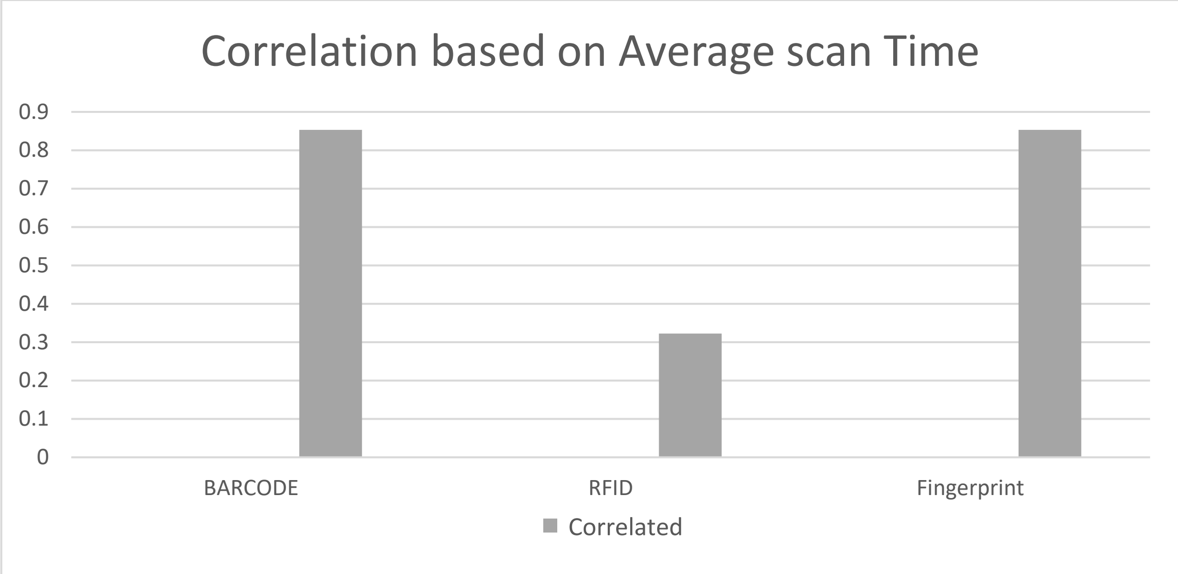


Chart 3.6: Correlation of Average Scan times (Sample data)

When making use of the average scan times and calculating the correlation as provided in Chart 3.6, conclusions can also be drawn. For example, in this figure it can be seen that two EID's (Barcode Scanner and Fingerprint Scanners) had a good correlation which could mean that reasons for choosing a specific EID should come from other aspects. The EID RFID had a poor correlation which would indicate the device under achieved and must be eliminated. It must be noted that the correlation of the total scanning times data and the average scan times differ. Where the average sample data scan times that was used to calculate the correlation as in Chart 3.6 possibly indicate that one or more participants scanned very fast or very slow that result in anomalies when using the average scan time.

The frequency chart could be created next. The sample values of Table 3.8 and 3.9 would be used and Chart 3.7 could be created.

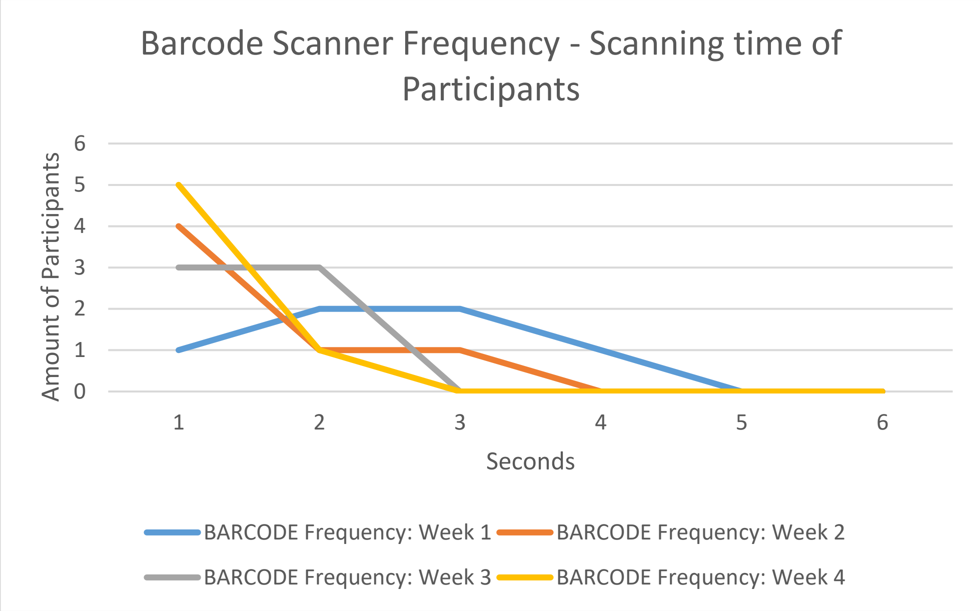


Chart 3.7: Frequency analysis of participants scanning time in amounts

Conclusions can be drawn with chart 3.7. It can be seen in the sample data illustrated above, that most of the participants scanned in the one- and two-seconds range. This could indicate the rest of the participants scanned a bit longer. Thus, most participants scanned very fast and understood this specific scanning device.

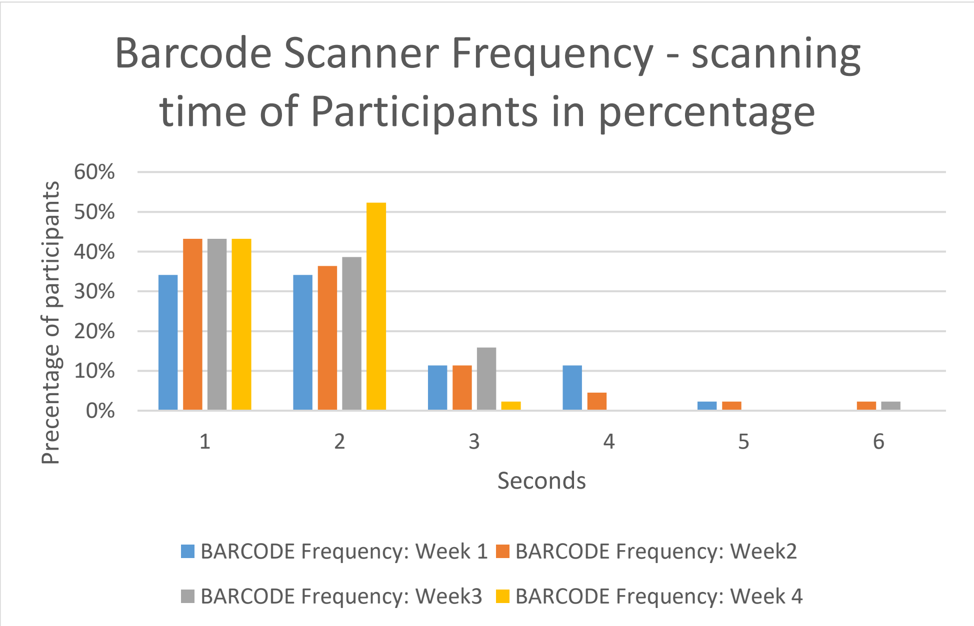


Chart 3.8: Frequency analysis of participants scanning time in percentage

Chart 3.8 indicates the scanning time of participants in percentage for each week. It can be seen that most of the participants scanned in the one- and two-second range for this specific scanning device.

3.3. QUALITATIVE DATA GATHERING

An open-ended questionnaire was administered with the aim to identify trends among the students' opinions regarding Electronic Input Devices. The qualitative questionnaire was administered after the four-week scanning cycle of classes for students to determine their perceptions of EIDs and the traditional method of capturing student class attendance. The questionnaire can be seen in ANNEXURE F.

The questionnaire is divided into different sections. The first section collects data regarding gender, age and for which year of study the participant is enrolled. The second and crucial section of the questionnaire will collect data on each scanning device's usability, security and efficiency. The last section of the questionnaire concentrates on recommendations and observations from the participants.

With the questionnaire conclusions can be made from the experience perceived by the participants when using the electronic scanning devices. The questionnaire data was collected after the scanning data collection. This ensured that the participants had enough exposure to each scanning device to truly express themselves in the questionnaire, providing valuable data.

3.3.1. Questionnaire Design

A qualitative questionnaire was developed with multiple sections testing the participants' perceptions regarding their demographics, course enrolment, device usability, security, efficiency, device recommendation and feedback questions. Most of the questions in the questionnaire were asked in multiple-choice format with an optional space provided for feedback.

3.3.2. Questionnaire Questions

The Demographics sections consisted of Gender, Age Group and the Study Year for the current course the participants are enrolled for. With this information, additional conclusions could be drawn from the participant's perceptions in the questionnaire as the participant's year of study, gender and age group could provide background information and possibly indicate how technology-fit the participant was at this point in time.

The Electronic Input Devices (EIDs) section of the questionnaire provides feedback and personal views of the participants on their experience with the EIDs. The Usability questions in the questionnaire were asked to determine which device was the easiest or the most difficult to scan with. Each sub-section provided an area for optional written feedback from the participants.

Device security was the next series of questions which provided feedback from the participants on which device in their opinion was the most secure or the least secure. This will be asked to find which of the EIDs the participants felt was the most secure when they performed scanning and then the least secure when scanning took place. Each sub-section provided an area for optional written feedback.

Another part that played a critical role in the questionnaire covered which of the EIDs scanning devices' Time was efficient in the participants' view and which of one these devices they would recommend if an Electronic Attendance System would be implemented. The questions in the questionnaire were asked to find which of the EIDs in the participants' view were the most time-efficient and which the least time-efficient. Each sub-section provides an area for optional written feedback.

In the last section of the questionnaire, the participants' personal view on which EID device they would recommend if an electronic attendance system would be implemented. Participants were also requested to indicate if they would prefer electronic or paper-based class attendance records. The last question was in multiple-choice format, asking whether participants were aware of buddy signing and written feedback space regarding the participants' view on this topic was provided. Participants had to indicate if they were aware of buddy signing, testing their moral opinion on the topic. If electronic attendance were implemented, would it motivate them to attend class? In their personal view, what were the benefits of taking attendance records? They were asked for any suggestions in their view.

3.3.3. Research Ethics

The students participating in this study were requested to complete an indemnity form. This form informs the students that they will be part of this study and receiving their consent.

- Information obtained will be treated as confidential and no names or personal details will be made available in reporting the results obtained.
- The questionnaire will be completed anonymous and involve no sensitive information.
- Participation will be completely voluntary.

The research ethics release form that participants completed, can be seen at ANNEXURE E.

3.3.4. Method of gathering data for the questionnaire

When the last session of taking attendance records electronically with the EID scanners was concluded a printed copy of the questionnaire was handed to each participant and the research ethics explained. Each participant was given enough time to complete the questionnaire and submit it to the researcher.

A Microsoft Excel Spreadsheet was created in the image of the questionnaire that was handed to the participants, with different sheets for the different sections in the questionnaire. Four such sheets were created in an Excel spreadsheet, namely:

- Demographics Section Sheet
- Usability, Security and Efficiency Section Sheet
- Recommendations Sheet and
- Observations Sheet

All questionnaires were gathered, and the feedback counted manually and recorded in the Microsoft Excel sheets created. The sections with questions which had multiple choice answers, meaning there could only be a certain predetermined collection of answers, were counted on the Excel sheets as stated above.

3.4. SUMMARY

This chapter discussed and illustrated the scientific approaches conducted to investigate the identified scanning devices for the study and which role the research population, or rather the participant, played in the data capturing process by using the electronic scanning devices in a simulated electronic attendance system.

The methods of how scanned data would be collected from the scanning devices by using the custom-written C# software connected to a custom-designed Microsoft Access Database was discussed and how this data would be processed by making use of the Correlation Coefficient, Standard Deviation and frequency analysis calculations. With these calculations performed on the time data captured in the custom-designed database conclusions could be made and these calculations could then be represented visually with graphical charts.

This chapter also described how the equations of Correlation Coefficient, Standard Deviation and frequency analysis could be used and what conclusions could be made. Ultimately the purpose and goal would be to recommend which scanning device would be best suitable for a student attendance recording system. Three devices were chosen for this study because they were the most commonly used s in attendance recording and industry tracking procedures where the factor of cost and availability were also an influence.

CHAPTER 4

RESULTS

In this chapter, the results of the qualitative questionnaire and the quantitative data gathered from the mentioned scanning devices are presented. A qualitative questionnaire was developed to determine the research participants' perceptions of Electronic Input Devices (EIDs).

The quantitative method was applied to determine the most suitable Electronic Input Device (EID) and the three mentioned scanning devices analysed data will be discussed. The quantitative and qualitative results were statistically analysed to recommend the most suitable EID for class attendance at a UoT in terms of the pre-determined usability metrics.

4.1. QUANTITATIVE RESULTS

The following sections provide the results on the data recorded in the custom-designed Microsoft Access Database from the custom written C# software to which each of the three EIDs were connected for the study. The data to be discussed in this section for each device are:

- The total scan time for each EID in a specific week for each of the four-week cycles.
- Comparing the total scan time of a specific EID in the four-week scans times against the other EID's.
- The average scanning time for participants for a specific EID for that specific week in a cycle
- Comparing the participants average scan time for the different EIDs

4.1.1. Student absenteeism in the data capture process

Throughout the data capturing process which commenced over a period of twelve weeks, each EID was tested for a four-week cycle, it is worth mentioning that some of the original sixty-three research participants that formed part of the study were absent for the scheduled electronic attendance data-capturing sessions. These absent participants attended some of the cycles of a specific device and were absent for other devices.

These absent participants' recorded time data was removed completely from the usable data in the Microsoft Excel sheets and only date from participants attending all data-gathering sessions were used. Table 4.1 below summarizes the total number of participants present for every session of data capturing.

Table 4.1: Number of useful Participants present for the research study

DEVICE:	BARCODE SCANNER (Device 1)	RFID SCANNER (Device 2)	FINGERPRINT SCANNER (Device 3)
NUMBER OF USEFUL PARTICIPANT'S:	44	44	44

With Table 4.1 above in mind, it can be seen how the number of participants decreased from the original sixty-three (63) from the first scanning device to the last. Since participants started scanning their attendance electronically from the first scanning session to the last session, about nineteen (19) participants' data needed to be removed from the collection of useful data due to factors like absenteeism or other unknown factors.

These absent participants' data needed to be removed from the collection of useful data for the reason that when the data was analysed and when applying mathematical calculations, all these calculations would be consistent and would be correctly interpreted. Table 4.2 illustrates the number of participants that were absent for each scanning device.

Table 4.2: Participants absent for the data capturing sessions.

DEVICE:	**BARCODE SCANNER ABSENTEES**	**RFID SCANNER ABSENTEES**	**FINGERPRINT SCANNER ABSENTEES**
Absent Participants	13	10	9

It is worth mentioning that in Table 4.2 above, the participants that were absent in the Barcode Scanner data-capture sessions were different participants each time. The same occurrence happened in the data- capturing session for the RFID Scanner session and Fingerprint Scanner session. With this in mind, these participants' scanned data was removed from all scanning devices.

This will ensure that all data that is used would be of participants that attended all the sessions for each scanning device. To conclude, there were nineteen (19) fewer data sets that could be used in the Barcode Scanner data, the RFID Scanner data and the fingerprint due to participants' absenteeism or other factors outside the researcher's hands.

The number of nineteen (19) participants removed originate from where different participants were absent for a particular scanning session. This means all the unique student numbers that were absent overall with all the scanning sessions added together and removed from the useful data of participants.

4.1.2. Electronic Input Device (EID) 1 – Barcode Scanner - Results

This section illustrates and discusses the data collected in the four-week cycle of the barcode scanning device. Chart 4.1 illustrates the total scan time for each class in the four-week cycle for the barcode scanner. A total of 44 valid scans were recorded and four (4) different totals were recorded by the custom C# software that was connected to the Barcode Scanner. The timer started when the first participant started scanning until the last student scanned and the program was signalled that the attendance capture process was completed. This approach indicated the total scan time since the scanning started until the last participant scanned. With this information a total scan time for each class can be determined. To analyse the individual performance of the participants, the frequency analysis was done as indicated in section 4.1.9. This was used to determine how individual participants performed each week for each scanning device.

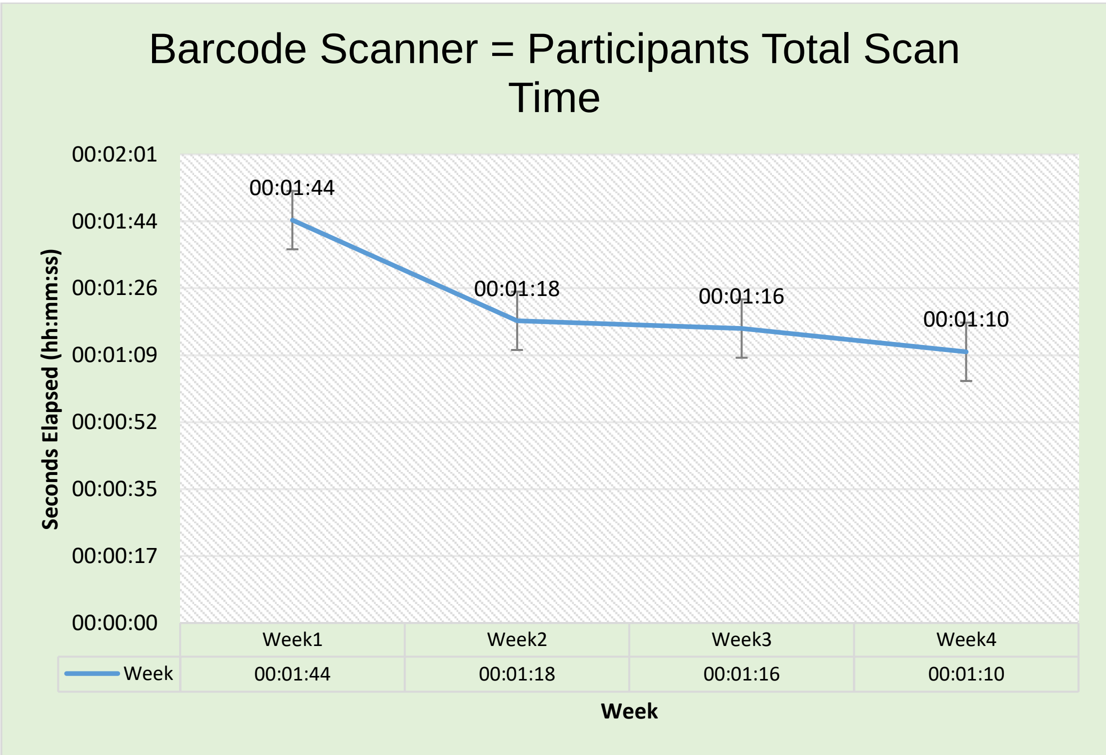


Chart 4.1: Barcode Scanner -- Participant's Total scan time per week

From the above chart 4.1 when comparing week 1 class attendance total scan time and week 4 total scan time and performing a comparison, it can be concluded as each week passed the participants became used to the technology and adjusted to scanning their barcoded student cards more efficiently. It can be seen in the above graph that the students adjusted to the scanning technology and each week the scanning time decreased.

This could indicate the participants became confident with this scanning device and with practice or repeat the participants knew how to align their barcoded student card correctly for a line of sight of the Barcode Scanner's laser. If using an average calculation, it could also have just meant that the last student came in earlier or later than in previous weeks, which would influence the average scan time per student. To resolve this anomaly the standard deviation formula was used in section 4.1.7. Chart 4.2 illustrated the total average scan time for all participants when attendance was scanned with the Barcode Scanner each week for four weeks.

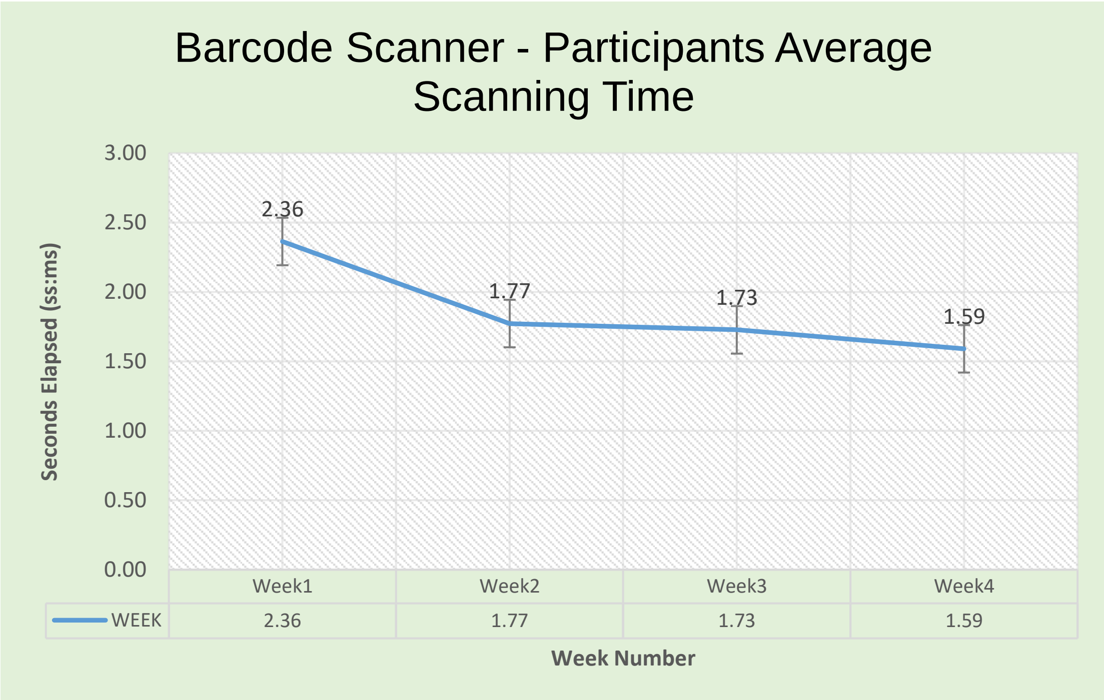


Chart 4.2: Barcode Scanner -- Participants' average scan time per week

When investigating the average scan time of the Barcode Scanner illustrated in Chart 4.2 above it can be perceived that the participants' scanned more easily each following week. It could be concluded that the participants adjusted well to barcode scanning technology. Some observations when the participants were in the process of scanning for attendance were that some of them had the challenge of correctly aligning their student card to the laser of the barcode scanner and in other instances by accident obstructed their barcode on their student card with their finger.

Also, worth mentioning was the issue where participants were unsure of the distance to hold their student card from the Barcode Scanner, which delayed scans in some instances. See ANNEXURE G for all the data captured for the Barcode Scanner.

4.1.3. Electronic Input Device (EID) 2 – RFID Scanner – Results

This section illustrates and discusses the data that was collected in the four-week cycle for the RFID scanning device. Chart 4.3 illustrates the total scan time for each class in the four-week cycle for the RFID Scanner. A total of 44 valid scans were recorded each week and 4 (four) different total scan times were recorded by the custom C# software that was connected to the RFID Scanner. The timer started when the first participant started scanning until the last participant scanned and the program was signalled that the attendance capture process was completed. This approach indicated the total scan time since the scanning started until the last participant scanned. With this information a total scan time for each class can be determined. To analyse the individual performance of the participants, the frequency analysis was done as indicated in section 4.1.9. This was used to determine how individual participants performed each week for each scanning device.

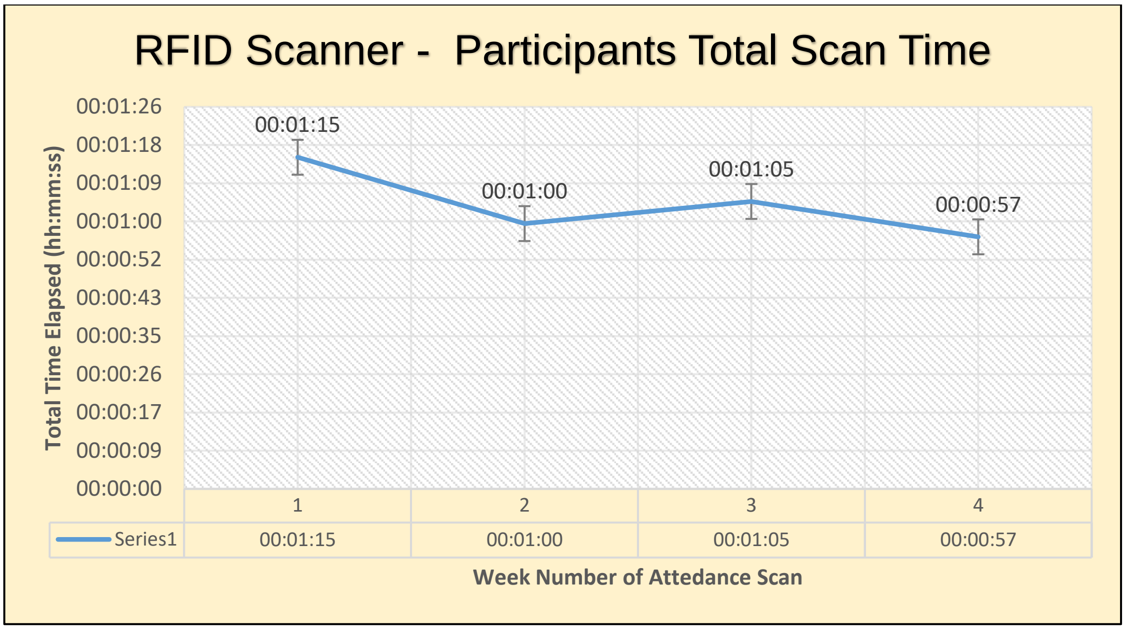


Chart 4.3: RFID Scanner -- Participant's Total scan time per week

From chart 4.3, it is clear that when a comparison is done between the week 1 total scan time and week 4 total scan time it could be concluded as each week progressed the participants became familiar with the technology and with each passing week the scans became more efficient.

One anomaly which could be found in week 3's total scan time, could be explained that one or more participants had a challenge of making a successful scan due to over-confidence by tapping the card too fast and moving on or not tapping their student card on the RFID Scanner itself or other factors.

Chart 4.4 illustrated the total average scan time for the all participants as attendances were scanned with the RFID scanner in each week for the four-week cycle.

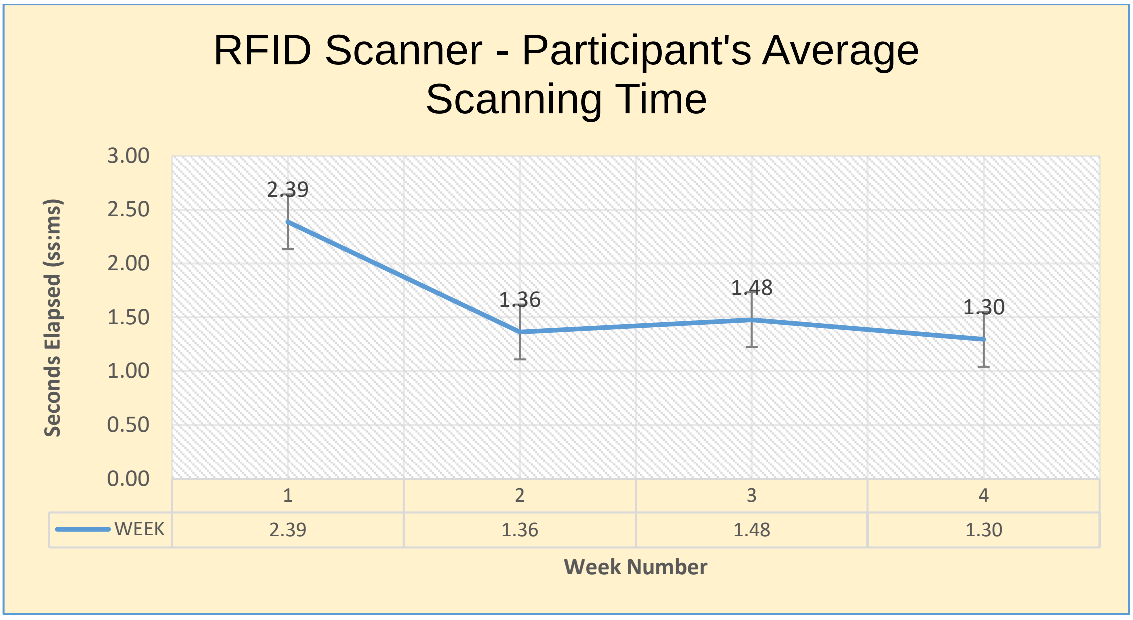


Chart 4.4: RFID Scanner -- Participant's Average scan time per week

When investigating the average scan time of the RFID scanner illustrated in Chart 4.4 above, it can be perceived in most weeks the participants started scanning faster than previous weeks. It could also be determined that the participants adjusted well to the RFID scanning technology and the scanning device could have been a stress-free device to use due to the speed of the scanning device and no special skills are needed to make a successful scan. It can be seen in week 3 that the anomaly of the previous Chart 4.3 also had an effect on the average scan time for week 3. If using an average calculation, it could also have just meant that the last student came in earlier or later than in previous weeks, which would influence the average scan time per student. To resolve this anomaly the standard deviation formula was used in section 4.1.7.

