DURBAN UNIVERSITY OF TECHNOLOGY

Intelligent Decision Support Systems for Managing the Diffusion of Social Computing in School-Based Ubiquitous Learning

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A thesis submitted in fulfilment of the requirement for the Doctor of Philosophy in Information and Communications Technology

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2021

DECLARATION

I, *Caitlin Sam*, declare that:

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Signature: *Caitlin Sam*

Date: 10 April 2021

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ACKNOWLEDGEMENTS

I would like to give thanks to my God, Jesus Christ for the strength and will to face life's adversities. My accomplishments would have never been realised if not for you. In my oasis of despair, you were and are my salvation and my joy.

It gives me immense pleasure to acknowledge my research supervisor, Dr N. Naicker, for the relentless supervision provided to me throughout this journey. You have made my research experience transcendental to say the least. Special thanks to my co-supervisor, Dr M. Rajkoomar for the insightful guidance she afforded me since the inception of this research.

My utmost gratitude to my parents Allen Sam and Arlene Sam, for their love, empathy, motivation, and tolerance provided to me during the course of this study and beyond. I love you with my entire heart and I will spend a lifetime repaying all that you have bestowed upon me. "I am everything born of your guidance." ~Richelle E. Goodrich.

My heartfelt thanks to my best friend and soulmate Lorraine Lin for encouraging me to do my PhD, and for her love and encouragement in the completion of my studies. Many thanks to Deborah Nomlala, Shoval Pillay, Annette Pather, Kerry Dawson, Rosa Naidoo, and Melissa Gouws for their friendship and personal assistance during this tumultuous period of study.

My sincere appreciation to the senior management, staff, learners, and parents of Curro Heritage House for their support during my years of study.

Finally, I convey my appreciation to the academic staff of the Durban University of Technology for their unyielding assistance and guidance during my study.

"Calamity propelled me into the role of a lifetime…the day I became my beau ideal."
~ Caitlin Sam

ABSTRACT

The past decade has seen an explosion in social media applications. Most adolescents in South Africa have access to social media applications despite the country's economic inequalities. The drive for social media applications is important to enhance human connectedness. In unprecedented times social computing can be utilised in school-based learning to benefit learners. Climate change has propagated extreme weather patterns which has increased the occurrence of natural disasters and diseases. The emergence of the novel Coronavirus resulted in most countries implementing nation-wide forms of lockdown to curb the spread of infection. Consequently, these adverse phenomena across the globe are disruptive to conventional school-based education. Ubiquitous learning (u-learning) relates to learning that occurs at any place without time constraints. In some schools, u-learning has become a conventional learning approach and pedagogy but there are various education and technology attributes that must be addressed for the penetration of social computing in schools. Therefore, there is a need to guide learners and school-based instructors on their preferences of digital access and social media applications. The main aim of the study was to investigate social media-driven Intelligent Decision Support Systems using live data, to assist instructors and learners manage the diffusion of social computing in school-based ubiquitous learning. In pursuing this study, a quantitative research methodology was used for the collection of data from learners and instructors from the schools in the eThekwini Region, namely, Umlazi District and Pinetown District of KwaZulu-Natal Province, South Africa. A survey was conducted to elicit data from participants on their use of social computing for u-learning. The approximate target population size was 129 421 individuals with a sample size of 384 participants. There were 260 respondents with an acceptable response rate of 67,71%. The study derived attributes for ranking the social media applications and Principal Component Analysis which is an unsupervised Machine Learning algorithm reduced the dimensionality of the attributes. The multi-criteria decision-making algorithm, Fuzzy Technique of Order Preference Similarity Ideal Solution was implemented to rank the social media applications in line with the dimensionality reduced criteria based on the subjective decisions of expert decision makers. Data Envelopment Analysis, another multi-criteria analysis method was utilised to score the efficiency of the devices for u-learning. The results showed the most precise, mathematically approved social media applications and devices that can support u-learning in schools. An automated application based on research evidence using Intelligent Decision Support Systems was designed as a research output.

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LIST OF ACRONYMS AND ABBREVIATIONS

The most important and frequently used acronyms in this study are listed below:

AI	: Artificial Intelligence
DEA	: Data Envelopment Analysis
DMU	: Decision Making Unit
e-Learning	: Electronic Learning
ERD	: Entity Relationship Diagram
FNIS	: Fuzzy Negative Ideal Solution
FPIS	: Fuzzy Positive Ideal Solution
Fuzzy TOPSIS	: Fuzzy Technique of Order Preference Similarity to the Ideal Solution
ICASA	: Independent Communications Authority of South Africa
IDSS	: Intelligent Decision Support Systems
IDT	: Innovation Diffusion Theory
IT	: Information Technology
IS	: Information Systems
LMS	: Learning Management System
MCDM	: Multiple Criteria Decision Making/ Multi-Criteria Decision-Making
m-Learning	: Mobile Learning
PC	: Principal Component
PCA	: Principal Component Analysis
PRISMA	: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SA	: South Africa
SIMM	: Strategic Innovation Management Model
SM	: Social Media
SVD	: Singular Value Decomposition
ULE	: Ubiquitous Learning Environment
u-Learning	: Ubiquitous Learning
UML	: Unified Modelling Language

LIST OF TERMINOLOGY

The following terminology are defined for this study:

Alternatives**:** the list of options from which decision makers choose. In terms of Fuzzy TOPSIS, it is the social media applications; and in terms of DEA, it is the different types of devices.

Benefit Criteria**:** the output criteria in the DEA method, which is advantageous to the decision maker and is used to determine the efficiency of the devices for u-learning.

Closeness Coefficient**:** how close the distance of an alternative is from the ideal solution in Fuzzy TOPSIS.

Connectivism**:** a theoretical framework for comprehending how learning happens with internet technologies.

Cost Criteria**:** the input criteria in the DEA method which is non-beneficial to the decision maker and is used to determine the efficiency of the devices for u-Learning. It is the cost required to reap the benefits of using the product.

Criteria**:** standards or principles by which something is decided or judged.

Data Envelopment Analysis**:** a benchmark MCDM analysis method for scoring the efficiency of a product.

Decision makers**:** the stakeholders who are direct users of the product and who have an opinion on the product's efficiency.

Decision Making Units**:** the features that are used to score the efficiency of devices for u-learning.

Decision Theory**:** a theoretical framework that determines the optimal decision or investigates the outcomes of a decision.

***Device*:** is a medium for digital access to the internet.

***Education Requirements*:** criteria of social media applications and devices that are specific to education or are required for the fulfilment of the school curriculum.

***Fuzzy TOPSIS*:** a MCDM tool employed for ranking various alternatives using numerous selected criteria to resolve problems requiring multiple decision-making processes.

***Innovation Diffusion Theory*:** is a theoretical framework that investigates how ideas diffuse among people. It focuses on the reasons for and the likelihood of an innovation, product, or a new idea being adopted by people.

***Principal Component Analysis*:** a dimensionality reduction method to reduce the high dimension data space into a smaller dimension data space that is typical of the original data.

***Social Computing*:** the utilisation of social media application and devices by learners and school-based instructors. It is a field of computer science that involves the convergences of computational systems and social behaviour. It focuses on developing social contexts and conventions with the employment of technology and software.

***Social Media Applications*:** applications that can be downloaded and used on devices. They are usually employed for instant messaging, media creating and sharing, voice and video calling, and publishing interactive content.

***Technology Criteria*:** the criteria of the social media applications and devices that are specific to the technical aspects to be investigated.

***u-Learning*:** is an amalgamation of m-learning and e-learning which endeavours towards 'anytime and anyplace' teaching and learning.

CHAPTER ONE: INTRODUCTION TO STUDY

1.1 Introduction

Over the past twenty years, the traditional communication technologies such as email or landline telephones have been superseded by global networked digital connectedness. In the past ten years, the upsurge of social media or Web 2.0 technologies, has manifested an interconnected world influencing how people collaborate and communicate with each other and how they manage the myriad information around them (Gupta 2018; Zgheib and Dabbagh 2020: 50) that can be explained by the Connectivism Theory (Siemens 2005: 2). Recent statistics have shown that from the 36,4 million people using internet in South Africa, approximately 22 million people have social media accounts (Statista 2020a). The numerous characteristics of social media applications have propagated the plethora of social media platforms which are categorised as media sharing tools, resource and experience sharing tools, communication tools, and social networking tools (Zgheib and Dabbagh 2020: 51).

Social computing is the collective term for social media applications along with the devices they operate on. Social computing is a novel paradigm of technology development and computing and concerns systems that encourage the processing, representation, gathering, dissemination and use of information that is shared among social collectives of people (Mao and Wang 2012: 61). In social computing, human social dynamics and social studies are computationally facilitated by the design and use of communication technologies and information within a social context (Posard and Rinderknecht 2015: 235). Social software such as emails, instant messaging, blogs, social networking services, social bookmarking, and wikis, along with other technologies create and recreate social contexts and social conventions (Mao and Wang 2012: 62). Research in social computing assists our understanding and analysis of individual and organisational behaviour, namely, businesses or institutes of learning (Rachael and Wagner 2005: 221).

Learners are fascinated by social media applications (Shava and Chinyamurindi 2018: 2) which can be explained by the juvenile brain having a delicate nucleus accumbens. Studies have shown that adolescents' use of social media applications activate the reward circuitry of their brain, a function of the nucleus accumbens, more than in adults. Research has also found social media applications stimulate the social brain and the part of the brain is related to visual attentiveness (Wolpert 2016). Additionally, a fascinating fact is that of the twelve million

Facebook users in South Africa, no less than a fifth of that population comprise adolescents between the age range of 13 to 18 years (Shava and Chinyamurindi 2018: 1; BusinessTech 2019).

Climate change is the principal issue of our era that has propagated unstable weather patterns resulting in natural disasters (Kramer and Ware 2019: 1-24). Climate change also increases the occurrence of infectious diseases (Patz *et al.* 2000: 1396; World Health Organization 2020). Towards the end of 2019, a collection of pneumonia cases in China was related to a novel Coronavirus. It swiftly spread in 2020, giving rise to an exponential number of cases in other countries globally, including, South Africa (McIntosh 2020). The spread of the virus has since been declared a pandemic based on the Disaster Management Act of South Africa and a National State of Disaster followed. This resulted in an enforced nation-wide lockdown as decided upon by The National Coronavirus Command Council. Subsequently, schools among other organisations, were closed to mitigate the impact of the pandemic (Government of South Africa 2020). The challenge lay in continuing the delivery of the school curriculum without face-to-face classroom interactions. A short-term solution for well-resourced schools in South Africa was to implement remote teaching and learning with the Learning Management Systems already in place (Kolo and Zuva 2018: 1-2). Subsequently, the COVID-19 pandemic and the resulting levels of the lockdown increased the need for feasible electronic learning.

A sudden change from conventional teaching to electronic learning is an imperfect solution (Miller 2020: 3-4). According to Anstey and Watson (2018: 1-9), the numerous technology criteria of the electronic learning tools must first be addressed such as technical complexity, and technical compatibility. Additionally, there are various education requirements that needed to be considered when implementing an electronic learning tool such as the relative advantage or ease of use. The notion of aligning the technology criteria and education requirements with electronic learning can be verified with the Innovation Diffusion Theory (Lee, Hsieh and Hsu 2011: 125).

Considering the technology criteria and education requirements previously mentioned, there is a greater demand for learners to access learning resources ubiquitously (Mishra, Yadav and Choudhary 2013: 66) and a robust solution will not be necessitated by a single online learning platform (Gupta 2018: 303). Social media has become essential in today's learning environments with their emphasis on content distribution, user generated content, collaboration and personalisation, (Shava and Chinyamurindi 2018: 4).

Ubiquitous learning describes an environment of learning that facilitates access to learning and teaching contents via wireless networks using digital access regardless of time or place (Jaiswal 2012: 198). The characteristics of ubiquitous learning are universal accessibility to learners; permanency where unless removed by learners, the information remains; immediacy where the content is instantly acquired by the learners; context-awareness where context-aligned information is offered to learners by adaption of the learning environment; and interactivity which facilitates learners interaction with experts, teachers and peers effectively and efficiently via multimedia (Ogata and Yano 2004: 27-28; Chiu *et al.* 2008: 79; Yahya, Ahmad and Jalil 2010: 120-121).

Ubiquitous learning is founded on the Connectivism Theory which emphasises that learning and knowledge are not located in any specific place but are distributive and comprise a network of connections created from interactions and experiences and with an informed community (Kim, Caytiles and Kim 2012: 5). The connection between digital access and the computers embedded in the environment connects and permits learning in a world that stimulates and keeps learners' interest while they are moving. Hence, social computing can easily infiltrate educational environments of learners (Kim, Caytiles and Kim 2012: 5).

However, it is a mammoth task to make decisions that encourage ubiquitous learning with the surplus of social media applications, the varying characteristics of each, and the devices on which they optimally operate. In the current study, the choice of the Decision Theory was justified as the basis of the theoretical framework due to Multi-Criteria Decision-Making tools being simulated on Intelligent Decision Support Systems for managing the diffusion of social computing in u-learning at schools. The overarching theoretical frameworks used to guide the simulation of the Intelligent Decision Support Systems were the Decision Theory, Innovation Diffusion Theory and the Connectivism Theory as school-based instructors and learners require support in their choice of devices and social media applications to promote ubiquitous learning. An automated software application using Intelligent Decision Support Systems ensure that educationally sound social media applications and technology compliant digital access would permeate school-based ubiquitous learning. A literature search revealed that no research studies were conducted internationally or locally relating to this topic. Therefore, this study addressed the complexities involved in arriving at a decision to help schools manage social computing diffusion for school-based ubiquitous learning.

1.2 Statement of the Problem

Schools are evolving to become resilient with digital technologies as a response to the many social crises and natural disasters faced in the 21st century. These global adverse phenomena include cyclones, earthquakes, tsunamis, floods, and wildfires (Kramer and Ware 2019: 1), not forgetting the most recent pandemic of the novel Coronavirus (McIntosh 2020). Reacting to such catastrophes, school-based learning has experienced an acceleration in the education and digital technologies co-evolution (Ayebi-Arthur 2017: 260). A disaster may be viewed as an unprecedented occurrence, but it also presents an opportunity to achieve technological, organisational, and cognitive benefits. Schools must be equipped to respond to crises such as the partial or complete lockdown of school-based institutions. The closing of doors does not necessarily infer the downing of tools as society needs to adapt flexibly and creatively into virtual environments when traditional operations are disrupted (Ayebi-Arthur 2017: 261).

Ubiquitous learning (u-learning) presents a solution to emergency remote learning where a learning environment can be any setting which allows learners to become completely submerged in the process of learning (Shanmugapriya and Tamilarasi 2011: 22-23). u-Learning includes electronic learning (e-learning), mobile learning (m-learning), mobile devices, wireless technologies, and social networking technologies (Lee, Hsieh and Hsu 2011: 129). According to Elkaseh, Wong and Fung (2016: 193), the propelling reasons for social computing adoption are the convenience of social technologies, functionality, and the progressively ubiquitous access.

The value of social media (SM) in education has been echoed throughout literature over the past decade (Zgheib and Dabbagh 2020: 50-53). Each u-learning appropriate SM application has characteristics that are advantageous and disadvantageous which must be known before integrating them into lessons (Sirait *et al.* 2018: 161-163). Such characteristics and features are broadly classified as technology criteria and education requirements which require engagement by the instructor to achieve the learning objectives of the lesson (Anstey and Watson 2018: 1-9). These criteria also lend themselves to the devices that serve as the operational interface of

SM applications. The choice of SM applications and devices for u-learning presents an enormous undertaking for learners and school-based instructors. Therefore, there is a need to simulate Intelligent Decision Support Systems (IDSSs) to assist instructors and learners manage the diffusion of social computing in school-based u-learning as this would optimise the selection process of the most beneficial SM applications and predominant devices for u-learning.

Previous studies focused on the e-participation of higher education students in government using SM (Sirait *et al.* 2018: 158); and on the increase of engagement of higher education students within the university using SM (Meyliana, Hidayanto and Budiardjo 2015: 1676). Although studies involved the quantitative assessment of SM applications, the studies were internationally based, involved higher education institutions, and employed Technique of Order Preference Similarity to the Ideal Solution (TOPSIS) to investigate SM preference (Meyliana, Hidayanto and Budiardjo 2015: 1676-1679; Sirait *et al.* 2018: 158-163). A literature search revealed that no research studies were conducted internationally or locally relating to the use of IDSSs for the management of social computing diffusion in school-based u-learning which invokes the need for the current study. Furthermore, the criteria for the selection of social computing applications and devices for school-based learning could help instructors align lesson plans with these criteria in mind thereby enhancing their pedagogy.

It is necessary for instructors to be effectively trained to teach with technology and to successfully implement e-learning. Instructors must also teach learners how to use the e-learning application or platform which according to Woodcock, Sisco and Eady (15: 21-34) is a time consuming and costly process. As learners are already proficient in social computing, its use in u-learning has the potential to eliminate the time that it would take to train instructors and learners to use the e-learning applications which advocated for such a study to be carried out.

A literature review reflected a divergence between instructors' and students' views on the practice of social computing in higher education. Instructors have shown scepticism whilst students have shown eagerness towards the use of social computing in education. Instructors' reluctance has been largely based on their perception of social computing as being an unprofessional means of curriculum delivery and that communication via social computing might negatively impact on their authority over learners (Ndyalivana 2018: 157). Hence, there is a need to conduct a study that outlines the importance of social computing in u-learning as this could alter perceptions of instructors and change school policy on the employment of social computing in education.

Although well-resourced South African schools already have Learning Management Systems (LMSs) in place, most state-owned schools lack the capacity and resources to go online with LMS's which require broadband connectivity (Sokutu 2020). While internet connectivity is relatively slow compared to first world countries, South Africa (SA) has telecommunication networks similar to that of industrialised countries (Shava and Chinyamurindi 2018: 6). Studies revealed that SM and mobile phone access in rural areas has never been a problem due to the "sharing behaviour" of South Africans. This "sharing behaviour" entails the sharing of devices in rural areas (Dalvit and Strelitz 2013: 76). In addition, the latest report by the Independent Communications Authority of South Africa (ICASA) revealed that network coverage in rural South African areas was above 90% (Francis 2019), which could be seen to facilitate the use of social computing for u-learning. Therefore, there is potential to resolve the disparities of bandwidth or connectivity in remote learning and teaching in all South African schools by conducting a study which ranks and scores the social computing applications and devices, respectively.

1.3 Aim and Objectives

The aim of the study is to investigate social media-driven Intelligent Decision Support Systems using live data, in order to assist instructors and learners manage the diffusion of social computing in school-based ubiquitous learning.

Aligned with the aim of the research the following research objectives [ROs] were set:

[RO 1]: Determine the extent to which social computing could be used for school-based ubiquitous learning.

[RO 2]: Ascertain the most pertinent criteria of social media applications for ubiquitous learning.

[RO 3]: Select the optimal social media applications for ubiquitous learning using Multi-Criteria Decision Making with live data.

[RO 4]: Determine the efficiency of devices used for ubiquitous learning using multi-criteria decision analysis with live data.

[RO 5]: Design an automated application using Intelligent Decision Support Systems based on research evidence.

1.4 Significance of the Study

The significance of this study was to:

1. Use Fuzzy TOPSIS as a novel method to assist making intelligent decisions on several SM applications. Simulated a real-life IDSS using a programming language with live data.
2. Create an innovative intelligent decision support system utilising DEA to ensure the use of the most proficient digital access in times when u-learning is gaining momentum. Simulate a real-life application using a programming language with live data.
3. Ensure cost efficiency and optimisation of social computing in u-learning. This system was based on impacting factors from the research to support school policy makers in preferences for u-learning.
4. Design a real-life application using an ensemble of Fuzzy TOPSIS and Data Envelopment Analysis as an intelligent decision support system for school decision makers to utilize when confounded by choices for u-learning. These scientific techniques implemented concurrently within a single application would ensure efficiency in u-learning.

1.5 Scope and Delimitations of Study

The main delimitation for this study was the fact that the current study focused on school-based education. The preferences of SM applications and digital access were elicited from high school learners due to their age-related cognition to answer the questionnaire and their parental permission to engage with social computing. The approximate target population size was 129 421 learners and instructors in the eThekwini region of KwaZulu-Natal Province, SA and the sample population was restricted to 384 participants. Another limitation of using a questionnaire was the limited control that the researchers had over the time taken by respondents to complete the questionnaire (Saunders, Lewis and Thornhill 2012: 326).

1.6 Research Output

The following Department of Higher Education and Training (DHET) approved journal publications were published from this research study:

1. Sam, C., Naicker, N. and Rajkoomar, M. 2020. **Meta-analysis of artificial intelligence works in ubiquitous learning environments and technologies**. *International Journal of Advanced Computer Science and Applications*, 11 (9): 603-613. DOI: http://dx.doi.org/10.14569/IJACSA.2020.0110971.

This publication provided a systemic review and meta-analysis of the artificial intelligence works in u-learning environments and technologies which served to map out the terrain for the current study. Additionally, it analysed and highlighted the specific application areas of leading artificial intelligence algorithms in u-learning for this study.

2. Sam, C., Naicker, N. and Adebiyi, M. 2021. **Dimensionality reduction of social media application attributes for ubiquitous learning using principal component analysis**. *Mobile Information Systems*, 2021: 1-10. DOI: https://doi.org/10.1155/2021/6633223.

This research paper established the most crucial and high impacting criteria to evaluate SM applications for school-based u-learning to cater for Research Objective 2 in the current study.

3. Sam, C., Naicker, N. and Rajkoomar, M. 2021. **Selection of social media applications for ubiquitous learning using fuzzy TOPSIS**. *International Journal of Advanced Computer Science and Applications*, 12 (2): 231-239.
   DOI: http://dx.doi.org/10.14569/IJACSA.2021.0120230.

This publication established the most relevant and beneficial SM applications for u-learning in a South African schooling context using fuzzy TOPSIS which satisfies Research Objective 3 of the current study.

1.7 The Research Process Model

Figure 1.1 serves as an outline and guide for upcoming chapters and the research process.

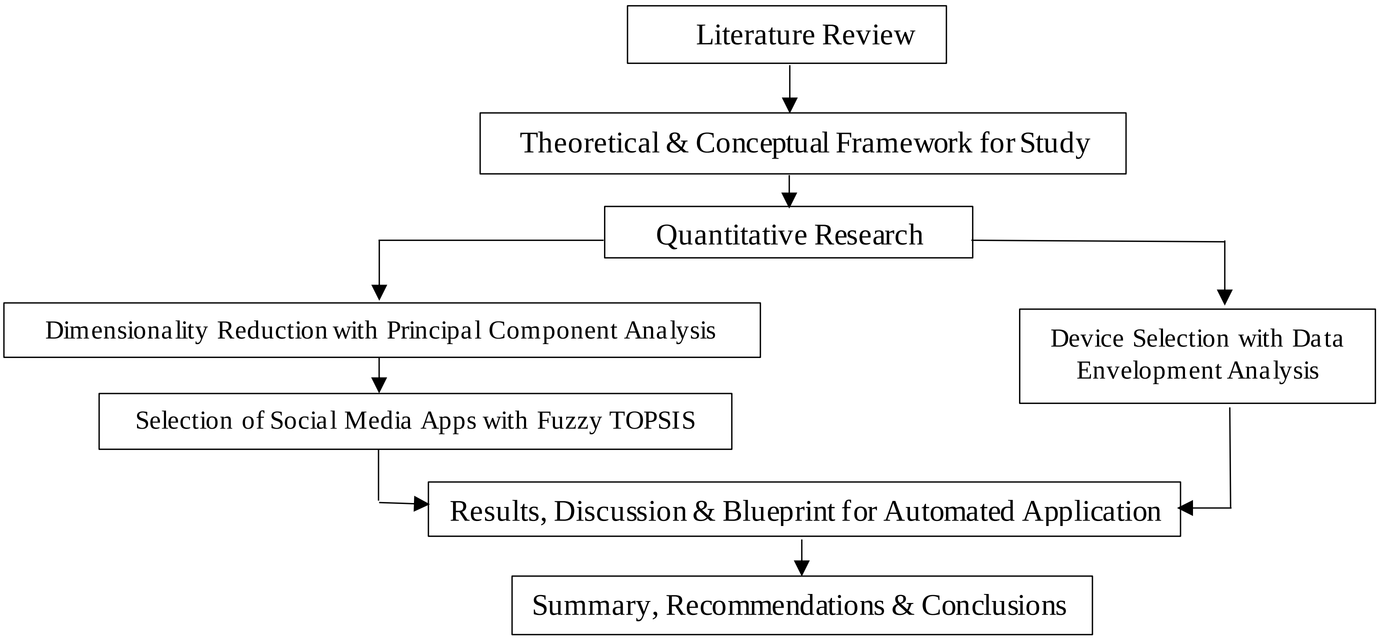

Figure 1.1: Study Process Model

Source: Researcher's own construction

A research project plan is presented in Annexure A which gives the approximate duration of each research task to be fulfilled.