Some personal observation which was noticed in the third-week cycle of data gathering for the RFID Scanner was that some participants became very confident with the RFID Scanner and it was observed that the participants' queue progressed very fast. See ANNEXURE H for all the data captured for the RFID Scanner.

4.1.4. Electronic Input Device (EID) 3 – Fingerprint Scanner - Results

This section illustrates and discusses the data collected in the four-week cycle for the fingerprint scanning device. Chart 4.5 below illustrates the total scan time recorded for each class in the four-week cycle for the Fingerprint Scanner. A total of 44 valid scans were recorded and four different totals were recorded by the custom C# software that was connected to the Fingerprint Scanner. The timer started when the first student started scanning until the last student scanned and the program was signalled that the attendance capture process was completed. This approach indicated the total scan time since the scanning started until the last participant scanned. With this information a total scan time for each class can be determined. To analyse the individual performance of the participants, the frequency analysis was done as indicated in section 4.1.9. This was used to determine how individual participants performed each week for each scanning device.

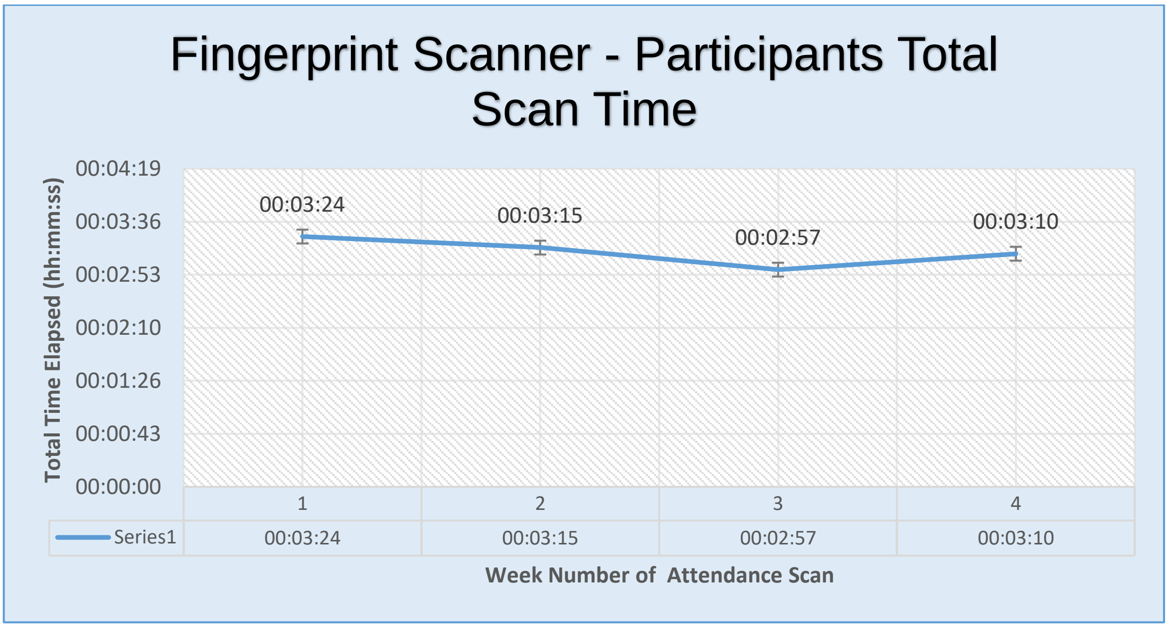


Chart 4.5: Fingerprint Scanner -- Participant's Total scan time per week

From chart 4.5 it was noticed that there were fluctuations between week 3 and week 4's total scan time. It was noticed in week 4's recorded total scan time that there was a higher peak difference in comparison to the previous weeks.

This could possibly indicate that the participants had challenges in week 4 to the fingerprint technology and that there could be different factors causing a higher scanning times in this specific week. When comparing week 1 scan time with week 4 scan time there is a slight difference in comparison with these weeks. If using an average calculation, it could also have just meant that the last student came in earlier or later than in previous weeks, which would influence the average scan time per student. To resolve this anomaly the standard deviation formula was used in section 4.1.7. This could indicate that the scan difficulty remained constant or the challenges also remained the same. The concept of challenges is mentioned because with personal observation, it was noticed that some participants indicated their frustration in scanning their attendance with this scanning device technology.

In most instances, the participant misaligned their finger when scanning their attendance, causing an unsuccessful scan or error scan and the scan attempt had to be redone. Some of the participants indicated their frustration of a slow-moving queue due to participants that needed to rescan their fingerprint to register a successful scan. Chart 4.6 illustrated the total average scan time for the all participants as attendance was scanned with the Fingerprint Scanner in each week for the four-week cycle.

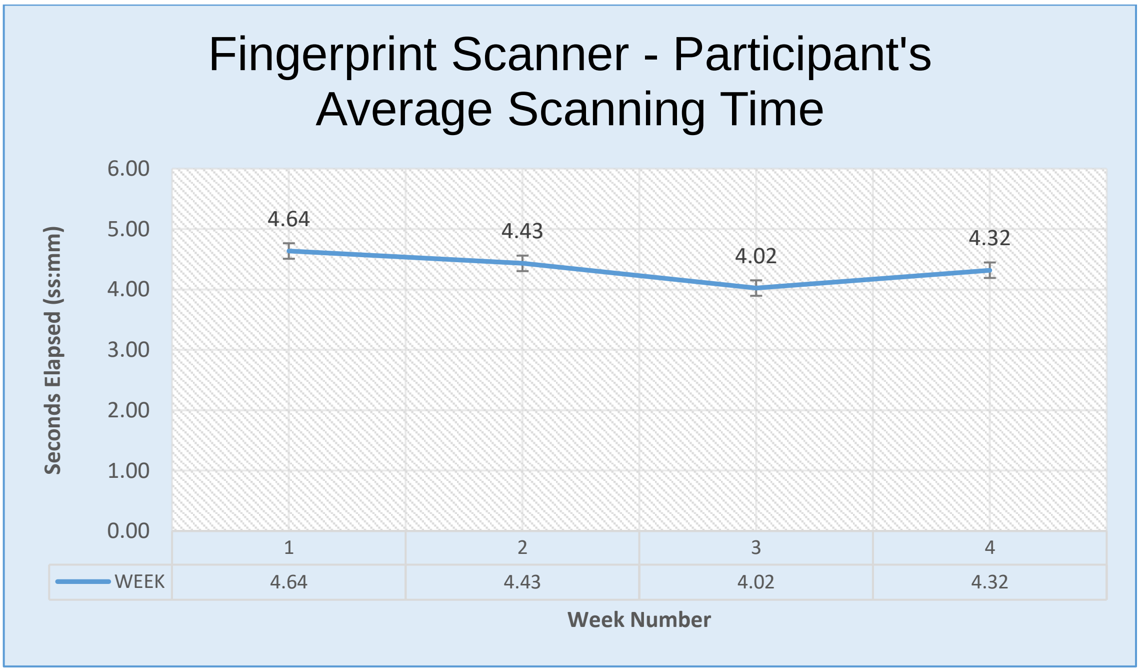


Chart 4.6: Fingerprint Scanner -- Participant's Average scan time per week

When investigating the average scan time of the Fingerprint Scanner illustrated in Chart 4.6 above, it can be seen that the average scan time fluctuated in the final and fourth week. It could be concluded that the participants had challenges scanning with the fingerprint Scanner technology and that there could be many factors at work resulting in these fluctuations, as in the case of the total scan time for each week that was mentioned. Some personal observation was noticeable while participants were scanning their attendance with the Fingerprint Scanner.

As mentioned in the total scan time in Chart 4.5 one observation worth mentioning was the frustration of some participants attempting to align their finger correctly to achieve a successful scan of their attendance. This can be concluded for the average time also. Another observation that was noticeable was participants standing in the queue that started to get restless as the waiting time was longer to get a chance to scan their fingerprint than in the other EIDs in this study. See ANNEXURE I for all the data captured for the Fingerprint Scanner.

4.1.5. The Three EIDs In Comparison

The following section illustrates and discusses comparisons between the three EIDs used in this research study. The main finding to be discussed will be to compare each device's total scan times recorded for each week. The same will be done for the recorded total average scan times for the participants in each scanning device.

Chart 4.7 below illustrates a comparison between the three EIDs' Total scanning time for each week's scheduled class of attendance that was recorded in seconds. With this comparison graph the total scan time differences for each scanning device are indicated.

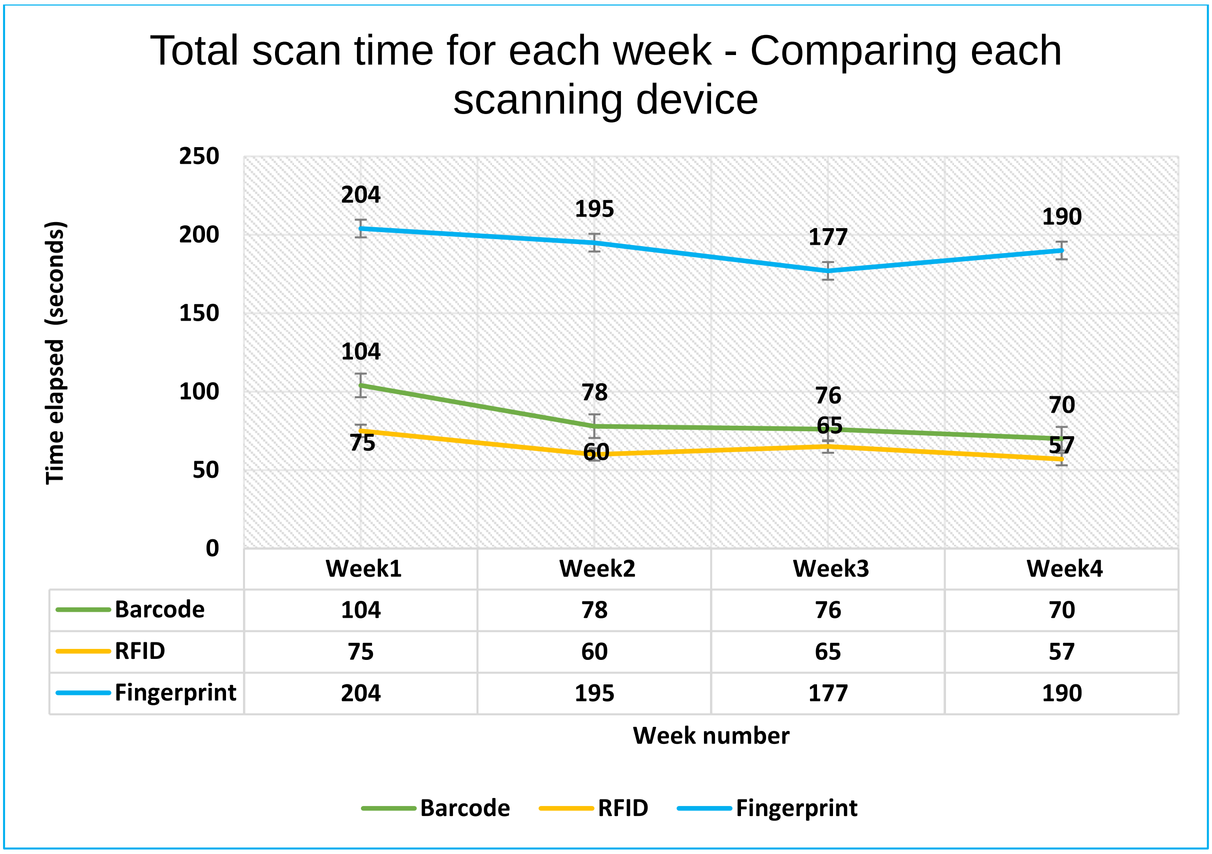


Chart 4.7: Comparison between the three EIDs' Total Scan Time each week

With the total scan times indicated in Chart 4.7, it can be concluded that the RFID Scanner was the most efficient device to scan with, then as indicated the scanning device Fingerprint Scanner was the least efficient scanning device. It can be concluded that the RFID Scanner functioned as a tap on device scanning method which takes little time to register an attendance for this device which was the fastest to scan with.

The Barcode Scanner only needed to be aligned correctly with the card or object with the barcode printed on it to make a successful scan which was the only challenge for this scanning device. With the Fingerprint Scanner, the user, or in this case the participant, needed to correctly align their finger to make a successful scan. Another factor worth mentioning was the security component which validated an encrypted image of the enrolled fingerprint, making a comparison for a successful scan to register.

4.1.6. Correlation Coefficient Results of The Data Recorded

In this section, the formula of Equation One which was discussed in Chapter 3 under section 3.2.3.1 Correlation Coefficient were applied to the total scan time of each week for every EID as laid out in Table 4.3 below. The data shown in Table 4.3 below indicates the total scan times for every week recorded by the EIDs which were connected to the custom C# software and custom Microsoft Access Database. Each scanning device total scan time was recorded in four contact sessions, thus four weeks for each device.

When making use of correlation the results would indicate how close or not the EID's is to one another. Good correlation would indicate that reasons for choosing a specific EID should come from other aspects, but poor correlation would indicate that the EID should be eliminated, poor scan times, or included in the final decision, for good scan times. Thus, depending on performance poor correlation would indicate a stand out device that's either an over or under achiever.

Table 4.3: Total Scan Times for each device per week by participants.

WEEK	BARCODE SCANNER	RFID SCANNER	FINGERPRINT SCANNER
1	01:44	01:15	03:24
2	01:18	01:00	03:15
3	01:16	01:05	02:57
4	01:10	00:57	03:10

With the data in Table 4.3 the formula of Correlation Coefficient Matrix (correlation coefficient more than two variables – MS Excel Correlation Excel data analysis) calculations could be performed. It must be noted that the format of the data in Table 4.3 is populated as minutes:seconds (mm:ss).

Table 4.4 below indicates the results of calculating the correlation coefficient on the weekly Total Scan Times of the three EIDs. The colour coding in this table below has been used where blue is the most related, orange the second most related and red the least related. The value closest to positive 1 is the most related, as discussed in the literature.

Table 4.4: Correlation Coefficient Results on the three EIDs -- Total Scan Time per week

	Barcode Scanner	RFID Scanner	Fingerprint scanner
Barcode Scanner	*1*		
RFID Scanner	**0.942875858**	*1*	
Fingerprint Scanner	**0.719058362**	**0.447997007**	*1*

With the calculations completed in Table 4.4 above, conclusions could be drawn that the correlation between the Barcode Scanner and the RFID Scanner is the most positively (closest to +1) correlated with the value of 0.942. This could indicate that these two devices, according to the correlation answer, could be the most related and the time data recorded had a good correlation to one another. The Fingerprint Scanner had a poor correlation and would indicate the device is the under achiever against the other devices and could be eliminated as a recommended EID.

The positive correlation indicates when one variable decreases in the set of data as the other variable also decreases in the other set of data that is correlated, or one variable increase while the other increases. In this case the variables in the two devices decrease most positively each week.

The Barcode Scanner and Fingerprint Scanner are less related. with a correlation value of 0.719. and these two scanning devices are the second most related pair of devices. With this correlation answer it could indicate that these two devices time-recorded per week correlated less than the previous pair of devices. This is still a positive correlation, but as the answers (results) indicated, these two devices come second in relation to the others.

The Fingerprint Scanner and the RFID Scanner are the least related pair when comparing the first and second pair of scanning devices and have a correlation value of 0.447, the least related in comparison. This is illustrated in scatter chart 4.8 below. The values in Table 4.4 that is displayed as a value 1 indicates that the device is related to itself. These values of 1 can be ignored. It can be concluded that the Fingerprint Scanner had a low performance, which only correlated 44.7% (0.447) and as can be seen in the data used to calculate the correlation the scan times for the Fingerprint Scanner was higher than the other scanning devices. It could be concluded that participants experienced challenges when using this scanner.

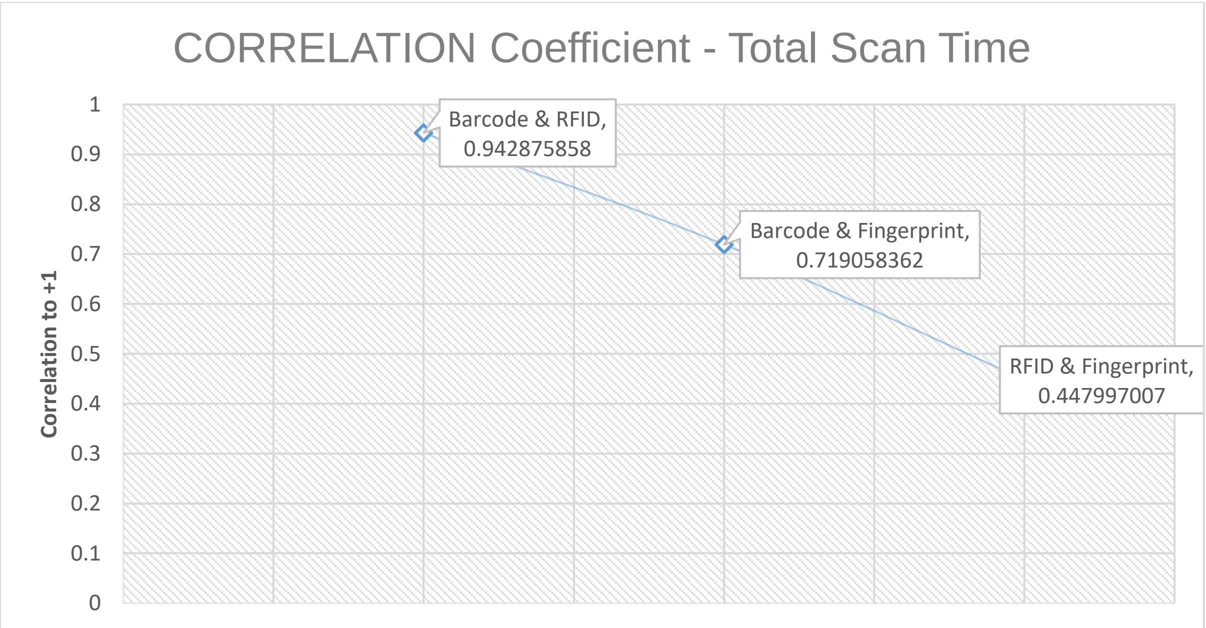


Chart 4.8: Correlation Coefficient -- total scan times of scanning devices

In this case the RFID Scanner was the best performing device with a correlation of 94.3% (0.9423) and with this result this scanner was the device that over achieved above all the other device and could be recommended as the EID to be used.

The data shown in Table 4.5 indicates the average scan times of participants which was calculated for each week attendance that was scanned. This was calculated for each scanning device. This data indicates the average scanning duration it took a participant to scan their attendance for a specific device for a specific week. It must be noted that the format of the data in Table 4.5 is populated as seconds:milliseconds (ss:ms).

Table 4.5: Average Scan Times for each device per week by participants.

WEEK	BARCODE SCANNER	RFID SCANNER	FINGERPRINT SCANNER
1	2.36	2.30	4.49
2	1.77	1.37	4.38
3	1.73	1.44	3.89
4	1.82	1.31	4.30

With the average scan times data in Table 4.5 above, the formula of Correlation Coefficient Matrix (correlation coefficient more than two variables – MS Excel Correlation Excel data analysis) calculations could be performed. Table 4.6 below indicates the results of calculating the correlation coefficient on the average Scan Time of the participant on the three EIDs.

The colour coding in this table below has been used where blue is the most related, orange the second most related and red the least related. The value closest to positive 1 is the most related, as discussed in the literature.

Table 4.6: Correlation Coefficient Results on the three EID's -- Average Scan Time per week

	BARCODE Scanner	RFID Scanner	Fingerprint Scanner
BARCODE Scanner	*1*		
RFID Scanner	**0.970947958**	*1*	
Fingerprint Scanner	**0.648767548**	**0.493777348**	*1*

With the correlation calculations completed in Table 4.6 above by using the participants' average scanning times for each device, conclusions could be drawn that the correlation between the Barcode Scanner and the RFID Scanner is again the most positively (closest to +1) correlated with the value of 0.9709 (97.1%). This would indicate that the RFID Scanner was the device that had a good correlation and could be the device to recommend when choosing a EID to be used. This scanner was the over achiever above the other scanners.

The barcode scanner and fingerprint Scanner are less related with a correlation value of 0.6487, and these two scanning devices are once again the second most related pair of devices. With this correlation answer it could indicate that with these two devices participants' average time recorded per week correlated less than the previous pair of devices. Again, these two devices come second in relation.

The Fingerprint Scanner and the RFID Scanner are the least related pair when comparing the first and second pair of scanning devices and have a correlation value of 0.4937 (49.4%); this value is the least related in comparison and had a poor correlation. This would indicate this device was the under achiever against the other two scanners and could be eliminated as a recommended EID. This is illustrated in scatter chart 4.9 below. The values in Table 4.6 that is displayed as a value 1 indicates that the device is related to itself. These values of 1 can be ignored.

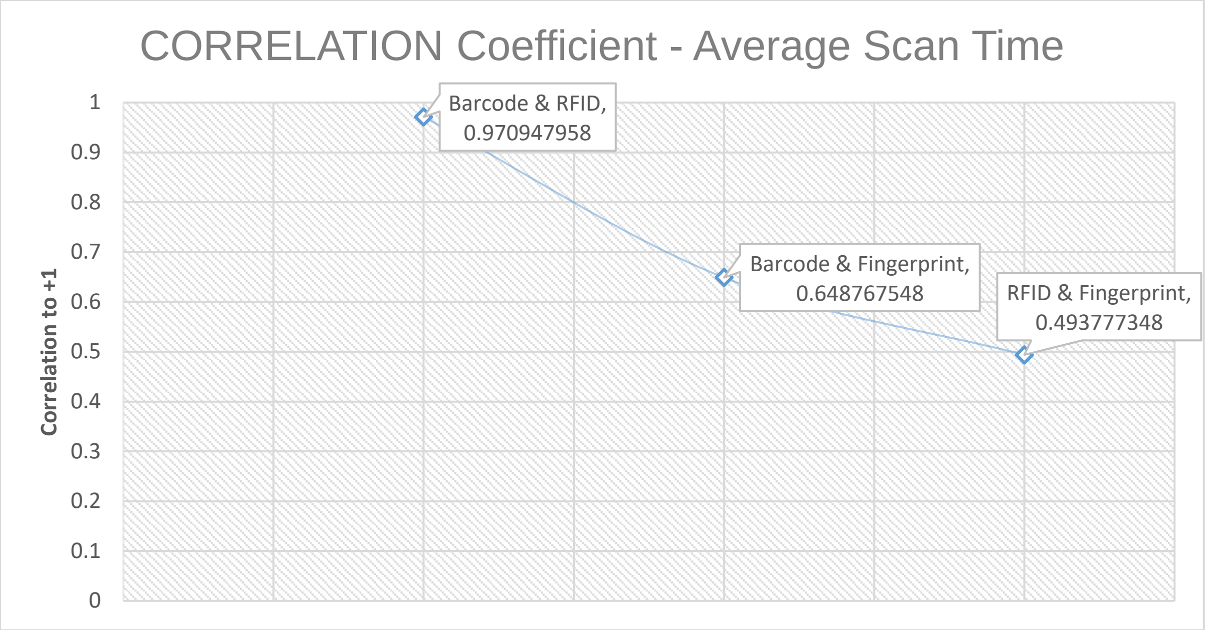


Chart 4.9: Correlation Coefficient -- average scan times of scanning devices

With the correlation completed between total scanning times and the average scan times of the participants, the results above indicate in both sets of data (total scan times and average scan times) that the Barcode Scanner and the RFID Scanner are the most related, where the Barcode Scanner; the Fingerprint Scanner are the second most related. and the RFID Scanner and the Fingerprint Scanner are the least related.

All scanning devices was positively related, but with the correlation answers above, it could be concluded which pair of the scanning devices were the most related, where the scanning time for each week and scan times of each device closest to another device decreased in the same proportion were closely related and had the highest correlation.

When analysing the data presented in Table 4.3 and Table 4.5, it can be seen that each week's scan times differs. This is due to incorrect alignment of the finger of the participant or the fingerprint scanner became dirty. Another point to note is that the Fingerprint Scanner had high scan times.

4.1.7. Standard Deviation - Results of EIDs Data Captured

The following section discusses the findings when performing the calculations of standard deviation on the four weeks total scan time data sets for each scanning device. By making use of the Equation Two (2), discussed in chapter 3 under section 3.2.3.2, the formula for Standard Deviation can be calculated for each set of the four totals or the Standard Deviation function in MS Excel can be used.

With this information, the results could either indicate if there were a high deviation between each week's scan times for each scanning device or a low deviation. A higher deviation value in a set of data could indicate in this research study that participants either had challenges with the scanning technology or there were other factors. A low deviation value in a set of data in this research study could indicate that the participants adjusted well to the scanning technology.

This will be done for each scanning device. Once again, as mentioned in the literature, to convert the standard deviation answer to percentage, the standard deviation answer must be divided by the average of the data that was used to calculate the standard deviation. Table 4.7 indicates the total scan times for each week and where the standard deviation was calculated for each set of the four weeks' total scan times. This was done for each EID and the standard deviation values were converted to percentage.

Table 4.7: Standard Deviation -- EIDs Participants Total Scan Time -- Results

WEEK	BARCODE SCANNER	RFID SCANNER	FINGERPRINT SCANNER
1	104	75	204
2	78	60	195
3	76	65	177

4	70	57	190
Average	**82.00**	**64.25**	**191.50**
Standard Deviation	**15.055**	**7.890**	**11.269**
Deviation Percentage:	**18.36%**	**12.28%**	**5.88%**

In Table 4.7 above it can be seen that there is a low deviation percentage in the Fingerprint Scanner which could indicate that there was a low or slight change in how the participants scanned and that the challenges for the participants could have been the same when using this scanning technology. Even though the scanning times for the Fingerprint Scanner were the highest in comparison to the other scanning devices, the standard deviation was low in comparison to the others.

With the RFID Scanner, the standard deviation percentage is slightly higher which could indicate the participants took longer to adjust to this scanning technology as the different total scan times slightly fluctuated. With the Barcode Scanners standard deviation being the highest of the three EIDs, this could indicate that the participants had the same challenge week after week adjusting to this scanning technology.

This could confirm the visual observations of some participants which had a challenge to align their student card correctly to the laser of the scanner. It must also be kept in mind that the Barcode Scanner was the first device the participants scanned with and needed to understand the setup of the experiment.

Chart 4.10 provides a summary of the standard deviation between the three-scanning devices in this research study.