1.8 Structure of the Thesis

This study is documented in eight chapters, which are arranged in the following manner:

Chapter One: Introduction to Study

Chapter One provides the study's context and clearly explains the problem statement. The aim, research objectives, and significance of the study are stated. Integral study concepts such as IDSS and u-learning are defined, and the main concepts covered by the research are provided.

Chapter Two: Literature Review

Chapter Two presents a crucial and comprehensive analysis of the literature on the proliferation of SM, learner gravitation towards SM, the myriad SM application, climate change and unprecedented times, greater reliance on u-learning, technology criteria, education requirements, and device choices. Additionally, literature on IDSS such as Principal Component Analysis (PCA), Fuzzy TOPSIS, and DEA are discussed.

Chapter Three: Theoretical Frameworks and Conceptual Model

Chapter Three discusses the Connectivism Theory, the Innovation Decision Theory and the Decision Theory and links these theories to the research objectives. An emergent theory called the Strategic Innovation Management Model is developed based on the Decision Theory and the Innovation Decision Theory. The pyramid framework in this chapter shows the thread of theories in the study.

Chapter Four: Research Design

Chapter Four elucidates how the quantitative research methodology was employed and how the questionnaire was administered to the respondents, i.e. instructors and learners from schools in the KwaZulu-Natal Province, particularly, two districts (Umlazi and Pinetown) in the eThekwini Region. The chapter also comprehensively described the methods and instruments of data collection that were utilised to collect data from respondents.

Chapter Five: Strategic Decision-Making Methods – A Scientific Approach

Chapter Five discusses the scientific tools and techniques used in this research study. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), and Document Analysis are discussed considering their use in eliciting the criteria for SM applications and devices, respectively. The PCA is elucidated with regards to reducing the dimensionality of variables in the project. Fuzzy TOPSIS is described in detail for making decisions with multiple criteria regarding the hierarchical ordering of SM applications for u-learning. The DEA is presented and used to illustrate the efficiency of devices in u-learning.

Chapter Six: Results and Discussion of Strategic Decision-Making Methods

Chapter Six delivers the results of the PCA and reviews the steps involved in the dimensionality reduction of the attributes of SM applications. The results of Fuzzy TOPSIS are presented and discussed using the steps of the algorithm. The efficiency of devices used for u-learning is assessed using DEA. Thereafter, the chapter presents the results of the DEA and provides a discussion using intermediate matrices of the DEA algorithm. The chapter also reveals the results relating to respondents' digital access.

Chapter Seven: Results and Discussion of Survey and Blueprint for an Automated Evidence-Based Application

Chapter Seven gives the biographical data results of the survey along with results of the education requirements and technology criteria. The results are analysed and explanations of the results are provided. The design for an evidence-based automated application using the IDSSs, Fuzzy TOPSIS and DEA founded on the impacting technology criteria and education requirements to support end-users (learners and school-based instructors) is presented using screen mock-ups.

Chapter Eight: Summary, Recommendations, and Conclusions

Chapter Eight summarises, concludes, gives implications of the study, recaps the significant contributions to the body of knowledge, details the implications of the study, states the limitations of the study and provides considerations for future work.

1.9 Chapter Summary

Chapter One put into place the current global education context with regards to technology use during normal and unprecedented times. U-learning was briefly defined, and the associated theoretical frameworks such as IDT, the Connectivism Theory, and Decision Theory were outlined. The context of most South African schools was that learners have access to SM applications which could support and promote successful u-learning diffusion. However, due to the plethora of SM applications and the various education requirements and technology criteria, it is difficult for learners and school-based instructors to make intelligent and practical decisions; hence, there is a need for IDSSs. The research aim, and objectives were discussed along with the significance of the study. The aim of the study is to investigate social media-driven Intelligent Decision Support Systems using live data, in order to assist instructors and learners manage the diffusion of SM applications and devices in school-based u-learning. Lastly, the scope and delimitations, the research outputs, and the organisation of the thesis were delineated. In Chapter Two, a critical review of literature that is applicable to the current study is presented along with the terminologies, the theoretical milieu, and criticisms.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The expansion of Information and Communication Technology innovations and the development of various applications have instituted learning environments that are digitalised. Furthermore, the establishment of a connectivism-based society has resulted in the insistence for progressive learning systems coupled with lifelong learning (Jung 2014: 97). "Ubiquitous" describes an ethos where devices help individuals with daily tasks, presenting infinite access to learning resources anytime and anywhere (Rani and Sattanathan 2017: 616). In a secondary school education setting, learners and instructors can exploit new developments in ubiquitous computing by utilising technologies and digital devices that occur ubiquitously in the learning locale. Commonly, and consistent with literature, children have ubiquitous access to mobile devices and enjoy occupying themselves with new devices and applications (Cook and Das 2012: 23; Rani and Sattanathan 2017: 616). Therefore, instructors and curriculum developers must recognise this actuality and embrace "Learning device gadgets on 21st century tools for 21st century learners" (Rani and Sattanathan 2017: 617).

Electronic learning settings are exemplified by the sharing of information via the Internet. Electronic learning can be enabled with the use of desktop computers or laptops, e-tutoring software tools, and communication and self-assessment applications, for instance forums, video calls, and chat. Mobile-learning is regarded as a division or an augmentation of electronic learning (Mellow 2005: 470-471; Rani and Sattanathan 2017: 617-618). With the employment of mobile-learning, information is recovered regardless of time (asynchronous and synchronous interactions), place (spatial mobility), and by anyone permitted to do so (individually or collaboratively) (Herrington, Herrington and Mantei 2009: 130; Rani and Sattanathan 2017: 618). The advent of High-speed Downlink Packet Access and reduced costs have propagated wide access and commercialisation of mobile internet services created on wireless broadband throughout society. This has brought about a convergence of mobile learning, electronic learning, mobile devices, social networking technologies and wireless technologies to offer ubiquitous learning availability to learners, regardless of place or time (Mishra, Yadav and Choudhary 2013: 66-68; Rani and Sattanathan 2017: 618), as depicted in Figure 2.1.

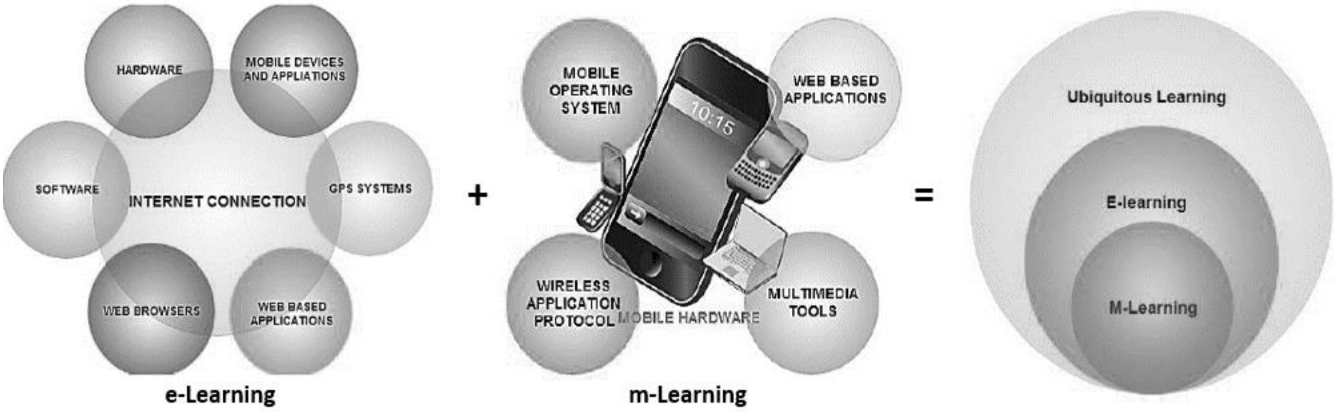

Figure 2.1: An overview of ubiquitous learning

Source: Adapted from Mishra, Yadav and Choudhary (2013: 61-63).

This chapter is presented using a funnelling of concepts as described in Figure 2.2 which outlines the literature review on the elements of ubiquitous learning.

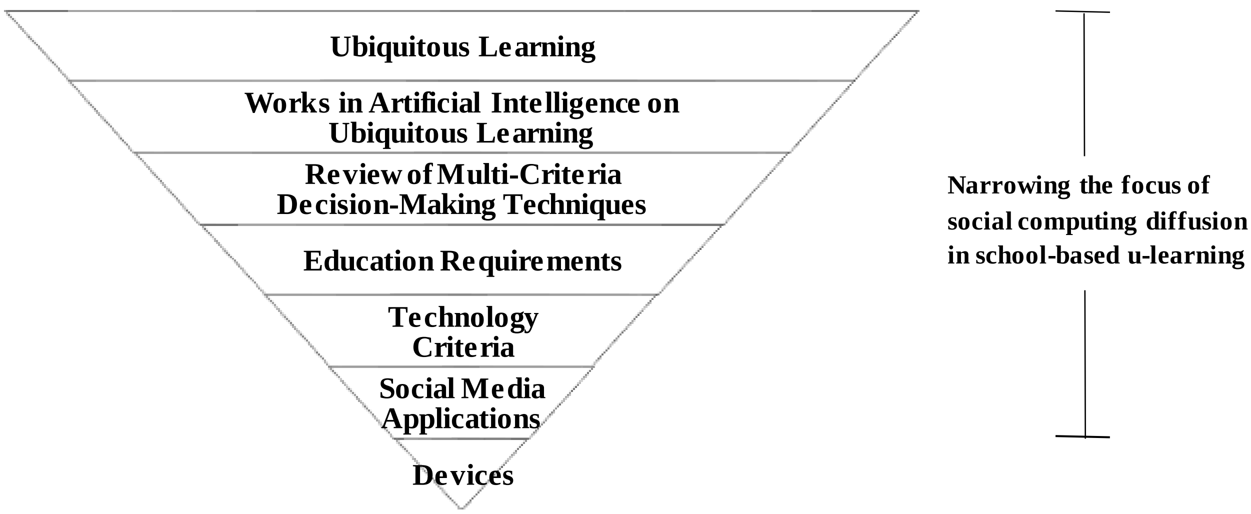

Figure 2.2: Outline of Literature Review

Source: Researcher's Construction

Figure 2.2 shows how the literature review starts very broadly with ubiquitous learning and subsequently narrows the focus to create more depth in the research.

2.2 Ubiquitous Learning

Ubiquitous Learning (u-learning) is founded on the Connectivism Theory which emphasises that learning, and knowledge are not located in any specific place but are distributive and comprise a network of connections created from interactions and experiences within an informed community (Kim, Caytiles and Kim 2012: 1-2). The connection between the devices and environment embedded computers, allows learners to learn in an environment in which they are engrossed whilst commuting. Social media (SM) applications facilitate this by linking the learning environment to learners (Kim, Caytiles and Kim 2012: 4). Each major SM application suitable for u-learning has various features which are widely categorised as technology criteria and education requirements that require probing by the instructor for it to correspond with the lesson outcomes (Anstey and Watson 2018: 1).

2.3 Application of Artificial Intelligence on Ubiquitous Learning

Education systems across the world have become progressively co-dependent on technology. It is therefore essential to explore scientific works in u-learning to comprehend its influence on the evolution of technology for learning and pedagogy. A meta-analysis and systematic review can assess what research has been performed and elucidate gaps for future studies to be conducted. A meta-analysis involves a statistical way of incorporating various studies in a field of research. A systematic review affords a high-level, objective synopsis of the research topic from inception until present-day (Tabuenca, Wu and Tovar 2019: 10-14; Sam, Naicker and Rajkoomar 2020: 603).

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) technique was employed to mine the articles related to Artificial Intelligence (AI) in the current study. The research articles were broadly sourced from commonly employed databases, namely, Springer Link, Science Direct, Academia, Semantic Scholar, and IEEE. The PRISMA had two main objectives in this study: 1. exhibit the advancement of u-learning's AI works to delineate the landscape for potential scientific studies; 2. analyse and emphasise particular application areas of leading AI algorithms in u-learning. The study analysed various AI works in u-learning technologies and environments founded on the four key scientific approaches, namely Educational Data Mining (EDM), Intelligent Decision Support Systems (IDSS), Machine Learning (ML), and Intelligent Systems which are briefly outlined in this section.

It is evident that technology has altered the learning terrain and that learning is enriched by various approaches to education. The acceptance of new technology, for example the use of electronic books (e-books) by learners, is important in Malaysia. The study by Elyazgi *et al.* (2016: 11), outlined the importance of technology acceptance by school children in Malaysia. The study discovered the Children Computer Interaction (CCI) interface factors and the usability factors steering the acceptance behaviour of e-books by 417 school children. With the amalgamation of the Technology Acceptance Model (TAM) and the literature relating to the e-book technology, the research hypotheses were generated from the interrelatedness of a comprehensive set of constructs (Elyazgi *et al.* 2016: 22-23). A structured questionnaire consisting of a five-point Likert scale quantified the measurement framework which was built on the research hypotheses. The significance of the interface factors was deduced using Technique of Order Preference Similarity to the Ideal Solution (TOPSIS and the questionnaire. A data analysis revealed positive results about learner behaviour, perceived usefulness, usability, perceived ease of use, and about the interface. Through the merging of TAM factors and CCI, the results reflected that learners agreed to the utilisation of e-books. Perceived ease of use was ranked the highest whilst behaviour intention ranked the lowest. Perceived ease of use was credited to the characteristics and functions of e-books which appeared user friendly. The usability scale was significantly less than the interface scale, which suggested that learners' acceptance of e-book technology increases if it is seen as supporting higher levels of interactivity (Elyazgi *et al.* 2016: 23; Sam, Naicker and Rajkoomar 2020: 604).

El Aissaoui, Oughdir and El Allioui (2019: 1943) offered a general method for detecting learning styles related to a definite learning styles model automatically. There were two main steps in the study: 1) extracting learning sequences from students' log files on Moodle by employing web mining techniques; and 2) classifying the sequences extracted with clustering algorithms in a definite learning style model. The study was exacted using the Felder-Silverman Model (FSM), which is a classification Learning Style Model, Fuzzy C-Means (FCM-clustering algorithm), among a sample size of 1 235 university students. The K-means algorithm, FCM algorithm and the MCQ method were used to assess the goodness of approach of the study. The results reflected that this learning style model offered assurance and outperformed conventional approaches (El Aissaoui, Oughdir and El Allioui 2019: 1957; Sam, Naicker and Rajkoomar 2020: 605).

Grouping learners specifically is an important process to categorise and sort them into classes based on their abilities and interests as it promotes their academic success. This is a yearly task that can be overwhelming (Purbasari, Puspaningrum and Putra 2020: 4). The Self-Organising Map (SOM) which is a representative of an unsupervised learning algorithm and a clustering technique that employs an artificial neural network structure for dimensionality reduction of the given input, was used (Purbasari, Puspaningrum and Putra 2020: 2) to form three distinct groups from 275 school learners according to their rapport books along with their national examination results. Thus, the study found that using a decision support system can eliminate the manual grouping of learners by automating the process (Sam, Naicker and Rajkoomar 2020: 606).

It is critical for educational institutes to forecast students' academic performance as these predictions can help instructors to support students who may be at risk of not being ready to progress to the next grade at the expected time. These predictions can be accomplished by using Educational Data Mining (EDM) which combines data mining and Machine Learning (ML) (El Aissaoui *et al.* 2020: 9). The study by El Aissaoui *et al.* (2020: 9-21) recommended a ML technique called the Multiple Linear Regression (MLR) model, to build a student performance prediction model. The methodology had three steps, namely 1) using a collection of statistical analysis techniques to pre-process and analyse the attributes/variables of students; 2) employing different methods for choosing important variables; and 3) using the chosen variables to generate MLR models and implementing the technique of k-fold cross-validation for relating the academic performance of 395 students. The results reflected that the Multivariate Adaptive Regression Splines (MARS) method, outperformed the other built models (El Aissaoui *et al.* 2020: 21; Sam, Naicker and Rajkoomar 2020: 606).

The systematic literature review on AI works in u-learning focussed on the following AI methods: IDSS, EDM, Intelligent Systems, and ML. The best result was from the studies employing ML, which has earned considerable interest and intervention effects that are being assessed vary in their results. Such studies show heterogeneity regarding sample size and the selection of algorithms. However, EDM and Intelligent Systems reflected no heterogeneity and IDSSs demonstrated high heterogeneity. Studies showed that IDSSs have variant intervention effects, smaller datasets and use a smaller number of standard algorithms than ML studies. In future studies, there is scope in all areas of AI to propose solutions for use in different u-learning technologies and environments (Sam, Naicker and Rajkoomar 2020: 610). Additionally, the conducted meta-analysis provided more information to guarantee that field practitioners make educationally sound decisions on u-learning applications and that scientific researchers obtain an invaluable understanding to make improved research decisions for future u-learning trends (Sam, Naicker and Rajkoomar 2020: 612).

2.4 Review of Multi-Criteria Decision-Making Techniques

Multi-Criteria Decision Making (MCDM) techniques have been designed to rank alternatives in a preference order, choose an ideal alternative, and categorise alternatives (Mardania *et al.* 2015: 516). The MCDM techniques assist decision-making according to people's preferences when there are conflicting criteria (Ho 2008: 211; Mardania *et al.* 2015: 517). It breaks complex problems into smaller components and after making judgements and weighing considerations, the components are reassembled to offer a holistic picture to the decision makers (Mardania *et al.* 2015: 518). A set or sets of criteria are assigned values determined in intervals as cardinal or fuzzy information to deal with discrete alternatives (Mardania *et al.* 2015: 518). To resolve MCDM problems, various optimisation techniques can be employed, some of which are discussed below.

A type of decision-making approach is the Analytic Hierarchy Process (AHP) which was introduced by Saaty (1980), to decrease the intricacy of a problem system to an element system that is clear. The Eigenvector is employed to signify the ratio of priority between the elements in a hierarchical system. The Eigenvalue is used to evaluate the dual comparison matrix consistency achieved on the nominal scale (Chen 2020: 6-7). The AHP entails the hierarchical arrangement of multiple-choice criteria, evaluation of the relative weights of the criteria, comparison of each criterion's alternatives, and ranking of the alternatives based on benefits, cost and risk (Sehra, Brar and Kaur 2012: 11). With this approach, decision makers are required to make judgements on the significance in relation to each criterion and then stipulate their inclination to each criterion's alternatives. The output is ranked alternatives centred on the overall preference. The disadvantages of the AHP include its failure to manage the subjectivity and the imprecision in the process of pairwise comparison and its assignment of singular, crisp values (Sehra, Brar and Kaur 2012: 11).

Entropy is a MCDM technique adapted by Shannon (1948) from the original thermodynamic concept which serves to measure the signal uncertainty of information sources. The Entropy weight technique employs the magnitude of the entropy in the theory of information to display the uncertainty of the information (Chen 2020: 6). Information entropy measures the degree of system disorder and the amount of valuable information from the afforded data. An indicator that provides useful information is denoted by a small entropy and a large difference in value between the assessing objects on the same indicator (Chen 2020: 6). If the entropy value is larger and the difference is smaller, the corresponding weight is smaller. In simple terms the larger the dispersion degree, the larger the differentiation degree and the larger the amount of resulting information. Therefore, the Entropy Theory is an equitable method for the determination of attribute weights (Zhu, Tian and Yan 2020: 1). The weight of the attributes typifies its importance which helps decision makers make efficient decisions on the data in reasonable time (Işık and Adalı 2017: 80). A disadvantage of entropy is that its index weights can distort decision-making (Zhu, Tian and Yan 2020: 1).

TOPSIS is a MCDM technique proposed by Hwang and Yoon (1981) which is built on the notion that the optimal alternative should be furthest from the Fuzzy Negative Ideal Solution (FNIS) and the closest to the Fuzzy Positive Ideal Solution (FPIS). Alternatives are chosen based on identified criteria and their assigned weights presented as crisp numbers (Dashore *et al.* 2013: 2184). The disadvantage of TOPSIS is its inability to map the uncertain and fuzzy preferences made by decision makers into comparison ratios with crisp numerical values (Garg, Agarwal and Choubey 2015: 2).

The need for a fuzzy system is imperative to evaluate multi-criteria problems with dissonant dimensions of criteria. In Fuzzy TOPSIS, fuzzy numbers are used to make the analysis of criteria simpler for evaluation in TOPSIS (Garg, Agarwal and Choubey 2015: 2). Fuzzy TOPSIS allows for systematic and objective multi-criteria assessment of alternatives and provides a realistic and superior form of modelling compared to other ranking methods. This optimisation technique assists to reduce human efforts, by reducing the likelihood of errors in mathematical calculations using live data. Using fuzzy tools and software like MATLAB presents an ideal forum to implement Fuzzy TOPSIS and avert the challenges incurred in TOPSIS (Kabir and Hasin 2012: 171). According to the study by Kabir and Hasin (2012: 172), Fuzzy TOPSIS has a ratio ranking scale which gives the magnitude of the ranking and is an ideal technique for solving group decision-making problems. Considering the current study, criteria such as education requirements and technology criteria can be used to rate and rank numerous alternatives such as SM applications.

As opposed to the Fuzzy TOPSIS, the DEA method focuses on performance variations among Decision Making Units (DMUs). This benchmarking technique is a distribution free performance evaluation method which means that it does not make suppositions about functional forms (Ali and Lerme 1997: 215-216). Employing the production function in DEA shows the technological relation of how any possible input combination can achieve the maximum output (Zbranek 2013: 12). One of the main benefits of DEA is its capability to accommodate multiple outputs and inputs. In calculating efficiency, DEA considers returns to scale which facilitates the concept of decreasing and increasing efficiency founded on output levels and size (Johnes 2006: 280). Compared to other benchmarking techniques, DEA has the ability to employ any output-input quantity, and the inefficiency sources can be quantified and analysed for each assessed unit (Johnes 2006: 282). Additionally, the dual of the optimisation problem that can be used to identify which DMUs are being assessed against which other DMUs (The International Benchmarking Network 2021). Regarding the current study, DEA provides an ideal method for determining whether the identified DMUs, which are the devices, are suitable for u-learning by evaluating the device efficiency with the chosen features through the maximum output affordance.

Fuzzy TOPSIS and DEA form the Intelligent Decision Support Systems (IDSSs) to be simulated in the current study to satisfy the research objectives. An IDSS is a combination of a Decision Support System and Artificial Intelligence which applies expert system technology to solve multifaceted decision problems using logical reasoning and human expert knowledge (Changlin and Yufen 2017: 201). There are three types of IDSS but the current study employs IDSSs based on AI. This category is further divided in three subcategories, namely, IDSS based on expert system, which is akin to the current study, IDSS based on agent, and IDSS based on Machine Learning. The IDSS based on expert systems consists of database, inference engine and knowledge base (Changlin and Yufen 2017: 202). It expresses knowledge through non-quantitative logical statements and solves questions with automatic reasoning. The quantification method in IDSS is mainly used to model problems and provide decision support employing the value model calculation result (Changlin and Yufen 2017: 202). Ideally, an IDSS based on an expert system should emulate a human consultant's behaviour by assisting decision makers to collect and investigate data, diagnose and identify problems, and propose and assess probable solutions (Matsatsinis and Siskos 1999: 339).

2.5 Education Requirements

This section presents selected criteria to assess SM applications' appropriateness for u-learning by reviewing many related research studies. The majority of the selected criteria can be broadly categorised into education requirements. Education requirements in this study are referred to as criteria of applications and devices that are specific to education or are required for the fulfilment of the school curriculum (Sam, Naicker and Adebiyi 2021: 2).

Yahya, Ahmad and Jalil (2010: 117), defined u-learning as a learning concept championed by ubiquitous computing technologies. The subsequent education requirements were permanency (work cannot be misplaced), learning concept (learning the correct thing in the right way at the correct time and in the correct place), immediacy (information acquisition is immediate), and interactivity (collaboration between learners, peers, teachers, and experts using the u-learning systems' interfaces). Lastly, some u-learning applications were clarified to improve the information of the u-learning concept (Yahya, Ahmad and Jalil 2010: 120-126).

In the study by Al-Alwani (2014: 532), a framework in a survey format to assess the digital content quality and its functioning in an e-learning platform was proposed. The survey was designed using a 42-expert panel in the higher education field to assess e-learning quality in higher education courses in Saudi Arabia. The survey presented a simple structure for evaluating the capability of an e-learning digital course to enable classification and standardisation of e-content. Questions were partitioned under different criteria to evaluate key performance restrictions of an e-learning content programme (Al-Alwani 2014: 539). The education requirements identified were: socio-cultural stimuli that impact the adaptableness of an e-learning course; e-content legitimacy; suitable integration with the e-learning platform; level/quality of content; presentation methods (text simplicity and clarity, readability, suitable format with topics list, choice of content-aligned media, potential to rectify entries and choices, and time display mandatory to view media); teaching methods; and quality assurance (knowledge suitability, fitness for purpose; language level; user interface, interaction level and graphic approach) (Al-Alwani 2014: 541).