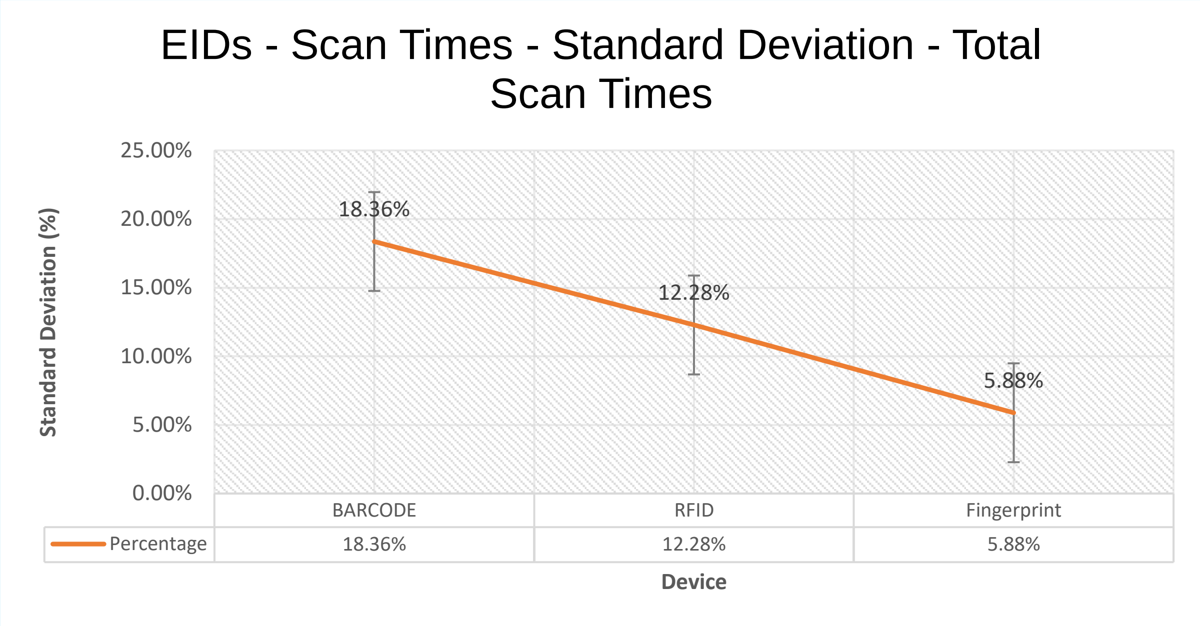


Chart 4.10: Standard Deviation between the three EIDs weekly total scan times -- Results

In Chart 4.10 above it can be seen that if the standard deviation is compared between the three scanning devices, the standard deviation decreases with each device from the Barcode Scanner, to the RFID Scanner to the Fingerprint Scanner. This is a random anomaly as the order in which the devices were used to capture the time data was chosen randomly. It must be kept in mind that in this experiment the order of using the scanning devices was first the Barcode Scanner, then the RFID Scanner and lastly the Fingerprint Scanner.

However, with this information of Chart 4.10 above in this order it can be seen that the Standard Deviation decreased for the scanning devices in this order. It could be concluded that as the participants were introduced to the next scanning device, the deviation went down and could mean that the participants used their experience of the previous device to scan with the next device.

Table 4.8 below indicates the average scan times for each week of the participants and where the standard deviation was calculated for each set of the four-weeks' average scan time for all participants. This was done for each EID and the standard deviation for each EID was converted to a percentage.

Table 4.8: Standard Deviation -- EIDs Participants Average Scan Time -- Device Comparison

WEEK	BARCODE SCANNER	RFID SCANNER	FINGERPRINT SCANNER
1	2.36	2.30	4.49
2	1.77	1.37	4.38
3	1.73	1.44	3.89
4	1.82	1.31	4.30
Average	**1.92**	**1.61**	**4.27**
Standard Deviation	**0.298**	**0.466**	**0.262**
Percentage:	**15.49%**	**29.06%**	**6.14%**

As indicated in Table 4.8 above, the average scan time's standard deviation percentage results for the RFID Scanner were higher than the Barcode Scanner or the fingerprint scanner. This was not the case also with the total scan times in Table 4.7, where the Barcode Scanner had the highest standard deviation percentage when making use of the total scan times. But when making use of the average scan times, the standard deviation answer indicates the RFID has the highest deviation.

It could be concluded that one or more participants specifically scanned possibly relatively fast on one occasion and possibly slower in another attendance session for the RFID Scanner. This will have a drastic effect on the average scanning times in each week for the specific scanning device.

This could explain the anomaly where when making use of average scan times to calculate the standard deviation percentage that does not have the same result as when making use of the total scanning times. Chart 4.11 provides a summary of the average percentage standard deviation indicated in Table 4.8 between the three scanning devices in this research study.

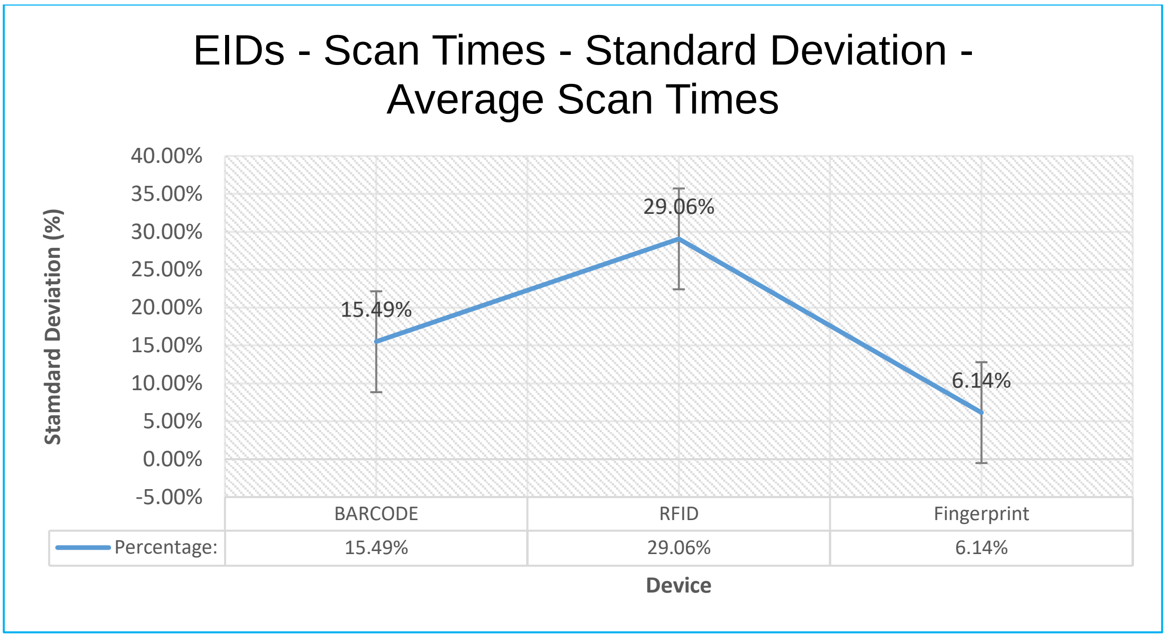


Chart 4.11: Standard Deviation between the three EIDs' weekly average scan times

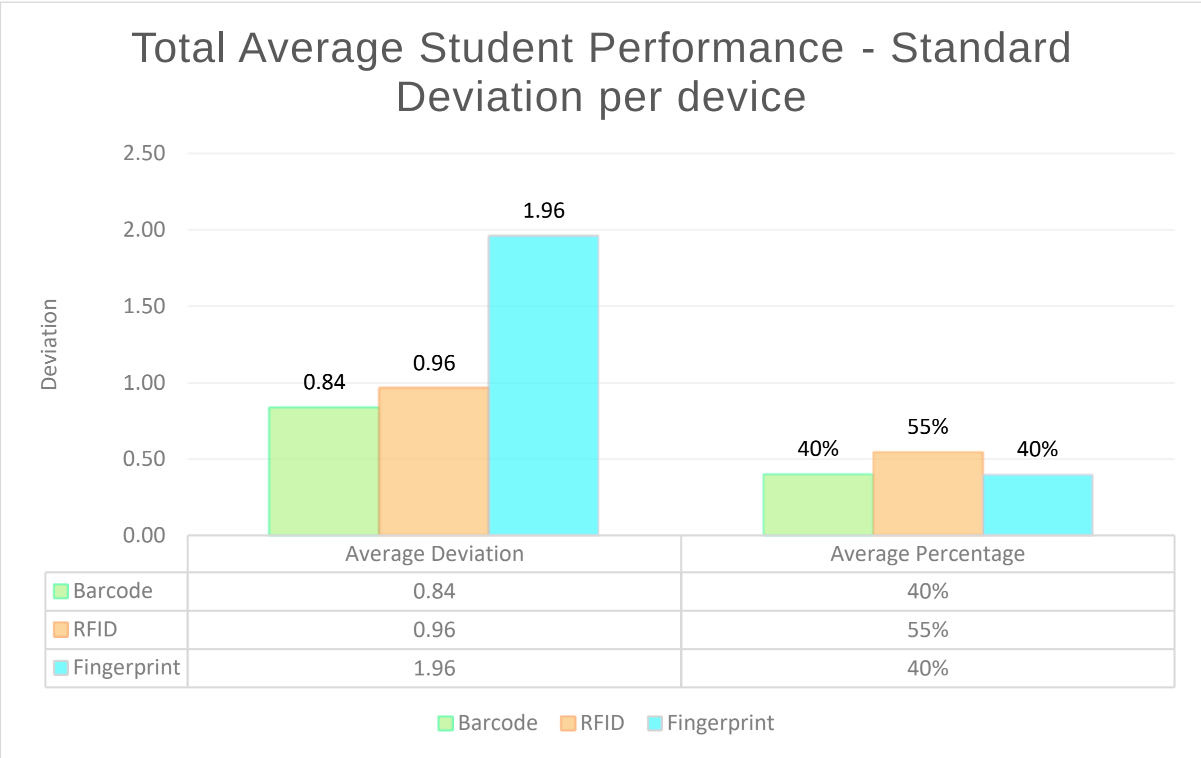
As discussed earlier in Table 4.8, it can be seen in Chart 4.11 that the RFID Scanner had a high standard deviation against the other scanning devices. This standard deviation was calculated from the average total scanning from all research participants for all the cycles in each scanning device.

It can be concluded that one or more participant had a challenge using this technology or even the topic of abuse can be mentioned. With personal observation when data was gathered for this scanning device, it was seen that some participants become playful in the queue and were running past the RFID Scanner making accidental missed- scans. They needed to return only to make a successful scan. It can also be concluded that one of the effects of this easy scanning device, caused over-confidence in the participants.

4.1.8. Standard Deviation – Student Performance of EIDS In Scan Cycles

As the research participants scanned their attendance in the four weeks of data capturing for each EID, the standard deviation could be calculated to investigate the participants' scan time performance for each device. With the participants' recorded scan times of each week, the average scan time for each week could be calculated and the standard deviation for each scanning device could be calculated. With this standard deviation calculation, conclusions could be drawn to see how the participants' scan time performance changed for each scanning device.

With this calculated information, it could be concluded how participants performed on each scanning device in this research study with the custom C# software. Chart 4.12 below illustrates the total average standard deviation for all participants for each scanning device. The standard deviation values have also been converted to percentage and been presented in Chart 4.12 below.



	Average Deviation	Average Percentage
Barcode	0.84	40%
RFID	0.96	55%
Fingerprint	1.96	40%

Chart 4.12: Standard Deviation -- Student Average Performance per Scanning Device

With the standard deviation results presented in Chart 4.12 it could be concluded that the RFID Scanner's participant's deviation percentage (average standard deviation for all participants) was higher than the other two devices. This could indicate that not all the participants' recorded scanning times were consistent each week. Thus, some participants scanned relatively consistently and others scanned longer or shorter times over the four weeks, which means that these participants' data points are spread out over a wider range of values.

Although the RFID Scanner device was the fastest scanning device of the three devices, according to results earlier discussed in this chapter, inspecting the results of the RFID Scanner's standard deviation percentage in Chart 4.12, a high deviation percentage is indicated which could indicate that one or more participants had abnormal scanning times. This could be due to a faulty RFID chip or the participant did not scan relatively fast. This can be seen in the scanning data for a participant who scanned 26 seconds for the first week's data. See ANNEXURE J to L for standard deviation for each participant.

4.1.9. Frequency Analysis

Quantitative time data that was recorded in section 4.1 and making use of the data in Annexure J to L for each participant. the frequency analysis can be calculated. As mentioned in the literature chapter 2, the Microsoft Excel function method would be used to calculate the frequency analysis. This frequency analysis could graphically indicate the performance of the participants' interaction with the three identified scanning devices per week. With these calculations and visual presentation conclusions from the participants' recorded times can be drawn. Tables 4.9 to 4.14 caters for up to 34 seconds of data, as the maximum scan time in one of the devices was 34 seconds.

Table 4.9 indicates the frequency analysis results of the scanning times recorded for each participant with the Barcode Scanner by using the method described earlier. Most of the participants' scan times have fallen in the range of 1 to 5 seconds. In week 1 there were 15 participants who scanned 1 second and in the subsequent weeks t the number of students became 19. In this table mentioned, one can either investigate how many participants scanned 1 second for each week or a specific week and how many participants scanned for a specific time.

Table 4.9: Barcode Scanner Frequency Analysis -- in numbers

Barcode Scanner Frequency Analysis:				
Seconds	**Week 1**	**Week 2**	**Week 3**	**Week 4**
1	15	19	19	19
2	15	16	17	23
3	5	5	7	1
4	5	2	0	0
5	1	1	0	0
6	0	1	1	0
7	1	0	0	1
8	1	0	0	0
9	1	0	0	0

With the results of the frequency analysis in Table 4.9 above, it is now possible to graphically present this data as indicated below in chart 4.13

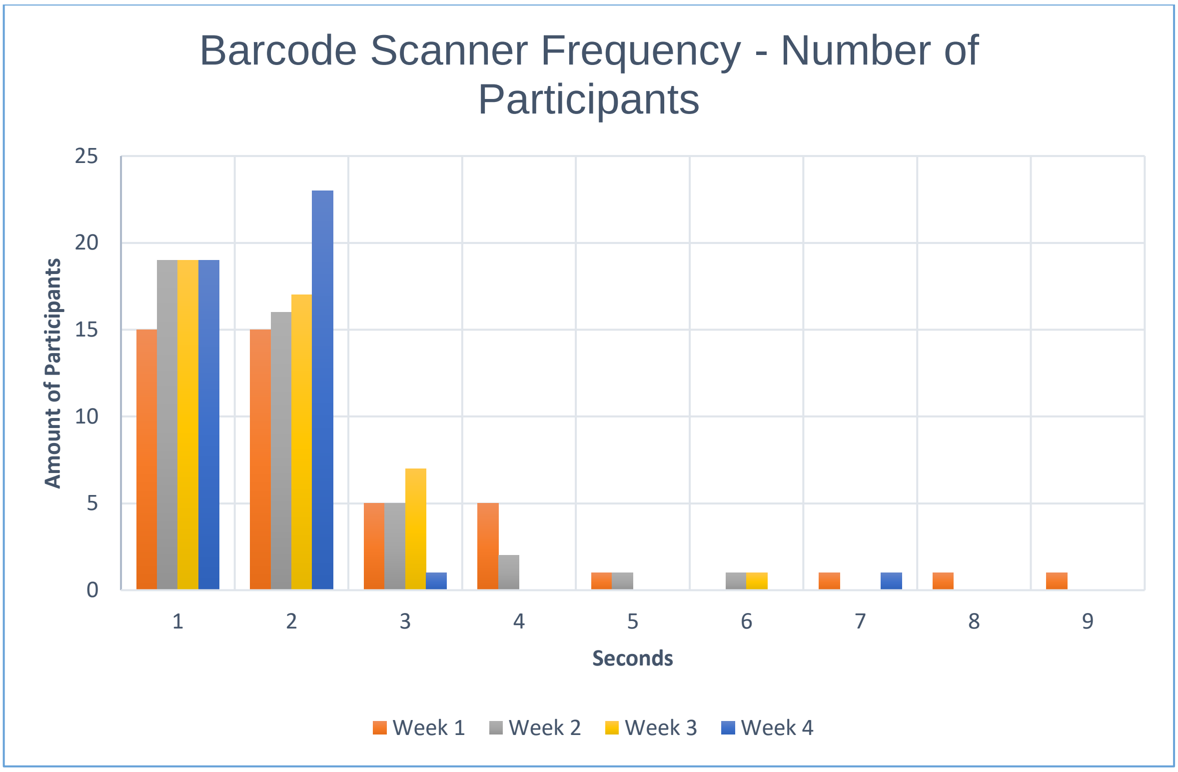


Chart 4.13: Barcode Scanner Frequency Analysis -- in numbers

It can be seen that the majority of recorded scan times fall in the range of 1 to 5 seconds. This could indicate that the scanning times are relatively fast, where the participants with longer scanning times (6 to 9 seconds) were mostly in the first week and improved their scanning times within weeks 2 to 4.

This might indicate that the participants started to understand the scanning technology better after the first week and in the weeks that followed it can be seen how the scan times improved.

The data presented in Table 4.9 and Chart 4.13 above can be converted to percentages and could indicate a clearer picture of the performance for each week versus the time that elapsed in seconds. This can be seen in Table 4.10 below, where the number of participants has been converted to percentages.

Table 4.10: Barcode Scanner Frequency Analysis -- as percentage

Barcode Scanner Frequency:				
Seconds	**Week 1**	**Week 2**	**Week 3**	**Week 4**
1	34%	43%	43%	43%
2	34%	36.5%	39%	52.5%
3	11.5%	11.5%	16%	2.25%
4	11.5%	4.50%	0%	0%
5	2.25%	2.25%	0%	0%
6	0%	2.25%	2%	0%
7	2.25%	0%	0%	2.25%
8	2.25%	0%	0%	0%
9	2.25%	0%	0%	0%

With the frequency analysis data converted to percentages as indicated in Table 4.10 above, Chart 4.14 below can be created from these percentages. In week 1, 68% scanned in 2 seconds. It can be seen as each week progresses, that the scanning times are improving overall. In week 4 95% scanned in less than 2 second.

There are only two students that took more than 2 seconds to scan. This is a clear indication that the device is user-friendly and easy to learn. In week 4 there was 1 student that took 7 seconds. This can actually be seen as a discrepancy.

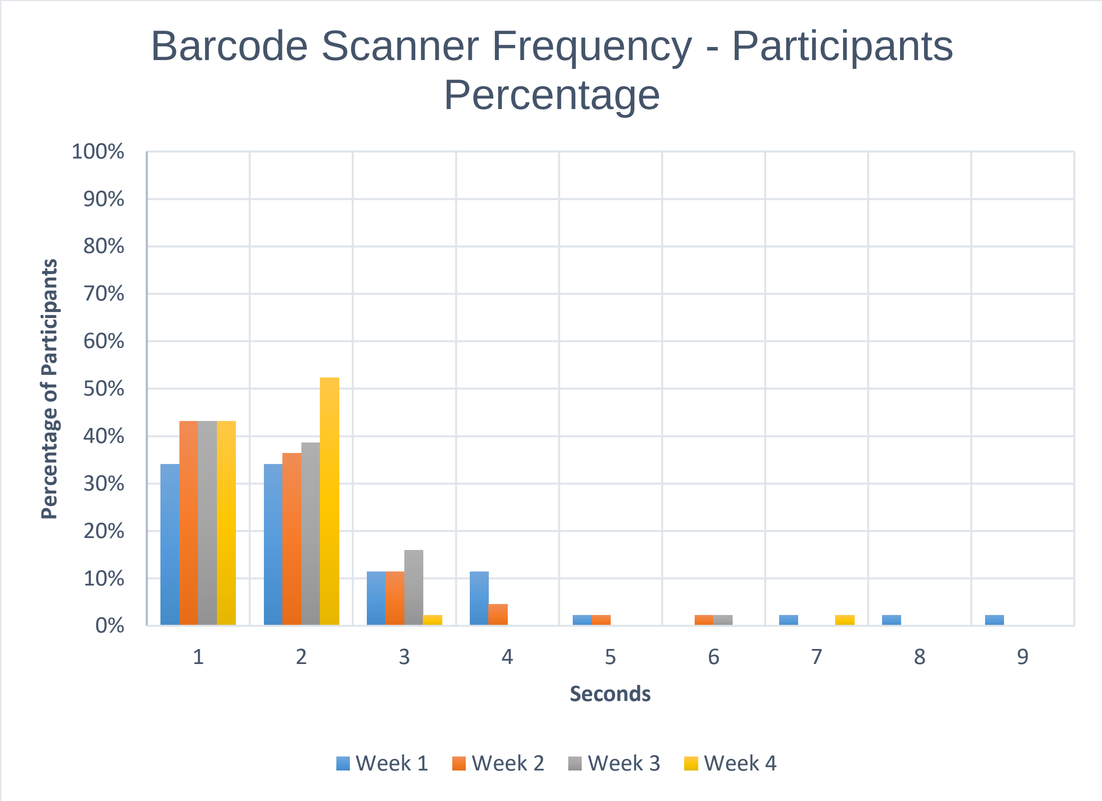


Chart 4.14: Barcode Scanner Frequency Analysis -- as percentage

Table 4.11 below indicates the frequency analysis results of the scanning times recorded for each participant with the RFID Scanner by using the frequency analysis method as described.

Table 4.11: RFID Scanner Frequency Analysis -- in numbers

RFID Frequency Analysis:				
Seconds	**Week 1**	**Week 2**	**Week 3**	**Week 4**
1	20	31	24	27
2	13	8	16	14
3	6	2	3	2
4	2	2	1	1
5	1	1	0	0
6	1	0	0	0
26	1	0	0	0

Most of the participant's scan times have fallen in the range of 1 to 6 seconds and in week 1 there were 20 students who scanned in 1 second by using the RFID Scanner. As the subsequent weeks followed the number of students became 31 in week 2, and so on. In the table above, one can either investigate how many participants scanned 1 second for each week or a specific week and how many participants scanned for a specific time. Most of the participants scanned in the first 2 seconds for each week, which could indicate a fast scanning technology.

With this frequency analysis, results indicated in Table 4.11 above, a graphical representation of these results can be illustrated. This can be seen in Chart 4.15 below, where the chart indicates from week 2 more than 50% of the participants scanned in less than 1 second. It could be concluded that this specific scanning device could be easy to use scanning device and that with each week that passed, there where improvements in less time to scan.

It could also be seen in Table 4.11 and Chart 4.15, there was one participant whose scan time was 26 seconds for the first week. It can be concluded that the participant was unsure how to scan with this scanning device and needed assistance. One possible conclusion could be that the participant compared the RFID scanning device with the Barcode Scanner and approached the RFID Scanner technology wrongly.

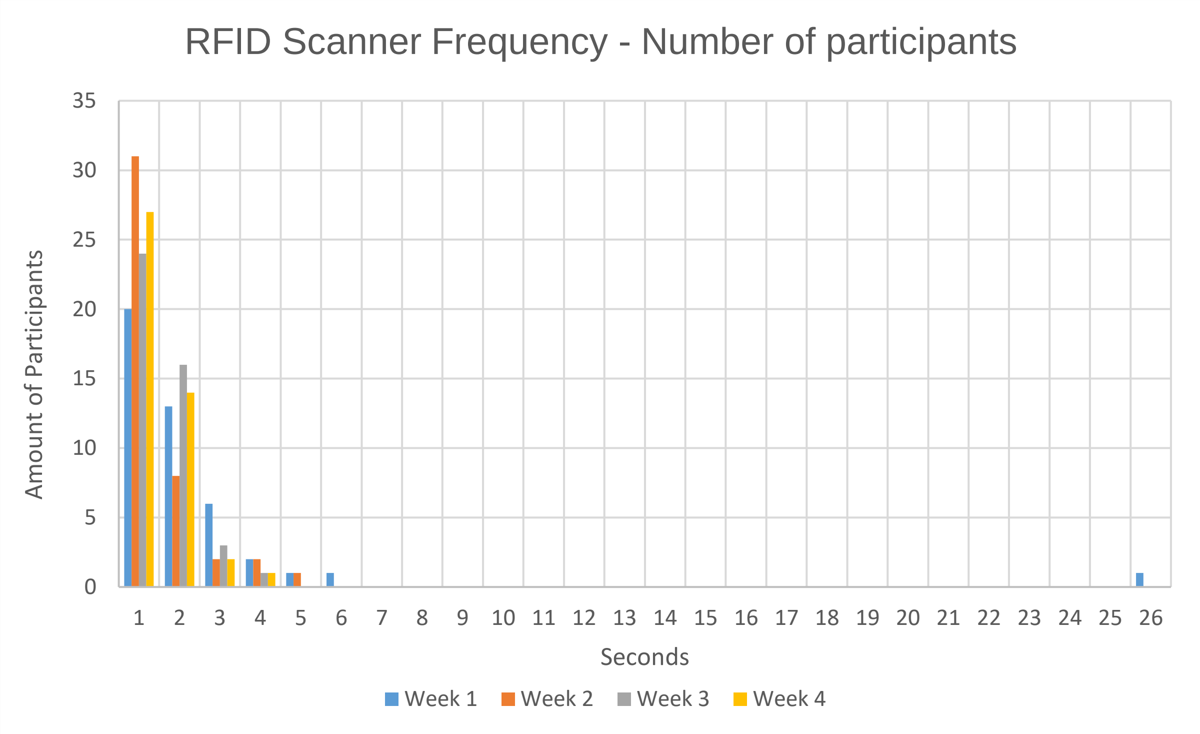


Chart 4.15: RFID Scanner Frequency Analysis -- in numbers

If the data presented in Table 4.11 and Chart 4.15 above is converted to percentages, another presentation can be made: this data as percentages could sketch a clear picture of the performance for each week versus the time that elapsed in seconds. This can be seen in Table 4.12 below.

Table 4.12: RFID Scanner Frequency Analysis -- as percentage

RFID Frequency Analysis:				
Seconds	**Week 1**	**Week 2**	**Week 3**	**Week 4**
1	45%	70%	55%	61%
2	30%	18%	36%	32%
3	14%	5%	7%	5%
4	5.%	5%	2%	2%
5	2%	2.%	0%	0%
6	2%	0%	0%	0%
26	2%	0%	0%	0%

With the frequency analysis data converted to percentage as indicated in Table 4.12 above, the chart 4.16 could be created. It can be seen in this chart that more than 90% of the participants scanned in the first 2 seconds from the second week. As each week progresses the scanning times improves overall. There is, however, a small number of discrepancies where some participants scanned fast one week and then slowly in one week.

There was one participant that scanned 26 seconds in the first week, which could be an indication that this participant needed to understand the RFID technology better.