The study by Jung (2014: 97) used a dataset of 376 Korean students to ascertain the main aspects influencing English Language Learners' (ELLs') fulfilment with u-learning. The projected model incorporated ubiquitous learner traits and their effect on ELLs' satisfaction. Education requirements identified were learner satisfaction; learning motivation; omnipresence; interactivity; context customisation; perceived enjoyment; computer self-efficacy, and self-directed learning. Additionally, the study assessed the impact of satisfaction on English learning expectation and employed the Structural Equation Modelling (SEM) to investigate the hypotheses. The results reflected that computer self-efficacy and innovation had substantial effects on u-learning satisfaction and subsequently had a positive impact on expectation (Jung 2014: 117).

Islas-Perez *et al.* (2015: 27) proffered a yardstick of e-learning tools and a comparison approach founded on histogram specification concepts in their study. The analysis was based on the set of criteria definitions which were desirable and useful features of learning management systems. The results revealed that the appraisal of each e-learning tool was founded on the implementation of a three-dimensional model that arranged the criteria into three different axes in accordance with their performance inside the model, specifically: instructional, technological, and managerial (Islas-Perez *et al.* 2015: 30). Education requirements were curriculum management, content sharing and reuse, online grading tools, offline courses/synchronisation, online journal/notes, virtual library, student portfolio, automated testing and scoring, discussion forums, wiki, bookmarks, self-evaluation, calendar/progress review, real-time chat, teamwork, video services, whiteboard, communities, student tracking and remote laboratory use (Islas-Perez *et al.* 2015: 32). The goal of the study was to assist developers and end-users of e-learning tools to make sound decisions on which tool had optimal features for generating learning and training systems and for the creation and administration of courses, resources, and learning objects (Islas-Perez *et al.* 2015: 35).

The study by Meyliana, Hidayanto and Budiardjo (2015: 1676) used TOPSIS to establish that the use of SM applications was more reliant on information quality than service quality. It also revealed that usefulness and comprehensiveness of information, system availability, efficiency, and fulfilment were essential to students as they directly affected their active learning process and expectations (Meyliana, Hidayanto and Budiardjo 2015: 1690; Sam, Naicker and Rajkoomar 2020: 605).

A synchronous online platform's efficiency for training preservice teachers utilising a mixed learning approach was explored by Woodcock, Sisco and Eady (2015: 21). The education requirements identified were e-learning efficiency and competency, and an environment that is psychologically safe (Woodcock, Sisco and Eady 2015: 31).

The paper by Kaplan and Haenlein (2016: 441) provided a historical summary of online distance learning, which included classifications and definitions of main concepts. The identified education requirements were return on investment and student assessment; student challenge, commitment, control, competition; teaching staff competence, charisma, compensation, constancy, contribution; quality assurance and learning goals (Kaplan and Haenlein 2016: 442).

The paper by Zare *et al.* (2016: 108) reviewed forty-two published papers to provide a comprehensive view of MCDM techniques in e-learning. The sources comprised thirty-three international conference papers and journal articles published between 2001 and 2015. The educational requirements recognised were interactivity which includes social interaction, system interaction, and community interactive learning (Zare *et al.* 2016: 123).

The study by Elkaseh, Wong and Fung (2016: 192) used the TAM to examine the employment of SM applications among higher education instructors and students in Libya. Data collection was from a sample population of Libyan students and instructors of four universities. The SEM was performed to assess the predictive behaviour of the proposed factors. Education requirements were identified as attitude towards use, perceived usefulness, and perceived ease of use (Elkaseh, Wong and Fung 2016: 198).

The findings of the study by Debattista (2018: 93) revealed the following education requirements: assessment (learning objectives and goals, learning strategies, fair and transparent grading, mutual feedback, and assessment management); interaction and community (fostering, and peer learning); instructional design (learning objectives and aims, learning structure, learning outcomes, instructional methods and strategies); course closing and opening (instructor role, accessibility, academic integrity, course description, learner ownership, and ethics, policies, and regulations that administrate the course); accessibility (learners' access to their course material and grades after the course closure, final grades delivered within reasonable timeframe, and resource archiving in a secure and safe way); instructional resources (resource application, learning provision, openness, and academic integrity which is best practice, academic research/writing practices, and anti-plagiarism practices); learner support (academic, administrative, and instructional support); instructional design cycle; and course evaluation (Debattista 2018: 101).

The SM application criteria (11) that enhance student involvement in government activities and alternatives (8) that best correspond to the criteria were established in the study by Sirait *et al.* (2018: 158). The study also determined an order for evaluating SM application popularity and underlined the SM applications that were favoured to facilitate e-participation (Sirait *et al.* 2018: 160). The generated criteria were founded on the utilitarian motivation and hedonic theory. Data collection was from Indonesian university students via a questionnaire. Fuzzy AHP was implemented to allocate criteria weights which were subsequently used with TOPSIS to rank the SM applications that improved government activities' e-participation. The results showed that education requirements such as hedonic gratification (enjoyment, social presence, social interactivity, and popularity) were also of high importance for SM application adoption (Sirait *et al.* 2018: 162; Sam, Naicker and Rajkoomar 2020: 604).

A rubric for measuring higher education e-learning tools by choosing the optimal criteria from existing literature, was generated in the study by Anstey and Watson (2018: 1). Education requirements were teaching presence (customisation, facilitation, and learning analytics); social presence (collaboration); diffusion; cognitive presence (higher order thinking, metacognitive engagement, and enrichment of cognitive tasks) and user accountability (Anstey and Watson 2018: 1-5).

Sadiku, Adebo and Sarhan (2018: 73) documented the following education requirements: cooperation, student participation engagement, reflection, and active learning; high expectations; quick feedback; time on task; addressing and regarding different talents, individual differences, and learning methods; information overload avoidance; motivation; and generating a real-world context (Sadiku, Adebo and Sarhan 2018: 74-75).

According to Virtanen *et al.* (2018: 985), u-learning and the Ubiquitous Learning Environment (ULE) herald a modern higher education era. Additionally, the paper noted that the area of research encompassing the u-learning approach is precise and the criteria of the ULE have not been systemically defined. The aim of the study was to identify criteria for ULE; to review the related information in this research area; detect gaps in the research; and plot the ULE scope for its employment in higher education. Nine international databases were systematically searched for pertinent literature and seven articles were chosen after filtering. The chosen education requirements were context awareness, content personalisation, interactivity, flexibility, satisfaction, usefulness, and peer learning (Virtanen *et al.* 2018: 996).

Kimwise, Benjamin and Mugabirwe (2019: 404-410) recognised the education requirements as being attitude towards technology, quality of the multimedia technology and e-learning content. Zgheib and Dabbagh (2020: 50) revealed the following education requirements in their study: facilitation of e-content; use of key words, printable content, self-assessment collaboration; and application proactivity and user's activity. Pishtari *et al.* (2020: 1078) identified the following education requirements: impact on learning, learning gains, adoption, and usefulness.

Table 2.1 presents a synthesis of the education requirements for assessing SM applications for u-learning from the extant literature.

Table 2.1: Education requirements for evaluating social media applications for ubiquitous learning

No.	Educational Requirements	References
1.	Learning Content Quality	Al-Alwani (2014); Meyliana, Hidayanto and Budiardjo (2015); Kimwise, Benjamin and Mugabirwe (2019); Sam, Naicker and Rajkoomar (2020);
2.	Presentation of Learning Content	Al-Alwani (2014); Islas-Perez *et al.* (2015)
3.	Enjoyment Factor	Jung (2014); Rad *et al.* (2015); Sam, Naicker and Rajkoomar (2020); Sirait *et al.* (2018)
4.	Social Interactivity	Yahya, Ahmad and Jalil (2010); Meyliana, Hidayanto and Budiardjo (2015); Sam, Naicker and Rajkoomar (2020); Rad *et al.* (2015); Zare *et al.* (2016); Elyazgi *et al.* (2016); Sirait *et al.* (2018); Virtanen *et al.* (2018)
5.	Clear Instructions Provided	Debattista (2018)
6.	Instructor Opinion	Kaplan and Haenlein (2016)
7.	Compatibility with Course Description	Debattista (2018); Islas-Perez *et al.* (2015)
8.	Learner Behaviour	Rad *et al.* (2015); Sam, Naicker and Rajkoomar (2020); Kaplan and Haenlein (2016); Debattista (2018); Kanagarajan and Ramakrishnan (2018); Kimwise, Benjamin and Mugabirwe (2019)
9.	Integrity	Anstey and Watson (2018)
10	Suitable Technical Competences for Learning	Islas-Perez *et al.* (2015); Kanagarajan and Ramakrishnan (2018)
11.	Ownership of Learning	Jung (2014); Woodcock, Sisco and Eady (2015); Kaplan and Haenlein (2016); Debattista (2018)
12.	Instructional Design	Islas-Perez *et al.* (2015); Debattista (2018)
13.	Assessment of Learning	Islas-Perez *et al.* (2015); Kaplan and Haenlein (2016); Debattista (2018)

14.	Peer Learning	Yahya, Ahmad and Jalil (2010); Sam, Naicker and Rajkoomar (2020); Meyliana, Hidayanto and Budiardjo (2015); Zare *et al*. (2016); Debattista (2018); Virtanen *et al*. (2018)
15	Instructional Resources for Teaching and Learning	Islas-Perez *et al*. (2015); Debattista (2018)
16.	Learner Support	Islas-Perez *et al*. (2015); Debattista 2018); Sadiku, Adebo and Musa (2018)
17.	Course Evaluation	Debattista (2018)
18.	Archiving/Repository	Islas-Perez *et al*. (2015)
19.	Collaboration	Yahya, Ahmad and Jalil (2010); Meyliana, Hidayanto and Budiardjo (2015); Sam, Naicker and Rajkoomar (2020); Zare *et al*. (2016); Sadiku, Adebo and Musa (2018); Kanagarajan and Ramakrishnan (2018); Zgheib and Dabbagh (2020); Anstey and Watson (2018)
20.	User Accountability	Woodcock, Sisco and Eady (2015); Rad *et al*. (2015); Anstey and Watson (2018)
21.	Diffusion	Anstey and Watson (2018)
22.	Instructor Facilitation	Debattista (2018); Zgheib and Dabbagh (2020); Anstey and Watson (2018)
23.	Learning Analytics	Debattista (2018); Sadiku, Adebo and Musa (2018); Anstey and Watson (2018)
24.	Enhancement of Cognitive Task(S)	Anstey and Watson (2018)
25.	Higher Order Thinking	Sam, Naicker and Rajkoomar (2020); Meyliana, Hidayanto and Budiardjo (2015); Anstey and Watson (2018)
26.	Meta-Cognitive Engagement	Kanagarajan and Ramakrishnan (2018); Anstey and Watson (2018)
27.	Permanency	Yahya, Ahmad and Jalil (2010)
28.	Immediacy	Yahya, Ahmad and Jalil (2010); Sam, Naicker and Rajkoomar (2020); Meyliana, Hidayanto and Budiardjo (2015)
29.	Adaptability	Al-Alwani (2014); Kanagarajan and Ramakrishnan (2018)
30.	Management of Interactive Learning Objects	Islas-Perez *et al*. (2015); Kaplan and Haenlein (2016); Debattista (2018)
31.	u-Learning Training Factors	Anstey and Watson (2018)
32.	Quality Assurance	Al-Alwani (2014); Kaplan and Haenlein (2016)
33.	Learnability and Memorability	Debattista (2018)
34.	Perceived Usefulness and Satisfaction	Jung (2014); Meyliana, Hidayanto and Budiardjo (2015); Sam, Naicker and Rajkoomar (2020); Elkaseh, Wong and Fung (2016); Elyazgi *et al*. (2016); Virtanen *et al*. (2018); Pishtari *et al*. (2020)
35.	Curriculum Management	Islas-Perez *et al*. (2015); Debattista (2018)
36.	Customisation	Jung (2014); Virtanen *et al*. (2018); Anstey and Watson (2018)

2.6 Technology Criteria

This section presents the selected criteria's ability to gauge SM applications' pertinence to u-learning by examining various related research studies. The studies presented, highlighted certain selected attributes which most frequently arose from the extant literature that can be broadly categorised into technology criteria. Technology criteria refers to the criteria of the SM applications and devices that are specific to the technical aspects to be investigated in this study (Sam, Naicker and Adebiyi 2021: 2).

Yahya, Ahmad and Jalil (2010: 117) reflected that the technology criteria were accessibility which used ubiquitous computing technologies for system access, and awareness of context where the system can comprehend the environment of the learner with the database and sense the personal, environmental and locational situations of learners (Yahya, Ahmad and Jalil 2010: 117).

Mishra, Yadav and Choudhary (2013: 66-67) compared the various types of learning technologies modified in the education system. The study noted a paradigm shift in education to high technology-based u-learning for seamless dissemination of information in an effective way, irrespective of time and place. The study discussed the technology criteria of u-learning technologies which were: hardware requirements (wearable computers, sensor networks, projectors based on virtual reality, geographical information systems, and Radio Frequency Identification RFID systems); software requirements (location aware protocols, operating systems, and sensor network software packages); computation techniques (mobile + cloud + context cognisant computing); privacy concerns; discovery and research support; device type (invisible, wireless or wired); complexity; and accessibility. The study concluded that despite the high installation cost of a u-learning system, the system becomes cost effective after its implementation, in the long-term (Mishra, Yadav and Choudhary 2013: 66-68).

Al-Alwani (2014: 532,541-542) identified the following technology criteria in their study: user-friendly interface; technical information (installation and uninstallation ease, transparency of update time, availability of online help or technical support, and limitations information); multimedia control (sound control, audio-readings, image and graphics clarity, clarity of video clips, final display process adjustment, augmented size for multimedia contents); and software characteristics' quality (reliability, functionality, usability, maintainability, efficiency, portability, easy accessibility of materials, easy control and navigation tools, and use of external websites links).

Jung (2014: 97,117-119) identified the following technology criteria: mobility; accessibility; portability; personalisation; and ubiquity into web-based learning environments while Islas-Perez *et al.* (2015: 27,36-37) noted that the technology criteria were: orientation/help with technology, instructor helpdesk, enable/disable information, import/export extensible markup language (XML) data, server software, software version, required browser, database requirements, open source, accessibility compliance, integration with other tools and applications, operation in mobile gadgets, course management, course templates, compliance with standards, online search, hosted services, authentication, course authorisation, email, registration, cost of licences, file exchange, instructional design tools, company profile, customised look and feel, and alerts.

Meyliana, Hidayanto and Budiardjo (2015: 1680) explored the technology criterion service quality which comprised system availability, efficiency, fulfilment and system privacy. The paper by Sarrab, Al-Shihi and Al-Manthari (2015: 27) offered characteristics of system quality for choosing m-learning platforms based on the systematic outcome. m-Learning applications offer high social interaction and flexibility in the learning process. The technology criteria arising from the paper were performance, usability, availability, functionality, dependability, service quality and information quality (security, reusability, maintainability and testability) (Sarrab, Al-Shihi and Al-Manthari 2015: 27).

Rad *et al.* (2015: 25-28) suggested that technology criteria (facilitating conditions, privacy, security and trust) had an influence on the implementation of a Social Networking Service in their study. The technology criterion ease of use was discussed by Woodcock, Sisco and Eady (2015: 29-33). Kaplan and Haenlein (2016: 445-449) identified technology criteria as being digital and SM use policy in their study.

Zare *et al.* (2016: 108-129) reviewed the following technology criteria: response (answering time, login time, transferring time, and timely response); usability (ease of use, usefulness, of content and user-friendliness); web and course design (display of instructional materials, design of curriculum, service design, design of user interface and display of webpage); reliability;

cost-effectiveness; accessibility (access time, ease of access, access speed, accessibility of learning materials and internet access); security; functionality; stability; accuracy; trust; flexibility; continuity and interoperability (Zare *et al.* 2016: 108-129).

Elyazgi *et al.* (2016: 11-25) identified the technology criteria as usability (resulting errors when using the system); interface (windows, icons, menus, and pointers); and Child Computer Interaction (CCI). Debattista (2018: 93) acknowledged technology criteria as: course opening and closing (issue resolution, and technical competences); technology design (learner and instructor centricity, support, open standards and formats, authentication, interface, accessibility, software, hardware, and online services investment, and policies, rules, and regulations at institutional management); instructional resources (hypermediality and no unwarranted technical, financial, or administrative barriers); and instructional design cycle (technical infrastructure review) (Debattista 2018: 103-104).

Technology criteria, for example, system quality (ease of use, privacy protection, time of response and interactivity) and information quality (up-to-date, accuracy and media richness) were identified by Sirait *et al.* (2018: 162) as having high importance in the adoption of SM applications by students (Sirait *et al.* 2018: 162; Sam, Naicker and Adebiyi 2021: 3).

The technology criteria in the study by Anstey and Watson (2018: 2-9) were: functionality (ease of use, scale, hypermediality and technical support or help availability); accessibility (cost of use, accessibility standards, required equipment and user focused participation); technical (additional downloads, embedding/integration within a Learning Management System (LMS) and laptop/desktop browser and operating systems); mobile design (offline access, online access and functionality); and privacy, data protection and rights (saving data, sign in/up; data privacy and ownership; archiving and exporting) (Anstey and Watson 2018: 2-9; Sam, Naicker and Adebiyi 2021: 3).

In the study by Kanagarajan and Ramakrishnan (2018: 569-598), technology criteria comprised visual and audio synchronisation and cost-effectiveness (Sam, Naicker and Adebiyi 2021: 4). According to the study by Virtanen *et al.* (2018: 985) the technology criteria were cost-effectiveness, remote access and synchronous and asynchronous communication (Virtanen *et al.* 2018: 997).

Kimwise, Benjamin and Mugabirwe (2019: 404-410) acknowledged the technology criteria in their study as being Information Communication Technology (ICT) technical staff support and multimedia and e-learning technology quality. Zgheib and Dabbagh (2020: 56) revealed the technology criteria: functionalities (network failure, offline usability, synchronous and asynchronous communication tools, hypermediality); application proactivity (ease of use and error prevention); usability and presentation (easy navigation, didactics and personalised access to content) in their study. Lastly, the study by Pishtari *et al.* (2020: 1078-1091) ascertained the following technology criteria: usability, user satisfaction and reliability.

Table 2.2 presents a synopsis of technology criteria for assessing SM applications for u-learning derived from the literature review.

Table 2.2: Technology criteria for evaluating social media application for ubiquitous learning

No.	Technical Criteria	References
1.	Accessibility Standards	Yahya, Ahmad and Jalil (2010); Mishra, Yadav and Choudhary (2013); Al-Alwani (2014); Jung (2014); Islas-Perez *et al.* (2015); Zare *et al.* (2016); Anstey and Watson (2018); Kanagarajan and Ramakrishnan (2018); Virtanen *et al.* (2018)
2.	Web and Course Design	Yahya, Ahmad and Jalil (2010); Zare *et al.* (2016); Debattista (2018)
3.	Scalability	Al-Alwani (2014); Anstey and Watson (2018)
4.	Ease of Use	Sarrab, Al-Shihi and Al-Manthari 2015); Torun and Tekedere (2015); Woodcock, Sisco and Eady (2015); Zare *et al.* (2016); Elyazgi *et al.* (2016); Sirait *et al.* (2018); Anstey and Watson (2018); Zgheib and Dabbagh (2020); Pishtari *et al.* (2020)
5.	Integration/Embedding within a Learning Management System (LMS)	Jung (2014); Islas-Perez *et al.* (2015); Anstey and Watson (2018)
6.	Operating Systems	Mishra, Yadav and Choudhary (2013); Debattista (2018); Anstey and Watson (2018)
7.	Browser	Mishra, Yadav and Choudhary (2013); Al-Alwani (2014); Islas-Perez *et al.* (2015); Zare *et al.* (2016); Anstey and Watson (2018)
8.	No Additional Downloads Needed	Anstey and Watson 2018)
9.	Access on The Mobile Platform	Mishra, Yadav and Choudhary (2013); Islas-Perez *et al.* (2015); Anstey and Watson (2018)
10.	Seamless Functionality Between Mobile and Desktop	Mishra, Yadav and Choudhary (2013)
11.	Offline Access	Zgheib and Dabbagh (2020); Kanagarajan and Ramakrishnan (2018); Zare *et al.* (2016)

12.	Data Privacy and Ownership	Mishra, Yadav and Choudhary (2013); Meyliana, Hidayanto and Budiardjo (2015); Rad *et al.* (2015); Debattista (2018); Sirait *et al.* (2018); Anstey and Watson (2018)
13.	Downloading, Saving and Exporting Data	Islas-Perez *et al.* (2015); Anstey and Watson (2018)
14.	Technical Information	Mishra, Yadav and Choudhary (2013); Al-Alwani (2014); Anstey and Watson (2018); Kimwise, Benjamin and Mugabirwe (2019)
15.	Multimedia Control	Al-Alwani (2014); Kaplan and Haenlein (2016); Debattista (2018); Kanagarajan and Ramakrishnan (2018); Kimwise, Benjamin and Mugabirwe (2019)
16.	Software Characteristics Quality	Mishra, Yadav and Choudhary (2013); Al-Alwani (2014); Debattista (2018)
17.	User-Friendly Interface	Al-Alwani (2014); Zare *et al.* (2016); Elyazgi *et al.* (2016); Debattista (2018); Zgheib and Dabbagh (2020)
18.	Functionality	Mishra, Yadav and Choudhary (2013); Al-Alwani (2014); Sarrab, Al-Shihi and Al-Manthari (2015); Zare *et al.* (2016); Anstey and Watson (2018); Zgheib and Dabbagh (2020)
19.	Hypermediality	Al-Alwani (2014); Debattista (2018); Sirait *et al.* (2018); Anstey and Watson (2018); Zgheib and Dabbagh (2020)
20.	Facilitation of e-Content	Rad *et al.* (2015); Debattista (2018); Al-Alwani (2014)
21.	Operational Stability	Yahya, Ahmad and Jalil (2010); Mishra, Yadav and Choudhary (2013)
22.	Offline Mobile Access	Virtanen *et al.* (2018); Islas-Perez *et al.* (2015)
23.	Security of Technology	Mishra, Yadav and Choudhary (2013); Sarrab, Al-Shihi and Al-Manthari (2015); Rad *et al.* (2015); Zare *et al.* (2016)
24.	Fault Tolerance of Technology	Zgheib and Dabbagh (2020)

2.7 Social Media Applications

The numerous features of SM applications have propagated countless applications which can be categorised as social networking tools, tools that share media, tools that share resources and experiences, communication tools (Zgheib and Dabbagh 2020: 58). The top 14 SM applications as of August 2020 are discussed below (HelloYes 2020; SmartInsights 2020; Sam, Naicker and Rajkoomar 2021: 231).

Generation Z are the generation identified as being accustomed to the internet from a young age and who are approaching adulthood in the subsequent decade of the 21st century. Researchers identify the start birth years of Generation Z as the late 1990's and the ending birth years as being the early 2010's (Francis and Hoefel 2018). Generation Z learners have vast experience with the photo and video sharing SM application YouTube (Mei and Yeo 2014: 53). YouTube enables a classroom built on constructivism which integrates tools for learners to vigorously create their own learning experiences by generating, broadcasting, and watching videos. Instructors can utilise these learning tools to captivate learners (Mei and Yeo 2014: 62; Sam, Naicker and Rajkoomar 2021: 232).

Facebook has social and collaborative traits that promote dynamic social networking and participation of learners and teachers. Facebook has more than 2,701 billion users (Tankovska 2021a) and it authorises the sharing of pictures, articles, videos, music, thoughts, and opinions of users. Facebook has progressively improved over the years as a learning and teaching tool (Mei and Yeo 2014: 56; Sam, Naicker and Rajkoomar 2021: 232).

WhatsApp is an instant messaging service connecting over 2 billion active users around the world (Statista 2018; Manca 2020: 2). The application permits the sharing of images, text, voice messages, and videos by users and the making of video and voice calls. WhatsApp's ubiquity, along with its flexibility, has given rise to a lot of studies involving different research areas in education (Pimmer and Rambe 2018: 218; Manca 2020: 4). Academic benefits consist of peer collaboration, teacher availability, peer assessment, better access to materials for learning, and extra learning beyond school time (Bouhnik and Deshen 2014: 217; Manca 2020: 4). WhatsApp as an assessment tool, permits instructor's access to all learners' responses in the group chat whilst preserving their anonymity (Manca 2020: 5; Sam, Naicker and Rajkoomar 2021: 232).

Facebook Messenger has over 107 million active users (Tankovska 2021a). Its educational application has rarely been acknowledged but it has various characteristics that are useful for teaching and learning for example: developing engaging posts with images, text and videos; creating and exchanging web content and infographics; broadcasting learners' success stories to inspire others; engaging learners with content by arranging challenges and stimulating an online community of learning (Smutny and Schreiberova 2020: 1; Sam, Naicker and Rajkoomar 2021: 233).

WeChat has over 1,2 billion active users (Tankovska 2021a). As a teaching platform was shown to facilitate communication between students and instructors (Shi and Luo 2016: 71). It is a voice and instant messaging service platform. In this study, WeChat expedited university students' communication for u-learning. Shi and Luo (2016: 73-75) also demonstrated that

WeChat competently enabled communication in translation teaching and cultivated students' translation competence (Sam, Naicker and Rajkoomar 2021: 233).

Instagram has 1,082 billion active users (Dean 2021a) and permits users to asynchronously publish and exchange videos and photos and to photo and video edit with digital filters. Instagram presents Instagram Stories which broadcasts time-restricted content (Boulos, Giustini and Wheeler 2016: 1-2). Instagram's most important educational application is sharing videos and photos for reference by learners or for analysis purposes. Instagram assists direct communication between teachers and learners by enabling communication, encouraging collaboration, displaying applicable articles and videos to enhance the learning experience (Boulos, Giustini and Wheeler 2016: 8-10; Sam, Naicker and Rajkoomar 2021: 233).

TikTok has a user base of over 1 billion subscribers with most users being between the ages of 14 and 30 years. With TikTok, the user can create 15 second videos which comprise script imitation, dance performance, emotional expression, talent expression, life record and skill sharing, just to name a few. EduTok was launched in India due to the application's popularity to support English and Mathematics teaching. TikTok's Pedagogical offerings consist of realistic experiences delivery, motivational influence, content review and control and the instatement of learners as content creators (Commonwealth of Learning 2020; Sam, Naicker and Rajkoomar 2021: 234).

QQ is a potent tool for communication that has helped a number of learners with online learning. It has a user base of 595 million subscribers. It has ensured dynamic interaction between learners and teachers and the subsequent provision of efficient feedback to learners. Asynchronous and synchronous teaching is assisted by the QQ group video where learners can communicate with teachers and vice versa on video call. By teachers sharing their computer screen via QQ, learners can learn conveniently (Nan 2020: 57-59; Sam, Naicker and Rajkoomar 2021: 234).

QZone which has 600 million subscribers (Collins 2019), comprises instant messaging software and is a multimedia weblog. The QZone interface is user-friendly and the 'sharing needs permission' tab permits access to resources. The implementation of QZone in English learning and teaching has been documented in numerous studies. In these studies, QZone fast-tracked the sharing of learning resources, encouraged peer feedback, satisfied instructional feedback and incited detailed communication (Wang 2009: 114-115; Xie 2010: 84; Wen and Lai 2012: 145-146; Du 2013: 107; Zhu 2013: 33). The application has unlimited storage and satisfies the text editing requirements (Xianwei, Samuel and Asmawi 2016: 131; Sam, Naicker and Rajkoomar 2021: 234).

Reddit is a prevalent, global online aggregator of content with 430 million active users (Dean 2021b). Learners can comment on posts, publish content and up-vote or down-vote content they like or dislike, respectively. Reddit employs a ranking algorithm where popular up-voted content is advertised more on the post listings (Tannebaum 2018: 167). Stakeholders of education can add to stimulating, meaningful and reflective discussions about technology, research, politics and educational policy. Reddit presents learners and teachers with a useful platform for participating in educational content through inquiry. It offers numerous strategies for learners to engage with educational content (Hostetler 2012: 100; Diacopoulos 2015: 139; Tannebaum 2018: 168; Sam, Naicker and Rajkoomar 2021: 235).

Snapchat is a mobile photo messaging and multimedia exchanging application. It has 265 million active users with its main users being millennials. Millennials are Generation Y who have birth years between early 80's and mid 90's (Tankovska 2021c). Learners and teachers can produce Snapchat Stories integrating visual elements with text to make the application attractive for multimodal composition and literacy intents (Bartels 2017: 90; Manca 2020: 8; Sam, Naicker and Rajkoomar 2021: 235).

Twitter is a microblogging platform which promotes educational collaboration and participation and has proved to change traditional classrooms in numerous studies (Gao, Luo and Zhang 2012: 783; Tang and Hew 2017: 97). Additionally, studies showed that Twitter was the most frequently employed application for communication and assessment. It has an active user base of 187 million subscribers (Tankovska 2021b). The most advantageous functions of Twitter consist of teachers posting test deadlines, homework assignments crucial course information and facilitating collaboration (Tang and Hew 2017: 100; Sam, Naicker and Rajkoomar 2021: 235).

Pinterest organises, harvests, shares, and re-shares photos with commentaries, and keeps the user updated with republishing. It has 495 million actives users (Tankovska 2021d). Pinterest's educational value greatly relies on browsing for, arranging, and integrating digital resources into projects (Geraths and Kennerly 2015: 119; Manca 2020: 10). Pinterest offers an opportunity for teachers to create and make sense of learning resources (Hu *et al.* 2018: 102-103; Manca 2020: 10; Sam, Naicker and Rajkoomar 2021: 235).

Viber is primarily an instant messaging and voice call application with 250 million active users (Mehta 2021). Learners and teachers can forward audio, photo and video media messages (Godwin-Jones 2008: 5-6; Farahmand 2016: 33-38). Viber was seen to provide an appealing ethos for learners to enhance their learning, improve human collaboration and increase communication (Farahmand 2016: 31-32; Sam, Naicker and Rajkoomar 2021: 236).

2.8 Devices Utilised for Ubiquitous Learning

Devices are actively employed in education to enhance the learning outcomes and service quality. Device peripherals such as video, audio and graphical aids are used to create multimedia presentations which transform traditional lessons into interactive participatory pedagogy (Kazaure, Matthew and Okafor 2019: 1-3). The extant literature revealed that there are innumerable applications of devices for m-learning and e-learning but that the principal roles of devices for u-learning should focus on the internet, knowledge flow and information broadcasts, learning resources and global sharing, and learning flexibility to overcome problems of time and distance (Liu and Wang 2009: 192; Arkorful and Abaidoo 2014: 397). Identified characteristics of devices for u-learning are the provision of a multimedia environment, incorporation of different kinds of information, facilitation of collaborative communication and independent learning, delivery of support networks for retrieving information and functioning with at least one of the available computer operating systems (Arkorful and Abaidoo 2014: 398).

According to AnySoftwareTools (2020), learners should find a good balance between budget and performance when buying a computing device. Learners should also consider the processor of the device which is called the Central Processing Unit (CPU). The CPU determines the speed and power of the device, for example, a lower end processor can bottleneck the system. CPUs are within the range of Core i3, Core i5, Core i7, and Core i9 processors with the latter being the higher specification and generally more expensive (Transcend 2020). Storage space is another important feature to consider when choosing a device for u-learning because while simple tasks, for example typing Microsoft Word documents, require minimal space, saving videos or photos or downloading applications can use a substantial amount of space. This feature refers to the Random-Access Memory (RAM) and Internal Memory of the device (AnySoftwareTools 2020). The RAM can be categorised as Double Data Rate (DDR) and has generations DDR1 to DDR5 with the latter being the premium specification (Transcend 2020). Solid State Drives (SSD) can be used to supplement the device storage capacity (AnySoftwareTools 2020).

Darko-Adjei (2019: 21) pointed out that for effective m-learning and e-learning, learners need to be able to retrieve learning materials from the internet irrespective of the time and place. Portability, i.e. the transportability and movability of low-weighted devices, is therefore key for u-learning. The study also revealed that the screen size of devices for u-learning was important as smaller screens led to physical discomfort and negatively impacted learners' "perceived ease of use" (Darko-Adjei 2019: 22). A wider screen size also accommodates easy navigation through the learning content. The battery life of devices also played a major role in learners' adoption of devices as power cuts would prevent learners from ubiquitously accessing the learning materials and engaging in learning processes (Darko-Adjei 2019: 24). Durability is a key feature that learners should consider when choosing a device for u-learning. Due to the portable nature of u-learning tools, the screen must be thick so that if the device falls, the screen will not easily crack, thus not compromising the integrity of the imagery of the e-content (Campbell 2018: 52).

With regards to the article by eLearning Industry (2017), sufficient display resolution is imperative for the interactive nature of u-learning. Higher resolutions allow for more space and detail of the content to be viewed on the screen of the device and the optimal resolution is 1080p (1920×1080). Similarly, camera quality of devices for u-learning is essential for creating e-content. Camera resolution refers to the number of pixels the image sensor captures and is usually measured in megapixels. The higher the megapixels, the better the image or video created on the device (VdoCipher 2017). Table 2.3 shows the features of the top twenty devices for u-learning as synthesised from the various web sources which are listed below the table.

Table 2.3: Features of devices for u-learning as of December 2020

Type of Device	Name of Device	Input		Output							
		Cost in Rand	Weight in grams	RAM (DDR) in GB	Screen Size in Inches	CPU in GHz	Internal Memory in GB	Battery Life in min	Resolution in pixels	Camera in Mega pixels	Screen thickness in mm
1. Desktop	Dell Inspiron 3470	8 999	4 800	8	15,6	3,6	1 000	381	1 049 088	0,9	14,8
2. Gaming Tablet	Samsung Galaxy Tab S5e	11 999	400	4	10,5	2,0	49,1	540	4 096 000	13,0	5,5
3. Mobile Phone	Samsung Galaxy A51	5 999	172	6	6,5	1,8	64	5 160	2 592 000	48,0	7,9
4. iPhone Smartphone	iPhone 11 Pro	16 999	188	4	5,8	3,8	256	420	2 740 500	12,0	8,3
5. Customized Business Tablet	Microsoft Surface Pro 6	19 499	770	16	12,3	3,8	512	810	4 990 464	8,0	8,5
6. 2-in-1 PC	Lenovo IdeaPad Flex 5 14	12 999	1 600	16	14,0	2,5	512	720	2 073 600	0.9	7,9
7. iPad	iPad Air 3	18 199	464	3	10,5	2,49	64	600	37 009 632	8,0	6,1
8. Mini Tablet	Samsung Galaxy Tab S6 Lite	6 499	467	4	10,4	2,3	64	780	2 400 000	8,0	7,0
9. Handheld PC	Samsung Galaxy Tab A8 2019 Black LTE	1 999	358	2	8,0	2,0	32	600	5 038 848	13,0	8,0
10. Traditional Laptop	Acer Swift 3	12 859	1 200	8	14,0	1,8	512	1 020	2 073 600	0,00072	18,0
11. Phablet (Phone-Tablet)	Samsung Galaxy Note 10 Plus	10 999	196	12	6,8	2,73	256	7 242	4 377 600	16,0	7,9
12. Slate	Huawei Media Pad T5 10.1-inch Black	4 299	460	2	10,1	2,36	16	1 020	2 304 000	5,0	7,8
13. Android Smartphone	Google Pixel 4a	9 999	143	6	5,81	2,2	128	420	2 527 200	12,2	8,2
14. Android Tablet	Samsung Galaxy Tab S7	18 999	575	6	12,4	3,09	128	420	4 905 600	13,0	6,3
15. Notebook.	Acer Chromebook 314	3 794	1 700	4	14,0	1,1	32	750	1 049 088	0,9	20,0
16. Desktop Replacement Laptop	ASUS ROG Strix Scar 17	29 999	2 860	32	17,3	2,4	2 000	318	2 073 600	5,0	22,0
17. Netbook	ACER Chromebook 15.6	2 168	1 950	4	15,6	1,1	32	547	2 073 600	0,9	22,0
18. Subnotebook /Ultraportable	Dell Inspiron 14 7000	10 240	1 600	16	14,0	2,4	512	540	2 073 600	1,0	22,0
19. Business Laptop	Lenovo ThinkPad X1 Carbon	10 840	1 080	8	14,0	4,9	16	1 080	2 073 600	8,0	14,9
20. Windows Phone	Lumia 950 XL	3 477	165	3	5,7	1,8	32	660	3 686 400	20,0	8,1

Sources: (Androidcentral 2020; AnySoftwareTools 2020; CNET 2020b; Creative Bloq 2020; Familyproof 2020; Gamesradar 2020; iMore 2020; Incredible Connection 2020; Laptop Study 2020; PC 2020; T3 2020; Techradar 2020; Tom's Guide 2020; Windows Central 2020).

It is important to note that u-learning is not limited to reading textbooks on digital devices but involves the digital transformation of education. U-learning encourages learners to engage with learning materials, to be critical thinkers, problem solvers and content creators using technology (Kim, Caytiles and Kim 2012: 4). Custom reader devices such as e-readers or Kindles have a singular purpose where they are ideal for reading e-books but do not encompass the features aligned with the criteria for u-learning. They have low-performance specs, no applications, no camera, relatively small storage chips, low refresh rates and are generally limited to black and white content (WiredShopper 2021). Consequently, custom reader devices were not included in the search of digital devices for u-learning.

2.9 Chapter Summary

Chapter Two delivered an in-depth definition of u-learning and discussed its role in higher secondary education. An extensive literature review on the resulting education requirements and technology criteria of u-learning was conducted and three tables were synthesised to summarise the findings of the literature review. The literature review relativized what studies were carried out and exposed voids in the literature that could be explored for prospective studies. The literature revealed limited studies on artificial intelligence works in u-learning; and no studies on IDSS, namely PCA, fuzzy TOPSIS and DEA for managing the diffusion of social computing in school-based u-learning. Lastly, the advantages and disadvantages of several MCDM techniques were outlined. Chapter Three that follows centres on discussing the Connectivism Theory, the IDT, the Decision Theory, and the emergent conceptual model and links these theories to the research objectives.

CHAPTER THREE: THEORETICAL FRAMEWORKS AND CONCEPTUAL MODEL

3.1 Introduction

A theory is a well-informed account of a certain component of the natural world. It is an assemblage of propositions to illuminate the principles of a study and to validate a strategy. It is also a structured body of established knowledge that is applicable in an assortment of contexts to explain a particular set of events, incorporating facts, hypotheses and laws (Merriam-Webster 2021).

The following theoretical frameworks have been chosen for the study: Connectivism Theory, Innovation Diffusion Theory, and Decision Theory. These theories are reflective of the study concepts and provide constructs for expressing the problem situation. The Strategic Innovation Management Model was designed from these existing theories to underpin the plan of the research and inform the research methods and data collection tools. Figure 3.1 illustrates how the theories were utilised in the study and how they were linked to the Research Objectives (RO).

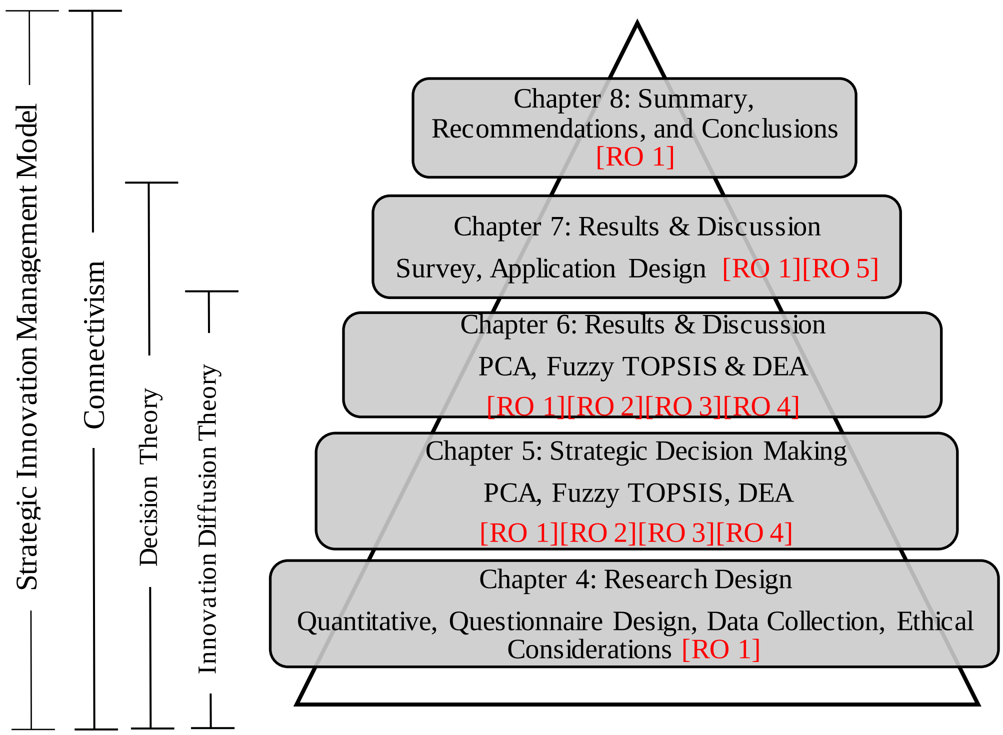

Figure 3.1: Pyramid Framework showing the thread of theories in the study

Source: Researcher's own construction

3.2 Connectivism

Connectivism is a theoretical model developed by George Siemens which offers an alternative learning theory (Alger 2005). Learning is not confined to a certain environment, a certain time, or a certain place. The theory acknowledges the societal influence of technology and the subsequent shift in teaching and learning. It accepts that learning depends on informal participation in personal networks, communities of practice and work-related tasks (Siemens 2005: 3). Connectivism involves establishing connections between technology and people. Connectivists explain that to deal with the complexity and surplus of information, teaching and learning happens within learning communities, ecologies and networks which enable connections and communicating information while promoting lifelong learning for all (Siemens 2005: 4).

The Connectivism principles are identified as follows: knowledge and learning lie in the difference of views; the process of learning involves linking information sources or specialised nodes; learning may exist in appliances that are not human; the ability to know more supersedes what is presently known; continual learning is facilitated by maintaining and nurturing connections; a core skill is to observe connections between ideas, fields and concepts; all learning activities should include up-to-date and accurate knowledge; and decision-making is a process of learning. The interpretation of incoming information and deciding what to learn is perceived through a lens of changing reality, owing to changes in the information climate that affects the decision, the right answer today may be the wrong answer tomorrow (Siemens 2005: 6).

Siemens believes that today's learning depends on a nexus of technology and people to accumulate, retrieve, and access knowledge and encourage its usage (Siemens 2011: 1-2). Learning is seen as multi-faceted with specific pedagogical approaches aligned to the learner. Therefore, different attributes of the learning development require a variety of methodologies (Siemens 2008: 9). As a pedagogical approach, connectivism allows learners to communicate with each other using collaborative tools or social networking tools. Figure 3.2 portrays the characteristics of connectivism, namely: learner-centric, learner choice/management, activity-based, experiential, focus on participation/collaboration pedagogies; a many to many communication model; social networking; and a range of hosting options including mobile technologies (Siemens 2011: 3).

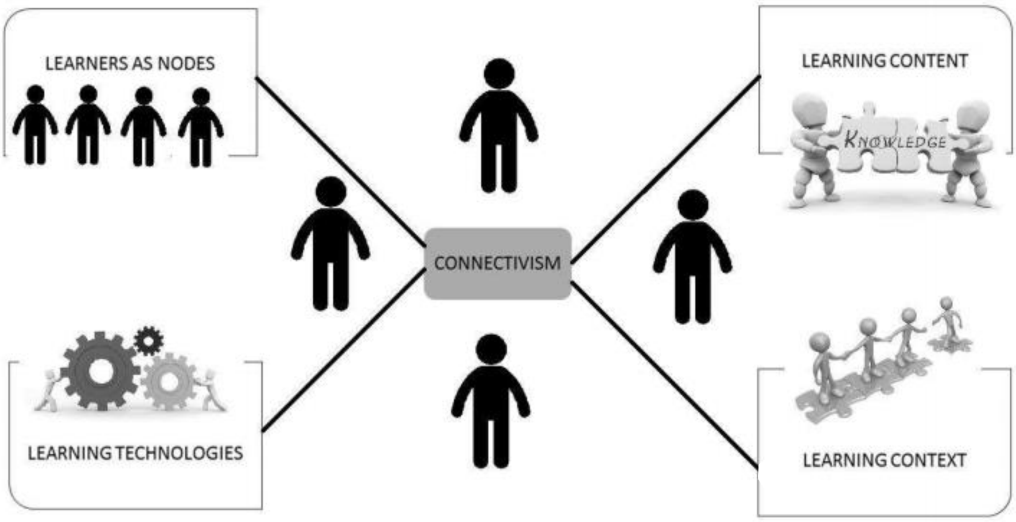

Figure 3.2: Connectivism and Learning

Source: Chetty (2013: 180).

3.2.1 Connectivism model in Relation to the Study

The justification for the choice in the current study, is that the connectivism theoretical framework will serve as an overarching paradigm for explaining school-based instructors' and learners' preference of social media (SM) applications and devices for the promotion of ubiquitous learning (u-learning). Decision making is integral to connectivism. Figure 3.2 shows the complex network of choices of applications and devices students must make for learning.

3.3 The Innovation Diffusion Theory

Research on the Innovation Diffusion Theory (IDT) is broadly employed in disciplines like Information Technology (IT), communication, education, and sociology (Karahanna, Straub and Chervany 1999: 188; Agarwal 2000: 91; Rogers 2003: 275; Lee, Hsieh and Hsu 2011: 125). The original five characteristics of the theory which described end-user's acceptance of innovations and the process of decision-making were expanded to eight factors by Moore and Benbasat (1991: 100) who were operating within an Information Systems (IS) context to determine the impact of the factors on IT adoption. These factors are compatibility, relative advantage, voluntariness, ease of use, result demonstrability, visibility, image and trialability. Over the years, the IDT in IS has been adapted and applied in various ways but the important attributes like relative advantage (perceived need), technical compatibility and technical complexity (ease of use) have persisted to be significant antecedents in innovation acceptance (Crum, Premkumar and Ramamurthy 1996: 47; Bradford and Florin 2003: 206) generating the generalised model in Figure 3.3.

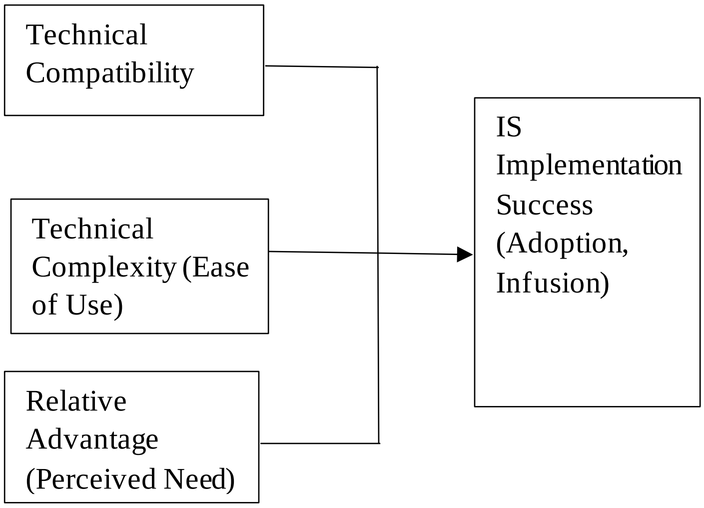

Figure 3.3: IS Diffusion Variance Model

Source: Cooper and Zmud (1990: 132); Crum, Premkumar and Ramamurthy (1996: 47)

3.3.1 Innovation Diffusion Theory in Relation to the Study

The justification for the choice of IDT in respect to the current study, is that the criteria for choosing u-learning applications and devices aligns with the IS Diffusion Variance Model. Technical Compatibility refers to how aligned the innovation is with the experiences, needs and values of the adopters (Bradford and Florin 2003: 207). Relative Advantage relates to the degree by which the innovation is perceived to exceed the previous programme, idea, or product (Bradford and Florin 2003: 207). Technical Complexity relates to how challenging the innovation is to use or comprehend (Bradford and Florin 2003: 207).

With regards to SM criteria, Technical Compatibility comprises Instructional Design, Academic Integrity, Curriculum Management, Learning Analytics, Enhancement of Cognitive Tasks, Higher Order Thinking, and Metacognitive Engagement. Relative Advantage consists of Ownership of Learning, Adaptability, Peer Learning, Social Interactivity, Hypermediality, Multimedia Control. Technical Complexity involves Quality Assurance, u-Learning Training Factors, Archiving/Repository, Facilitation, Operational Stability, Fault Tolerance of Technology, Security of Technology, Facilitation of e-Content, Technical Information, Software Characteristics Quality, Ease of Use, Operating System, Browser Access, Data Privacy and Ownership, Downloading, Saving and Exporting Data, Additional Downloads.