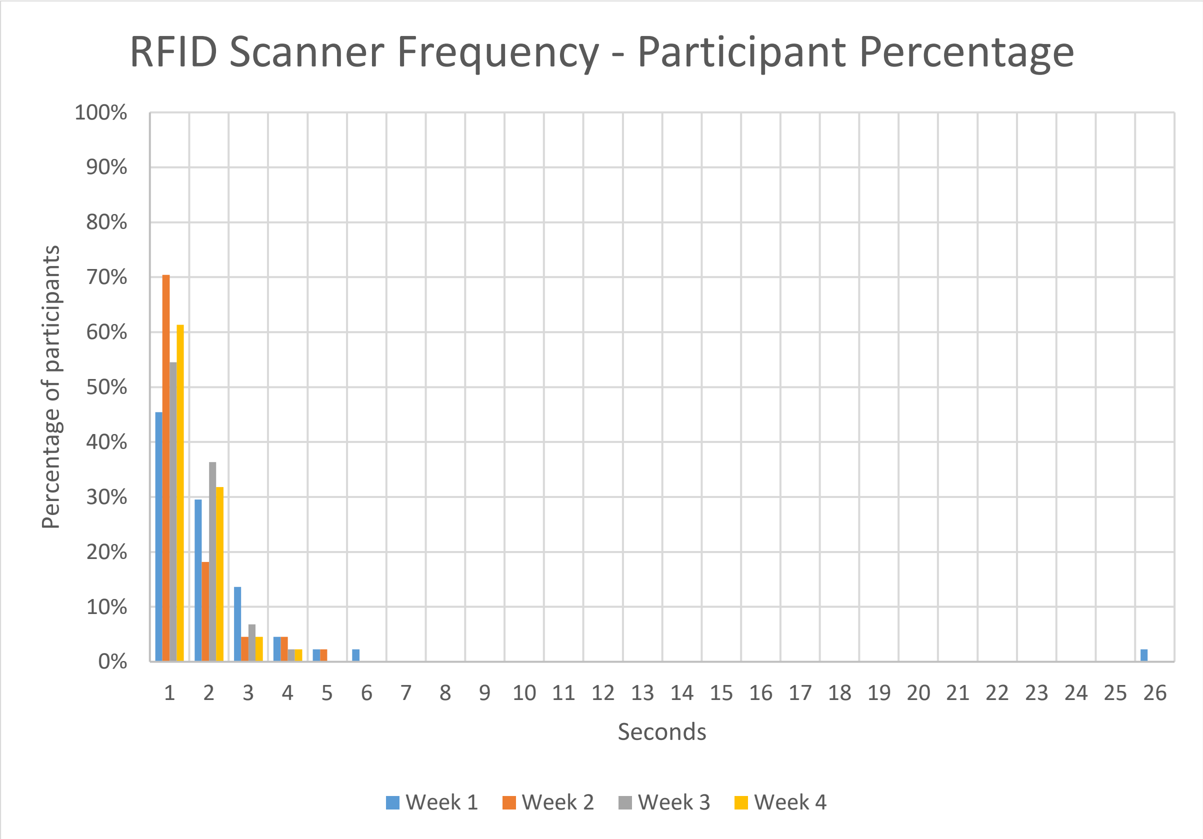


Chart 4.16: RFID Scanner Frequency Analysis -- as percentage

Table 4.13 below indicates the frequency analysis results of the scanning times recorded for each participant with the Fingerprint Scanner by using the frequency analysis method as mentioned earlier.

Table 4.13: Fingerprint Scanner Frequency Analysis -- in numbers

Fingerprint Frequency Analysis:				
Seconds	**Week 1**	**Week 2**	**Week 3**	**Week 4**
1	0	1	2	1
2	11	13	11	10
3	16	12	13	15
4	5	4	7	6
5	4	6	3	3
6	3	2	1	2
7	1	2	2	3
8	1	0	1	1
9	0	0	2	1
10	0	1	0	0
11	0	2	1	0
12	1	0	0	0
15	1	0	1	0
16	0	0	0	1
19	0	0	0	0
20	0	0	0	1
28	0	0	0	0
29	0	1	0	0
34	1	0	0	0

Most of the participants scanned in the 2 to 3 seconds range where some of the other participants scanned between 4 to 7 seconds, as indicated in the table below. The participants that scanned more than 7 seconds are scattered all over the time and week ranges. This could indicate that some participants had challenges to adjust to this Fingerprint Scanner technology. Different challenges could be identified, where misalignments could have occurred when pressing down a finger to scan for a fingerprint scan. It's worth mentioning with the frequency analysis in Table 4.17 below, that the seconds it took to scan were higher than the previous devices and this could indicate how the participants' interaction was with the scanning device.

With this frequency analysis, results indicated in Table 4.13 give a graphical representation of how these results can be illustrated. This can be seen in Chart 4.17 below and visually indicates that most of the scan times of the participants were recorded in the first 2 to 7 seconds. It could also be seen that scan time after 8 seconds is scattered over all the ranges up to 34 seconds. It could be concluded that some participants had challenges with this specific Fingerprint Scanner and had challenges to adapt how this scanner works and to scan successfully.

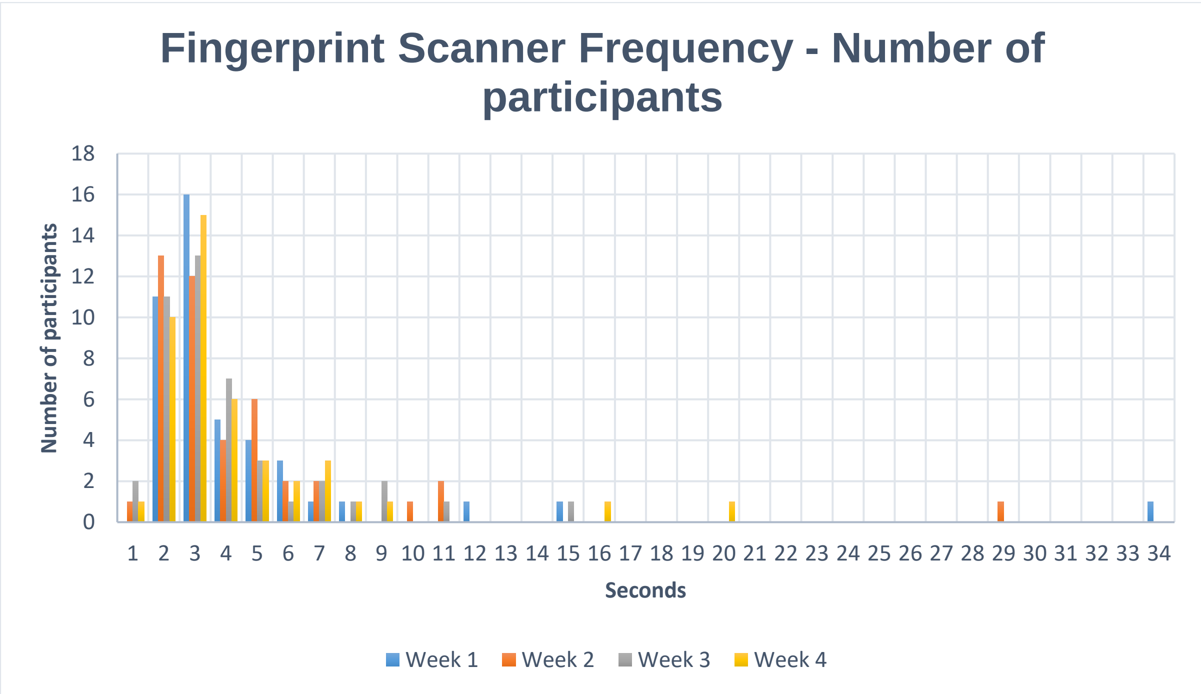


Chart 4.17: Fingerprint Scanner Frequency Analysis -- in numbers

If the data presented in Table 4.13 and chart 4.17 above is converted to percentages, another presentation can be made where the data as percentages could sketch a clear picture of the performance for each week versus the time that elapsed in seconds. This can be seen in Table 4.14 below.

Table 4.14: Fingerprint Scanner Frequency Analysis -- as percentage

Fingerprint Frequency Analysis:				
Seconds	**Week 1**	**Week 2**	**Week 3**	**Week 4**
1	0%	2.25%	4.50%	2%
2	25%	29.50%	25%	23%
3	36.50%	27.25%	29.50%	34%
4	11%	9%	16%	14%
5	9%	14%	7%	7%
6	7%	4.50%	2%	5%
7	2.25%	4.50%	5%	7%
8	2.25%	0%	2%	2%
9	0%	0%	5%	2%
10	0%	2.25%	0%	0%
11	0%	4.50%	2%	0%
12	2.25%	0%	0%	0%
15	2.25%	0%	2%	0%
16	0%	0%	0%	2%
20	0%	0%	0%	2%
29	0%	2.25%	0%	0%
34	2.25%	0%	0%	0%

With the frequency analysis data converted to percentages as indicated in Table 4.14 above, chart 4.18 below could be created. It can be seen in this chart that only during week 3 there were more than one participant that was able to scan in less than 1 second and it was only 2 participants. The scan times were also more scattered than the previous devices scan times. This is clearly an indication that this device is less user friendly. There were participants that scanned in longer intervals with a maximum of 34 seconds for one participant in the first week.

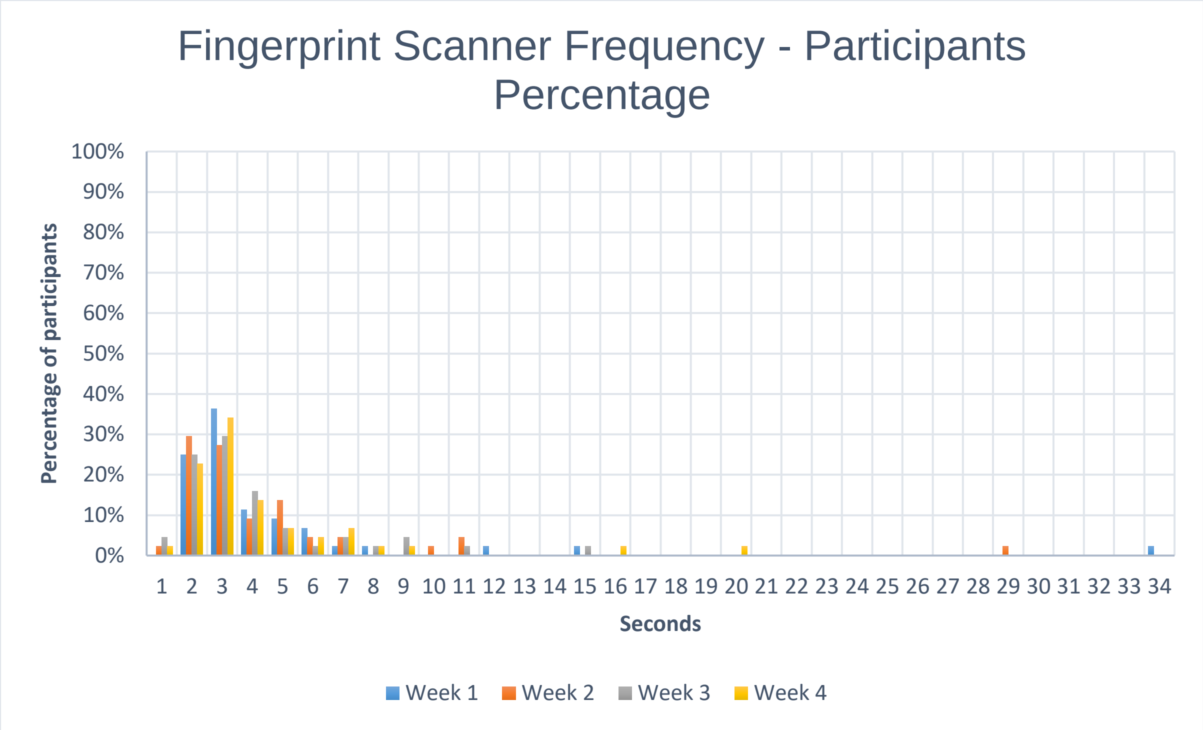


Chart 4.18: RFID Scanner Frequency Analysis -- as percentage

Overall, if the scanning data of Table 4.14 and Chart 4.18 is compared to previous scanning devices, it can be seen how the scanning times differ for each device and week. But in relation to each other, comparisons can be made how close the scanning time is from 1 to 3 seconds for each device. With the implementation of frequency analysis above, the scanning devices can be compared, and the scanning times can be measured against each other to conclude the performance of these devices.

4.1.10. Conclusion of Hardware Quantitative Methods Results

Various tests have been done on the EIDs as mentioned in this research study, making use of custom-written C# software connected to a custom-designed Microsoft Access database considerable time data were collected. The useful time data was separated and analysed; from this time data different types of comparisons have been made. With all this information and calculated information, conclusions could be drawn from the manipulated quantitative method's data.

It could be concluded that if an electronic attendance system were to be implemented and one of the mentioned devices in this research study should be used, some factors need to be considered. If the requirement would be for an efficient device, the RFID Scanner could be recommended as it has been seen in the reported data that this scanner was the fastest performing device. If the requirements were a device that would fall in the category of high security, the Fingerprint Scanner would be recommended as the data indicated in the research data feedback earlier.

4.2. QUALITATIVE RESULTS

An open-ended questionnaire was administered with the aim to identify trends among the student's opinions regarding Electronic Input Devices. The qualitative questionnaire was administered after the four-week scanning cycle of classes for students to determine their perception of EIDs and the traditional method of capturing student class attendance. The questionnaire can be seen in ANNEXURE F.

In this section, the questionnaire results will be illustrated and discussed. Important conclusions have been drawn from these results which indicate the participant's opinion. Summarized feedback from the participants' written feedback will also be provided.

4.2.1. Questionnaire Participants Demographic Profiles

The first question in the questionnaire was the demographic section and was used to determine the different age groups of the participants. Chart 4.19 below illustrates that 27 participants indicated that they were under the age of 20 years old.

Thirty-two participants indicated they were between the age of 20 and 24 years old. Lastly, only one participant indicated that he or she fell in the age category of between 25 and 30. This provided a total of 60 voluntary participants for this research study that completed the questionnaire. Originally there were 63 participants at the time of pre-enrolment when the scanning of attendance was done, but at the time of the questionnaire three (3) of the participants did not participate in answering the questionnaire. Only the participants that was present in all the session of scanning's data was used in section 2.1. It must be noted that the questionnaire was done after the last scanning session where there were 60 participants. But because the questionnaire is anonymity, there was no way to indicate which of the questionnaire's participant were present in every session. As some participant attended for example 10 out of 12 or 7 out of 12 of the sessions.

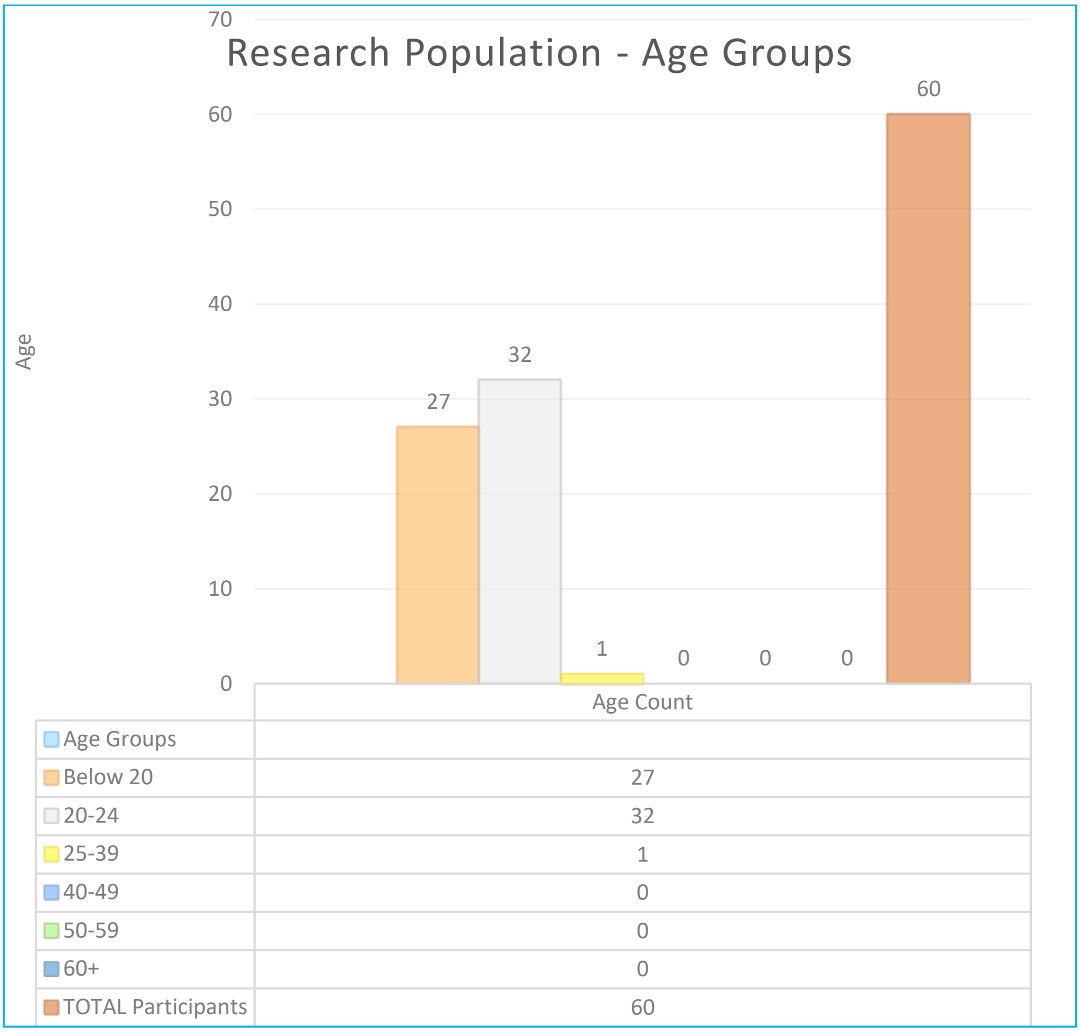


Chart 4.19: Participant's Age Groups

The questionnaire further investigated which year of study the participants currently were enrolled for. This indicated the maturity level of the participants. Chart 4.20 below indicated that the participants were mostly enrolled for the Extended Curriculum Programme (ECP) in Information Technology, while only one participant was enrolled for the Main Stream Information Technology Programme.

There were three students that did not complete the question and not applicable response was recorded.

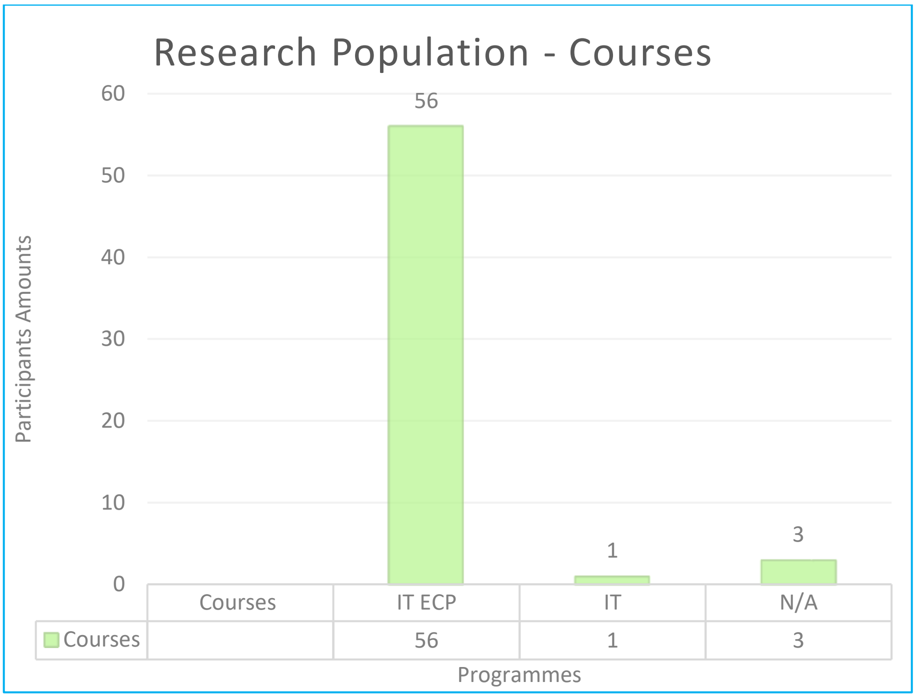


Chart 4.20: Participant's Courses

The last section under the demographics section identified the participants' gender. This data could be used to investigate how different genders react to the different EIDs in the area of electronic attendance systems for further research. Chart 4.21 illustrates that there were more male participants (43), in the study than female participants (17).

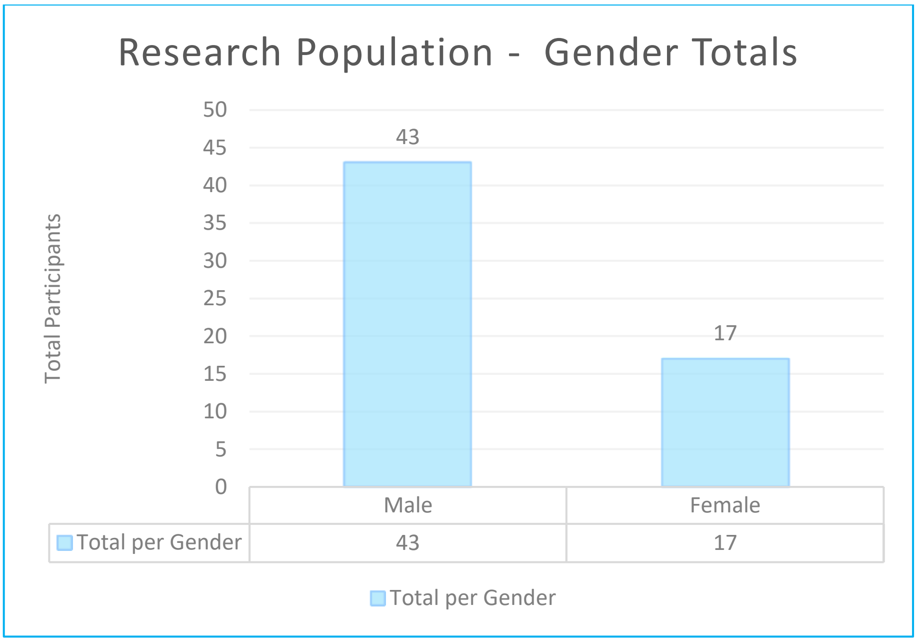


Chart 4.21: Participant's Gender Totals

4.2.2. EIDs' Usability, Security and Efficiency

The following sections were a crucial part of the qualitative questionnaire, where multiple questions were asked regarding the scanning devices with which the participants interacted. The critical data needed from this questionnaire would be find in this section where the participants indicate their experience in the form of usability, security and efficiency of the EID scanning devices. It must be noted that each of the sub-sections below had provided space for optional comments or feedback. These comments were summarized and will be mentioned at the end of each sub-section below.

4.2.2.1. Questionnaire - EIDs' Usability - Results

This sub-section of the questionnaire was developed to record the participants' view on the usability of the electronic input devices that were used in the four-week cycle where each of the mentioned devices were used to scan the class attendance. This part one of three of the critical section of the questionnaire was designed as multiple-choice questions regarding the usability of the EID devices.

Responses of the participants' answers to the usability of the EID devices in the questionnaire were recorded and displayed in Chart 4.22. It can be perceived that the participants reacted mostly positively to the Radio-frequency identification (RFID) scanner, and conclusions can be drawn that this device was the easiest to be used by the participants. There was one participant that did not provide an answer for this question in the questionnaire.

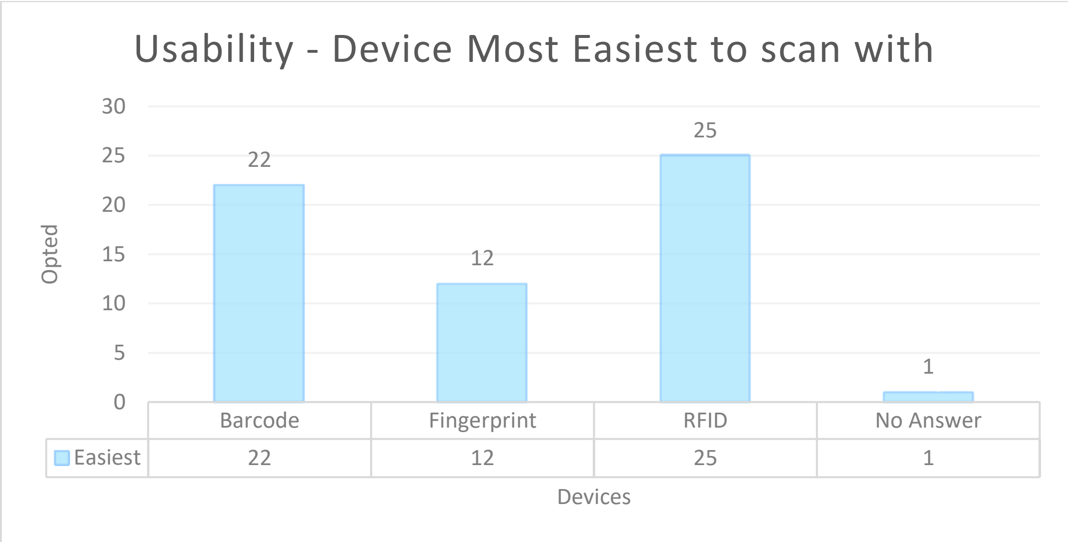


Chart 4.22: EID's Usability -- Most User Friendly -- Results

Participants' Written Feedback (Usability – Most User Friendly): The majority of participants indicated their preference for using a card method (RFIDs and Barcodes) rather than a biometric Fingerprint Scanner method. The participants preferred RFID Scanners above the other scanners. Participants indicated that they only need to hold their student card near the RFID Scanner machine to engage a successful scan, whereas barcodes need to be held at the right angle for the device to successfully scan the barcode. Biometric scanners were least favoured because they were much slower than the card methods.

The next question in this sub-section was which EID scanning device the participants found the most challenging to use. The questionnaire results on this question were recorded and are shown Chart 4.23. The feedback provided indicates the Fingerprint

Scanner as the scanning device that was the most difficult to scan with. It could be concluded that this is a new technology to the participants or the technology is difficult to use. There was one participant who did not provide an answer for this question in the questionnaire.

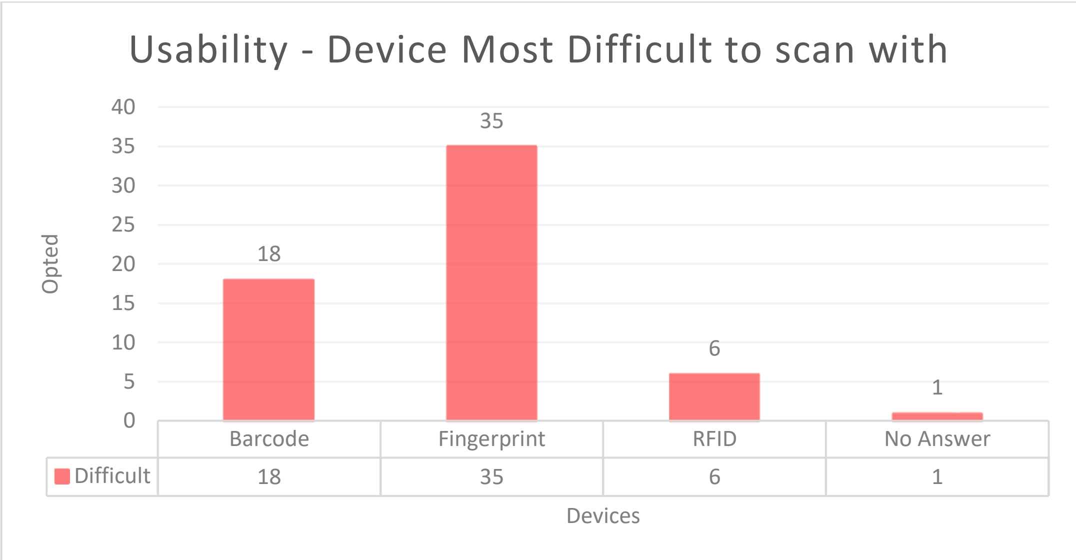


Chart 4.23: EID's Usability -- Least User Friendly -- Results

From the above questionnaire results regarding usability, it could be concluded that the participants would prefer to use the RFID Scanner above the Fingerprint scanner in the sense of usability.

Participants' Written Feedback (Usability – Least User Friendly): Most participants indicated that the Biometric scanner (Fingerprint Scanner) was the most difficult scanning device to scan with. The participants indicated that the Fingerprint Scanner took the most time and noted their concerns that if their fingerprint were damaged in any way, the Fingerprint Scanner would not recognize them. They might have to find other means to prove that they attended the class. This could be disrupting for the current class attendance. Although participants were aware that multiple fingers were enrolled, the concern was still raised.

4.2.2.2. Questionnaire - EIDs' Security - Results

This sub-section of the questionnaire was developed to record the participant's view on the security of the electronic input devices that were used in the four-week cycle where each of the mentioned scanning devices were used to scan the class attendance.

This part two of three in this critical section of the questionnaire was designed as a multiple-choice question regarding the security, usability and efficiency of the EID devices. The results of this part were the most important in the questionnaire, as the participants provided critical feedback regarding their practical experience with the EID devices.

Participants' feedback regarding the security of the EIDs in the questionnaire was recorded and illustrated in Chart 4.24 below. It can be seen that the participants reacted mostly positively to the Fingerprint Scanner. Ironically, keeping in mind the previous answers regarding usability, the same device (Fingerprint Scanner) was found the most difficult device to scan with, and in the next question of the questionnaire, the same device was reported to be most secure.

It can be concluded that, even if the technology is new or difficult to use, the participants' perception of security regarding EIDs depended on the participants realizing that a fingerprint is unique. There was one participant that did not provide feedback in this question in the questionnaire.

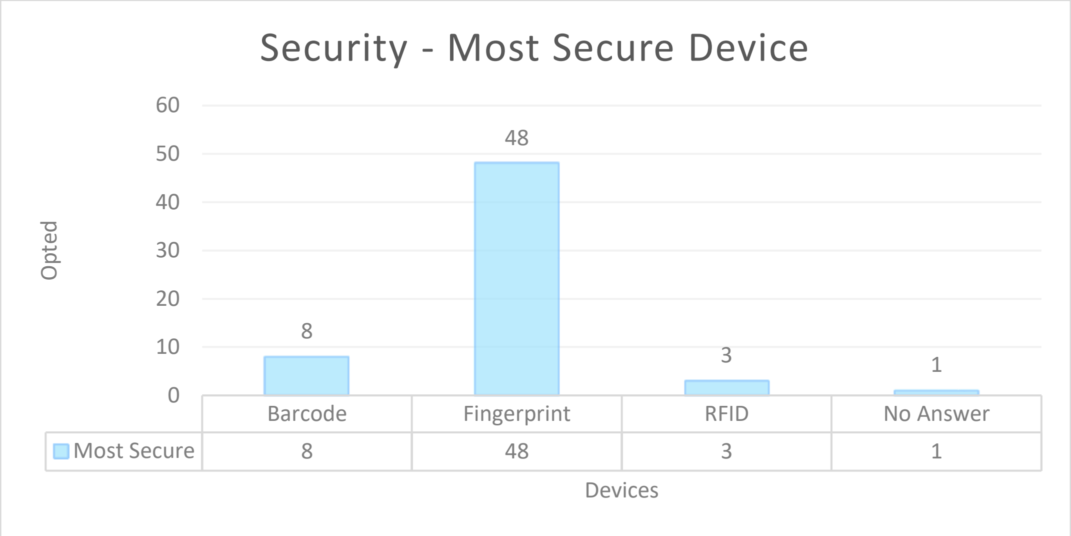


Chart 4.24: EID's Security -- Most Secure Device -- Results

Participants' Written Feedback (Security – Most Secure Device): The participants indicated that the biometric Fingerprint Scanner was the most secure of the three scanning devices used in this research study. The reason provided by participants in their view was that each person's fingerprint is unique and cannot be duplicated or abused. Participants also mentioned that they were aware of fellow students signing attendance for each other in their absence. The overall recommendation was that biometric scanning devices would prevent this "buddy signing/scanning" from occurring.

Most participants also stated that they believed that this method of cheating attendance is morally wrong and should be condemned. Lastly, participants mentioned that in some occurrences, they forgot their student card at their home, and if a card attendance system would be implemented it could negatively impact on them.

The next question in the questionnaire regarding EIDs was which of the scanning devices was the least secure. In chart 4.25 below, the participants indicated that the Barcode Scanner was the least secure scanning device. It could be concluded that a barcode label can easily be copied or remanufactured. The student cards used in the case study all had printed barcodes and participants reported that in some instances some of these cards got lost or stolen.

This could be a possible result of this outcome. There were four participants that provided duplicate answers in this question in the questionnaire. This could indicate that participants did not understand the question in the questionnaire or felt that they had more than one answer for the question. Unfortunately, there could be only one answer for this question.

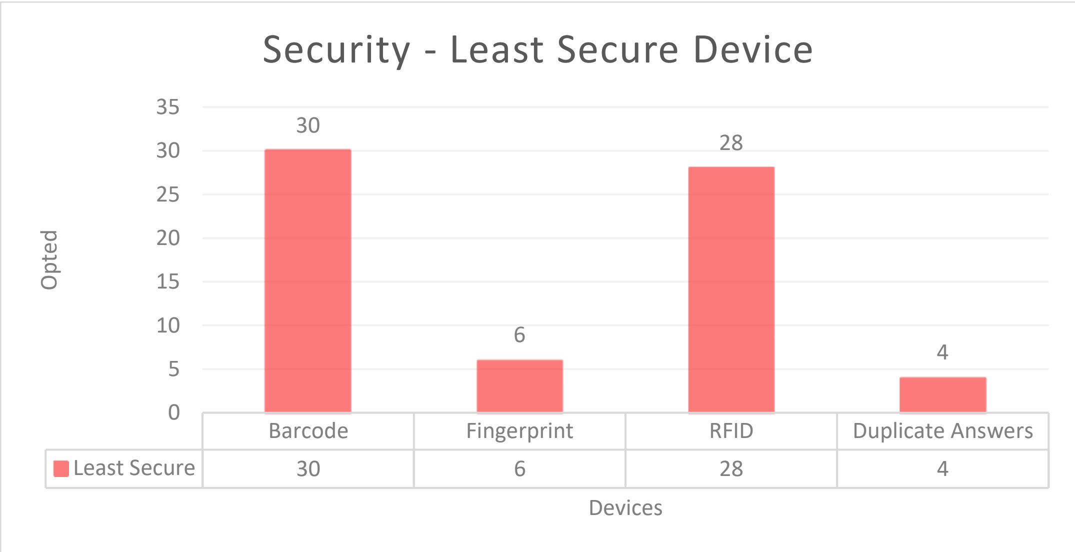


Chart 4.25: EIDs Security -- Least Secure Device -- Results

In conclusion, regarding security of EIDs in this questionnaire, participants felt that the Fingerprint Scanner EID was the most secure device and that the Barcode Scanner EID was the least secure device. This was a predictable outcome as a fingerprint is unique while a barcode, as indicated previously, can be manufactured and be duplicated.

Participants Written Feedback (Security – Least Secure Device): The participants indicated that the Barcode Scanner in their view was the least secure device due to the fact that students can borrow each other's student cards and perform' buddy scanning'. The participant raised their concern on lost or stolen student cards and an important fact was noted from the comments made by the participants, namely: Replacing a lost or stolen student card is a very lengthy process.

Participants felt this could negatively impact on their attendance when not having a student card. Lastly, participants reported that there is no secure component in the RFID scanning as the scanning method is a touch or tap-and-go scanner. Thus, any person can use any student card to make an attendance scan, which in turn student can scan for each other which we call buddy scanning. Participants indicated that this is not a useful way to take attendance as buddy scanning can easily take place.

4.2.2.3. Questionnaire - EIDs' Efficiency - Results

This last part of the three parts in this sub-section of the questionnaire was designed as a multiple-choice question regarding the efficiency of the EID devices, with the participants' answers regarding efficiency of the EID in the questionnaire being recorded and illustrated in Chart 4.26. It can be concluded that the participants reacted mostly positively to the Radio-frequency Identification (RFID) scanner and assumptions can be drawn that this EID scanner was the fastest to scan with.

The goal of this question was to test ' the view of the participant about receiving feedback regarding the effectiveness of the EID scanning devices in the sense of speed of scanning their attendance. There was one participant that did not provide feedback in this question in the questionnaire.

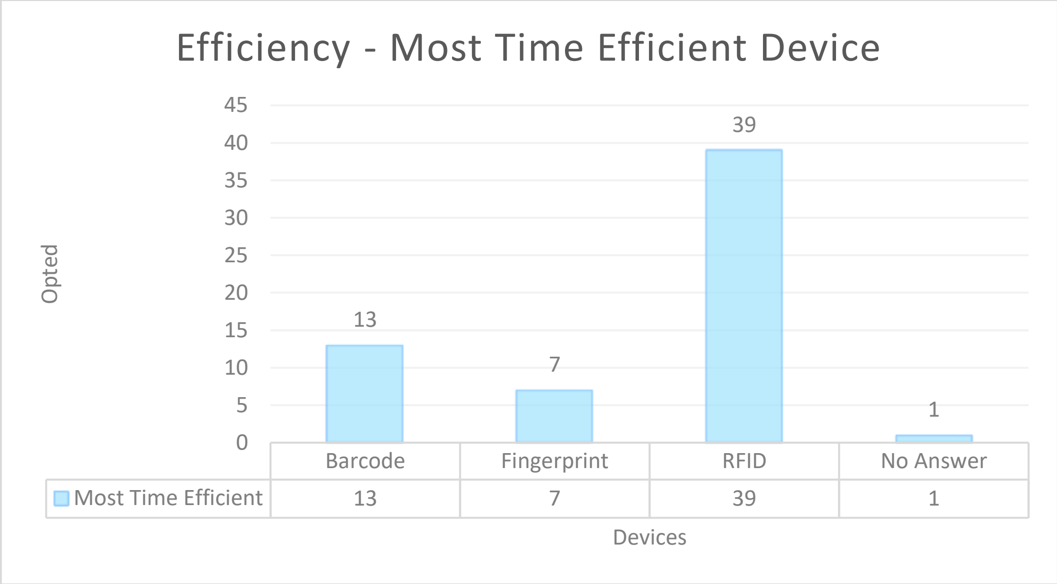


Chart 4.26: EID's Efficiency -- Most Efficient Device -- Results

Participants' Written Feedback (Efficiency – Most Efficient Device): The participants reported that, in their view, there was general consensus that the RFID Scanner was by far the most superior scanning device against the others with regard to time efficiency. Most participants mentioned that the RFID cards functioned as a "tap-and-go" scanning tool.

Participants overwhelmingly reported that there was a fast flow of students in the queue to scan their attendance and waiting time was little to none. The next question in the questionnaire requested the participants to indicate which EID, in their view, was the least efficient scanning device. The results captured were recorded and illustrated in Chart 4.27.

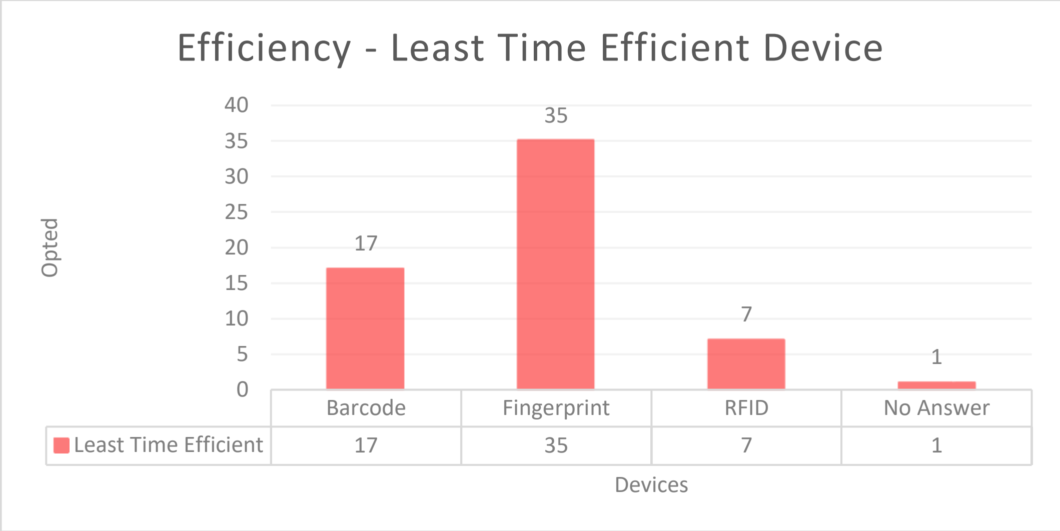


Chart 4.27: EID's Efficiency -- Least Efficient Device -- Results

Participants indicated that the Fingerprint Scanner was the least efficient scanning device. It can be concluded that the fingerprint scanning device scanning duration was longer than the other devices.

Participants' Written Feedback (Efficiency – Least Efficient Device): The participant's reported that the Fingerprint Scanner was the least efficient scanning device and the device was very time-consuming and in some instances, the user had to re-align their finger for an acceptable scan to register their attendance. The participants noted their frustration standing in a slow-moving queue to take attendance, and some participants mentioned they felt intimidated as they sometimes struggled to align their fingers correctly to get a successful scan from the Fingerprint Scanner.

In conclusion, the participants indicated that the Radio-frequency Identification (RFID) scanner was the most efficient EID and the Fingerprint Scanner EID was the least efficient. It can be concluded that even if the participant indicated the Fingerprint Scanner as the most secure device, there was a time factor that played a role in this regard.

In the participants' written feedback, the Fingerprint Scanner consumed the most time to scan their attendance and caused frustration. In some instances, participants did not align their finger correctly to make a positive scan and had to try again. The participants became restless because of this hold-up. With the participants' feedback in the questionnaire regarding usability, security and efficiency, it can be concluded that if a secure EID scanning device is required, the fingerprint scanner will be suitable. If the need is, however, for an efficient scanning device, the RFID Scanner will be their choice. The Barcode Scanner mainly averaged in the middle on all questions asked.

4.2.3. Questionnaire – Participants Recommendations, Awareness and Observations - Results

The questions in this short section in the questionnaire mainly focus on the participants' view on which EID device they would recommend and which method of taking attendance the participant would recommend for the future. The last questions in this section tested the student's perception on current methods of class attendance and their motivation of attending class if attendance is taken. The questions in this section were listed as multiple-choice questions in the questionnaire and there can be only one answer for each question.

Chart 4.28 below illustrates the participants' reaction on which EID device used in this research study would be recommended for an electronic attendance system. It can be seen that most participants recommended the Fingerprint Scanner as their choice of an EID for an electronic attendance system.

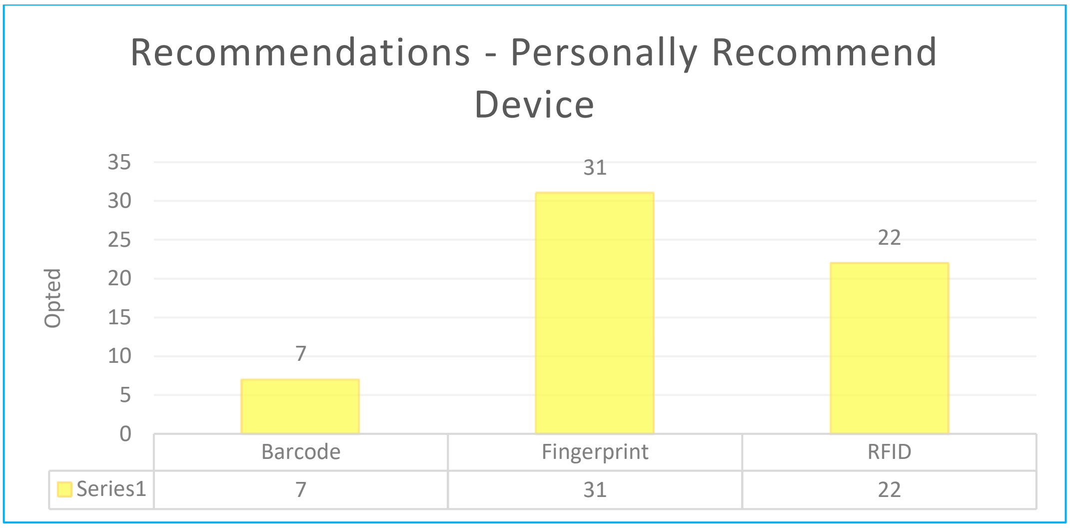


Chart 4.28: Recommendation -- Device Recommendations

Participants Written Feedback (Recommendations – Device Recommendations)

The participants were mostly in favour of the biometric Fingerprint Scanner, even though this device has proven to be the slowest of all the scanning devices in their view. Participants emphasized mainly promoting scanner that has more security features or at least does not allow cheating in the sense of scanning for attendance.

The next question for this section in the questionnaire investigated if the participants would prefer a method of taking attendance with EIDs or remain with a paper-based attendance system. In Chart 4.29 the result indicates overwhelmingly that the participants would prefer an electronic method of taking attendance above a manual paper-based attendance recording process. There was one participant that provided feedback on both answers. This might have been because the participant did not understand the question or was uncertain of the answer.

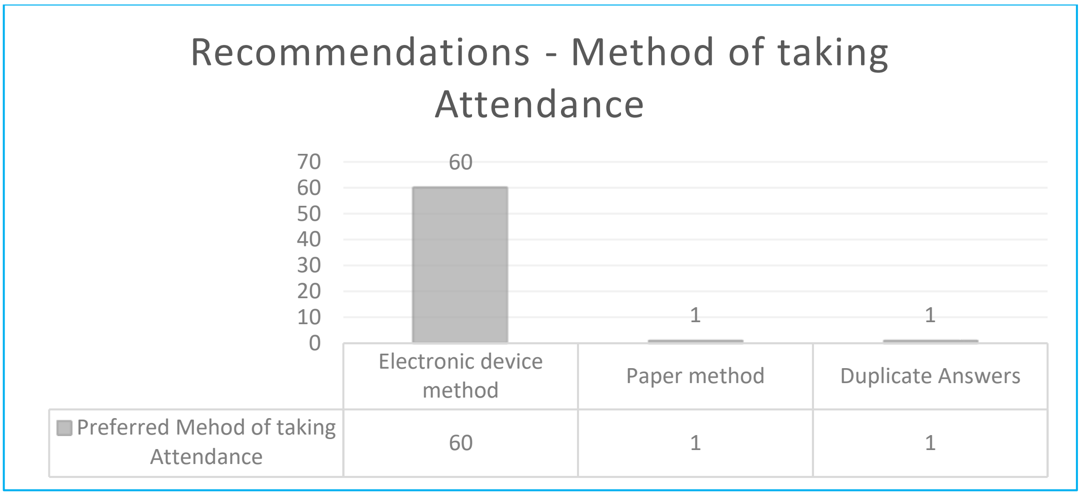


Chart 4.29: Recommendation -- Attendance Method Recommendations

Participants Written Feedback (Recommendations – Attendance Method Recommendations): The participants indicated that in their view one of the most important aspects of tertiary education was attending classes.

The next question in the questionnaire relates to buddy signing. This occurs when one student signs attendance on behalf of another student on a paper-based attendance register. This question was added to the questionnaire to determine the student's perception and awareness on this. Chart 4.30 below illustrates how many of the participants are aware of such occurrences. There was one student that answer both Yes and No on this question.

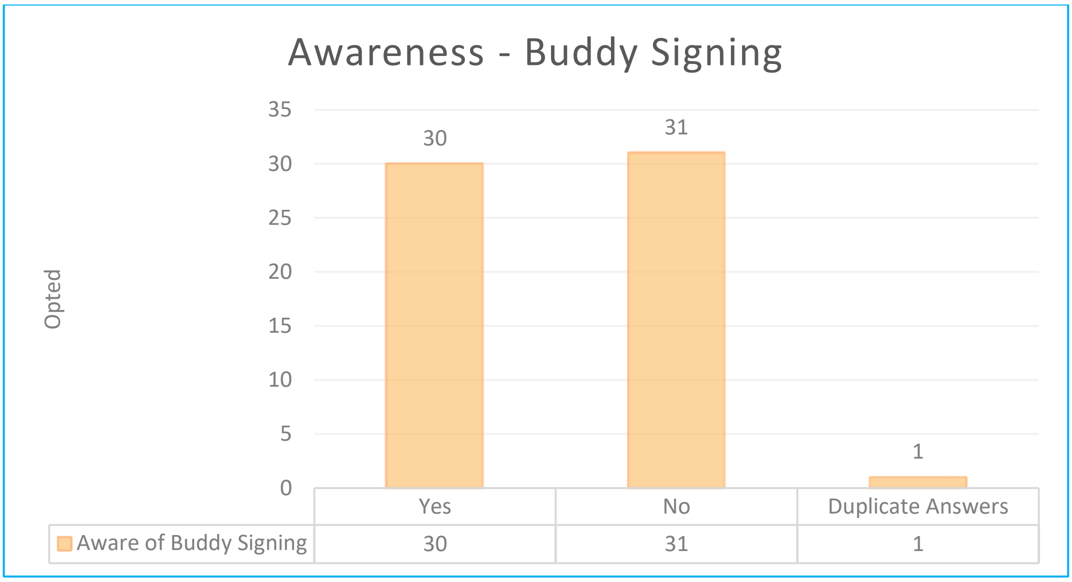


Chart 4.30: Awareness -- Buddy Signing

The vast majority of the participants indicated that buddy signing or scanning was ethically unacceptable, and recommended a biometric scanner above the RFID and Barcode Scanners.

Participants' Written Feedback (Personal view – Buddy Signing): When the data was captured regarding this question on buddy scanning, there was a clear indication that some of the participants were not sure of the term 'Buddy Scanning'. The participants that understood the term, indicated that they felt strongly against this practice and that in their personal view that it is unethical to sign attendance for a fellow student. Some of the participants provided the interesting feedback of fellow students abusing this buddy signing concept to sleep late, requesting fellow students to sign the attendance register on their behalf.

Participants mentioned in the questionnaire that students who were convinced to perform buddy signing had to explain the work to the fellow student that had missed the work in class. Some of the participants acknowledged to have been part of buddy signing and realized how negatively this impacted on their studies and results.

It can be concluded that about half of the participants were aware of buddy signing taking place in an environment familiar to them where a manual paper-based attendance register was circulated. With this data recorded it raised concerns on the legitimate of manual attendance.

The last question in the questionnaire related to the issue if the approach of class attendance was taken appropriately it would it motivate students to attend class. The response to this question is captured and illustrated in Chart 4.31. It can be concluded that most participants felt that if an attendance system is implemented appropriately, it will motivate students to attend classes.

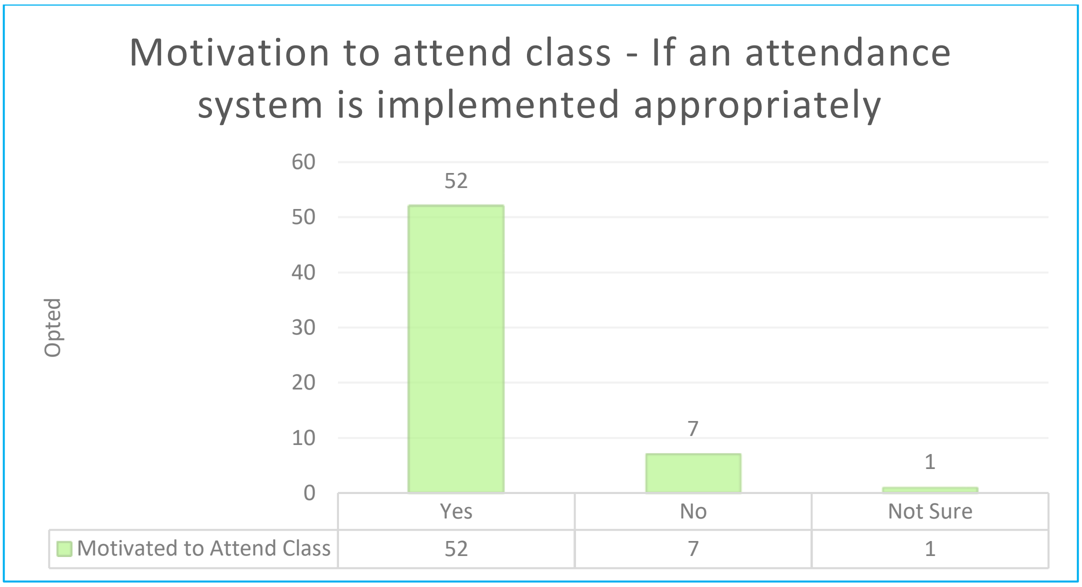


Chart 4.31: Motivation -- Attending class with an agreeable attendance system

Participants' Written Feedback (Personal view – Motivation to attend class if attendance is implemented appropriately): Participants indicated that in their view, if class attendance was implemented appropriately, students' academic performance would improve. Participants also suggested that if appropriate attendance systems could be put in place, a lecturer could utilize the system to identify students with poor class attendance.

It can be concluded that such data can be used to identify students that fall in this category at an early stage as a student at risk, and swift action can be taken. Some participants claimed that in their view attending class shows their loyalty to the lecturer and if they needed extra assistance in their subject that the lecturer could utilize an appropriate attendance system's statistic to assist a student with good class attendance. Some participants believe good class attendance must be rewarded.

4.2.4. Questionnaire Conclusion Summary

This concludes data that has been captured from the qualitative questionnaire. The main conclusions that can be drawn would be that the participants enjoyed a technological more than a manual method of recording attendance in classes. As indicated in the questionnaire's feedback, the participants were in favour of a secure device for scanning attendance. In this case it would be the fingerprint scanning device.

At the same time, the participants also indicated that there was a big need for efficiency where the participants would settle for a different device that scans faster to avoid being unsatisfied or frustrated with a device for taking attendance.

With the data captured from the questionnaire it could also be concluded that the participants became aware of scanning devices' security where explicit feedback around the fingerprint scanner was provided. The participants became aware that a biometric Fingerprint Scanner is a secure device, but realized that with security comes latency. With a four-week cycle of using EIDs and feedback gathered from the participants in the questionnaire, the correct EID could be identified, depending on the criteria set.

The criteria could be security, efficiency or usability. Future studies can be done to see how these three topics relate in the area of EIDs for an electronic attendance recording system. Lastly, the feedback around the awareness of buddy scanning and motivation indicated interesting feedback, where a moral component or factor came together with the data reflecting how students can be motivated and demotivated.

4.3. CORRELATION BETWEEN QUANTITATIVE RESULTS AND QUALITATIVE RESULTS

When inspecting the quantitative and qualitative results in the previous sections, comparisons between these two scientific research methods came to the fore. The results of each can be compared the outcomes summarized in Table 4.15 below.

Table 4.15: Quantitative vs Qualitative Results -- Summary

QUANTITATIVE VS QUALITATIVE RESULTS - SUMMARY		
SCANNING DEVICE	**QUANTITATIVE METHODS** Scanning Devices Data Results:	**QUALITATIVE QUESTIONNAIRE** Questionnaire Results:
Barcode Scanner	Analysed recorded scan data implied: • Second-best efficient device • The highest Standard Deviation • Average scan time was second best • Second highest positive Correlation between the Barcode and RFID Scanner	Participant's indicated: • The second-best usable device • The least secure device • The second most efficient device • Participants' third choice of recommended device
RFID Scanner	Analysed recorded scan data implied: • Most efficient device	Participants indicated: • The most usable device • The second least secure device to scan with

	• Have the lowest Standard Deviation • Average scan time was the best • Highest positive Correlation between the RFID and Barcode Scanner	• The most efficient device • Participant's second choice of recommended device
Fingerprint Scanner	Analysed recorded scan data implied: • Least efficient device with regard to scan time • Second highest Standard Deviation • Average scan time was the highest • The lowest positive correlation between the Fingerprint Scanner against the Barcode and RFID Scanner.	Participants indicated: • The least usable device • The most secure device • The least efficient device • Participants' first choice of recommended device

It is interesting to note the relationship or lack thereof between the quantitative and qualitative results. Table 4.15 above provides a summary comparison between the two methods. The quantitative results above indicate the results of the recorded data captured with the scanning devices and the qualitative results above indicate the question results which the research participants completed.

With the Barcode Scanner's quantitative and qualitative results, in both methods this device is considered the second-best choice between the three scanning devices. The scanning results indicated the Barcode Scanner as the second-fastest device to scan with and in the questionnaire the participants rated this scanner as the second most efficient and usable device. But in contrast, the participants recommended the Barcode scanner the least for an automated attendance recording system.