The device features can be interchangeably categorised as Technical Complexity, Technical Compatibility, and Relative Advantage. Technical Compatibility includes Cost, Weight, RAM, Screen Size, CPU, Internal Memory, Battery Life, Resolution, Camera, and Screen Thickness. Relative Advantage encompasses Cost, Weight, RAM, Screen Size, CPU, Internal Memory, Battery Life, Resolution, Camera, and Screen Thickness depending on what the user's previous device offered. Technical Complexity refers to Weight, and Screen Size. Succinctly, the IDT model served as a paradigm for the development of the questionnaires. However, a supplementary robust theoretical framework was required to facilitate the other steps of inquiry.

3.4 Decision Theory

The Decision Theory was created by Leonard Savage in 1954 and is the study of the choices made by decision makers – either a group of people or an individual (Bradley 2018: 611). Decision Theory is a framework for making important decisions in an assortment of contexts. It allows decision makers to choose an option from a range of potential decision alternatives when the future is uncertain. The aim of employing Decision Theory is to improve the resultant payoff considering the decision criterion (Bradley 2018: 612). Most decision-making theories are strategic in nature and multidisciplinary (Grant 2016: 428; Aristodemou and Tietze 2019: 6).

Various researchers maintain that the decision theories can be categorised as bounded rational, rational, and non-rational (Edwards 1954: 381; Eisenhardt and Zbaracki 1992: 17; Stanovich and West 2000: 649; Oliveira 2007: 1480; Aristodemou and Tietze 2019: 6). Rational theories presume a completely informed and rational decision-making process (Drummond 2012: 24; Aristodemou and Tietze 2019: 6), while the bounded rational theories presume a method-orientated opinion of fulfilment and decision making focused on the best choice with incomplete information (Turpin and Marais 2004: 144; Aristodemou and Tietze 2019: 7). This division is further augmented by the categorisation of Decision Theory as descriptive and normative (Ahmed *et al.* 2014: 79).

The Descriptive Decision Theory explains how decision makers make decisions and affords predictions of the choices made by decision makers (Bradley 2018: 623). It focuses on how decisions are actually made. The Normative Decision Theory focuses on what decisions decision makers should make by analysing the decision's outcome and opting for the rational alternative. It also establishes the decisions which are the best, considering the assumptions and constraints of the situation (Hansson 2005: 15). The Normative Decision Theory involves aspects of how to make decisions, how to evaluate the alternatives, what criteria should be employed, and what procedures should be followed (Bradley 2018: 623). Montibeller and Franco's (2010: 25) MCDA in Figure 3.4 outlines the general investigative process for identifying the most favoured option in complex decisions (Arsitodemou and Tietze 2019: 5).

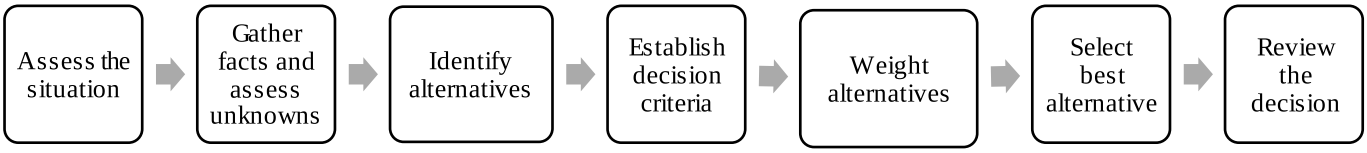

Figure 3.4: Classical decision-making process

Source: Arsitodemou and Tietze (2019:5); Montibeller and Franco (2010: 25)

Figure 3.4 shows the classical decision-making process as a sequential model having seven steps as outlined. The model is established on the notion that making decisions is based on intelligence (Arsitodemou and Tietze 2019: 5; Montibeller and Franco 2010: 25). There are various types of strategic decision-making methods that arise based on the problem at hand which can be categorised into Single Criterion Decision Making (SCDM) methods and MCDM methods, as depicted in Figure 3.5 (Verbano and Nosella 2010: 355; Zavadskas, Turskis and Kildiene 2014: 166; Golcuk and Baykasoglu 2016: 346).

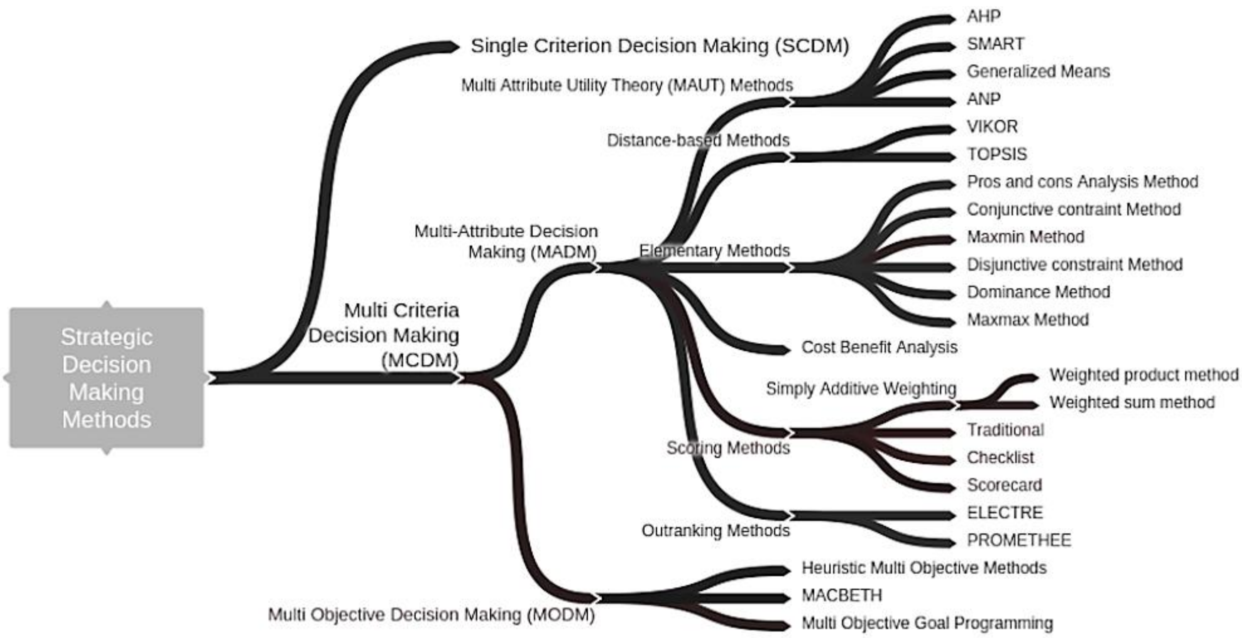

Figure 3.5: Traditional Classification Strategic Decision-Making Methods

Source: Aristodemou and Tietze (2019: 8)

In Figure 3.5, SCDM involves making comparisons between alternatives where the outcome is not governed by chance (no risk situation) (Kangas *et al.* 2015: 82). Multi-criteria decision making involves organising and deciphering planning problems and decisions using multiple criteria to help decision makers make logical decisions. Realistically, there is not a single ideal solution for multifaceted problems, and to distinguish between solutions it is essential to consider the preference of the decision makers (Golcuk and Baykasoglu 2016: 347). Finding an optimal solution may be referred to as finding a non-dominated solution where at least one criterion must be traded off against the host of other criteria for the decision maker to make a final choice (Golcuk and Baykasoglu 2016: 348). As the set of non-dominated solutions is large, MCDM tools are employed to help the decision maker in choosing the preferred alternatives or solutions. This gives rise to the various branches in Figure 3.5 where MCDM is separated into Multi-Attribute Decision Making (MADM) and Multi-Objective Decision Making (Golcuk and Baykasoglu 2016: 348; Zavadskas and Turskis 2011: 165; Verbano and Nosella 2010: 355). The former is further divided into multi-attribute utility theory methods, distance-based methods, elementary methods, cost benefit analysis, simply additive weighting, scoring methods and outranking methods (Golcuk and Baykasoglu 2016: 349; Zavadskas and Turskis 2014: 166; Verbano and Nosella 2010: 356). In terms of the Strategic Decision-Making Model in Figure 3.5, Fuzzy TOPSIS which is an extension of TOPSIS is distance-based and is considered as a MCDM method.

Strategic decision-making methods, with the advent of AI, can be further categorised into AI methods, mathematical programming methods, and multi-attribute decision-making methods, as portrayed in Figure 3.6 (Chai, Liu and Ngai 2013: 3873).

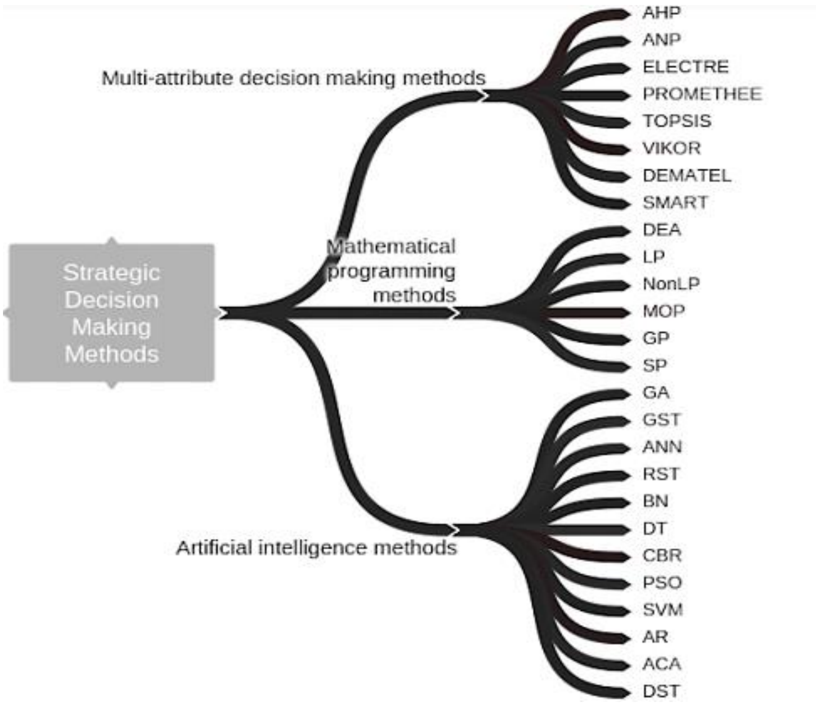

Figure 3.6: Radical Recent Classifications and Abbreviations

Source: Aristodemou and Tietze (2019: 8); Chai, Liu and Ngai (2013: 3873)

In reference to Figure 3.6, MADM include, Multi-Attribute Utility Methods (MAUT), Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP); outranking methods such as Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE) and Elimination and Choice Expressing Reality (ELECTRE); compromise methods such as Multi-criteria Optimisation and Compromise Solution (VIKOR) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS); other MCDM techniques such as Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Simple Multi-Attribute Rating Technique (SMART) (Chai Liu and Ngai 2013). Mathematical programming methods include Data Envelopment Analysis (DEA), Linear Programming (LP), Nonlinear Programming (NLP), Multi-Objective Programming (MOP), Goal Programming (GP), and Stochastic Programming (SP) (Chai Liu and Ngai 2013). Artificial intelligence methods comprise Genetic Algorithm (GA), Rough Set Theory (RST), Neural Network (NN), Grey System Theory (GST), Bayesian Networks (BN), Case-Based Reasoning (CBR), Ant Colony Algorithm (ACA), Particle Swarm Optimisation (PSO), Association Rule (AR), Dempster–Shafer Theory (DST), Decision Tree (DT), and Support Vector Machine (SVM) (Chai, Liu and Ngai 2013: 3873).

Owing to the disposition of technological uncertainty, technology strategic decision-making involves a reasonable sum of information pertaining to the category for which the technology is chosen (Kalbande and Thampi 2009: 379; Aristodemou and Tietze 2019: 2). Strategic decision-making involves steps for recognising and selecting strategic alternatives to decrease uncertainty, and to afford a rational decision (Simon 1993: 392; Mintzberg and Lampel 1999: 21; Ahmed *et al.* 2014: 80; Aristodemou and Tietze 2019: 2).

3.4.1 Multi-Criteria Decision Framework in this Study

The justification for the choice of strategic decision-making theory as a theoretical framework in the current study, was that the Multi-Criteria Decision Analysis Process Model, that is illustrated in Figure 3.7 was akin to the IDSS that was endeavoured in the study (Arsitodemou and Tietze 2019: 4).

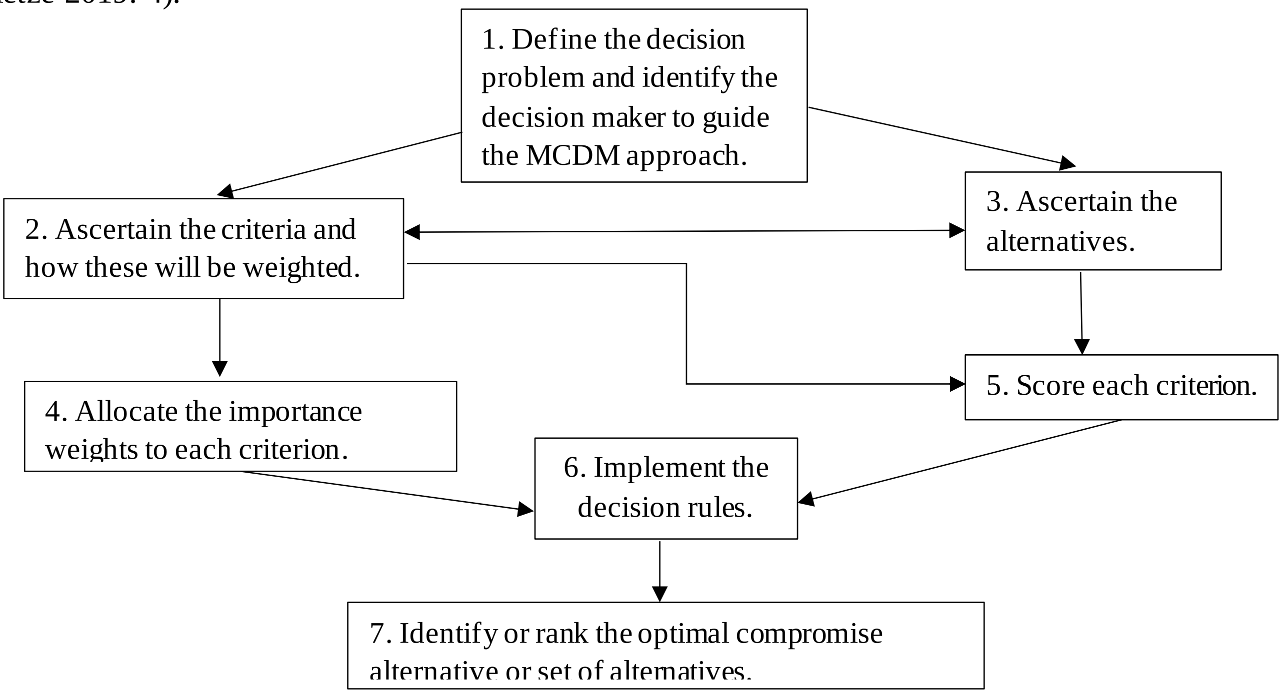

Figure 3.7: Multi-Criteria Decision Analysis Process Model

Source: Aristodemou and Tietze (2019: 4)

Figure 3.7 outlines the seven steps involved in a Multi-Criteria Decision Analysis Process. **Box 1** relates to a request for action to be taken to resolve a problem or some question (Ullman 2002: 61). For example, in the current study, there was a need to make informed decisions on the selection of SM applications and devices for u-learning such that the school curriculum could continue to be delivered indefinitely. An issue is limited and defined by the criteria employed to assess its resolution, as shown in **box 2** (Ullman 2002: 61). In the study, the criteria were identified as technology criteria and education requirements for the grading of SM applications using Fuzzy TOPSIS. In the DEA method, the criteria were identified as the input and output variables of a device's usage. The two main components of a criterion are the alternative to be measured attribute and the target value of the attribute (Ullman 2002: 61). Criteria are established by the stakeholders who are affected by the issue and their preference for the criterion to successfully resolve the issue in combination with the criterion derives the value model (Ullman, 2002: 61). For SM application selection, expert decision makers were used to add weights to the criteria and representative decision makers were used to rank the SM applications, as shown in **box 4** and **box 5**. An alternative is a choice developed to respond to or address a specific issue, as shown in **box 3**. In the study, the alternatives were the various SM applications and devices for u-learning. The target value of alternatives using Fuzzy TOPSIS and DEA were 1,000. The aim of making decisions is to discover an alternative that the decision makers decide to implement (Ullman 2002: 62). Evaluation information consists of the results developed from prior knowledge, information gathering, experimentation, and analysis which verify the ability of the alternative's issue resolution, as shown in **box 6** (Ullman 2002: 62). In the study, various methods forming an IDSS were implemented to select SM applications and devices for u-learning. A decision is the settlement to resolve an issue by implementing an alternative or alternatives, as shown in **box 7**. Decisions can be altered as preferences, criteria, or alternatives change (Ullman 2002: 62).

3.5 Emergent Conceptual Model

The Emergent Conceptual Model was designed to provide a framework that served as an overall model for the study. The Multi-Criteria Decision Analysis Process Model combined with IDT were used in this study to create the emergent conceptual framework called Strategic Innovation Management Model (SIMM), as depicted in Figure 3.8.

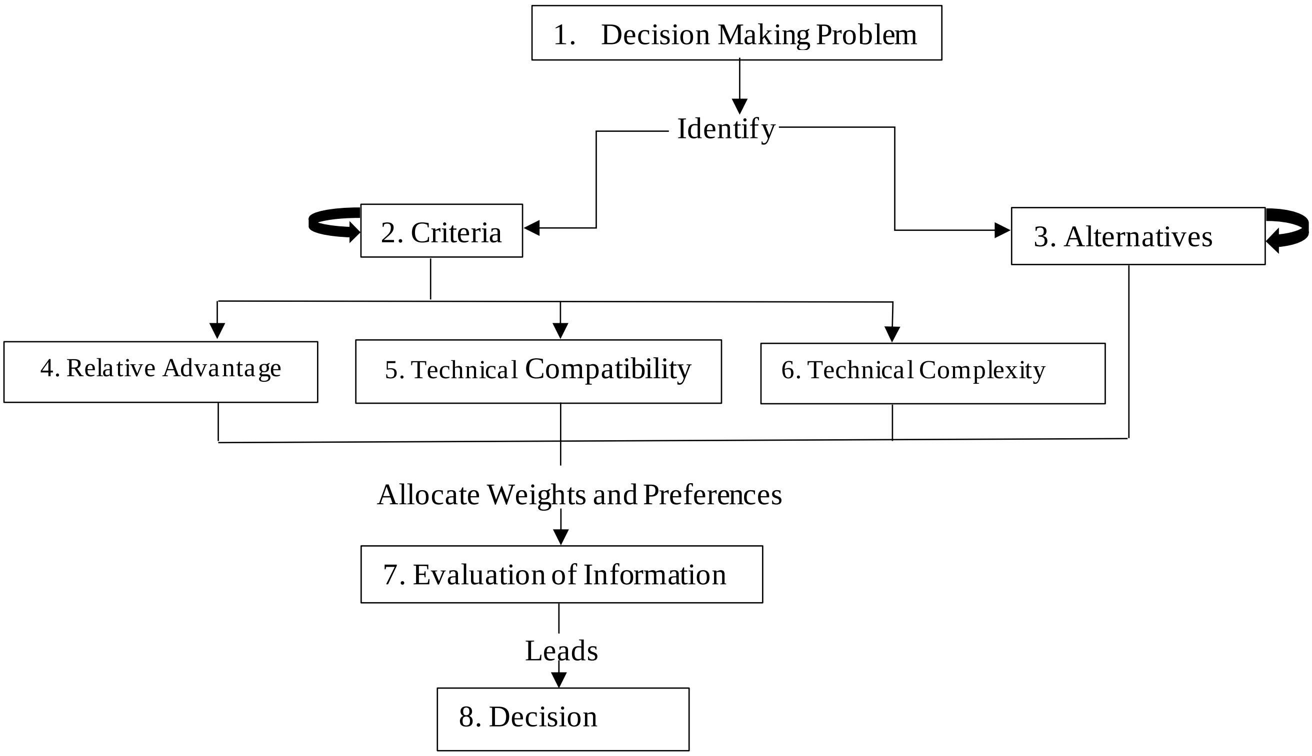

Figure 3.8: Strategic Innovation Management Model (SIMM) for Technology Selection

Source: Researcher's own adaptation

3.5.1 Validating the Strategic Innovation Management Model (SIMM)

The validation process of the conceptual framework involved the use of the mini-Delphi method. The Delphi method is a forecasting technique that is used to facilitate organised group communication of an expert panel to elicit a consensus on expensive endeavours, uncertain outcomes, and complex problems (Sivalingam 2020: 5608). The basic structure of the Delphi method is as follows: indication where time and/or money is not a factor; selection of experts who are knowledgeable and experienced on the issue, want to participate, have time to participate, and communicate effectively (Sivalingam 2020: 5611); Delphi round 1 which includes a limited number of open-ended questions, with the aim of idea generation; qualitative analysis where ideas are grouped with the use of affinity diagrams, fishbone diagrams, or NVivo; Delphi round 2 which includes close-ended questions generated from the information in round 1; assess consensus where the expert panel must agree with one another; Delphi is repeated until consensus is reached; ranking of the information that reached consensus and elimination of information that did not reach consensus (Sivalingam 2020: 5612).

Three experts, comprising two professors and one PhD holder were invited to give comments on the validity of the emergent conceptual framework referred to as the Strategic Innovation

Management Model. Three rounds of a mini-Delphi questionnaire were sent to the panellists who were expert methodologists in higher education. Refer to Annexure I for a sample of the mini-Delphi questionnaire that was forwarded to panellists. After the first round, one panellist advised that an additional box be placed in the framework for Technical Complexity. The framework was amended, and a second round of the mini-Delphi method was conducted. Two panellists advised that the criteria box and alternative box should each be augmented with a loop to cater for numerous attributes and choices, respectively. The panellists reached consensus in the third round. The results of the mini-Delphi showed that the SIMM was valid and could be used as a paradigm in the current study titled, "Intelligent Decision Support Systems for Managing the Diffusion of Social Computing in School-Based Ubiquitous Learning".

3.5.2 Usefulness of Emergent Theoretical Framework in this Study

Adhering to the **"Decision-Making Problem**" step in Figure 3.8, an assessment of the current education dilemma revealed that in unprecedented times, it is imperative to employ u-learning. However, there are countless devices and an upsurge in SM applications for u-learning to assist learners and teachers optimise their remote learning and teaching. The purpose of the study was to simulate IDSSs for SM applications and devices using live data to assist instructors and learners to manage the diffusion of social computing in school-based u-learning.

In the "**Decision-Making Problem**" step, the most popular SM applications for u-learning in SA were identified and investigated, along with the various devices. The aims of the study were achieved by gathering facts on the SM applications and devices for u-learning which were classified into technology criteria and education requirements. It was decided that the MADM method Fuzzy TOPSIS would be used for the selection of SM applications for u-learning. This method was selected based on the MAUT (Arsitodemou and Tietze 2019: 8) where the strategic decision-making theory managed the trade-off between various attributes, measuring weaknesses and strengths of alternatives. The order of preference of alternatives was revealed when the multi-attribute utility was measured to rank the alternatives (Arsitodemou and Tietze 2019: 8). The mathematical programming method DEA was employed for the measurement of the efficiency of devices for u-learning as existing literature portrayed the DEA method to be a robust optimisation and MCDM tool which is used to measure the technical and allocative efficacy of any sectoral unit (Venu, Ramadas and Ramasundaram 2017: 43).

The "**Alternatives**" step involved an internet search for the most frequently used SM applications by Generation Z. The resulting alternatives were Facebook, Facebook Messenger, YouTube, WhatsApp, WeChat, Snapchat, Instagram, TikTok, QQ, QZone, Viber, Reddit, Twitter, and Pinterest (HelloYes 2020). Alternatives in the DEA method were referred to as Decision Making Units (DMUs) (Venu, Ramadas and Ramasundaram 2017: 44). An internet search revealed that the best devices for learners were variations of desktops, tablets, smartphones, laptops, phablets, slates, notebooks, and netbooks.

In the "**Criteria**" step that is further sub-divided into "**Relative Advantage**" step, "**Technical Compatibility**" step, and "**Technical Complexity**" step, the criteria that were pertinent to measure m-learning, e-learning, and u-learning applications were determined. Sixty criteria comprising technology criteria and education requirements were synthesised from the existing literature. The criteria were evaluated by thirty teaching and learning experts and Principal Component Analysis (PCA) using singular value decomposition (SVD) on RStudio was employed to decrease the dimensionality of the data to the top thirty ranking criteria for selecting SM applications for u-learning.

The "**Evaluation of Information**" step entailed decision makers rating the SM applications in terms of linguistic scales in a survey questionnaire that were later assigned fuzzy numbers. The criteria and alternatives' aggregated fuzzy ratings were computed. The weighted normalised fuzzy decision matrix was attained by normalising the combined decision matrix and multiplying the matrix by the criteria weightage. The FPIS (A +) and FNIS (A −) were established and the A^+ and A^- matrix was derived from computing the distance of each alternative. The totality of each weighted alternative distance was determined utilising Fuzzy TOPSIS formulae.

In the DEA, the Output-Oriented CCR Multiplier Model with R Code was employed to weight the devices. Once the units in each column were normalised, the square root of the square sum of all the values in each column was found. These values were used as the divisors of each value in the respective columns. Thereafter, the g_k value which was the input minimisation value was calculated using the DEA mathematical programming algorithm on MATLAB R2020a.

For the "**Decision**" step in Fuzzy TOPSIS, for example, it meant that the Closeness Coefficient (CC_i) was calculated to rank the SM applications. The highest CC_i afforded the best SM application for u-learning. In DEA, once the g_k values are calculated along with the inverse values called H_k, the DMU is deemed efficient if it achieves a score of 1,000. In the CCR-Output model of DEA in the current study, devices that obtained a score less than 1,000 were considered inefficient.

In the **"Decision"** step the SM applications for u-learning which ranked the highest, and the devices which were most efficient in u-learning were compared to the existing literature to denote if a correlation existed between the results and what was previously known.

3.6 Chapter Summary

Chapter Three delivered a detailed account of the definition and usefulness of the Connectivism Theory, the IDT, and the Decision Theory in the current study. The emergent conceptual model called SIMM was constructed and validated using the mini-Delphi method. The usefulness of SIMM was discussed with respect to the current study, and this served as a blueprint for the processes to be followed throughout in the research. The SIMM integrated the Criteria, Alternatives, PCA, Fuzzy TOPSIS and DEA into a seamless method for designing an automated, evidence-based application using Intelligent Decision Support Systems (IDSSs). Chapter Four that follows focuses on highlighting the research design, with emphasis on the philosophical world view, the strategy of inquiry, research methods, reliability and validity, population and sampling, and ethical considerations.

CHAPTER FOUR: RESEARCH DESIGN

4.1 Introduction

When conducting research, the researcher adheres to a blueprint referred to as a research design (Saunders, Lewis and Thornhill 2012: 138). It reflects the composition of each step and every process foreseen by the researcher for the data analysis (Bhattacharyya 2013: 53). The data required is clearly outlined along with which research methods will be performed, how the collection and analysis of data will be conducted, and how the investigation and analysis of the data will fulfil every research question (Saunders, Lewis and Thornhill 2012: 138). The types of research designs are experimental design, correlational research and causal-comparative research, correlational research, exploratory research, and descriptive research (Johnson and Christensen 2014: 697). Descriptive research is a structured research method which involves providing a valid and an accurate description of a phenomenon (Johnson and Christensen 2014: 697). The method focuses on defining the variables in the situation which could be employed to generate a new theory. It includes the use of surveys, observational studies, and case studies as research tools (Bhattacharyya 2013: 53). This study, considering the aims and objectives was suited to descriptive research. Figure 4.1 displays the study's research design.

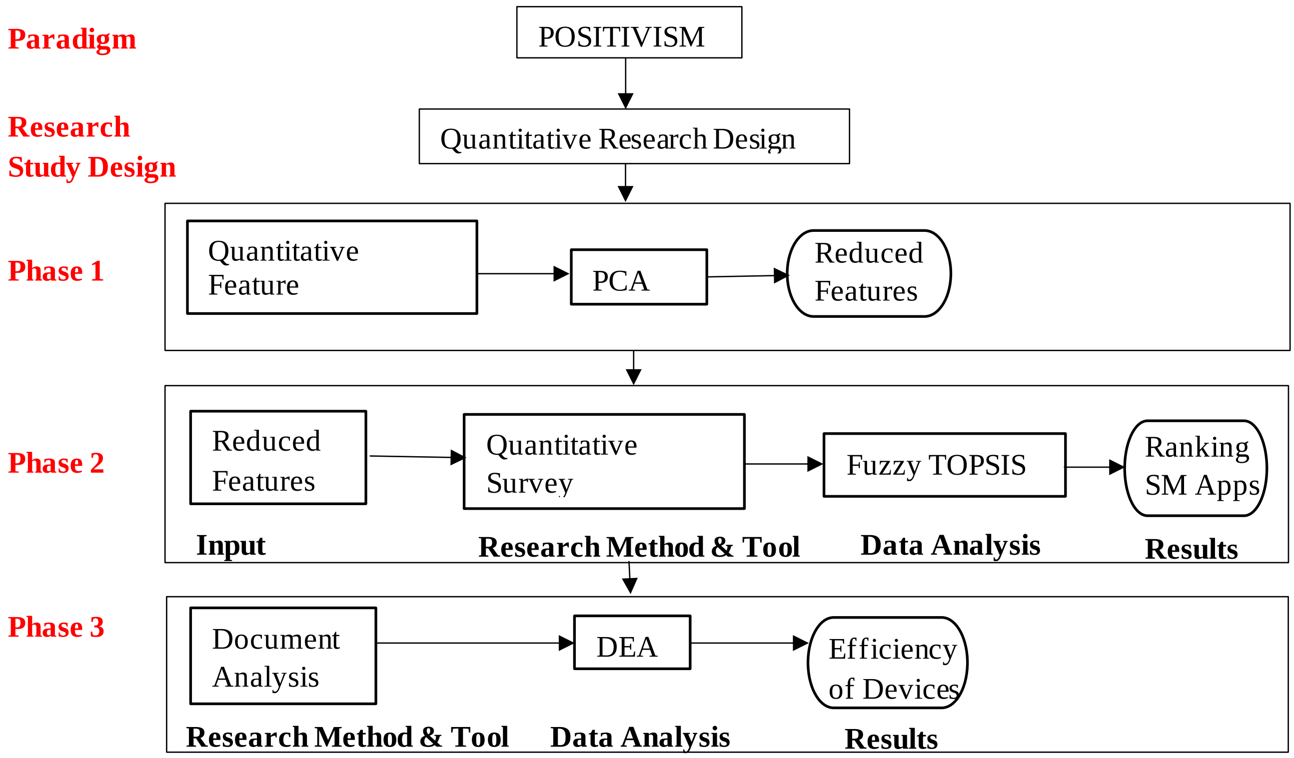

Figure 4.1: Model of the research design
Source: Researcher's own construction

4.2 Philosophical World View

To develop an Intelligent Design Support System (IDSS) for managing the diffusion of social computing in school-based u-learning, the study adopted a positivist research paradigm. Positivism believes that reality is constant and can be described and observed with an unbiased viewpoint, irrespective of the phenomena being studied (Bryman and Bell 2015: 24).

4.3 Strategy of Inquiry

Research strategies comprise positivist research strategies (surveys and experiments), phenomenological research strategies (focus groups, interviews, grounded theory, ethnography, case study, archival research and action research) and mixed research strategies (Saunders, Lewis and Thornhill 2012: 141). Due to the current study being quantitative, descriptive, and deductive in nature, a survey research strategy was implemented. Surveys are generally in the form of a questionnaire which is an excellent strategy for investigating large samples (Saunders, Lewis and Thornhill 2012: 144). Researchers must guarantee that the selected sample is characteristic of the entire population. Surveys are cost effective and give the researcher a certain amount of control over the research (Saunders, Lewis and Thornhill 2012: 144).

4.4 Research Methods

Research methodology describes the ways in which research should be conducted and the instruments required to collect and investigate information to establish solutions to the research problem (Saunders, Lewis and Thornhill 2012: 213).

4.4.1 Quantitative Method

The current study implemented a quantitative research methodology for the following reasons: it generates statistically reliable results if the data collection instrument (DCI) is planned and conducted correctly; it is time efficient and cost effective as opposed to qualitative methods; it is based on objective numerical results, therefore more reliable data is collected; it permits a great amount data collection and analysis; and it elicits relatively unbiased results (Saunders, Lewis and Thornhill 2012: 108).

Quantitative research is a method used to assess objective theories by exploring the correlation among study's variables (Creswell 2014: 4). It quantifies the problem by producing objective numerical data or converting the data into useful statistics (Saunders, Lewis and Thornhill 2012: 138). The case study approach was the selected strategy of inquiry for the management of social computing diffusion in school-based u-learning (Creswell 2014: 4).

4.4.2 Questionnaire Design

There are various forms of research instruments, namely, case studies, observations, questionnaires, interviews and diaries (Onwuegbuzie, Leech and Collins 2010: 696). As maintained by Saunders, Lewis and Thornhill (2012: 362), questionnaires consist of prompts and a series of questions to collect data from respondents. For optimal data collection, questionnaires need to be standardised. Questionnaires afford a comparatively economical and time efficient instrument for data collection from a large sample size (Onwuegbuzie, Leech and Collins 2010: 696). Due to the present study being quantitative and descriptive, using a deductive approach with simple random probability sampling and a large sample size, questionnaires were used to collect data.

4.4.2.1 Feature Questionnaire

A feature questionnaire forwarded as a link to the mobile device of experts was utilised to gather the dataset. Google Forms was used to afford online questionnaires that were economic and time-efficient for the collection of data of this magnitude. The questionnaire comprised closed-ended questions with a rating scale ranging from one to five. One was the least significant attribute and five was the most significant attribute. The respondent chose one applicable answer for each question. Section A of the questionnaire consisted of questions relating to the respondents' demographic details. Section B of the questionnaire comprised 31 items classified as education requirements and Section C comprised 23 items classified as technology criteria. The items that were crucial for managing the diffusion of SM applications for u-learning at school originated from the existing literature. Education requirements and technology criteria were refined with the employment of PCA, a dimension reduction method. The discrete values derived from the Likert scale of the questionnaire, were subsequently treated as continuous values in PCA. Refer to Annexure J for the Feature Questionnaire used in the study.

4.4.2.2 Study Survey Questionnaire

A survey questionnaire forwarded as a link to the mobile device of respondents was utilised to gather the dataset. Google Forms were used to distribute and collect online questionnaires that had a user-friendly interface. was economical and timesaving for the collection of data of this great size. An unrestricted number of matrix-formatted questions could be created on Google Forms in comparison to other survey creating platforms. The questionnaire comprised Likert scales, closed-ended questions where the respondent selected one appropriate answer for each question. ‘Not sure’, ‘very good’, ‘good’, ‘fair’, ‘poor’, or ‘very poor’ were possible answers. ‘Not sure’ was offered to respondents who were unacquainted with specific SM applications. Section A comprised six questions relating to the respondents’ demographic details and included questions such as the type of device, the type of internet connectivity, and the data option used by respondents. Section B surveyed fifteen education requirements and Section C explored fifteen technology criteria derived from the extant literature that was crucial to u-learning, m-learning, and e-learning. These were the dimensionality reduced attributes chosen from the results elicited from PCA. Refer to Annexure K for the main study Survey Questionnaire.

4.4.2.3 Reliability Testing of the Questionnaires

In the organisational and social sciences, Cronbach’s alpha reliability is the most extensively exercised reliability measure or measure of scale reliability (Cronbach 1951: 297). It measures the internal consistency of a group of items which is how closely related they are. In a technical sense, Cronbach’s alpha is a reliability coefficient and can be expressed as the mean intercorrelation between the items and the number of test items (Bonett and Wright 2014: 3). The Cronbach’s alpha formula is as follows:

$$\alpha = \frac{N\bar{c}}{\bar{v}+(N-1)\bar{c}} \qquad (4.1)$$

where N is the number of items

- $\bar{c}$: mean inter-item covariance among items
- $\bar{v}$: mean variance

By manipulation of the formula, Cronbach’s alpha score is high when there is a high number of items or when the mean inter-item correlation is high. Cronbach’s alpha score will be minimal if the inter-item correlation is low and if the number of items is constant (Bonett and Wright 2014: 5).

Cronbach's alpha was employed for the reliability test of the Feature Questionnaire. When the Cronbach's alpha score is 0,7 and less than 0,8, the research instrument is considered reliable. When the Cronbach's alpha score is 0,8 or more, the research instrument is deemed moderately reliability. When the Cronbach's alpha score is 0,9 and closer to 1, the research instrument is deemed highly reliable (Bonett and Wright 2014: 8).

4.4.3 Pilot Study

Performing a study on a smaller scale to evaluate carrying out the fully-fledged study is referred to as a pilot study (Brink, Van Der Walt and Rensburg 2018: 166). The purpose of a pilot study is to help identify problems or ambiguities and amend the Data Collection Instrument (DCI) before the study is conducted (Saunders, Lewis and Thornhill 2012: 420). This fine-tunes the DCI and contributes to the success of the study by improving the validity and reasonability of the questions to be asked, hence improving the interpretation of findings (Brink, Van Der Walt and Rensburg 2018: 166). To guarantee validity of the dataset to be collected, subjects like the target population are utilised for the pilot study (Sekaran and Bougie 2016: 245). According to extant literature, a pilot study sample should have ten to thirty participants (Isaac and Michael 1995: 124; Hill 1998: 7) and the exact number of the pilot study sample size should be twelve participants (Julious 2005: 287; Akaranga and Makau 2016: 5).

Piloting the current study included the responses of ten learners and two school-based instructors sourced from the school at which the researcher was based, that was not part of the main study. Parents were requested informed consent and permission to approach minor learners for the pilot study. Instructors and learners over the age of 18 years were afforded a Consent Form and a Letter of Information whilst learners under the age of 18 years were given an Assent Form to verify their participation in the pilot study. Once permission was obtained, a link to the pilot survey questionnaire was issued via email to all participants. The e-mail advised that participation was voluntary, the freedom of choice of the individual was respected, participants were provided with assurance of anonymity, and that no names were recorded on the questionnaire.

The pilot study measurement instrument was the online questionnaire generated on Google Forms. Pretesting: verified the feasibility of the study procedure; assessed the recruitment and consent rate; tested the questionnaire; and examined the data entry and analysis. Subsequently, the pilot study: tested if respondents understood the questions; identified practical problems and potential errors to be rectified before the questionnaire was carried out; assessed the time to complete the questionnaire; checked for excluded options; identified ethical issues that possibly made the respondent uncomfortable; ensured that the online interface was working optimally (Kenis *et al.* 2020: 395).

4.4.4 Data Collection

Data collection included three phases.

In **Phase 1**, thirty participants who were experts in m-learning and e-learning were solicited to evaluate the features of SM applications that were aligned with u-learning in schools. Experts were school-based or higher education practitioners, had three years or more experience, and had a teaching and learning university degree. Participants were afforded a week to complete the online Feature Questionnaire and ethical principles were adhered to by the researcher. Completing the survey took participants about fifteen minutes. Google Forms had an automatic tab for viewing the collection of data. The PCA method was applied to the generated data to reduce the dimensionally from 62 features into a more workable dataset.

In **Phase 2**, a total of 384 participants who were learners and instructors of various schools were requested to take part in the Survey Questionnaire for the rating of SM applications for u-learning. A general letter was sent via email to each school principal requesting permission for the study. Once a school agreed to participate in the study, parents were asked for permission and informed consent to approach minor learners for the study. Instructors and learners over the age of 18 years were afforded a Consent Form and a Letter of Information and learners under the age of 18 years were given an Assent Form to verify their participation in the study. Once permission was obtained an email with a link or mobile phone link to the survey questionnaire on Google Forms was sent to all participants. The link informed participants that participation was voluntary, participants' freedom of choice was respected, and that no names were recorded on the questionnaire. The survey was distributed to participants starting from the 19th of October 2020 until the 20th of November 2020. Participants took approximately 25 minutes to complete the questionnaire. Ethical principles of the research were adhered to by the researcher. Data was reflected automatically on the "responses" tab of Google Forms. Once the data was refined, it was analysed by Fuzzy TOPSIS for the selection of SM applications for u-learning.

In **Phase 3**, Document Analysis was used to define the quantitative features of devices. Document Analysis is a qualitative research method where all types of documents are elucidated by the researcher to give an opinion about and give meaning to an assessment topic (Bowen 2009: 30). Interpreting documents involves inscribing the content into themes (Bowen 2009: 31). Document Analysis entails schemes of triangulation to study a phenomenon. The aim of triangulating is to deliver a marriage of evidence that generates credibility and eliminates bias (Bowen, 2009: 31). To score or grade a document, a rubric can be employed which infers that Document Analysis is a mixed method study (O'Leary 2020: 329). The three categories of documents are public records (example: mission statements, student handbooks, and policy manuals etc.), personal documents (blogs, journals, newspapers, and e-mails, etc.), and physical evidence (training materials, flyers, and posters etc.) (O'Leary 2020: 329).

The current study explored a variety of documents to determine which type of devices were most frequently used for u-learning, the names of the specific devices being used, and the specifications of these specific devices. The specifications of devices that were essential for u-learning/m-learning/e-learning were also investigated. Key words and phrases typed into Google search were: "most common devices used for u-learning/m-learning/e-learning", "best devices used for u-learning/e-learning/m-learning", "best desktop for learners 2020", "best gaming tablet for learners 2020…", "spec of Dell Inspiron 3470", and "spec of Samsung Galaxy Tab S5e…", "best device features/specifications for e-learning/u-learning/m-learning". The type, name, and specifications of u-learning devices encountered in the extant literature were presented in Table 2.3 (Androidcentral 2020; AnySoftwareTools 2020; CNET 2020b; Creative Bloq 2020; Familyproof 2020; Gamesradar 2020; iMore 2020; Incredible Connection 2020; Laptop Study 2020; PC 2020; T3 2020; Techradar 2020; Tom's Guide 2020; Windows Central 2020).

Figure 4.2 shows the data collection phases implemented in this study:

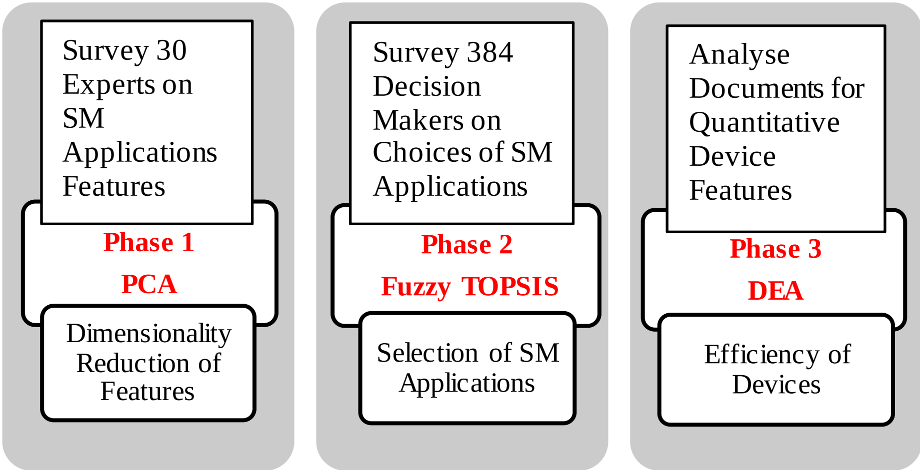

Figure 4.2: Data Collection in Three Phases
Source: Researcher's own construction

4.4.5 Data Analysis

Data analysis is the method of investigating, evaluating, and translating the dataset collected to discover new insights of a study (Saunders, Lewis and Thornhill 2012: 413). Data analysis in this study concerned the employment of Fuzzy TOPSIS and DEA. All algorithms for the data analysis were implemented on MATLAB R2020a.

4.4.5.1 Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate technique applied to convert high dimensional data into a manageable, lower-dimensional arrangement without losing excessive amounts of information by means of the dependencies between variables. It was developed by Pearson (1901: 560) and has evolved over time by numerous researchers. It is one of the most robust and easiest ways of dimensionality reduction. In PCA the data undergoes an orthogonal linear change to a different coordinate system which results in the highest variance by the data projection lying on the first coordinate termed the first principal component (PC1). The second highest variance will lie on the second coordinate and so forth. It is an intermediary step which requires further treatment of data such as indexing, assigning weights, or MCDM tools (Nikam, Jhajhria and Pal 2019: 10-11) and includes its use in the data analysis. Experts with tacit knowledge of u-learning were invited to rate education requirements and technology criteria and PCA was employed for the dimensionality reduction of SM applications features for u-learning.

4.4.5.2 Fuzzy TOPSIS

In the current study, Fuzzy TOPSIS was applied to rank the various SM applications used as u-learning tools among learners and school-based instructors via the reduced criteria generated from the PCA method. The higher the CC_i the higher the rank of the SM application for u-learning. The reasoning behind the MCDM tool Fuzzy TOPSIS is that the alternative that optimises the benefit criteria and reduces the cost criteria will be signified by an alternative with the least distance from the Fuzzy Positive Ideal Solution (FPIS) (Singh and Benyoucef 2011: 437). Alternately, the solution that reduces the benefit criteria and increases the cost criteria will be signified by an alternative with the most distance from the Fuzzy Negative Ideal Solution (FNIS) (Singh and Benyoucef 2011: 438). The alternatives' ranking order results from the Closeness Coefficient (CC_i). A superior alternative is denoted by a CC_i closest to the FPIS and farthest from the FNIS (Singh and Benyoucef 2011: 438).

4.4.5.3 DEA

Implicit to u-learning is device management. The MCDM tool DEA will evaluate the preference of digital access as u-learning tools among school-based instructors and learners using the input and output criteria elicited from the PCA Machine Learning tool. The reasoning behind the DEA method is that it compares the DMUs to an objective on the best practice frontier derived from the current dataset. Before the DEA model is implemented, a set of peer units are chosen (DMUs) which serve as the benchmarking units (Chandrasekar, Ramadas and Ramasundaram 2017: 82). The Efficient Frontier or frontier line is the benchmark which connects the most efficient point and envelops other data points. The deviation of the points from the efficient frontier gives the efficiency of the other unit. The efficiency of the other unit can be measured by the deviation of points from the frontier line (Chandrasekar, Ramadas and Ramasundaram 2017: 83). In the current study, a score of 1 inferred that the device was efficient to use in u-learning.

4.5 Reliability and Validity

Reliability determines if the results of the study are accurate, consistent, transparent, and replicable. Reliability may be affected by observer error, or observer bias, participant, or subject bias, participant, or subject error. Test-retest reliability, inter-rater reliability, and parallel-form reliability form the three types of reliability tests (Saunders, Lewis and Thornhill 2012: 157). The reliability and validity of the questionnaire was substantiated by implementing a pilot study. Validity determines the fidelity and accuracy of the results generated from the research conducted. Validity is related to the suitability and accuracy of the DCI and the instrument's ability to measure what it was planned to measure (Bryman and Bell 2015: 179). It establishes whether the research objectives will be fulfilled and if the research questions will be answered. Some of the different types of validity are convergent validity, face and content validity, concurrent and predictive validity, construct validity, and discriminant validity (Saunders, Lewis and Thornhill 2012: 157).

4.6 Population and Sampling

A population can be described as the entire complement of entities that interests the researcher and that the researcher wants to examine and base inferences on. A target population is the specific set of entities from which data is collected, according to the desired research objectives and the scope of the study (Sekaran and Bougie 2016: 242). In light of the research aim, objectives and questions, the target population were learners and school-based instructors from the eThekwini Region, namely, Umlazi District and Pinetown District. The size of the population in the study was 129 421 individuals which consisted of 124 388 learners and 4 853 school-based instructors, as derived from the March 2020 Schools Masterlist (Department of Basic Education 2020). The specific target size restricted to several inclusion and exclusion criteria that were aligned with the study's objectives.

Inclusion criteria were ordinary, fee-paying, public, and Independent Examination Board (IEB) high schools. Exclusion criteria encompassed schools where students experience severe behavioural problems, pre-primary learners, primary school learners, special schools for challenged learners, arts, drama, music and ballet, agriculture, commercial schools, technical schools, and comprehensive schools. The learners and school-based instructors were regarded as a single population. This was because the study's objective did not seek to distinguish between the opinions of learners and school-based instructors, but ultimately endeavoured to determine the extent that social computing could be used for school-based u-learning based on collective decision making. It is possible that instructors view SM applications differently to the learners due to their possible exposure and age difference resulting in biasness. Hence, the decision makers were the learners and instructors that applied social computing for u-learning.

Sampling must be reflected upon whenever research is being conducted as the time constraints and feasibility make it impossible to investigate all elements in the population. A representative sample is acquired and the subsequent conclusions are directed towards the entire population (Sekaran and Bougie 2016: 266). Sampling is categorised as probability and non-probability sampling (Saunders, Lewis and Thornhill 2012: 212). As the present study employed a survey research strategy for data collection, simple random probability sampling was utilised. Probability sampling refers to each entity in the population having an equal chance of being chosen for the study which eliminates bias of the researcher, to give the most accurate representation of the population (Sekaran and Bougie 2013: 22). The four stages in probability sampling are: identify the sampling timeframe; determine the sample size; select the sample and sampling technique; and ensure the selected sample accurately represents the target population (Sekaran and Bougie 2013: 22). Probability sampling methods comprise systematic sampling, simple sampling, cluster sampling and stratified random sampling (Rubin and Babbie 2009: 131). In the current study, simple random sampling was adopted due to the selected sample being accessible to the researcher and each sample case was uniquely and randomly numbered to avoid bias and to conserve anonymity (Sekaran and Bougie 2013: 22).