With the RFID Scanner's quantitative and qualitative results, in both methods this device is concluded as the most efficient device; as the results indicate. in both methods this scanner was the fastest scanning device. However, the participants recommended this device second for an automated attendance system. The Fingerprint Scanner's results in these two methods indicated that it is the least efficient device and had the lowest correlation to the other two devices. However, it is interesting to note that the participants recommended the Fingerprint Scanner to be used in an automated attendance system due to its security characteristics.

4.4. SUMMARY

When comparing the quantitative methods and the qualitative questionnaire, a few key findings were discovered. In both data collection methods, it was concluded that the most efficient and user-friendly device was the RFID Scanner. The data and feedback indicated that the participant adjusted the best to this scanning technology. In both methods, it was also discovered that the Fingerprint Scanner had negative feedback in the sense of time or efficiency, but due to the need for security, the willingness to sacrifice time or frustration for security was an option as the feedback in the questionnaire suggested. Participants in this case recommended the Fingerprint Scanner for an automated attendance system.

The qualitative data results in this chapter are especially suitable to discover qualitative relations such as pattern changes when recording time data. This could be seen from how the different scanning devices scanning times measured up against each other as well as itself with repeated scans. The heuristical research in this qualitative method could be identified in the search for the discovery of meaning and essence in significant human experience and interaction with electronic scanning devices. With the results in this chapter and especially referring to the questionnaire (qualitative results), each device had areas of reflecting, discovering, and elucidating the nature of comparing electronic input devices with a human factor that is interacting with this type of technologies.

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1. INTRODUCTION

The main purpose of the study was to investigate how a usability study on Electronic Input Devices can be used to assess and determine the most suitable Electronic Input Device for recording class attendance. The results and conclusions will form the basis for the Faculty of Engineering and Information Technology to decide on an Electronic Input Device for class attendance. In other words, the deliverable of the study is the optimal electronic input device that was evaluated qualitatively and quantitatively.

To determine the most suitable population, the correct demographic and sample size of students had to be identified. Students currently enrolled for Information Technology in the first year Extended Curriculum Programme were chosen to participate in this research study.

The rest of the chapter provides a summary of answering and revisiting the research questions and possible future work that can be done in line with this study.

5.2. RESEARCH EVALUATION

Research is driven by the need to answer questions and to explore or learn something from it. Research questions posed at the inception of this study will be reviewed in this section and answers will be provided from the data presented in Chapter 4. In order to provide adequate attention to each question and subsequent answer, each question is dealt with individually.

5.2.1. Response to Questions

Qualitative and quantitative methods was used to gather data. Qualitative questionnaires were used to gather facts about people's experience with an Electronic Input Device. This data was helpful to understand how students (research population) feel about the Electronic Input Device. This was used to determine the satisfaction of the students with each Electronic Input Device.

Quantitative data recordings were used to determine the efficiency and learn-ability of each Electronic Input Device. The scan times and average scan time per student, total scan time per session and average total scan times for the 4 weeks were used to determine efficiency. Standard Deviation and Frequency were also used to determine efficiency. The increase/decrease in, scan times and average scan times per student, as well as the increase/decrease in total scan time and average total scan times over the four weeks, were used to determine learn-ability. The satisfaction was determined by a questionnaire as well as by looking at the total scan time. The total scan time is very important to the institution as it form part of lecturing time. This must be limited as far as possible.

5.2.2. Response to First Sub-Question

What are the usability concerns when selecting an Electronic Input Devices for attendance systems in a Universities in South Africa delineated to the student-user?

The study determined that efficiency, learn-ability and satisfaction are the main usability concerns when selecting electronic input devices to record class attendance. Efficiency will be determined by the average scan time per student as well as total scan time for all students and the average of the total scan times for the four weeks. This will be very important especially with big classes of more than 200. It is also important that students can quickly learn how to use the device and that the students are satisfied with the device.

5.2.3. Response to Second Sub-Question

To what extent does Heuristic Evaluation in terms of usability aid in selecting the most suitable Electronic Input Devices for use in an attendance system at a Universities?

As already mentioned, the study was done with students enrolled for the Extended Curriculum Program for the Diploma in Information Technology. Heuristic Evaluation is a usability engineering method for finding the usability problems in an interactive product or system design (Electronic Input Device) so that they can be attended to as part of an iterative process. Heuristic evaluation was the ideal method to use, as it is one of the main discount usability engineering methods. It is easy (can be taught in a half-day seminar); is fast (about a day for most evaluations); and it is affordable (Nielsen & Molich, 1990) (Nielsen, 1992).

The results of the study indicated that heuristic evaluation in terms of the usability aspects of efficiency, learn-ability and satisfaction are a suitable method to use to determine the most suitable Electronic Input Devices to use in attendance systems at universities. The results as well as the recommendation in table 5.1 will form the basis to start from when deciding to implement Electronic Input Devices for conducting class attendance at the Faculty of Engineering and Information Technology at the Central University of Technology, Free State.

5.2.4. Response to Third Sub-Question

What are the constituents of the usability metrics utilised to assess electronic input devices?

Usability testing is the process of systematically observing and noting the assigned user while performing a task on a device. In this study it was observing students using Electronic Input Devices to record class attendance. This included quantitative data recordings as well as qualitative data from a questionnaire. Data concerning efficiency, learn-ability and satisfaction were used to assess the use of Electronic Input Devices by students, for class attendance. The scan times and average scan times per student, total scan time per session and average total scan times for the 4 weeks were used to determine efficiency. Standard Deviation and Frequency were also used to determine efficiency. The increase/decrease in, scan times and average scan times per student, as well as the increase/decrease in total scan time and average total scan times over the four weeks, were used to determine learn-ability. The satisfaction was determined by a questionnaire as well as by looking at the total scan time. The total scan time is very important to the institution as it form part of lecturing time.

5.2.5. Response to Main Research Question

How can a usability study on electronic input devices be employed to assess and determine the most suitable device for recording class attendance electronically?

The research population for the study was identified as well as the electronic input devices to be assessed. Heuristic Evaluation was identified as a suitable method to use to determine the usability aspects of efficiency, learn-ability and satisfaction for the most suitable Electronic Input Device. Quantitative data recordings as well as qualitative data from a questionnaire formed part of the Heuristic Evaluation. Scan times, Average Scan Times, Standard Deviation and Frequency were used to determine efficiency and learn-ability. Qualitative data from a questionnaire as well as total scan times supply the data for satisfaction.

5.3. CONTRIBUTION

The author proposes two ways to evaluate Electronic Input Devices. One is a mathematical analysis (quantitative method), which includes recording of total scan times, individual scan times and the research participants' progress on scan time over a certain period of time for each scanning technology. Secondly, a qualitative method that evaluate the students' or users 'perspective on the use of the different Electronic Input Devices where an open-ended questionnaire is administered with the aim of identifying trends among the participants' opinions.

The results of the quantitative testing indicate that the most efficient Electronic Input Device in this research study was the RFID Scanner. This device's scan time was the fastest (lowest scan time in seconds) in terms of total scan time for a class, and the average scan time (lowest average scan time) for all the participants in a class. If the criteria would be for a fast scanning technology the RFID technology would be the recommended technology.

The results of the qualitative approach indicate that the most efficient and usable Electronic Input Device in this study is the RFID Scanner. However, the results also indicate that the most secure Electronic Input Device is the Fingerprint Scanner. The participants in this research study recommended the Fingerprint Scanner to be used in an electronic attendance system. Most participants' feedback indicated that their preference would be a secure device above all the results of efficiency and usability.

As can be seen from Table 4.15 in Chapter 4, depending on the requirements of a prospective electronic attendance system, different Electronic Input Devices will be identified. Listed in Table 5.1 below is the recommendation for this research study with the Electronic Input Devices identified.

Table 5.1: Recommending the most suitable Electronic Input Device for recording class attendance electronically

RECOMMENDING THE MOST SUITABLE DEVICE FOR RECORDING CLASS ATTENDANCE ELECTRONICALLY	
CRITERIA & RECOMMENDATIONS	**SCANNING DEVICE**
• If an efficient scanning device is needed for an electronic attendance system, the Barcode scanner could be an option. • Due to the popularity of barcodes printed on most products and identification cards the barcode scanner is still widely used. • Security concerns needs to be investigated further.	Barcode Scanner
• If an efficient scanning device is needed for an electronic attendance system, the RFID Scanner could be an option to be used. • Security concerns also need to be investigated further.	RFID Scanner
• If a secure scanning device is a requirement for an electronic attendance system, the Fingerprint Scanner as a biometric scanner is an option to be used. • Efficiency needs to be investigated further. • Other biometric scanners need to be investigated further but could be a costly process.	Fingerprint Scanner

When investigating Table 5.1 above, it can be seen that depending on the criteria and recommendations, different Electronic Input Devices can be selected depending on what the criteria is. As can be seen from this study, if the emphasis was on security, the Fingerprint Scanner will be selected instead of the RFID Scanner.

5.4. LIMITATIONS OF THE STUDY

Only three Electronic Input Devices were part of the study. There are many different Electronic Input Devices available and those identified in this study were the most affordable, available and mostly used.

5.5. FUTURE WORK

The ultimate goal would be to have an acceptable electronic attendance system at universities that could automatically scan attendance of students as they enter a class and update the tertiary database system and provide updated feedbacks to the lecturer and even a parent or progress report. This could be added to future research. This approach of recording time data (quantitative method) of a specific electronic scanning device and then implementing a questionnaire (qualitative method) in this study, can be done for multiple electronic scanning devices.

Further research that could be conducted, for big classes of 200 students and more, would be:

- Using more than one, of the same Electronic Input Devices. Say two RFID scanners.
- Use more than one Electronic Input Device for class attendance, but different types, like a Fingerprint Scanner and RFID Scanner Finger. The use of different Electronic Input Devices can solve problems like security where the lecturer can create each week a random list of who must use which Electronic Input Device for class attendance.

Quantitative and qualitative evaluation is done on scanning technology not a specific device. Future work on specific devices could be done to improve scan times, but this should not influence qualitive outcomes.

This may have a huge impact on how class attendance will look in future.

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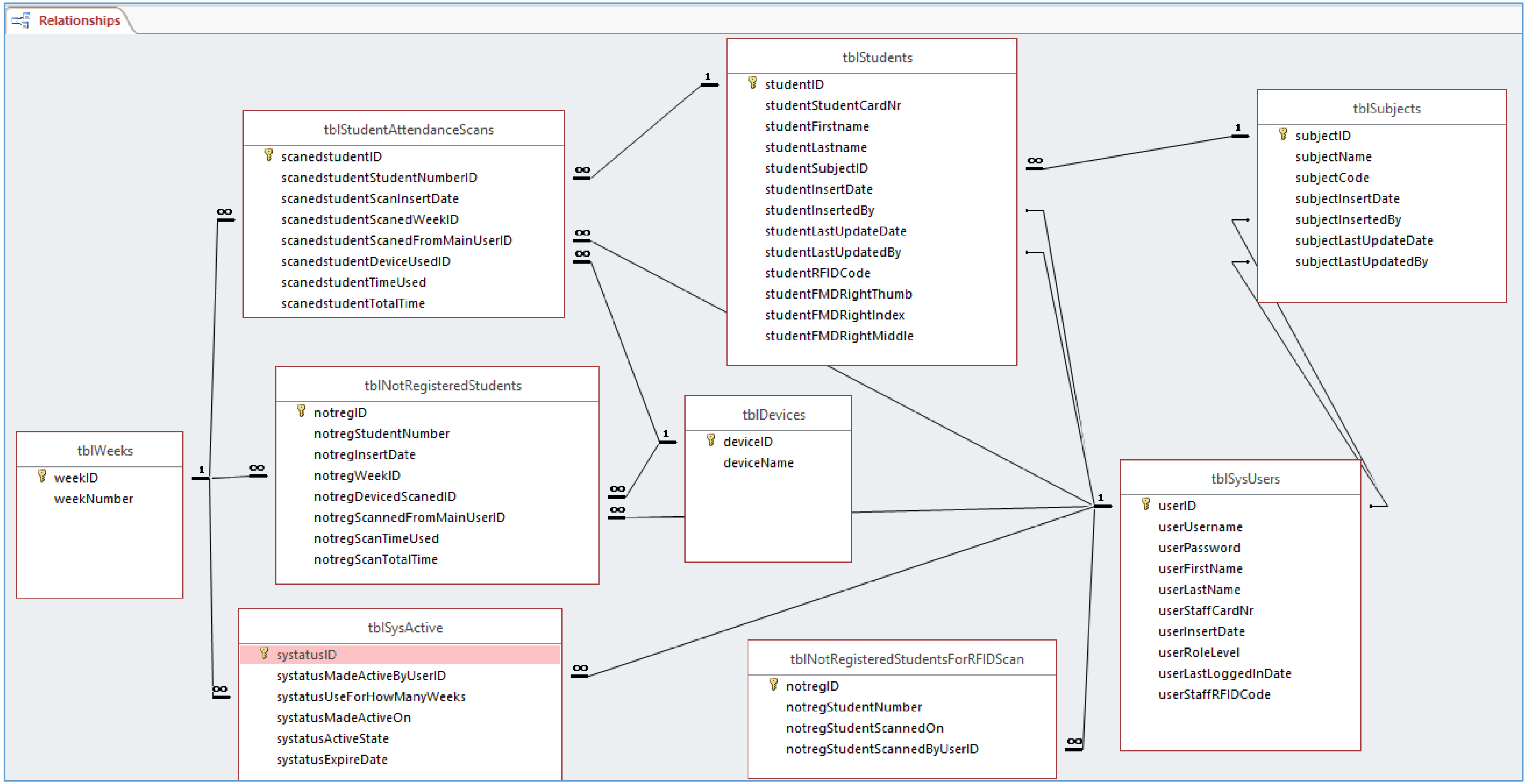
ANNEXURE A: CUSTOM MS ACCESS 2016 DATABASE



ANNEXURE B: CUSTOM MS ACCESS 2016 DATABASE ENROLLED PARTICIPANTS

Relationships | tblStudents | tblStudentAttendanceScans

studentID	studentInsertDate	studentRFIDCode	studentFMDRightThumb	studentFMDRightIndex	stu
1	2015-01-27 13:12:27 PN	1331564661	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABFgAz/v8AAAFlAYgAxQDFAQAAAFYp	<?xml version="1.0" encoding="UTF-	<?:
78	2016-07-20 14:17:02 PN				
79	2016-07-20 14:17:02 PN				
80	2016-07-20 14:17:02 PN				
81	2016-07-20 14:17:02 PN	1330610501	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABBAAz/v8AAAFlAYgAxQDFAQAAAFYn	<?xml version="1.0" encoding="UTF-	<?:
82	2016-07-20 14:17:02 PN				
83	2016-07-20 14:17:02 PN				
84	2016-07-20 14:17:02 PN				
85	2016-07-20 14:17:02 PN				
86	2016-07-20 14:17:02 PN				
87	2016-07-20 14:17:02 PN				
88	2016-07-20 14:17:02 PN				
89	2016-07-20 14:17:02 PN				
90	2016-07-20 14:17:02 PN				
91	2016-07-20 14:17:02 PN				
92	2016-07-20 14:17:02 PN				
93	2016-07-20 14:17:02 PN				
94	2016-07-20 14:17:02 PN				
95	2016-07-20 14:17:02 PN	2650173620	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABrAAz/v8AAAFlAYgAxQDFAQAAAFZC	<?xml version="1.0" encoding="UTF-	<?:
96	2016-07-20 14:17:02 PN				
97	2016-07-20 14:17:02 PN	1331646677	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAAApAAz/v8AAAFlAYgAxQDFAQAAAFYV	<?xml version="1.0" encoding="UTF-	<?:
98	2016-07-20 14:17:02 PN	1331767477	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABBAAz/v8AAAFlAYgAxQDFAQAAAFYn	<?xml version="1.0" encoding="UTF-	<?:
99	2016-07-20 14:17:02 PN				
100	2016-07-20 14:17:02 PN	0769185494	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABuAAz/v8AAAFlAYgAxQDFAQAAAFZE	<?xml version="1.0" encoding="UTF-	<?:
101	2016-07-20 14:17:02 PN	0770054006	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABZAAz/v8AAAFlAYgAxQDFAQAAAFY2	<?xml version="1.0" encoding="UTF-	<?:
102	2016-07-20 14:17:02 PN	1330240693	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAAA4AAz/v8AAAFlAYgAxQDFAQAAAFYg	<?xml version="1.0" encoding="UTF-	<?:
103	2016-07-20 14:17:02 PN	0770369990	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABLgAz/v8AAAFlAYgAxQDFAQAAAFYtg	<?xml version="1.0" encoding="UTF-	<?:
104	2016-07-20 14:17:02 PN				
105	2016-07-20 14:17:02 PN	0886690245	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABggAz/v8AAAFlAYgAxQDFAQAAAFY7	<?xml version="1.0" encoding="UTF-	<?:
106	2016-07-20 14:17:02 PN	0769721046	<?xml version="1.0" encoding="UTF-8"?><Fid><Bytes>Rk1SACAyMAABCgAz/v8AAAFlAYgAxQDFAQAAAFYn	<?xml version="1.0" encoding="UTF-	<?:
107	2016-07-20 14:17:02 PN				

Some tables in the database have been removed as the participants' Information has been omitted due to research ethics as discussed in Chapter 4.

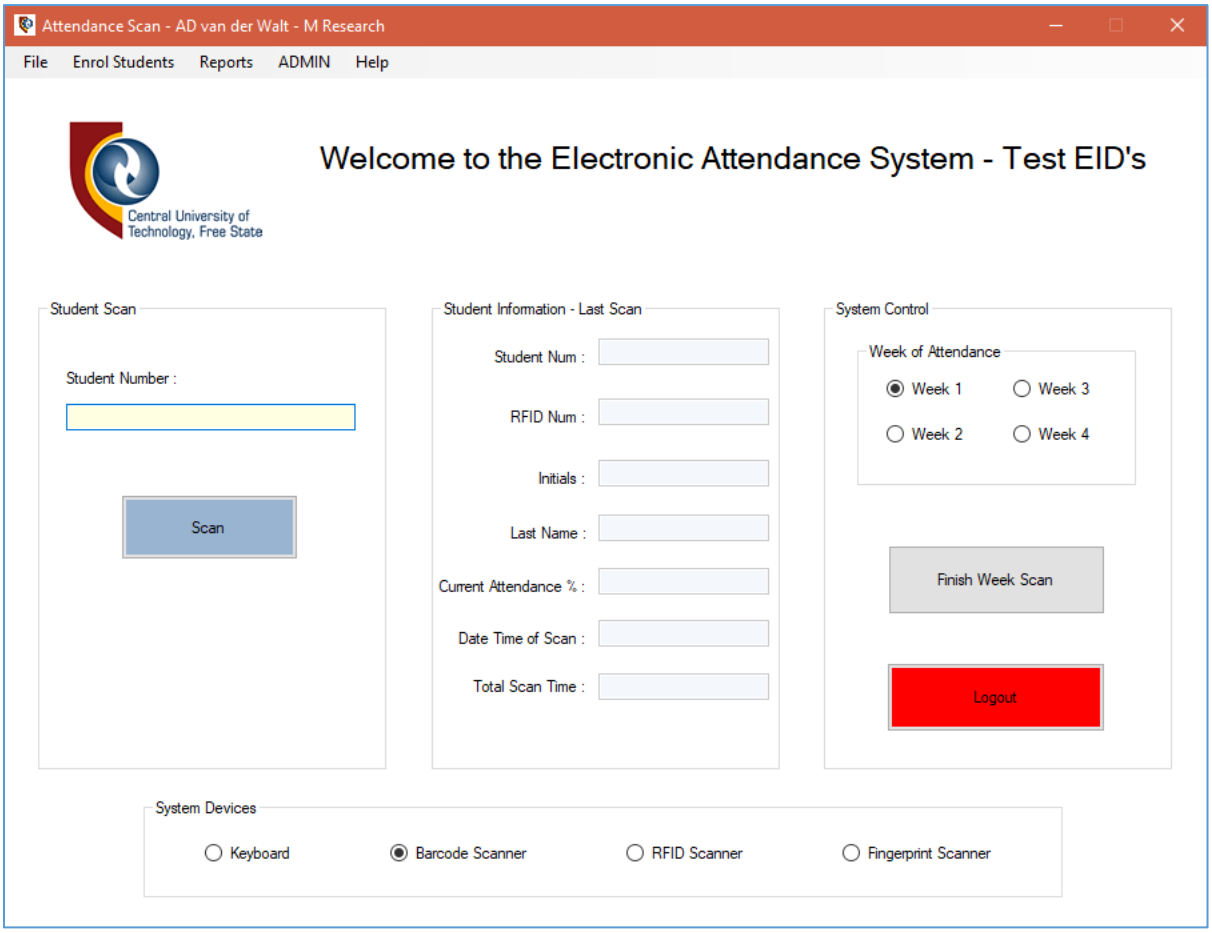
ANNEXURE C: RECORDED SCANNING DATA IN CUSTOM DATABASE (Sample)

Relationships | tblStudents | tblStudentAttendanceScans

scanedstudentStudentNumberID	scanedstudentScanInsertDate	scanedstudentWEEK	scanedstudentTimeUsed	scanedstude	Click to Add
146	2016-07-25 09:16:37 AM	1	00:00:00	00:00:00	
174	2016-07-25 09:16:45 AM	1	00:00:07	00:00:07	
160	2016-07-25 09:16:49 AM	1	00:00:04	00:00:12	
151	2016-07-25 09:16:53 AM	1	00:00:04	00:00:16	
148	2016-07-25 09:16:55 AM	1	00:00:02	00:00:18	
108	2016-07-25 09:16:57 AM	1	00:00:01	00:00:20	
138	2016-07-25 09:16:59 AM	1	00:00:02	00:00:22	
97	2016-07-25 09:17:01 AM	1	00:00:01	00:00:24	
102	2016-07-25 09:17:04 AM	1	00:00:02	00:00:26	
169	2016-07-25 09:17:07 AM	1	00:00:03	00:00:30	
136	2016-07-25 09:17:11 AM	1	00:00:03	00:00:33	
112	2016-07-25 09:17:14 AM	1	00:00:02	00:00:36	
139	2016-07-25 09:17:17 AM	1	00:00:03	00:00:39	
150	2016-07-25 09:17:20 AM	1	00:00:02	00:00:42	
134	2016-07-25 09:17:22 AM	1	00:00:02	00:00:45	
144	2016-07-25 09:17:24 AM	1	00:00:01	00:00:46	
164	2016-07-25 09:17:25 AM	1	00:00:01	00:00:48	
173	2016-07-25 09:17:27 AM	1	00:00:01	00:00:50	
154	2016-07-25 09:17:28 AM	1	00:00:01	00:00:51	
161	2016-07-25 09:17:30 AM	1	00:00:01	00:00:52	
137	2016-07-25 09:17:31 AM	1	00:00:01	00:00:54	
122	2016-07-25 09:17:33 AM	1	00:00:01	00:00:56	
135	2016-07-25 09:17:37 AM	1	00:00:03	00:01:00	
105	2016-07-25 09:17:40 AM	1	00:00:03	00:01:03	
119	2016-07-25 09:17:43 AM	1	00:00:02	00:01:05	
133	2016-07-25 09:17:45 AM	1	00:00:02	00:01:08	
131	2016-07-25 09:17:49 AM	1	00:00:03	00:01:11	
142	2016-07-25 09:17:59 AM	1	00:00:09	00:01:21	
118	2016-07-25 09:18:05 AM	1	00:00:05	00:01:27	
116	2016-07-25 09:18:07 AM	1	00:00:02	00:01:30	
101	2016-07-25 09:18:12 AM	1	00:00:04	00:01:35	

Some tables in the database have been removed as the participants' Information has been omitted due to research ethics as discussed in chapter 4.

ANNEXURE D: C# CUSTOM SOFTWARE INTERFACE



ANNEXURE E: RESEARCH ETHICS RELEASE FORM

Masters IT Research project

Research Ethics:

Full title of Project: Evaluation of electronic input devices for use in an attendance system at a UoT.

Andre van der Walt, ECP Coordinator;nd contact address of Researcher: CUT BHP207

This research uses the __________subject code Students group to use three devices, namely fingerprint scanner, Barcode scanner and RFID Scanner. These scanners will simulate to take attendance in a class environment. Each student will scan his/her student card or fingerprint.

This research measures the speed of multiple scans per scanner named above, by the student.

Please Initial Box

1. I confirm that I have read and understood the information sheet for the above-mentioned study and have had the opportunity to ☐

ask questions.

2. I understand that my participation is voluntary and that I am free to ☐

Withdraw at any time without giving reason.

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

☐

Agree	**Date**	**Student Number**

AD VAN DER WALT

Name of Researcher	Date	Signature

ANNEXURE F: QUALITATIVE QUESTIONNAIRE

A heuristic usability evaluation of electronic input devices with regard to recording class attendance at Universities: Case of Central University of Technology

Dear Student

Welcome to the survey on the evaluation of electronic input devices to be used in an attendance recording system at the Central University of Technology. This survey is designed to gather input from students regarding their perceptions of and experiences with attendance relevant / evaluated scanning devices. Your response is confidential, and the results of this survey will be in aggregate form to ensure your anonymity.

You may leave the session at any time without completing the questionnaire if you do not wish to continue with this process. You do not have to disclose any personal information about yourself, next of kin etc. The confidentiality of this data can be made available to you upon request / reasonable request. You have the right to know if any of the collected data is repurposed. Please ask if any ambiguity regarding this questionnaire exist.

For the purpose of this survey is to conduct with regard to the use of the three different electronic scanners, which include the

- Barcode scanner
- fingerprint scanner and
- RFID Scanner

This survey will take approximately 10 minutes to complete. We greatly appreciate your assistance. Space is provided at the end of the survey for you to add any additional comments you may have.

Thank you for your cooperation.

Mr. AD van der Walt

Study of A heuristic usability evaluation of electronic input devices with regard to recording class attendance at Universities: Case of Central University of Technology

051 507 3258

andrevdw@cut.ac.za

Demographics Section

1. Gender:

   1) Male ☐
   2) Female ☐

2. Indicate your age group:

   1) Below 20 ☐
   2) 20-24 ☐
   3) 25-39 ☐
   4) 40-49 ☐
   5) 50-59 ☐
   6) 60 + ☐

3. Indicate your study year

   1) Year 0 (ECP) ☐
   2) First year ☐
   3) Second year ☐
   4) Third year ☐
   5) Fourth year ☐
   6) Fifth year ☐
   7) Sixth year ☐

4. Indicate the course you are currently enrolled for.

____

The three types of scanners discussed in this questionnaire:

Figure 1 - Fingerprint Scanner

Figure 2 - Barcode Scanner

Figure 3 - RFID Scanner

5. Of the following options, which electronic scanner do you consider to be the **easiest** to scan with? (Select **ONE** scanner only).

USABILITY	Easy
a. Scanning with the barcode scanner.	☐
b. Scanning with the fingerprint scanner.	☐
c. Scanning with the RFID Scanner.	☐

Why do you find the device chosen as the easiest device?

____

____

____

6. Of the following options, which electronic scanner do you consider to be the most difficult to scan with? (Select **ONE** scanner only).

USABILITY	Difficult
a. Scanning with the barcode scanner.	☐
b. Scanning with the fingerprint scanner.	☐
c. Scanning with the RFID Scanner.	☐

Why do you find the device chosen as the most difficult device?

____

____

____

7. Of the following devices, which scanner do you consider as the **most secure** to scan with? (Choose **ONE** device only)

SECURITY	Most Secure
a. Scanning with the barcode scanner.	☐
b. Scanning with the fingerprint scanner.	☐
c. Scanning with the RFID Scanner.	☐

Why do you find the device chosen as the most secure device?

____

____

____

8. Of the following devices, which scanner do you consider as the **least secure** to scan with? (Choose **ONE** device only)

SECURITY	LEAST Secure
a. Scanning with the barcode scanner.	☐
b. Scanning with the fingerprint scanner.	☐
c. Scanning with the RFID Scanner.	☐

Why do you find your device chosen as the **least** secure device?

____

____

____

9. Of the following options, which scanner do you consider to be the **most** time efficient (fastest) to scan with?

EFFICIENCY	Most Time Efficient
a. Scanning with the barcode scanner.	☐
b. Scanning with the fingerprint scanner.	☐
c. Scanning with the RFID scanner.	☐

Why do you find the device chosen as the **most** time efficient device?

____

____

____

10. Of the following options, which scanner do you consider to be the least time efficient (fastest) to scan with?

EFFICIENCY	LEAST Time Efficient
a. Scanning with the barcode scanner.	☐
b. Scanning with the fingerprint scanner.	☐
c. Scanning with the RFID Scanner.	☐

Why do you find the device chosen as the **LEAST** time efficient device?

____

____

____

11. Of the following options, which device would you **personally recommend**? For the purpose of taking attendance in classes. (Only select one device.)

	Recommend
a. Barcode Scanner	☐
b. Fingerprint Scanner	☐
c. RFID Scanner	☐

Why do you recommend the selected device?

____

____

____

12. In your personal opinion, which method is the **best method** to take attendance?

	Recommend
a. Paper method, class list circulating class.	☐
b. Attendance software with electronic device	☐

Why do you recommend the selected method?

____

____

____

13. Do you know if buddy signing take place at CUT (scanning/signing attendance for a friend that is not present in class")?

Buddy Signing @ CUT	
Yes	☐
No	☐

14. What is your personal view about "buddy scanning"?

____

____

____

____

15. Referring to question number 13, is it acceptable to scan/sign register for a friend? IF not, how do you think it is able to prevent it?

____

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16. Does it in any way motivate you to go to class when an attendance register is properly implemented?

____

____

____

17. In your personal views, what is the benefit of taking attendance?

____

____

____

18. Do you have any suggestions regarding this study?

____

____

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____

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Thank you for your time, it is greatly appreciated!

Mr. AD VAN DER WALT

OFFICE 051 507 3258

EMAIL: andrevdw@cut.ac.za

ANNEXURE G: SCANNING DATA - BARCODE SCANNER

BARCODE SCANNER DATA					
Week	Student ID	Scan Date and Time	Scanning Time	Accumulative Class Time	Stud Count
1	146	2016-07-25 09:16:37 AM	00:00:00	00:00:00	1
1	174	2016-07-25 09:16:45 AM	00:00:07	00:00:07	2
1	160	2016-07-25 09:16:49 AM	00:00:04	00:00:12	3
1	151	2016-07-25 09:16:53 AM	00:00:04	00:00:16	4
1	148	2016-07-25 09:16:55 AM	00:00:02	00:00:18	5
1	108	2016-07-25 09:16:57 AM	00:00:01	00:00:20	6
1	138	2016-07-25 09:16:59 AM	00:00:02	00:00:22	7
1	102	2016-07-25 09:17:04 AM	00:00:02	00:00:26	8
1	169	2016-07-25 09:17:07 AM	00:00:03	00:00:30	9
1	112	2016-07-25 09:17:14 AM	00:00:02	00:00:36	10
1	139	2016-07-25 09:17:17 AM	00:00:03	00:00:39	11
1	134	2016-07-25 09:17:22 AM	00:00:02	00:00:45	12
1	144	2016-07-25 09:17:24 AM	00:00:01	00:00:46	13
1	164	2016-07-25 09:17:25 AM	00:00:01	00:00:48	14
1	173	2016-07-25 09:17:27 AM	00:00:01	00:00:50	15
1	137	2016-07-25 09:17:31 AM	00:00:01	00:00:54	16
1	122	2016-07-25 09:17:33 AM	00:00:01	00:00:56	17
1	135	2016-07-25 09:17:37 AM	00:00:03	00:01:00	18
1	105	2016-07-25 09:17:40 AM	00:00:03	00:01:03	19

1	119	2016-07-25 09:17:43 AM	00:00:02	00:01:05	20
1	133	2016-07-25 09:17:45 AM	00:00:02	00:01:08	21
1	142	2016-07-25 09:17:59 AM	00:00:09	00:01:21	22
1	118	2016-07-25 09:18:05 AM	00:00:05	00:01:27	23
1	101	2016-07-25 09:18:12 AM	00:00:04	00:01:35	24
1	128	2016-07-25 09:18:14 AM	00:00:01	00:01:37	25
1	114	2016-07-25 09:18:16 AM	00:00:01	00:01:39	26
1	165	2016-07-25 09:18:18 AM	00:00:02	00:01:41	27
1	117	2016-07-25 09:18:19 AM	00:00:01	00:01:42	28
1	170	2016-07-25 09:18:28 AM	00:00:08	00:01:50	29
1	177	2016-07-25 09:18:30 AM	00:00:01	00:01:52	30
1	149	2016-07-25 09:18:35 AM	00:00:02	00:01:58	31
1	147	2016-07-25 09:18:39 AM	00:00:01	00:02:02	32
1	145	2016-07-25 09:18:47 AM	00:00:01	00:02:10	33
1	113	2016-07-25 09:18:53 AM	00:00:02	00:02:15	34
1	109	2016-07-25 09:18:54 AM	00:00:01	00:02:17	35
1	106	2016-07-25 09:18:56 AM	00:00:02	00:02:19	36
1	100	2016-07-25 09:19:05 AM	00:00:02	00:02:28	37
1	175	2016-07-25 09:19:07 AM	00:00:02	00:02:30	38
1	95	2016-07-25 09:19:09 AM	00:00:01	00:02:31	39
1	152	2016-07-25 09:19:11 AM	00:00:02	00:02:33	40
1	168	2016-07-25 09:19:14 AM	00:00:02	00:02:36	41
1	141	2016-07-25 09:19:52 AM	00:00:00	00:00:00	42

1	81	2016-07-25 09:20:04 AM	00:00:03	00:00:11	43
1	172	2016-07-25 09:20:13 AM	00:00:04	00:00:20	44
BARCODE Scanning WEEK 1 Class TOTAL:			**00:01:44**	**00:02:36**	**44**
2	146	2016-08-01 09:21:41 AM	00:00:00	00:00:00	1
2	174	2016-08-01 09:21:44 AM	00:00:03	00:00:03	2
2	160	2016-08-01 09:21:46 AM	00:00:01	00:00:05	3
2	151	2016-08-01 09:21:48 AM	00:00:02	00:00:07	4
2	148	2016-08-01 09:21:49 AM	00:00:00	00:00:08	5
2	108	2016-08-01 09:21:51 AM	00:00:01	00:00:09	6
2	138	2016-08-01 09:21:54 AM	00:00:03	00:00:13	7
2	102	2016-08-01 09:21:57 AM	00:00:01	00:00:15	8
2	139	2016-08-01 09:22:01 AM	00:00:04	00:00:19	9
2	112	2016-08-01 09:22:06 AM	00:00:02	00:00:24	10
2	144	2016-08-01 09:22:10 AM	00:00:03	00:00:28	11
2	134	2016-08-01 09:22:13 AM	00:00:02	00:00:31	12
2	136	2016-08-01 09:22:14 AM	00:00:00	00:00:32	13
2	164	2016-08-01 09:22:16 AM	00:00:01	00:00:34	14
2	173	2016-08-01 09:22:18 AM	00:00:01	00:00:36	15
2	161	2016-08-01 09:22:22 AM	00:00:00	00:00:40	16
2	122	2016-08-01 09:22:24 AM	00:00:01	00:00:42	17
2	135	2016-08-01 09:22:27 AM	00:00:02	00:00:45	18
2	119	2016-08-01 09:22:29 AM	00:00:02	00:00:47	19
2	105	2016-08-01 09:22:32 AM	00:00:03	00:00:51	20

2	133	2016-08-01 09:22:38 AM	00:00:06	00:00:57	21
2	142	2016-08-01 09:22:42 AM	00:00:01	00:01:01	22
2	118	2016-08-01 09:22:47 AM	00:00:05	00:01:06	23
2	101	2016-08-01 09:22:50 AM	00:00:01	00:01:08	24
2	128	2016-08-01 09:22:52 AM	00:00:01	00:01:10	25
2	114	2016-08-01 09:22:54 AM	00:00:02	00:01:12	26
2	117	2016-08-01 09:22:58 AM	00:00:04	00:01:16	27
2	170	2016-08-01 09:23:00 AM	00:00:01	00:01:18	28
2	165	2016-08-01 09:23:03 AM	00:00:03	00:01:22	29
2	177	2016-08-01 09:23:05 AM	00:00:01	00:01:23	30
2	149	2016-08-01 09:23:16 AM	00:00:02	00:01:35	31
2	147	2016-08-01 09:23:20 AM	00:00:00	00:01:38	32
2	145	2016-08-01 09:23:34 AM	00:00:01	00:01:52	33
2	113	2016-08-01 09:23:39 AM	00:00:02	00:01:57	34
2	109	2016-08-01 09:23:41 AM	00:00:01	00:01:59	35
2	106	2016-08-01 09:23:43 AM	00:00:02	00:02:01	36
2	100	2016-08-01 09:23:46 AM	00:00:01	00:02:05	37
2	175	2016-08-01 09:23:49 AM	00:00:02	00:02:07	38
2	95	2016-08-01 09:23:50 AM	00:00:01	00:02:08	39
2	152	2016-08-01 09:23:52 AM	00:00:02	00:02:11	40
2	168	2016-08-01 09:23:54 AM	00:00:01	00:02:12	41
2	141	2016-08-01 09:23:56 AM	00:00:02	00:02:14	42
2	172	2016-08-01 09:24:05 AM	00:00:02	00:02:23	43

2	98	2016-08-01 09:24:08 AM	00:00:02	00:02:26	44
BARCODE Scanning WEEK 2 Class TOTAL:			**00:01:18**	**00:02:26**	**44**
3	146	2016-08-08 09:24:46 AM	00:00:00	00:00:00	1
3	174	2016-08-08 09:24:48 AM	00:00:01	00:00:01	2
3	160	2016-08-08 09:24:52 AM	00:00:02	00:00:06	3
3	151	2016-08-08 09:24:55 AM	00:00:02	00:00:08	4
3	148	2016-08-08 09:24:56 AM	00:00:01	00:00:10	5
3	108	2016-08-08 09:24:58 AM	00:00:01	00:00:11	6
3	138	2016-08-08 09:25:01 AM	00:00:03	00:00:14	7
3	102	2016-08-08 09:25:05 AM	00:00:02	00:00:19	8
3	169	2016-08-08 09:25:08 AM	00:00:02	00:00:21	9
3	112	2016-08-08 09:25:14 AM	00:00:02	00:00:27	10
3	144	2016-08-08 09:25:18 AM	00:00:03	00:00:31	11
3	134	2016-08-08 09:25:20 AM	00:00:01	00:00:33	12
3	136	2016-08-08 09:25:22 AM	00:00:02	00:00:35	13
3	164	2016-08-08 09:25:24 AM	00:00:02	00:00:37	14
3	173	2016-08-08 09:25:25 AM	00:00:01	00:00:39	15
3	161	2016-08-08 09:25:30 AM	00:00:01	00:00:43	16
3	122	2016-08-08 09:25:33 AM	00:00:02	00:00:46	17
3	135	2016-08-08 09:25:34 AM	00:00:00	00:00:47	18
3	119	2016-08-08 09:25:36 AM	00:00:02	00:00:49	19
3	105	2016-08-08 09:25:38 AM	00:00:01	00:00:51	20
3	133	2016-08-08 09:25:40 AM	00:00:01	00:00:53	21

3	142	2016-08-08 09:25:58 AM	00:00:03	00:01:11	22
3	118	2016-08-08 09:25:59 AM	00:00:01	00:01:12	23
3	101	2016-08-08 09:26:03 AM	00:00:01	00:01:16	24
3	128	2016-08-08 09:26:04 AM	00:00:01	00:01:18	25
3	114	2016-08-08 09:26:05 AM	00:00:00	00:01:18	26
3	117	2016-08-08 09:26:25 AM	00:00:02	00:01:38	27
3	170	2016-08-08 09:26:27 AM	00:00:02	00:01:40	28
3	165	2016-08-08 09:26:29 AM	00:00:02	00:01:42	29
3	177	2016-08-08 09:26:32 AM	00:00:03	00:01:46	30
3	149	2016-08-08 09:26:37 AM	00:00:01	00:01:50	31
3	147	2016-08-08 09:26:42 AM	00:00:01	00:01:55	32
3	145	2016-08-08 09:26:51 AM	00:00:01	00:02:04	33
3	113	2016-08-08 09:26:57 AM	00:00:02	00:02:10	34
3	109	2016-08-08 09:26:59 AM	00:00:02	00:02:12	35
3	106	2016-08-08 09:27:01 AM	00:00:02	00:02:15	36
3	100	2016-08-08 09:27:14 AM	00:00:02	00:02:27	37
3	175	2016-08-08 09:27:20 AM	00:00:06	00:02:34	38
3	95	2016-08-08 09:27:22 AM	00:00:01	00:02:35	39
3	152	2016-08-08 09:27:25 AM	00:00:03	00:02:38	40
3	168	2016-08-08 09:27:29 AM	00:00:03	00:02:42	41
3	141	2016-08-08 09:27:31 AM	00:00:01	00:02:44	42
3	172	2016-08-08 09:27:37 AM	00:00:02	00:02:50	43
3	98	2016-08-08 09:27:40 AM	00:00:02	00:02:53	44

BARCODE Scanning WEEK 3 Class TOTAL:			00:01:16	00:02:53	44
4	146	2016-08-15 09:28:13 AM	00:00:00	00:00:00	1
4	174	2016-08-15 09:28:16 AM	00:00:02	00:00:02	2
4	160	2016-08-15 09:28:18 AM	00:00:02	00:00:05	3
4	151	2016-08-15 09:28:21 AM	00:00:02	00:00:07	4
4	148	2016-08-15 09:28:23 AM	00:00:01	00:00:09	5
4	108	2016-08-15 09:28:23 AM	00:00:00	00:00:10	6
4	138	2016-08-15 09:28:26 AM	00:00:02	00:00:12	7
4	102	2016-08-15 09:28:30 AM	00:00:01	00:00:16	8
4	169	2016-08-15 09:28:32 AM	00:00:02	00:00:19	9
4	112	2016-08-15 09:28:38 AM	00:00:02	00:00:25	10
4	144	2016-08-15 09:28:40 AM	00:00:01	00:00:27	11
4	134	2016-08-15 09:28:41 AM	00:00:01	00:00:28	12
4	136	2016-08-15 09:28:44 AM	00:00:02	00:00:31	13
4	164	2016-08-15 09:28:45 AM	00:00:00	00:00:32	14
4	173	2016-08-15 09:28:47 AM	00:00:01	00:00:34	15
4	161	2016-08-15 09:28:51 AM	00:00:00	00:00:37	16
4	122	2016-08-15 09:28:53 AM	00:00:02	00:00:40	17
4	135	2016-08-15 09:28:55 AM	00:00:02	00:00:42	18
4	119	2016-08-15 09:28:58 AM	00:00:02	00:00:44	19
4	105	2016-08-15 09:28:59 AM	00:00:01	00:00:46	20
4	133	2016-08-15 09:29:02 AM	00:00:02	00:00:49	21
4	142	2016-08-15 09:29:13 AM	00:00:02	00:01:00	22

4	118	2016-08-15 09:29:21 AM	00:00:07	00:01:07	23
4	101	2016-08-15 09:29:25 AM	00:00:01	00:01:11	24
4	128	2016-08-15 09:29:27 AM	00:00:02	00:01:14	25
4	114	2016-08-15 09:29:29 AM	00:00:01	00:01:15	26
4	117	2016-08-15 09:29:31 AM	00:00:02	00:01:18	27
4	170	2016-08-15 09:29:33 AM	00:00:02	00:01:20	28
4	165	2016-08-15 09:29:36 AM	00:00:03	00:01:23	29
4	177	2016-08-15 09:29:39 AM	00:00:02	00:01:26	30
4	149	2016-08-15 09:29:58 AM	00:00:02	00:01:44	31
4	147	2016-08-15 09:30:02 AM	00:00:01	00:01:49	32
4	145	2016-08-15 09:30:06 AM	00:00:01	00:01:53	33
4	113	2016-08-15 09:30:12 AM	00:00:02	00:01:59	34
4	109	2016-08-15 09:30:14 AM	00:00:01	00:02:00	35
4	106	2016-08-15 09:30:16 AM	00:00:02	00:02:03	36
4	100	2016-08-15 09:30:20 AM	00:00:01	00:02:06	37
4	175	2016-08-15 09:30:22 AM	00:00:01	00:02:08	38
4	95	2016-08-15 09:30:23 AM	00:00:01	00:02:10	39
4	152	2016-08-15 09:30:25 AM	00:00:01	00:02:11	40
4	168	2016-08-15 09:30:27 AM	00:00:01	00:02:13	41
4	141	2016-08-15 09:30:29 AM	00:00:02	00:02:16	42
4	172	2016-08-15 09:30:35 AM	00:00:02	00:02:22	43
4	98	2016-08-15 09:30:38 AM	00:00:02	00:02:24	44
BARCODE Scanning WEEK 4 Class TOTAL:			**00:01:10**	**00:02:24**	**44**

WEEK	**Student Scan Time Total Per week**	**Class Scan Time Total Per week**	**Student Count**	**Average sec per Student Scan**	
1	00:01:44	00:02:06	44	2.36	
2	00:01:18	00:02:11	44	1.77	
3	00:01:16	00:02:16	44	1.73	
4	00:01:10	00:01:52	44	1.59	
Average	**00:01:22**	**00:02:35**	**44**	**1.86**	
TOTAL	**00:05:28**	**00:08:25**			

Central University of Technology, Free State

ANNEXURE H: SCANNING DATA - RFID SCANNER

RFID SCANNER DATA					
Week	Student ID	Scan Date and Time	Scanning Time	Accumulative Class Time	Stud Count
1	146	2016-08-22 09:31:41 AM	00:00:26	00:00:26	1
1	174	2016-08-22 09:31:45 AM	00:00:04	00:00:30	2
1	160	2016-08-22 09:31:48 AM	00:00:02	00:00:33	3
1	151	2016-08-22 09:31:50 AM	00:00:01	00:00:35	4
1	148	2016-08-22 09:31:52 AM	00:00:02	00:00:37	5
1	108	2016-08-22 09:31:53 AM	00:00:01	00:00:38	6
1	138	2016-08-22 09:31:54 AM	00:00:00	00:00:39	7
1	102	2016-08-22 09:31:57 AM	00:00:02	00:00:42	8
1	169	2016-08-22 09:32:02 AM	00:00:03	00:00:47	9
1	139	2016-08-22 09:32:03 AM	00:00:00	00:00:48	10
1	112	2016-08-22 09:32:06 AM	00:00:01	00:00:51	11
1	144	2016-08-22 09:32:08 AM	00:00:01	00:00:53	12
1	134	2016-08-22 09:32:09 AM	00:00:00	00:00:54	13
1	164	2016-08-22 09:32:12 AM	00:00:01	00:00:57	14
1	173	2016-08-22 09:32:14 AM	00:00:01	00:00:59	15
1	137	2016-08-22 09:32:17 AM	00:00:01	00:01:02	16
1	122	2016-08-22 09:32:27 AM	00:00:02	00:01:11	17
1	142	2016-08-22 09:32:34 AM	00:00:02	00:01:18	18
1	135	2016-08-22 09:32:40 AM	00:00:04	00:01:25	19

1	119	2016-08-22 09:32:43 AM	00:00:02	00:01:28	20
1	105	2016-08-22 09:32:46 AM	00:00:03	00:01:31	21
1	133	2016-08-22 09:32:48 AM	00:00:01	00:01:33	22
1	118	2016-08-22 09:32:50 AM	00:00:02	00:01:35	23
1	101	2016-08-22 09:32:54 AM	00:00:02	00:01:39	24
1	128	2016-08-22 09:32:56 AM	00:00:01	00:01:40	25
1	114	2016-08-22 09:32:56 AM	00:00:00	00:01:41	26
1	117	2016-08-22 09:32:58 AM	00:00:02	00:01:43	27
1	170	2016-08-22 09:33:00 AM	00:00:01	00:01:45	28
1	165	2016-08-22 09:33:03 AM	00:00:02	00:01:47	29
1	177	2016-08-22 09:33:04 AM	00:00:01	00:01:49	30
1	149	2016-08-22 09:33:15 AM	00:00:03	00:02:00	31
1	147	2016-08-22 09:33:23 AM	00:00:02	00:02:08	32
1	145	2016-08-22 09:33:35 AM	00:00:02	00:02:20	33
1	113	2016-08-22 09:33:49 AM	00:00:05	00:02:34	34
1	109	2016-08-22 09:33:54 AM	00:00:03	00:02:39	35
1	106	2016-08-22 09:33:57 AM	00:00:03	00:02:42	36
1	100	2016-08-22 09:34:01 AM	00:00:01	00:02:46	37
1	175	2016-08-22 09:34:08 AM	00:00:06	00:02:53	38
1	95	2016-08-22 09:34:10 AM	00:00:01	00:02:54	39
1	152	2016-08-22 09:34:11 AM	00:00:01	00:02:56	40
1	168	2016-08-22 09:34:13 AM	00:00:01	00:02:58	41
1	141	2016-08-22 09:34:20 AM	00:00:03	00:03:05	42

1	81	2016-08-22 09:34:22 AM	00:00:02	00:03:07	43
1	172	2016-08-22 09:34:26 AM	00:00:01	00:03:11	44
RFID Scanning WEEK 1 Class TOTAL:			**00:01:15**	**00:03:11**	**44**
2	146	2016-08-29 09:35:02 AM	00:00:00	00:00:00	1
2	174	2016-08-29 09:35:05 AM	00:00:03	00:00:03	2
2	160	2016-08-29 09:35:07 AM	00:00:02	00:00:05	3
2	151	2016-08-29 09:35:09 AM	00:00:01	00:00:07	4
2	148	2016-08-29 09:35:10 AM	00:00:01	00:00:08	5
2	108	2016-08-29 09:35:11 AM	00:00:00	00:00:09	6
2	138	2016-08-29 09:35:12 AM	00:00:00	00:00:10	7
2	102	2016-08-29 09:35:16 AM	00:00:01	00:00:13	8
2	169	2016-08-29 09:35:17 AM	00:00:01	00:00:15	9
2	139	2016-08-29 09:35:19 AM	00:00:01	00:00:17	10
2	112	2016-08-29 09:35:22 AM	00:00:01	00:00:19	11
2	144	2016-08-29 09:35:23 AM	00:00:01	00:00:21	12
2	134	2016-08-29 09:35:25 AM	00:00:01	00:00:22	13
2	164	2016-08-29 09:35:28 AM	00:00:01	00:00:26	14
2	173	2016-08-29 09:35:30 AM	00:00:01	00:00:28	15
2	137	2016-08-29 09:35:33 AM	00:00:01	00:00:31	16
2	122	2016-08-29 09:35:36 AM	00:00:00	00:00:34	17
2	142	2016-08-29 09:35:43 AM	00:00:01	00:00:41	18
2	135	2016-08-29 09:35:47 AM	00:00:02	00:00:45	19
2	119	2016-08-29 09:35:51 AM	00:00:04	00:00:49	20

2	105	2016-08-29 09:35:53 AM	00:00:02	00:00:51	21
2	133	2016-08-29 09:35:55 AM	00:00:02	00:00:53	22
2	118	2016-08-29 09:35:56 AM	00:00:00	00:00:54	23
2	101	2016-08-29 09:36:04 AM	00:00:01	00:01:02	24
2	128	2016-08-29 09:36:06 AM	00:00:01	00:01:04	25
2	114	2016-08-29 09:36:08 AM	00:00:01	00:01:05	26
2	117	2016-08-29 09:36:09 AM	00:00:01	00:01:07	27
2	170	2016-08-29 09:36:11 AM	00:00:01	00:01:08	28
2	165	2016-08-29 09:36:13 AM	00:00:02	00:01:11	29
2	177	2016-08-29 09:36:15 AM	00:00:01	00:01:13	30
2	149	2016-08-29 09:36:19 AM	00:00:01	00:01:17	31
2	147	2016-08-29 09:36:22 AM	00:00:02	00:01:20	32
2	145	2016-08-29 09:36:35 AM	00:00:02	00:01:32	33
2	113	2016-08-29 09:36:40 AM	00:00:01	00:01:38	34
2	109	2016-08-29 09:36:42 AM	00:00:01	00:01:39	35
2	106	2016-08-29 09:36:47 AM	00:00:05	00:01:45	36
2	100	2016-08-29 09:36:50 AM	00:00:01	00:01:48	37
2	175	2016-08-29 09:36:51 AM	00:00:01	00:01:49	38
2	95	2016-08-29 09:36:52 AM	00:00:00	00:01:50	39
2	152	2016-08-29 09:36:54 AM	00:00:01	00:01:52	40
2	168	2016-08-29 09:37:02 AM	00:00:03	00:02:00	41
2	141	2016-08-29 09:37:04 AM	00:00:01	00:02:01	42
2	81	2016-08-29 09:37:06 AM	00:00:02	00:02:04	43

2	172	2016-08-29 09:37:12 AM	00:00:04	00:02:10	44
RFID Scanning WEEK 2 Class TOTAL:			**00:01:00**	**00:02:10**	**44**
3	146	2016-09-05 09:37:47 AM	00:00:00	00:00:00	1
3	174	2016-09-05 09:37:51 AM	00:00:03	00:00:03	2
3	160	2016-09-05 09:37:53 AM	00:00:01	00:00:05	3
3	151	2016-09-05 09:37:56 AM	00:00:03	00:00:08	4
3	148	2016-09-05 09:37:58 AM	00:00:01	00:00:10	5
3	138	2016-09-05 09:38:00 AM	00:00:01	00:00:12	6
3	108	2016-09-05 09:38:03 AM	00:00:02	00:00:15	7
3	102	2016-09-05 09:38:07 AM	00:00:02	00:00:20	8
3	169	2016-09-05 09:38:13 AM	00:00:01	00:00:25	9
3	139	2016-09-05 09:38:15 AM	00:00:01	00:00:27	10
3	112	2016-09-05 09:38:18 AM	00:00:01	00:00:30	11
3	144	2016-09-05 09:38:19 AM	00:00:01	00:00:32	12
3	134	2016-09-05 09:38:26 AM	00:00:02	00:00:39	13
3	164	2016-09-05 09:38:30 AM	00:00:02	00:00:42	14
3	173	2016-09-05 09:38:33 AM	00:00:02	00:00:45	15
3	137	2016-09-05 09:38:36 AM	00:00:01	00:00:48	16
3	122	2016-09-05 09:38:40 AM	00:00:00	00:00:52	17
3	142	2016-09-05 09:38:44 AM	00:00:01	00:00:57	18
3	135	2016-09-05 09:38:47 AM	00:00:01	00:01:00	19
3	119	2016-09-05 09:38:58 AM	00:00:03	00:01:10	20
3	105	2016-09-05 09:39:00 AM	00:00:02	00:01:12	21