4.6.1 Sample size

The size of the sample is reliant on the population size, and the purpose, the accuracy and the non-responsive error of the study (Sekaran and Bougie 2016: 266). The most appropriate and simplest method for determining the size of the sample for a given population is expressed by Sekaran and Bougie's (2016: 266) book which includes scientific guidelines to decide on the sample size of the study as depicted in Table 4.1. The sample size of the current study was 384 participants for a target population size of approximately 129 421 (Department of Basic Education 2020) which corresponds the guidelines set by Sekaran and Bougie (2016: 320). According to literature, the target response rate a survey questionnaire should be around 60% (Fincham 2008: 2). Accordingly, the current study's response rate was acceptable.

Table 4.1: Establishing Sample Size from a Given Population

N	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*
10	10	85	70	220	140	440	205	1 200	291	4 000	351
15	14	90	73	230	144	460	210	1 300	297	4 500	354
20	19	95	76	240	148	480	214	1 400	302	5 000	357
25	24	100	80	250	152	500	217	1 500	306	6 000	361
30	28	110	86	260	155	550	226	1 600	310	7 000	364
35	32	120	92	270	159	600	234	1 700	313	8 000	367
40	36	130	97	280	162	650	242	1 800	317	9 000	368
45	40	140	103	290	165	700	248	1 900	320	10 000	370

50	44	150	108	300	169	750	254	2 000	322	15 000	375
55	48	160	113	320	175	800	260	2 200	327	20 000	377
60	52	170	118	340	181	850	265	2 400	331	30 000	379
65	56	180	123	360	186	900	269	2 600	335	40 000	380
70	59	190	127	380	191	950	274	2 800	338	50 000	381
75	63	200	132	400	196	1 000	278	3 000	341	75 000	382
80	66	210	136	420	201	1 100	285	3 500	346	1 000 000	384

N is the population size.

S is the sample size.

Source: Sekaran and Bougie (2016: 266)

Table 4.2 was an expected sample population of the number of participants per age cohort which was representative of the target population. According to Barry *et al.* (2017: 2), most learners under the age of 15 do not have permission to use social media due to parental concerns. Additionally, the proportion of the age group 19 years or more for learners in high school is low (The Mail and Guardian 2010). Furthermore, the ratio of teachers to learners in South African high schools is approximately 1:30 (Index Mundis 2019). Based on the evidence from the extant literature, Table 4.2 reflected the estimation of the number of participants for each age group.

Table 4.2: Estimation of the number of participants for each age group

AGE	PERCENT	TOTAL
13 – 15	25%	96
16 – 19	50%	192
≥ 20	22%	84
Instructors	3%	12

4.6.2 Margin of Error and Confidence Level

The Margin of Error (MOE) is the extent of error in the results obtained from random sampling surveys. A greater margin of error indicates a smaller probability of relying on the survey's results, meaning that there will be a lower confidence level on the results to characterise a population (Kosar, Bohrab and Mernik 2018: 441). A confidence level is the unpredictability degree with a given statistic. Together with the MOE, it is employed to represent the confidence of the researcher in gauging whether the survey results are creditable to represent the total population or not (Kosar, Bohrab and Mernik 2018: 441). In respect to the current study and according to Table 4.3, for a confidence level of 95%, and a sample size of 384 participants the MOE would be 5% which would afford reliable results from the survey.

Table 4.3: Some Common Margins of Error with Needed Sample Size

Margin of error	Confidence level	Sample size
6%	95% ($z_{\alpha/2} = 1.96$)	267
6%	99% ($z_{\alpha/2} = 2.58$)	462
5%	95% ($z_{\alpha/2} = 1.96$)	384
5%	99% ($z_{\alpha/2} = 2.58$)	666
4%	95% ($z_{\alpha/2} = 1.96$)	600
4%	99% ($z_{\alpha/2} = 2.58$)	1040

Source: Kosar, Bohrab and Mernik (2018: 441)

4.7 Ethical Considerations

According to Sekaran and Bougie (2013: 313), a host of ethical considerations must be adhered to by the researcher when carrying out the research process. The researcher must guarantee that no harm comes to participants, participants have given informed consent, that ethical and organisational approval has been confirmed, and that their confidentiality and anonymity is kept (Sekaran and Bougie, 2013: 313). As most of the participants were minors, an informed letter of consent was given to parents/guardians of the learners for their participation in the study. Organisational approval was sought, and the identity of the schools remained anonymous throughout the study. No harm came to respondents and their anonymity was preserved. Ethical approval was confirmed by the Ethics Committee of the Durban University of Technology (DUT) (refer to Annexure G). An Ethics Training Certificate was awarded to the researcher for successfully completing the Introduction to Ethics programme (refer to Annexure H).

4.7.1 Recruitment of Participants

Schools in the eThekwini region was approached to take part in the current study. Prior permission for the study was attained from the district managers of the Umlazi District and Pinetown District (Annexure E). Approval to perform the study was also acquired from the Head of the Department of Education (Annexure F). The list of schools was sourced from the publicly accessible schools master list available at: https://www.education.gov.za/Programmes/EMIS/EMISDownloads.aspx.This list contained the name of the school, the contact details of the school, and the number of learners and educators in the school. A general letter was sent via email to each school principal requesting permission for the study.

Due to COVID-19, social distancing and sanitary practices were maintained. Therefore, all correspondence and responses were conducted electronically. Once principals agreed to the study being conducted, each school principal made available the contact details of instructors, parents and learners who decided to participate in the study. The contact details included telephone/cell phone numbers and email addresses.

Parents of learners at the selected school were requested to provide informed consent and permission to approach learners for the study. Instructors were afforded a Letter of Information and a Consent Form and learners were issued an Assent Form to verify their participation in the study. The required signatures were obtained. Both consent and assent forms were submitted by emailing the researcher a response. Once permission was obtained, all participants were forwarded an e-mail or mobile phone link to the survey questionnaire with a message that advised that participation was voluntary.

4.7.2 Informed Consent

A general letter was sent to each school principal requesting permission for the study. Informed consent and permission were gained from learners over the age of 18 years (Annexure C). Once permission was obtained an email with a link to the survey questionnaire, generated on Google Docs was sent to all learners and school-based instructors.

4.7.3 Assent for Learners

Once a school confirmed their participation in the study, parents of learners less than 18 years of age were asked for informed consent and permission to approach learners for the study. Both assent and permission were received from learners that were minors (Annexure D).

4.7.4 Anonymity and Confidentiality

The researcher ensured that participants' anonymity was preserved. No names were recorded on the questionnaire. Organisational approval was sought, and the identity of the schools remained anonymous throughout the study. The researcher ensured participants that confidentiality and security of all responses provided during interviews were maintained and that all records of the questionnaires were stored securely, to be deleted after five years.

4.7.5 Protection of Participants

The researcher ensured participants that their rights and welfare were protected, that there was no harm or victimisation directed at them because of their participation in this research, and that findings of this research were available on request. Participants' freedom of choice was respected, and participation was voluntary. The participants that were minors could decline to participate in the study irrespective of their parents' approval for them to participate. Participants' participation in this study was voluntarily and they could retract from this study at any stage. No reasons were required if they wished to withdraw. The data and documents related to the study were lodged with the Department of Information Technology for quality assurance audits and safekeeping. This included a lock-up safe and the premises at the university was secured by armed guard protection and camera surveillance.

4.8 Chapter Summary

The chapter commenced with the blueprint of the research design utilised for the study. The philosophical world view of the study was positivism, and the quantitative research method was the strategy of inquiry used in this study. The survey questionnaires for the research were designed by the guidelines extracted from the extant literature and the questionnaires' reliability were measured using the Cronbach's alpha score. The pilot study was conducted with responses of ten learners and two school-based instructors. Data was collected in three phases. The first phase involved information required by thirty experts on the criteria of SM applications for u-learning. The second phase allowed 384 respondents to choose the most pertinent SM applications through multi-criteria decision making and finally the third phase involved the collection of data on the features of u-learning devices to measure device efficiency. Details of the data analysis, population and sampling and ethical considerations were included in this chapter. Chapter Five presents the Strategic Decision-Making Methods used in this study.

CHAPTER FIVE: STRATEGIC DECISION-MAKING METHODS – A SCIENTIFIC APPROACH

5.1 Principal Component Analysis

In this study, Principal Component Analysis is applied in a multivariate analysis of data perspective to mine significance from a dataset of sixty dimensions (Sam, Naicker and Adebiyi 2021: 7).

5.1.1 Introduction

Principal Component Analysis uses a mathematical algorithm for dimensionality reduction of a dataset while upholding the variability (Ringnér 2008: 303). A cursory view of the plethora of technology criteria (twenty-four) and education requirements (thirty-six) afforded by the meta-analysis of extant literature in the current study, can confound and cloud the most important features for determining the aptness of the social media applications for ubiquitous learning. This urges the need for a powerful analytical method such as Principal Component Analysis to make sense of the data. It is an empirical feature extraction algorithm from linear algebra that can adjust the data to be distributed and afford a diagonalisable matrix of covariance on a reduced dimensionality subspace (Sharma 2008: 87; Sam, Naicker and Adebiyi 2021: 7). In this regard, Principal Component Analysis is employed in an unsupervised manner to assess the main dataset of the multi-dimensional dataset. A Principal Component Analysis benefit is that every dimension is measured to express the dataset's disparity. Each calculated score offers a way for comprehending the importance per dimension relative to one another (Sharma 2008: 87; Sam, Naicker and Adebiyi 2021: 7). Compared to the lower score dimensions, the higher score dimensions called principal components deliver a better illustration of the criteria employed to evaluate the applicability of social media applications for ubiquitous learning (Sharma 2008: 88; Sam, Naicker and Adebiyi 2021: 7).

The most variation amongst the sample criteria is presented by the first principal component (PC1). In the feature set, PC1 is the greatest fundamental trend (Sharma 2008: 88; Sam, Naicker and Adebiyi 2021: 7). The second highest variation amongst the sample criteria is accounted for by the second principal component (PC2). It is the direction unrelated to the PC1 along which the samples reflect the second highest variation. The same applies to the other PCs (Sharma 2008: 88; Sam, Naicker and Adebiyi 2021: 7). The Principal Component Analysis method is founded on the notion that when components are assessed, the greatest variation component that is usually PC1 can describe more of the dependent variable variation in contrast to a lesser variation component (Sharma 2008: 88).

5.1.2 Principal Component Analysis Method

In the study, Principal Component Analysis (PCA) was applied on RStudio Version 1.3.1056 by means of the pre-built-in R *stats* package, prcomp. The previously executed functions on the PCA data matrix were utilised to 1) create graphs that exemplify the relatedness of the samples to each other, 2) further decrease the variables' dimensionality. The prcomp() function on RStudio yields values for three parameters, specifically:

- Principal component is "$\boldsymbol{x}$".
- Standard deviation is "**sdev**". It reflects how much variation is attributed to each PC in the original data and can be calculated by finding the square of standard deviation.
- Loading score is "**Rotation**". A specific loading score is allocated to each PC in every sample, which generates an eigenvectors matrix. The matrix can determine if the criteria loading scores are negative or positive.

On RStudio, "x", "sdev" and "rotation" more accurately returns the following:

- "x" that prcomp() returns sums (the rotation * the original data) but compressed to the unit vector.
- "sdev" value that prcomp() returns (and thus related to the eigenvalues)
- "rotation" that prcomp() returns a matrix of loading scores.

The ggplot2 and base graphics on RStudio can be used to draw the PCA plot (Sam, Naicker and Adebiyi 2021: 8).

5.1.3 Data Standardisation

Data standardisation is imperative to the summarisation of data. In PCA this is referred to as scaling, where the dataset is standardised utilising equation (5.1). This infers that the attribute mean becomes zero and a unit standard deviation is given to the resultant distribution.

Considering equation (5.1), the dataset was standardised:

$$x_{ij} = (X_{ij} - X_m)/\sigma \qquad (5.1)$$

$$i = 1, 2, 3, \ldots 30 \text{ and } j = 1, 2, 3, \ldots .60$$

where i is the expert number and j is the criteria number

The i^{th} expert rating of the j^{th} criteria is represented by the original value X_{ij}. The mean is X_m. The series' standard deviation developed from the values of the i^{th} expert for all sixty criteria is represented by σ (Mirkin 2011: 201). The data was standardised by the RStudio function `scale (). It implements scaling on the columns by taking a numeric matrix as an input (STHDA 2019).

5.1.4 Dimensionality Reduction of Education Requirements and Technology Criteria

Table 5.1 presents a synopsis of the criteria for evaluating SM applications for u-learning derived from extant literature. Each criterion was given an alphabetised identification as is seen in the 'Column ID'.

Table 5.1: Criteria for evaluating social media application for ubiquitous learning

No.	Educational Requirements	Column ID	Technology Criteria	Column ID
1.	Learning Content Quality	B	Accessibility Standards	AL
2.	Presentation of Learning Content	C	Web and Course Design	AM
3.	Enjoyment Factor	D	Scalability	AN
4.	Social Interactivity	E	Ease of Use	AO
5.	Clear Instructions Provided	F	Integration/Embedding within a Learning Management System (LMS)	AP
6.	Instructor Opinion	G	Operating Systems	AQ
7.	Compatibility with Course Description	H	Browser	AR
8.	Learner Behaviour	I	No Additional Downloads Needed	AS
9.	Integrity	J	Access on the Mobile Platform	AT
10.	Suitable Technical Competences for Learning	K	Seamless Functionality Between Mobile and Desktop	AU
11.	Ownership of Learning	L	Offline Access	AV
12.	Instructional Design	M	Data Privacy and Ownership	AW
13.	Assessment of Learning	N	Downloading, Saving and Exporting Data	AX
14.	Peer Learning	O	Technical Information	AY
15.	Instructional Resources for Teaching and Learning	P	Multimedia Control	AZ
16.	Learner Support	Q	Software Characteristics Quality	BA
17.	Course Evaluation	R	User-Friendly Interface	BB
18.	Archiving/Repository	S	Functionality	BC
19.	Collaboration	T	Hypermediality	BD
20.	User Accountability	U	Facilitation of E-Content	BE
21.	Diffusion	V	Operational Stability	BF
22.	Instructor Facilitation	W	Offline Mobile Access	BG
23.	Learning Analytics	X	Security of Technology	BH
24.	Enhancement of Cognitive Task(s)	Y	Fault Tolerance of Technology	BI

25.	Higher Order Thinking	Z		
26.	Meta-Cognitive Engagement	AA		
27.	Permanency	AB		
28.	Immediacy	AC		
29.	Adaptability	AD		
30.	Management of Interactive Learning Objects	AE		
31.	u-Learning Training Factors	AF		
32.	Quality Assurance	AG		
33.	Learnability and Memorability	AH		
34.	Perceived Usefulness and Satisfaction	AI		
35.	Curriculum Management	AJ		
36.	Customisation	AK		

5.2 Fuzzy TOPSIS

This research study will use Fuzzy TOPSIS to evaluate the preference of Social Media (SM) applications as electronic learning (e-learning) tools among learners and teachers in school.

5.2.1 Introduction

Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a technique created by Hwang and Yoon (1981) to objectively and systematically resolve Multiple Criteria Decision Making (MCDM) problems by assessing the numerous alternatives against multiple chosen criteria (Sodhi and Prabhakar 2012). In Fuzzy TOPSIS, the solution that maximises the benefit criteria and minimises the cost criteria is the alternative with the minimum distance from the Positive Ideal Solution (PIS). The solution that maximises the cost criteria and minimises the benefit criteria is the alternative with the biggest distance from the Negative Ideal Solution (NIS) (Singh and Benyoucef 2011: 438). As human ideas are imprecise and cannot be quantified, typical TOPSIS cannot be used (Kannan, Pokharel and Kumar 2009: 30). Therefore, the fuzzy set theory must complement TOPSIS to assign crisp numerical data to the performance ratings of alternatives and the criteria weights (Kelemenis, Ergazakis and Askounis 2011: 2776). Fuzzy TOPSIS uses linguistic variables to define the ratings and weights which are subsequently denoted by fuzzy numbers. More scholars have extensively covered the Fuzzy TOPSIS techniques along with its functions in recent times (Han and Trimi 2018: 133).

5.2.2 Recent Studies that Use Fuzzy TOPSIS

In recent years, a few Fuzzy TOPSIS methods were established in the various applied fields. Safari, Faghih and Fathi (2012: 206) implemented Fuzzy TOPSIS for facility location selection which was strategically important for many companies. The study by Pattnaik *et al.* (2015: 1) used the Fuzzy TOPSIS technique, to enhance the parameters of cutting in Electrical Discharge Machining for S304 grade stainless steel. They achieved the goal of attaining the best surface quality with greater material removal rate simultaneously with minimum tool wear rate, using Fuzzy TOPSIS. Yavuz (2016: 425) performed a study using Fuzzy TOPSIS for the selection of open pit trucks used in open pit coal mines in Turkey. Additionally, Fuzzy TOPSIS was used to investigate the optimal solution of the equipment selection problem. Dharmarajan and Mary (2016: 1027) evaluated the TOPSIS and Fuzzy TOPSIS method in data mining of professional human resources for companies where the available information was imprecise and subjective. Here, Fuzzy TOPSIS proved to be an effective method for developing a group decision-making model in a fuzzy environment. In a study on waterways, Balioti, Tzimopoulos and Evangelides (2018: 624) employed Analytic Hierarchy Process (AHP) with Fuzzy TOPSIS to choose an appropriate spillway for Dam Pigi in the Kilkis district in Northern Greece. The study made it possible to make decisions about the optimum spillway form under complex circumstances.

Han and Trimi (2018) identified the criteria for designing and evaluating social commerce platforms to be used for reverse logistics in firms utilising Fuzzy TOPSIS with the software tool FLINSTONES. Haq and Ahmed (2019: 60) measured the performance of employees in a Bangladesh manufacturing plant by implementing Fuzzy TOPSIS as a MCDM technique to aid the employee evaluation and selection process. Demir (2019: 233) evaluated the service quality of airlines in Turkey with Fuzzy TOPSIS. This study would help airway transportation companies in gaining a competitive advantage by aligning their service quality with the ranked criteria. The study by Özsever *et al.* (2020: 282) provided chemical tanker companies with solutions to the critical issue of choosing the most effective tank coating prior to ship construction using Fuzzy TOPSIS to evaluate stainless steel, MarineLine, epoxy and zinc silicate coatings against the decided upon multiple criteria. In another case study, Huang *et al.* (2020: 36) applied the Fuzzy TOPSIS method for selecting the best candidate for a job based on their interview performance which facilitated a more realistic resolve to decision making. Fuzzy TOPSIS calculations were coded on a CORE i7 platform running Windows 10 Professional using MATLAB 2019a (Huang *et al.* 2020: 37).

5.2.3 Studies in Education Using Similar MCDM Techniques

Meyliana, Hidayanto and Budiardjo (2015: 1676) analysed students' SM preference to improve student and university engagement. Questionnaires were used to collect data from students at fifty-eight Indonesian universities. The data was processed with Entropy which was also used to allocate criteria weights for students' inclination towards SM applications. It was established by means of the TOPSIS method that the use of the SM application was less reliant on service quality than information quality. While the usefulness and comprehensiveness of information was important to students; efficiency, fulfilment, and system availability was also valued by students as it influenced their active learning process and expectation. Furthermore, TOPSIS was implemented to rank the SM platforms which resulted in the Podcast being ranked as the most unfavourable and LINE as the most favourable SM platform to improve student interaction with universities.

Sirait *et al.* (2018: 158) established eleven SM platform criteria to enhance student involvement in government undertakings and eight alternatives that best corresponded to the criteria. Sirait *et al.* (2018) presented a directive for measuring SM preferences and emphasised the popular SM to support e-participation. The generated criteria were founded on the theory of utilitarian and hedonic motivation. A questionnaire was used in this study to collect data from Indonesian university students and the data was then processed using fuzzy AHP to determine the weight of SM platforms that improve students' e-participation in government undertakings. The TOPSIS was used to rank SM platforms according to students' preferences.

5.2.4 Justification of Fuzzy TOPSIS in the Current Study

While there is considerable literature on the usage of Fuzzy TOPSIS in decision making in various fields, the literature on the utilisation of Fuzzy TOPSIS in school-based education is deficient. Most studies have used the method to rate the opinions of students in higher education, but the literature does not include the employment of Fuzzy TOPSIS with ratings by instructors and learners in schools. The available studies in higher education have been conducted in other countries and have focused on the use of TOPSIS to rate SM criteria that improve engagement or participation. Thus, the current study will enrich the literature on the use of Fuzzy TOPSIS in a South African schooling context. Regarding the current pandemic, going "online now" gives decision making on the use of SM applications as u-learning tools a novel focus. Previous studies addressing social e-learning tools in SA have either focused on the opinion of instructors or learners using qualitative methods. Therefore, Fuzzy TOPSIS will present a quantitative mathematical approach for assessing the opinions of instructors and learners in this study. Holistically, this study has the potential to:

- change school policy on the use of SM in education;
- resolve the disparities of bandwidth or connectivity in South African remote teaching and learning;
- eliminate the time that it would have taken to train instructors and learners to use the e-learning applications;
- reduce the effort made and time taken by instructors to select optimal SM applications with the afforded theoretical framework;
- establish weightage of criteria that is essential for e-learning and align lesson plans with these criteria in mind, thereby enhancing pedagogy.

5.2.5 Fuzzy Set Theory

Fuzzy Set Theory was first introduced by Zadeh (1965) to manage problems involving vagueness by means of linguistic variables to signify the choices made by decision makers. There are two definitions of the Fuzzy Set Theory. The first definition mathematically expresses a fuzzy set $\tilde{A}$ by a membership function called $\mu_{\tilde{A}}(X)$, where in the discourse X universe, each element x is mapped in the interval $[0,1]$ to a Real Number (Safari, Faghih and Fathi 2012: 207). The membership grade of x in $\tilde{A}$ refers to the function value of $\mu_{\tilde{A}}(X)$ and the higher it is, the closer the function value of $\mu_{\tilde{A}}(X)$ is to unity (Han and Trimi 2018: 136). Figure 5.1 illustrates the second definition of the Fuzzy Set Theory where a Triangular Fuzzy Number (TFN) is denoted as the triplet (a, b, c):

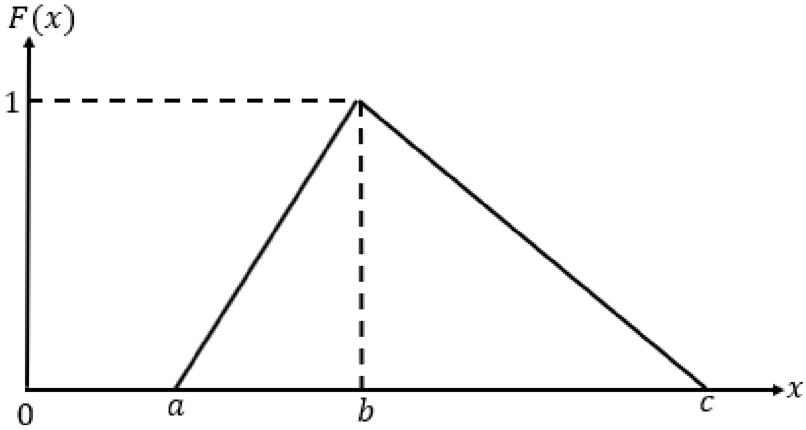

Figure 5.1: Membership function of triangular fuzzy numberMembership function of triangular fuzzy number

Source: Moayeri *et al.* (2015: 2)

Moayeri *et al.* (2015: 2) expressed $F(x)$ as:

$$\mu_{\tilde{A}}(X) = \begin{cases} \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & otherwise \end{cases} \tag{5.2}$$

The fuzzy triplets a, b and c are Real Numbers and $a < b < c$ (Han and Trimi 2018: 136). To establish the functional rules of the two TFNs, let $A_1 = (a_1, b_1, c_1)$ and $A_2 = (a_2, b_2, c_2)$.