3	133	2016-09-05 09:39:03 AM	00:00:02	00:01:15	22
3	118	2016-09-05 09:39:07 AM	00:00:02	00:01:19	23
3	101	2016-09-05 09:39:11 AM	00:00:02	00:01:23	24
3	128	2016-09-05 09:39:12 AM	00:00:01	00:01:24	25
3	114	2016-09-05 09:39:13 AM	00:00:00	00:01:25	26
3	117	2016-09-05 09:39:14 AM	00:00:01	00:01:26	27
3	170	2016-09-05 09:39:16 AM	00:00:02	00:01:28	28
3	165	2016-09-05 09:39:19 AM	00:00:02	00:01:31	29
3	177	2016-09-05 09:39:19 AM	00:00:00	00:01:32	30
3	149	2016-09-05 09:39:22 AM	00:00:01	00:01:34	31
3	147	2016-09-05 09:39:29 AM	00:00:04	00:01:41	32
3	145	2016-09-05 09:39:38 AM	00:00:02	00:01:50	33
3	113	2016-09-05 09:39:46 AM	00:00:02	00:01:58	34
3	109	2016-09-05 09:39:47 AM	00:00:01	00:02:00	35
3	106	2016-09-05 09:39:49 AM	00:00:01	00:02:01	36
3	100	2016-09-05 09:39:52 AM	00:00:02	00:02:04	37
3	175	2016-09-05 09:39:54 AM	00:00:01	00:02:06	38
3	95	2016-09-05 09:39:55 AM	00:00:01	00:02:07	39
3	152	2016-09-05 09:39:57 AM	00:00:02	00:02:10	40
3	168	2016-09-05 09:39:59 AM	00:00:01	00:02:11	41
3	141	2016-09-05 09:40:01 AM	00:00:02	00:02:13	42
3	81	2016-09-05 09:40:03 AM	00:00:01	00:02:15	43
3	172	2016-09-05 09:40:06 AM	00:00:01	00:02:18	44

RFID Scanning WEEK 3 Class TOTAL:			00:01:05	00:02:18	44
4	146	2016-09-12 09:40:37 AM	00:00:02	00:00:02	1
4	174	2016-09-12 09:40:39 AM	00:00:01	00:00:04	2
4	160	2016-09-12 09:40:40 AM	00:00:01	00:00:06	3
4	151	2016-09-12 09:40:42 AM	00:00:02	00:00:08	4
4	148	2016-09-12 09:40:43 AM	00:00:00	00:00:09	5
4	108	2016-09-12 09:40:45 AM	00:00:01	00:00:10	6
4	138	2016-09-12 09:40:45 AM	00:00:00	00:00:11	7
4	102	2016-09-12 09:40:49 AM	00:00:00	00:00:14	8
4	169	2016-09-12 09:40:51 AM	00:00:02	00:00:17	9
4	139	2016-09-12 09:40:53 AM	00:00:01	00:00:19	10
4	112	2016-09-12 09:40:56 AM	00:00:01	00:00:21	11
4	144	2016-09-12 09:40:57 AM	00:00:01	00:00:23	12
4	134	2016-09-12 09:40:59 AM	00:00:01	00:00:24	13
4	164	2016-09-12 09:41:05 AM	00:00:04	00:00:31	14
4	173	2016-09-12 09:41:08 AM	00:00:02	00:00:34	15
4	137	2016-09-12 09:41:11 AM	00:00:01	00:00:37	16
4	122	2016-09-12 09:41:17 AM	00:00:03	00:00:43	17
4	142	2016-09-12 09:41:21 AM	00:00:01	00:00:47	18
4	135	2016-09-12 09:41:24 AM	00:00:02	00:00:49	19
4	119	2016-09-12 09:41:26 AM	00:00:02	00:00:52	20
4	105	2016-09-12 09:41:29 AM	00:00:02	00:00:55	21
4	133	2016-09-12 09:41:31 AM	00:00:01	00:00:57	22

4	118	2016-09-12 09:41:32 AM	00:00:01	00:00:58	23
4	101	2016-09-12 09:41:35 AM	00:00:01	00:01:01	24
4	128	2016-09-12 09:41:36 AM	00:00:01	00:01:02	25
4	114	2016-09-12 09:41:42 AM	00:00:02	00:01:08	26
4	117	2016-09-12 09:41:43 AM	00:00:00	00:01:09	27
4	170	2016-09-12 09:41:45 AM	00:00:02	00:01:11	28
4	165	2016-09-12 09:41:46 AM	00:00:00	00:01:12	29
4	177	2016-09-12 09:41:48 AM	00:00:01	00:01:14	30
4	149	2016-09-12 09:41:50 AM	00:00:00	00:01:16	31
4	147	2016-09-12 09:41:56 AM	00:00:02	00:01:21	32
4	145	2016-09-12 09:42:04 AM	00:00:02	00:01:29	33
4	113	2016-09-12 09:42:09 AM	00:00:02	00:01:35	34
4	109	2016-09-12 09:42:10 AM	00:00:00	00:01:36	35
4	106	2016-09-12 09:42:12 AM	00:00:02	00:01:38	36
4	100	2016-09-12 09:42:17 AM	00:00:01	00:01:43	37
4	175	2016-09-12 09:42:18 AM	00:00:00	00:01:43	38
4	95	2016-09-12 09:42:19 AM	00:00:01	00:01:45	39
4	152	2016-09-12 09:42:21 AM	00:00:01	00:01:46	40
4	168	2016-09-12 09:42:22 AM	00:00:01	00:01:48	41
4	141	2016-09-12 09:42:25 AM	00:00:02	00:01:51	42
4	81	2016-09-12 09:42:28 AM	00:00:03	00:01:54	43
4	172	2016-09-12 09:42:31 AM	00:00:01	00:01:57	44
RFID Scanning WEEK 4 Class TOTAL:			**00:00:57**	**00:02:00**	**44**

WEEK	**Student Scan Time Total Per week**	**Class Scan Time Total Per week**	**Student Count**	**Average sec per Student Scan**	
1	00:01:15	00:02:52	44	2.39	
2	00:01:00	00:01:56	44	1.36	
3	00:01:05	00:02:05	44	1.48	
4	00:00:57	00:01:46	44	1.30	
Average	**00:01:04**	**00:02:10**	**44.00**	**1.63**	
	00:04:17	**00:08:39**			

ANNEXURE I: SCANNING DATA - FINGERPRINT SCANNER

Fingerprint SCANNER DATA					
Week	Student ID	Scan Date and Time	Scanning Time	Accumulative Class Time	Stud Count
1	146	2016-09-19 09:45:06 AM	00:00:15	00:00:15	1
1	174	2016-09-19 09:45:12 AM	00:00:05	00:00:21	2
1	160	2016-09-19 09:45:16 AM	00:00:03	00:00:25	3
1	151	2016-09-19 09:45:19 AM	00:00:02	00:00:28	4
1	148	2016-09-19 09:45:22 AM	00:00:03	00:00:31	5
1	108	2016-09-19 09:45:25 AM	00:00:02	00:00:34	6
1	138	2016-09-19 09:45:33 AM	00:00:08	00:00:43	7
1	102	2016-09-19 09:45:40 AM	00:00:03	00:00:49	8
1	169	2016-09-19 09:45:43 AM	00:00:02	00:00:52	9
1	139	2016-09-19 09:45:47 AM	00:00:03	00:00:56	10
1	112	2016-09-19 09:45:52 AM	00:00:02	00:01:01	11
1	144	2016-09-19 09:45:55 AM	00:00:02	00:01:04	12
1	134	2016-09-19 09:45:57 AM	00:00:02	00:01:07	13
1	164	2016-09-19 09:46:02 AM	00:00:04	00:01:12	14
1	173	2016-09-19 09:46:08 AM	00:00:05	00:01:17	15
1	137	2016-09-19 09:46:14 AM	00:00:03	00:01:24	16
1	122	2016-09-19 09:46:20 AM	00:00:02	00:01:30	17
1	142	2016-09-19 09:46:27 AM	00:00:06	00:01:36	18
1	119	2016-09-19 09:46:34 AM	00:00:04	00:01:43	19

1	135	2016-09-19 09:46:37 AM	00:00:02	00:01:46	20
1	133	2016-09-19 09:47:11 AM	00:00:34	00:02:20	21
1	105	2016-09-19 09:47:15 AM	00:00:04	00:02:25	22
1	118	2016-09-19 09:47:21 AM	00:00:05	00:02:30	23
1	101	2016-09-19 09:47:30 AM	00:00:03	00:02:40	24
1	128	2016-09-19 09:47:33 AM	00:00:02	00:02:43	25
1	114	2016-09-19 09:47:36 AM	00:00:02	00:02:45	26
1	117	2016-09-19 09:47:43 AM	00:00:07	00:02:53	27
1	170	2016-09-19 09:47:47 AM	00:00:04	00:02:57	28
1	165	2016-09-19 09:47:51 AM	00:00:03	00:03:01	29
1	178	2016-09-19 09:47:55 AM	00:00:03	00:03:04	30
1	149	2016-09-19 09:48:00 AM	00:00:05	00:03:09	31
1	147	2016-09-19 09:48:05 AM	00:00:02	00:03:15	32
1	145	2016-09-19 09:48:14 AM	00:00:03	00:03:24	33
1	113	2016-09-19 09:48:32 AM	00:00:03	00:03:42	34
1	109	2016-09-19 09:48:36 AM	00:00:03	00:03:46	35
1	106	2016-09-19 09:48:41 AM	00:00:04	00:03:50	36
1	100	2016-09-19 09:48:51 AM	00:00:06	00:04:01	37
1	175	2016-09-19 09:48:55 AM	00:00:03	00:04:04	38
1	95	2016-09-19 09:49:03 AM	00:00:03	00:04:13	39
1	152	2016-09-19 09:49:10 AM	00:00:06	00:04:19	40
1	168	2016-09-19 09:49:13 AM	00:00:03	00:04:23	41
1	141	2016-09-19 09:49:26 AM	00:00:12	00:04:35	42

1	81	2016-09-19 09:49:39 AM	00:00:03	00:04:48	43
1	172	2016-09-19 09:49:47 AM	00:00:03	00:04:56	44
Fingerprint Scanning WEEK 1 Class TOTAL:			**00:03:24**	**00:04:56**	**44**
2	146	2016-09-26 09:50:47 AM	00:00:00	00:00:00	1
2	174	2016-09-26 09:50:52 AM	00:00:04	00:00:04	2
2	160	2016-09-26 09:50:55 AM	00:00:03	00:00:08	3
2	151	2016-09-26 09:51:06 AM	00:00:11	00:00:19	4
2	148	2016-09-26 09:51:11 AM	00:00:05	00:00:24	5
2	108	2016-09-26 09:51:16 AM	00:00:05	00:00:29	6
2	138	2016-09-26 09:51:20 AM	00:00:03	00:00:32	7
2	102	2016-09-26 09:51:25 AM	00:00:05	00:00:38	8
2	169	2016-09-26 09:51:34 AM	00:00:05	00:00:46	9
2	139	2016-09-26 09:51:38 AM	00:00:04	00:00:51	10
2	112	2016-09-26 09:51:45 AM	00:00:03	00:00:57	11
2	144	2016-09-26 09:51:47 AM	00:00:02	00:01:00	12
2	134	2016-09-26 09:51:50 AM	00:00:02	00:01:03	13
2	164	2016-09-26 09:51:59 AM	00:00:02	00:01:12	14
2	173	2016-09-26 09:52:02 AM	00:00:03	00:01:15	15
2	137	2016-09-26 09:52:10 AM	00:00:02	00:01:23	16
2	122	2016-09-26 09:52:16 AM	00:00:02	00:01:28	17
2	142	2016-09-26 09:52:19 AM	00:00:03	00:01:32	18
2	135	2016-09-26 09:52:29 AM	00:00:07	00:01:41	19
2	119	2016-09-26 09:52:31 AM	00:00:02	00:01:44	20

2	133	2016-09-26 09:52:42 AM	00:00:10	00:01:55	21
2	105	2016-09-26 09:52:45 AM	00:00:03	00:01:58	22
2	118	2016-09-26 09:52:48 AM	00:00:03	00:02:01	23
2	101	2016-09-26 09:52:53 AM	00:00:02	00:02:06	24
2	128	2016-09-26 09:52:56 AM	00:00:02	00:02:09	25
2	114	2016-09-26 09:53:02 AM	00:00:06	00:02:15	26
2	117	2016-09-26 09:53:06 AM	00:00:03	00:02:18	27
2	170	2016-09-26 09:53:15 AM	00:00:06	00:02:28	28
2	165	2016-09-26 09:53:19 AM	00:00:03	00:02:32	29
2	178	2016-09-26 09:53:29 AM	00:00:07	00:02:42	30
2	149	2016-09-26 09:53:34 AM	00:00:04	00:02:47	31
2	147	2016-09-26 09:55:00 AM	00:00:02	00:04:12	32
2	145	2016-09-26 09:55:05 AM	00:00:02	00:04:18	33
2	113	2016-09-26 09:55:28 AM	00:00:04	00:04:41	34
2	109	2016-09-26 09:55:40 AM	00:00:11	00:04:52	35
2	106	2016-09-26 09:55:43 AM	00:00:03	00:04:56	36
2	100	2016-09-26 09:55:53 AM	00:00:02	00:05:05	37
2	175	2016-09-26 09:55:58 AM	00:00:05	00:05:11	38
2	95	2016-09-26 09:56:01 AM	00:00:02	00:05:14	39
2	152	2016-09-26 09:56:04 AM	00:00:03	00:05:17	40
2	168	2016-09-26 09:56:07 AM	00:00:02	00:05:20	41
2	141	2016-09-26 09:56:37 AM	00:00:29	00:05:49	42
2	81	2016-09-26 09:56:42 AM	00:00:05	00:05:55	43

2	172	2016-09-26 09:56:55 AM	00:00:03	00:06:07	44
Fingerprint Scanning WEEK 2 Class TOTAL:			**00:03:15**	**00:06:07**	**44**
3	146	2016-10-03 09:57:41 AM	00:00:00	00:00:00	1
3	174	2016-10-03 09:57:46 AM	00:00:04	00:00:04	2
3	151	2016-10-03 09:57:56 AM	00:00:09	00:00:14	3
3	160	2016-10-03 09:58:02 AM	00:00:05	00:00:21	4
3	148	2016-10-03 09:58:06 AM	00:00:04	00:00:25	5
3	108	2016-10-03 09:58:10 AM	00:00:03	00:00:28	6
3	138	2016-10-03 09:58:12 AM	00:00:02	00:00:31	7
3	102	2016-10-03 09:58:17 AM	00:00:05	00:00:36	8
3	169	2016-10-03 09:58:21 AM	00:00:03	00:00:39	9
3	139	2016-10-03 09:58:24 AM	00:00:03	00:00:43	10
3	112	2016-10-03 09:58:30 AM	00:00:02	00:00:48	11
3	144	2016-10-03 09:58:32 AM	00:00:02	00:00:51	12
3	134	2016-10-03 09:58:35 AM	00:00:02	00:00:53	13
3	164	2016-10-03 09:58:41 AM	00:00:03	00:01:00	14
3	173	2016-10-03 09:58:45 AM	00:00:03	00:01:03	15
3	137	2016-10-03 09:58:56 AM	00:00:11	00:01:14	16
3	122	2016-10-03 09:59:06 AM	00:00:07	00:01:25	17
3	142	2016-10-03 09:59:14 AM	00:00:04	00:01:32	18
3	135	2016-10-03 09:59:25 AM	00:00:04	00:01:44	19
3	119	2016-10-03 09:59:34 AM	00:00:08	00:01:52	20
3	133	2016-10-03 09:59:39 AM	00:00:04	00:01:57	21

3	105	2016-10-03 09:59:46 AM	00:00:03	00:02:04	22
3	118	2016-10-03 09:59:48 AM	00:00:02	00:02:06	23
3	101	2016-10-03 09:59:54 AM	00:00:03	00:02:13	24
3	128	2016-10-03 09:59:56 AM	00:00:01	00:02:15	25
3	114	2016-10-03 09:59:58 AM	00:00:02	00:02:17	26
3	117	2016-10-03 10:00:01 AM	00:00:02	00:02:20	27
3	170	2016-10-03 10:00:05 AM	00:00:03	00:02:24	28
3	178	2016-10-03 10:00:09 AM	00:00:04	00:02:28	29
3	165	2016-10-03 10:00:12 AM	00:00:03	00:02:31	30
3	149	2016-10-03 10:00:28 AM	00:00:15	00:02:47	31
3	147	2016-10-03 10:00:31 AM	00:00:02	00:02:50	32
3	145	2016-10-03 10:00:47 AM	00:00:03	00:03:06	33
3	113	2016-10-03 10:00:58 AM	00:00:02	00:03:16	34
3	109	2016-10-03 10:01:03 AM	00:00:05	00:03:21	35
3	106	2016-10-03 10:01:09 AM	00:00:06	00:03:27	36
3	175	2016-10-03 10:01:19 AM	00:00:07	00:03:38	37
3	100	2016-10-03 10:01:23 AM	00:00:03	00:03:41	38
3	95	2016-10-03 10:01:25 AM	00:00:02	00:03:44	39
3	152	2016-10-03 10:01:29 AM	00:00:03	00:03:47	40
3	168	2016-10-03 10:01:31 AM	00:00:02	00:03:50	41
3	141	2016-10-03 10:01:41 AM	00:00:09	00:03:59	42
3	81	2016-10-03 10:01:44 AM	00:00:03	00:04:03	43
3	172	2016-10-03 10:01:52 AM	00:00:04	00:04:10	44

Fingerprint Scanning WEEK 3 Class TOTAL:			00:02:57	00:04:10	44
4	146	2016-10-10 10:02:31 AM	00:00:00	00:00:00	1
4	174	2016-10-10 10:02:36 AM	00:00:05	00:00:05	2
4	160	2016-10-10 10:02:38 AM	00:00:02	00:00:07	3
4	151	2016-10-10 10:02:45 AM	00:00:06	00:00:14	4
4	108	2016-10-10 10:02:47 AM	00:00:02	00:00:16	5
4	138	2016-10-10 10:02:55 AM	00:00:08	00:00:24	6
4	148	2016-10-10 10:02:59 AM	00:00:03	00:00:27	7
4	102	2016-10-10 10:03:06 AM	00:00:07	00:00:35	8
4	169	2016-10-10 10:03:11 AM	00:00:04	00:00:40	9
4	139	2016-10-10 10:03:15 AM	00:00:04	00:00:44	10
4	112	2016-10-10 10:03:24 AM	00:00:06	00:00:53	11
4	144	2016-10-10 10:03:27 AM	00:00:03	00:00:56	12
4	134	2016-10-10 10:03:30 AM	00:00:03	00:00:59	13
4	164	2016-10-10 10:03:47 AM	00:00:05	00:01:16	14
4	173	2016-10-10 10:03:50 AM	00:00:02	00:01:19	15
4	137	2016-10-10 10:03:57 AM	00:00:04	00:01:26	16
4	122	2016-10-10 10:04:05 AM	00:00:05	00:01:34	17
4	142	2016-10-10 10:04:08 AM	00:00:03	00:01:37	18
4	135	2016-10-10 10:04:17 AM	00:00:03	00:01:46	19
4	119	2016-10-10 10:04:21 AM	00:00:04	00:01:50	20
4	133	2016-10-10 10:04:31 AM	00:00:09	00:02:00	21
4	105	2016-10-10 10:04:35 AM	00:00:03	00:02:03	22

4	118	2016-10-10 10:04:39 AM	00:00:04	00:02:08	23
4	101	2016-10-10 10:04:53 AM	00:00:03	00:02:22	24
4	128	2016-10-10 10:04:55 AM	00:00:02	00:02:24	25
4	114	2016-10-10 10:04:57 AM	00:00:02	00:02:26	26
4	117	2016-10-10 10:05:01 AM	00:00:03	00:02:30	27
4	170	2016-10-10 10:05:09 AM	00:00:03	00:02:38	28
4	165	2016-10-10 10:05:13 AM	00:00:04	00:02:42	29
4	178	2016-10-10 10:05:15 AM	00:00:02	00:02:44	30
4	149	2016-10-10 10:05:35 AM	00:00:20	00:03:04	31
4	147	2016-10-10 10:05:49 AM	00:00:07	00:03:18	32
4	145	2016-10-10 10:06:05 AM	00:00:03	00:03:34	33
4	113	2016-10-10 10:06:17 AM	00:00:03	00:03:46	34
4	109	2016-10-10 10:06:20 AM	00:00:03	00:03:49	35
4	106	2016-10-10 10:06:24 AM	00:00:03	00:03:53	36
4	175	2016-10-10 10:06:30 AM	00:00:02	00:03:59	37
4	100	2016-10-10 10:06:32 AM	00:00:02	00:04:01	38
4	95	2016-10-10 10:06:35 AM	00:00:02	00:04:04	39
4	152	2016-10-10 10:06:39 AM	00:00:03	00:04:08	40
4	168	2016-10-10 10:06:41 AM	00:00:02	00:04:10	41
4	81	2016-10-10 10:06:49 AM	00:00:07	00:04:18	42
4	172	2016-10-10 10:06:55 AM	00:00:03	00:04:24	43
4	141	2016-10-10 10:07:12 AM	00:00:16	00:04:40	44
Fingerprint Scanning WEEK 4 Class TOTAL:			**00:03:10**	**00:04:40**	**44**

WEEK	**Student Scan Time Total Per week**	**Class Scan Time Total Per week**	**Student Count**	**Average sec per Student Scan**	
1	00:03:24	00:04:22	44	4.64	
2	00:03:15	00:05:30	44	4.43	
3	00:02:57	00:03:41	44	4.02	
4	00:03:10	00:04:02	44	4.32	
Average:	**00:03:11**	**00:04:24**	**44**	**4.35**	
TOTAL:	**00:12:46**	**00:17:35**			

ANNEXURE J: STUDENT SCANNING PERFORMANCE BY STANDARD DEVIATION – BARCODE SCANNER

BARCODE SCANNER DATA - Scan time per student (seconds)					**Barcode**	
Student ID	Week 1 Scan Time	Week 2 Scan Time	Week 3 Scan Time	Week 4 Scan Time	Standard Deviation	
81	3	2	2	2	0.433	19%
95	1	1	1	1	0.000	0%
100	2	1	2	1	0.500	33%
101	4	1	1	1	1.299	74%
102	2	1	2	1	0.500	33%
105	3	3	1	1	1.000	50%
106	2	2	2	2	0.000	0%
109	1	1	2	1	0.433	35%
112	2	2	2	2	0.000	0%
113	2	2	2	2	0.000	0%
114	1	2	0	1	0.707	71%
115	4	2	3	0	1.479	66%
117	1	4	2	2	1.090	48%
118	5	5	1	7	2.179	48%
119	2	2	2	2	0.000	0%
122	1	1	2	2	0.500	33%
128	1	1	1	2	0.433	35%
133	2	6	1	2	1.920	70%

134	2	2	1	1	0.500	33%
135	3	2	0	2	1.090	62%
137	1	2	1	2	0.500	33%
138	2	3	3	2	0.500	20%
139	3	4	1	2	1.118	45%
141	0	2	1	2	0.829	66%
142	9	1	3	2	3.112	83%
144	1	3	3	1	1.000	50%
145	1	1	1	1	0.000	0%
146	0	0	0	0	0.000	0%
147	1	0	1	1	0.433	58%
148	2	0	1	1	0.707	71%
149	2	2	1	2	0.433	25%
151	4	2	2	2	0.866	35%
152	2	2	3	1	0.707	35%
160	4	1	2	2	1.090	48%
164	1	1	2	0	0.707	71%
165	2	3	2	3	0.500	20%
168	2	1	3	1	0.829	47%
169	3	1	2	2	0.707	35%
170	8	1	2	2	2.773	85%
172	4	2	2	2	0.866	35%
173	1	1	1	1	0.000	0%

174	7	3	1	2	2.278	70%
175	2	2	6	1	1.920	70%
177	1	1	3	2	0.829	47%
Average	**2.43**	**1.86**	**1.75**	**1.64**	**0.84**	**40%**

ANNEXURE K: STUDENT SCANNING PERFORMANCE BY STANDARD DEVIATION – RFID SCANNER

RFID SCANNER DATA - Scan time per student (seconds)					**RFID**	
Student ID	Week 1 Scan Time	Week 2 Scan Time	Week 3 Scan Time	Week 4 Scan Time	Standard Deviation	
81	2	2	1	3	0.707	35%
95	1	0	1	1	0.433	58%
100	1	1	2	1	0.433	35%
101	2	1	2	1	0.500	33%
102	2	1	2	0	0.829	66%
105	3	2	2	2	0.433	19%
106	3	5	1	2	1.479	54%
109	1	0	2	1	0.707	71%
112	3	1	1	0	1.090	87%
113	1	1	1	1	0.000	0%
114	5	1	2	2	1.500	60%
115	0	1	0	2	0.829	111%
117	2	1	1	0	0.707	71%
118	2	0	2	1	0.829	66%
119	2	4	3	2	0.829	30%
122	2	0	0	3	1.299	104%
128	1	1	1	1	0.000	0%
133	1	2	2	1	0.500	33%

134	0	1	2	1	0.707	71%
135	4	2	1	2	1.090	48%
137	1	1	1	1	0.000	0%
138	0	0	1	0	0.433	173%
139	0	1	1	1	0.433	58%
141	3	1	2	2	0.707	35%
142	2	1	1	1	0.433	35%
144	1	1	1	1	0.000	0%
145	2	2	2	2	0.000	0%
146	26	0	0	2	11.000	157%
147	2	2	4	2	0.866	35%
148	2	1	1	0	0.707	71%
149	3	1	1	0	1.090	87%
151	1	1	3	2	0.829	47%
152	1	1	2	1	0.433	35%
160	2	2	1	1	0.500	33%
164	1	1	2	4	1.225	61%
165	2	2	2	0	0.866	58%
168	1	3	1	1	0.866	58%
169	3	1	1	2	0.829	47%
170	1	1	2	2	0.500	33%
172	1	4	1	1	1.299	74%
173	1	1	2	2	0.500	33%

174	4	3	3	1	1.090	40%
175	6	1	1	0	2.345	117%
177	1	1	0	1	0.433	58%
Average	**2.39**	**1.36**	**1.48**	**1.30**	**0.96**	**55%**

ANNEXURE L: STUDENT SCANNING PERFORMANCE BY STANDARD DEVIATION – FINGERPRINT SCANNER

Finger Print SCANNER DATA - Scan time per student (seconds)					**Finger Print**	
Student ID	Week 1 Scan Time	Week 2 Scan Time	Week 3 Scan Time	Week 4 Scan Time	Standard Deviation	
81	3	5	3	7	1.658	37%
95	3	2	2	2	0.433	19%
100	6	2	3	2	1.639	50%
101	3	2	3	3	0.433	16%
102	3	5	5	7	1.414	28%
105	4	3	3	3	0.433	13%
106	4	3	6	3	1.225	31%
109	2	5	3	2	1.225	41%
112	3	11	5	3	3.279	60%
113	2	3	2	6	1.639	50%
114	3	4	2	3	0.707	24%
115	2	6	2	2	1.732	58%
117	7	3	2	3	1.920	51%
118	5	3	2	4	1.118	32%
119	4	2	8	4	2.179	48%
122	2	2	7	5	2.121	53%
128	2	2	1	2	0.433	25%
133	34	10	4	9	11.627	82%

134	2	2	2	3	0.433	19%
135	2	7	4	3	1.871	47%
137	3	2	11	4	3.536	71%
138	8	3	2	8	2.773	53%
139	3	4	3	4	0.500	14%
141	12	29	9	16	7.632	46%
142	6	3	4	3	1.225	31%
144	2	2	2	3	0.433	19%
145	3	2	3	3	0.433	16%
146	15	0	0	0	6.495	173%
147	2	2	2	7	2.165	67%
148	3	5	4	3	0.829	22%
149	5	4	15	20	6.745	61%
151	2	11	9	6	3.391	48%
152	6	3	3	3	1.299	35%
160	3	3	5	2	1.090	34%
164	4	2	3	5	1.118	32%
165	3	3	3	4	0.433	13%
168	3	2	2	2	0.433	19%
169	2	5	3	4	1.118	32%
170	4	6	3	3	1.225	31%
172	3	3	4	3	0.433	13%
173	5	3	3	2	1.090	34%

174	5	4	4	5	0.500	11%
175	3	5	7	2	1.920	45%
177	3	7	4	2	1.871	47%
Average	**4.64**	**4.43**	**4.02**	**4.32**	**1.96**	**40%**