Addition: $A_1 + A_2 = (a_1 + a_2,\ b_1 + b_2,\ c_1 + c_2)$ (5.3)

Subtraction: $A_1 - A_2 = (a_1 - c_2,\ b_1 - b_2,\ c_1 - a_2)$ (5.4)

Multiplication if k is a scalar: $k \times A_1 = \begin{cases} (ka_1, kb_1, kc_1), & k > 0 \\ (kc_1, kb_1, ka_1), & k < 0 \end{cases}$ (5.5)

$A_1 \times A_2 \approx (a_1 a_2,\ b_1 b_2,\ c_1 c_2),\ if\ a_1 \ge 0$ and $a_2 \ge 0$

Division: $A_1 \div A_2 \approx \left(\frac{a_1}{c_2}, \frac{b_1}{b_2}, \frac{c_1}{a_2}\right), \quad if\ a_1 \ge 0$ and $a_2 \ge 0$ (5.6)

5.2.5.1 The distance between Triangular Fuzzy Numbers

Let $\bar{a} = (a, b, c)$ and $\bar{b} = (a', b', c')$. The distance between the TFNs is derived using the vertex method:

$$d(\bar{a}\bar{b}) = \sqrt{\frac{1}{3}\ [(a - a')^2 + (b - b')^2 + (c - c')^2]} \tag{5.7}$$

In application, the measurement of the distance between fuzzy numbers $\tilde{a}$ and $\tilde{b}$ is given by d_v $(\tilde{a}, \tilde{b})$ (Han and Trimi 2018: 137).

5.2.5.2 Linguistic variables

Linguistic variables are natural sentences or artificial words that are transformed into TFNs using conversion scales of 1 to 9 to rate the alternatives and criteria. Table 5.2 reflects the linguistics terms and the related TFNs for alternatives and criteria (Kannan, Pokharel and Kumar 2009: 29).

Table 5.2: Linguistic terms for criteria and alternatives

Criteria	Alternatives	
	Linguistic term	**Triangular fuzzy numbers**
Very low (VL)	Very poor (VP)	(1, 1, 3)
Low (L)	Poor (P)	(1, 3, 5)
Medium (M)	Fair (F)	(3, 5, 7)
High (H)	Good (G)	(5, 7, 9)
Very High (VH)	Very good (VG)	(7, 9, 9)

5.2.6 Fuzzy TOPSIS Method

Fuzzy TOPSIS is implemented to assess numerous alternatives alongside the designated criteria. In the TOPSIS method an optimal alternative is farther from the Fuzzy Negative Ideal Solution (FNIS) and nearest to the Fuzzy Positive Ideal Solution (FPIS). The FPIS comprises each alternative's optimal performance values while, the FNIS comprises each alternative's unfavourable performance values. When implementing the Fuzzy TOPSIS algorithm a sequence of steps must be adhered to, as outlined below (Huang *et al.* 2020: 36).

7.2.6.1 Steps of the Fuzzy TOPSIS method

The fuzzy ratings and importance weight of the k^{th} decision maker, about the i^{th} alternative on j^{th} criterion are illustrated in the steps below:

"Step 1: Assignment of ratings to the alternatives and the criteria.

Assume that there are m possible alternatives called $A = \{A_1, A_2, \ldots, A_m\}$ which must be evaluated against n criteria, $C = \{C_1, C_2, \ldots, C_n\}$. Criteria weights are represented by w_g $(g = 1,2, \ldots, n)$. Each decision maker's $D_k(k = 1, 2, \dots, k)$ ratings for each alternative $A_i(i = 1, 2, \dots, m)$ regarding criteria $C_j(j = 1, 2, \dots, n)$ are indicated by $\tilde{R}_k = \tilde{x}_{igk}\ \tilde{R}$ with the membership function $\mu_{\tilde{R}_k}(x)$.

Step 2: Computation of aggregated fuzzy ratings for the alternatives and the criteria.

- If the importance weight and fuzzy rating of the decision maker k are:

$$\tilde{w}_{igk} = (w_{gk1}, w_{gk2}, w_{gk3}) \quad (5.8)$$

and $\tilde{x}_{igk} = (a_{igk}, b_{igk}, c_{igk}), \quad i = 1,2, \dots m \ , g = 1, 2, \dots, n$ (5.9)

respectively, then the aggregated fuzzy ratings $\tilde{x}_{ijk}$ of each alternative relating to each criterion is presented as: $\tilde{x}_{ij} = (a_{ig}, b_{ig}, c_{ig})$ (5.10)

where: $a_{ig} = min_k\{a_{igk}\}$ (5.11)

$$b_{ig} = \frac{1}{k}\sum_{k=1}^{k} b_{igk} \quad (5.12)$$

$$c_{ig} = max_k\{c_{igk}\} \quad (5.13)$$

The aggregated fuzzy weights $(\tilde{w}_{ij})$ of each criterion is calculated as:

$$\tilde{w}_{ig} = (w_{g1}, w_{g2}, w_{g3}) \quad (5.14)$$

where: $w_{g1} = min_k\{w_{gk1}\}$, $w_{g2} = \frac{1}{k}\sum_{k=1}^{k} w_{jk2}$, $w_{g3} = max_k\{w_{jk3}\}$ (5.15)

Step 3: Computation and normalisation of the fuzzy decision matrix.

The fuzzy decision matrix is computed as such:

$$\tilde{D} = \begin{matrix} A_1 \\ A_2 \\ A_m \end{matrix} \begin{pmatrix} \tilde{x}_{11} & \tilde{x}_{12} \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} \dots & \tilde{x}_{2n} \\ \tilde{x}_{m1} & \tilde{x}_{m2} \dots & \tilde{x}_{mn} \end{pmatrix} \quad (5.16)$$

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n) \quad (5.17)$$

A comparable scale is derived from normalising the numerous criteria scales. The normalised fuzzy decision matrix is $\tilde{R}$ and is given as:

$$\tilde{R} = [\tilde{r}_{ig}]\ m \times n\ ,\ i = 1, 2, \dots, m;\ g = 1, 2, \dots, n \quad (5.18)$$

thus the benefit criteria: $\tilde{r}_{ig} = \frac{a_{ig}}{c^+_g}, \frac{b_{ig}}{c^+_g}, \frac{c_{ig}}{c^+_g}$ (5.19)

where: $c^+_g = max_i c_{ig}$ of the benefit criteria (5.20)

and for cost criteria: $\tilde{r}_{ig} = \frac{\bar{a}_j}{c_{ij}}, \frac{\bar{a}_j}{b_{ij}}, \frac{\bar{a}_j}{a_{ij}}$ (5.21)

where: $\bar{a}_j = min_i a_{ig}$ of the cost criteria (5.22)

Step 4: Computation of the weighted normalised matrix

The weighted normalised fuzzy decision matrix $\tilde{v}_{ij}$ is derived by:

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n} \quad i = 1,2, \dots, n;\ \ j = 1,2, \dots, m \quad (5.23)$$

where: $\tilde{V}_{ij} = \tilde{r}_{ij} \times \tilde{w}_j$ (5.24)

Step 5: Computation of the FPIS (A^+) and FNIS (A^-).

The FPIS of the alternatives are computed as:

$$A^+ = (\tilde{v}^+{}_1, \tilde{v}^+{}_2, \dots, \tilde{v}^+{}_m) \quad (5.25)$$

where: $v^+{}_i = max_i\{v_{ig3}\}, \ g = 1, 2, \dots, n; \ i = 1, 2, \dots, m$ (5.26)

and the FNIS of the alternatives are computed as: $A^- = (\tilde{v}^-{}_1, \tilde{v}^-{}_2, \dots, \tilde{v}^-{}_m)$ (5.27)

where: $\tilde{v}^-{}_j = min_i\{v_{ig1}\}, \ g = 1, 2, \dots, n; \ i = 1, 2, \dots, m$ (5.28)

Step 6: Calculation of the distance of each alternative to get the A^+ matrix and A^- matrix.

The distance (d^+, d^-) of the A^+ and the A^- from each weighted alternative $i = 1,2, \dots, m$ is calculated using formula (5.2.6).

Step 7: Calculating the distance of each weighted alternative.

The sum of the distance of each weighted alternative is calculated by:

$$d_i^+ = \sum_{i=1}^{m} d_v(\tilde{v}_{ig}, \tilde{v}_{ig}^+), \ i = 1,2, \dots, m; \ g = 1,2, \dots, n \quad (5.29)$$

$$d_i^- = \sum_{i=1}^{m} d_v(\tilde{v}_{ig}, \tilde{v}_{ig}^-), \ i = 1,2, \dots, m; \ g = 1,2, \dots, n \quad (5.30)$$

Step 8: Computation of the closeness coefficient (CC_i) of each alternative.

CC_i signifies the distances to the FNIS and the FPIS, simultaneously. The calculation of each alternative's CC_i is as follows:

$$(CC_i) = \frac{d_1^-}{d_1^- + d_1^+}, \ i = 1, 2, \dots, m \quad (5.31)$$

Step 9: Ranking the alternatives.

The CC_i gives all the alternatives' ranking order. The optimal alternative is denoted by the closest CC_i to the FPIS and the furthest CC_i to the FNIS. Therefore, the higher the alternative rank, the higher the CC_i" (Han and Trimi 2018: 137).

5.2.7 Applying Fuzzy TOPSIS in an Example Scenario

In the example scenario, the preference of SM platforms is rated by two instructors (I). The two SM platform alternatives are WhatsApp and Facebook which are compared using four criteria. The three benefit criteria are Scale, Ease of Use and Hypermediality; and the cost criterion is Cost to Use. The following Fuzzy TOPSIS algorithm is applied to determine which SM platform is preferred.

Step 1: Assignment of ratings to the alternatives and criteria weightage by instructors

Linguistic terms are given to each criterion of each alternative by each instructor.

Table 5.3: Alternative Rating

Criteria	**WhatsApp**		**Facebook**	
	I_1	I_2	I_1	I_2
Scale	F	F	G	G
Ease of Use	VG	VG	G	VG
Hypermediality	P	F	P	P
Cost to Use	F	F	P	P

The criteria are also weighted by each instructor using linguistic terms.

Table 5.4: Criteria weightage

Criteria	I_1	I_2
Scale	H	M
Ease of Use	VH	H
Hypermediality	VH	H
Cost to Use	M	L

Fuzzy numbers are given to each linguistic term in Table 5.3 and Table 5.4 to generate Table 5.5 and Table 5.6, respectively.

Table 5.5: Fuzzy Numbers for Alternative Rating

Criteria	**WhatsApp**		**Facebook**	
	I_1	I_2	I_1	I_2
Scale	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)
Ease of Use	(7, 9, 9)	(7, 9, 9)	(5, 7, 9)	(7, 9, 9)
Hypermediality	(1, 3, 5)	(3, 5, 7)	(1, 3, 5)	(1, 3, 5)
Cost to Use	(3, 5, 7)	(3, 5, 7)	(1, 3, 5)	(1, 3, 5)

Table 5.6: Fuzzy Numbers for Criteria Weightage

Criteria	I_1	I_2
Scale	(5, 7, 9)	(3, 5, 7)
Ease of Use	(7, 9, 9)	(5, 7, 9)
Hypermediality	(7, 9, 9)	(5, 7, 9)
Cost to Use	(3, 5, 7)	(1, 3, 5)

Step 2*: *Computation of aggregated fuzzy ratings for the alternatives and the criteria.

The minimum a value which is the first value in each column is chosen to afford a_{ij}. To get b_{ij}, find the mean of the middle number (b) in each column. The maximum c value which is the third value in each column is chosen to afford c_{ij}.

Table 5.7: Aggregated Fuzzy Decision Matrix for Alternative

Criteria	WhatsApp	Facebook
Scale	(3,000, 5,000, 7,000)	(5,000, 7,000, 9,000)
Ease of Use	(7,000, 9,000, 9,000)	(5,000, 8,000, 9,000)
Hypermediality	(1,000, 4,000, 7,000)	(1,000, 3,000, 5,000)
Cost to Use	(3,000, 5,000, 7,000)	(1,000, 3,000, 5,000)

The same process is applied to aggregate the criteria weightage.

Table 5.8: Aggregated Fuzzy Decision Matrix for Criteria Weightage

Criteria	Aggregated Weightage
Scale	(3,000, 6,000, 9,000)
Ease of Use	(5,000, 8,000, 9,000)
Hypermediality	(5,000, 8,000, 9,000)
Cost to Use	(1,000, 4,000, 7,000)

Step 3: Normalisation of the fuzzy decision matrix.

The various criteria can be separated into benefit criteria and cost criteria and the aim is to minimise cost and maximise the benefit. Table 5.9 is normalised by dividing each aggregated fuzzy number by the highest c value in the row for the benefit criteria (Scale, Ease of Use, Hypermediality and Cost to Use). For the cost criteria, the lowest a value in the row is divided by each aggregated fuzzy number in reverse order (i.e. c, b and a).

Table 5.9: Normalised Aggregated Fuzzy Decision Matrix for Alternative

Criteria	WhatsApp	Facebook
Scale	(0,333, 0,556, 0,778)	(0,556, 0,778, 1,000)
Ease of Use	(0,778, 1,000, 1,000)	(0,556, 0,889, 1,000)
Hypermediality	(0,143, 0,571, 1,000)	(0,143, 0,429, 0,714)
Cost to Use	(0,143, 0,200, 0,333)	(0,200, 0,333, 1,000)

The ranges of normalised TFNs: [0,1].

Step 4: Computation of the weighted normalised matrix.

Multiply the normalised aggregated fuzzy decision matrix for alternatives by the aggregated fuzzy decision matrix for criteria weightage to achieve the weighted normalised fuzzy decision matrix.

Table 5.10: Weighted Normalised Fuzzy Decision Matrix

Criteria	WhatsApp	Facebook
Scale	(0,999, 3,336, 7,002)	(1,668, 4,668, 9,000)
Ease of Use	(3,890, 8,000, 9,000)	(2,780, 7,112, 9,000)
Hypermediality	(0,715, 4,568, 9,000)	(0,715, 3,432, 6,426)
Cost to Use	(0,143, 0,800, 2,331)	(0,200, 1,332, 7,000)

Step 5: Determining the FPIS (A^+) and FNIS (A^-).

A^+ is achieved by choosing the highest values in the weighted normalised fuzzy decision matrix row.

A^- is achieved by choosing the lowest values in the weighted normalised fuzzy decision matrix row.

Therefore: $A^+ = [v^+{}_1(9,9,9), v^+{}_2(9,9,9), v^+{}_3(9,9,9), v^+{}_4(7,7,7)]$

and: $A^- = [v^-{}_1(0{,}999, 0{,}999, 0{,}999), v^-{}_2(2{,}780, 2{,}780, 2{,}780), v^-{}_3(0{,}715,\ 0{,}715,\ 0{,}715), v^-{}_4(0{,}143, 0{,}143, 0{,}143)]$

Table 5.11: A^+ and A^- of Criteria

Criteria	A^+	A^-
Scale	(9, 9, 9)	(0,999, 0,999, 0,999)
Ease of Use	(9, 9, 9)	(2,780, 2,780, 2,780)

Hypermediality	(9, 9, 9)	(0,715, 0,715, 0,715)
Cost to Use	(7, 7, 7)	(0,143, 0,143, 0,143)

Step 6: Calculating the distance of each alternative to get the A^{+} and A^{-} matrix.

Table 5.12: Distance of Criteria of each Alternative from A^{+} and A^{-}

	A^{+}		A^{-}	
Criteria	**WhatsApp**	**Facebook**	**WhatsApp**	**Facebook**
Scale	5,776	4,917	3,719	5,097
Ease of Use	3,006	3,753	4,732	4,376
Hypermediality	5,425	5,952	5,275	3,651
Cost to Use	5,979	5,111	1,319	4,018

To calculate the A^{+} distance for WhatsApp's Scale criteria, the distance formula is substituted in the following way:

$$d^{+} = \sqrt{\frac{1}{3}[(0{,}999 - 9)^2 + (3{,}336 - 9)^2 + (7{,}002 - 9)^2]}$$

$$d^{+} = 5.776$$

The same method can be used to calculate the rest of the values in Table 5.12.

Step 7: Calculating the distance of each weighted alternative.

Table 5.13: Sum of FPIS and FNIS Distances of each Alternative

	WhatsApp	**Facebook**
d^{+}	20,186	19,733
d^{-}	15,045	17,142

The sum of the distance of each weighted alternative is calculated using formula (5.29) and (5.30).

Therefore:

$$d^{+}_{WhatsApp} = 5{,}776 + 3{,}006 + 5{,}425 + 5{,}979$$

$$= 20{,}186$$

The same method is used to complete Table 5.13.

Step 8: Obtaining the Closeness Coefficient (CC_i) of each Alternative.

For the closeness coefficient, divide the d^- by the sum of the d^+ and the d^-.

Thus

$$CC_{WhatsApp} = \frac{15{,}045}{15{,}045 + 20{,}186} = 0{,}427$$

$$CC_{Facebook} = \frac{17{,}142}{17{,}142 + 19{,}733} = 0{,}465$$

Step 9: Ranking of each Alternative.

Since $CC_{Facebook} > CC_{WhatsApp}$, Facebook is the preferred SM platform considering the given criteria.

5.3 Data Envelopment Analysis

In the current study, DEA was chosen to measure the efficiency of devices for u-learning in school-based education.

5.3.1 Introduction

The Data Envelopment Analysis (DEA) method was established by Charnes, Cooper and Rhodes (1978). It measures the Decision-Making Units' (DMUs) efficiency by estimating a piece-wise linear production function. The alternatives in DEA are termed DMUs. The DEA uses input (cost) and output (benefit) criteria to measure the efficiency of a DMU and hence the system. A DMU is deemed to be inefficient if it fails to attain the maximum output using the minimum input. The best DMUs are assigned a score of 1 and the most inefficient DMUs are less than 1. The DMUs can be firms, farms, products, universities, or devices, etc. (Charnes, Cooper and Rhodes, 1978).

Charnes, Cooper and Rhodes (1978) created a particular DEA model called the CCR Model which is popularly used to afford a nonparametric methodology for assessing the sets of comparable DMUs' efficiency (Zhen, Xing and Li 2008: 34). The main DEA model is denoted by a weighted outputs to weighted inputs ratio. This model generalises the Farrell efficiency of signal output and input. A noteworthy trait of DEA is its ability to afford efficiency scores, while accounting for multiple inputs and outputs (Zhen, Xing and Li 2008). Accordingly, it is a robust MCDM and optimisation tool which is employed to quantify the allocative and technical attributes of any set of DMUs. Prior to the application of the DEA model, a set of DMUs must be chosen to serve as the benchmarking units. Thereafter, the DEA model measures the DMUs against the best practice frontier derived from the existing dataset (Venu, Ramadas and Ramasundaram 2017: 77).The Efficient Frontier or frontier line is the benchmark which connects the most efficient point and envelops other data points. Hence, the method being called 'Data Envelopment Analysis'. The deviation of the points from the efficient frontier gives the efficiency of the other units (Venu, Ramadas and Ramasundaram 2017: 77). The performance of DMUs in DEA are measured in two ways:

1) Input-oriented model: establishes if the DMU can produce the same quantity of outputs while decreasing the current input.
2) Output-oriented model: establishes if the DMU can use the current input level to increase its current output (Venu, Ramadas and Ramasundaram 2017: 78).

Efficiency is the competency to attain maximum or minimum inputs or outputs from a given set of outputs or inputs, depending on the aims of the DEA model. For example, the cost-efficiency model entails having the lowest possible cost with the greatest output (Venu, Ramadas and Ramasundaram 2017: 78). The concept of cost efficiency is depicted in Figure 5.2 where there is 1 constant output, 2 inputs and 12 DMUs labelled in alphabetical order with their individual prices. The iso-cost-line's (NN^1) slope reflects the input price ratio, and the frontier line is reflected by the curve line which is generated from connecting the DMUs labelled A to M. This concept is imperative for efficiency analysis as efficiency is measured relative to the distance from the frontier. Technically inefficient DMUs such as B, D, G, I and K operate at points within the shaded region and technically efficient DMUs operate somewhere along the technology demarcated by the frontier. Thus, inputs are considered technically efficient when they are along the frontier line but are considered technically inefficient producers when situated above and to the right of the frontier line. In other words, the DMU uses a larger amount of both inputs to generate the same amount of output (Venu, Ramadas and Ramasundaram 2017: 79).

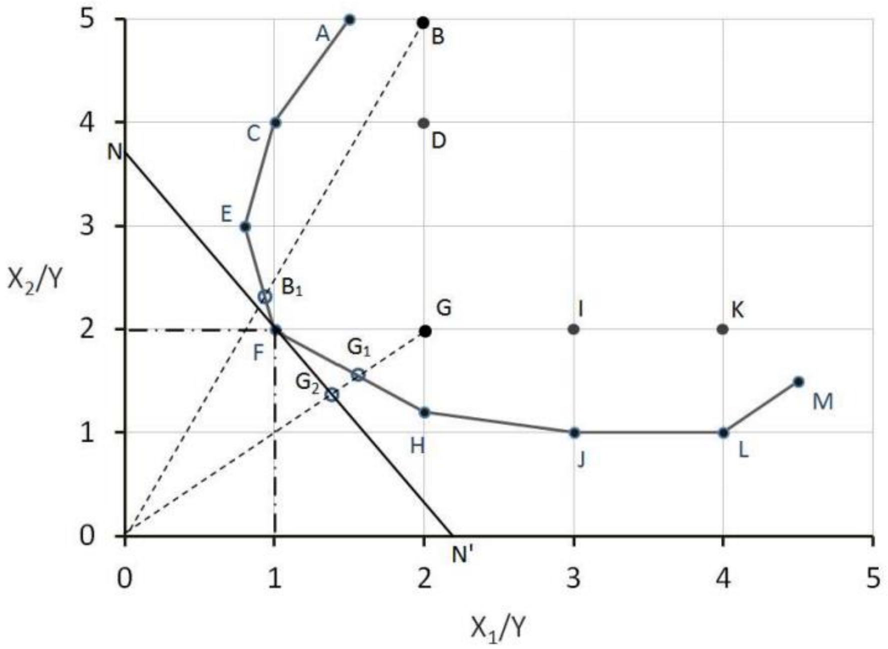

Figure 5.2: The Cost-Efficiency Concept

Source: Venu, Ramadas and Ramasundaram (2017: 79)

5.3.2 Recent Studies that Used DEA

The study by Jones and Jo (2004: 468) explored the advantages and disadvantages of various efficiency measurement methods in the higher education institutions in England. DEA proved to be the most effective method in handling multiple inputs and outputs once the method was redesigned to avert some of the disadvantages.

The paper revealed that scale and technical efficiency were high in the English higher education production process and therefore, inputs were significant. Martínez-Núñez and Pérez-Aguiar (2014: 712) assessed the efficiency of telecommunications firms in Spain that used and did not use SM in their business strategy. The use of DEA revealed large efficiency gains for companies integrating SM in their business plan and that the incorporation of SM from a business standpoint and strategically was essential to be successful in the current market.

Lui (2017: 6295) assessed the efficiency of e-learning at the departments in Kaohsiung City Government in Taiwan using DEA. The results of the study reflected a great number of the departments were not achieving scale efficiency and that the e-learning inputs should be reviewed and attuned to encourage competitiveness amongst departments.

The study by Lui and Kuo (2017: 382) employed DEA to evaluate the use of digital mobile e-learning on the efficiency of a Taiwanese high school. Assessed efficiencies were total efficiency, scale efficiency and technical efficiency. Results showed that digital mobile e-learning did improve classroom teaching, learning and operational efficiency of school management, and that the total equipment cost related to purchasing the required number of tablet PCs had a small negative impact on the efficiency of school management (Lui and Kuo 2017: 388).

While there is extensive literature on the use of DEA in decision making in various fields, there is limited literature on the application of DEA in school-based education. Most studies have used the method to rate the opinions of decision makers in businesses and the available studies in higher education have been conducted in other countries. Thus, the current study will employ the DEA method to measure the efficiency of devices for u-learning in SA.

5.3.3 Originality and Value of DEA for Device Efficiency

The current study will enrich the literature on novel methods to determine efficiency of contemporary devices for u-learning in school-based education. The DEA method brought to the fore the most significant features of u-learning devices. The method will enrich school-based practitioners' knowledge of the most beneficial devices based on MCDM that can be utilised for u-learning. More importantly, it will lessen the effort and time expended by instructors to choose the most efficient devices for u-learning when confronted with multiple confounding features.

5.3.4 Justification for Choice of Devices

In the u-learning environment, learners interact with the numerous device types (Jones and Jo 2004: 469). The device types used for u-learning include desktop computers, gaming tablets, mobile phones, iPhone Smartphones, customised business tablets, 2-in-1 Personal Computers (PCs), iPads (Ivec 2014), mini tablets, handheld PCs, traditional laptops, phablets (phone-tablet), slates, Android smartphones, Android tablets, notebooks, desktop replacement laptops, netbooks, subnotebooks/ultra-portables, business laptops, and Windows phones (Chandler 2018).

A refined Google search was conducted to find the names of the devices suited to each device type. Keywords that were used in the Google search engines were *'best computer for student 2020', 'best gaming tablets in 2020', 'best phones for back-to-school 2020', '15 best smartphones for students in 2020', 'best business tablets of 2020', 'the best 2-in-1 convertible and hybrid laptops for 2020', 'best iPad for students in 2020, 'the best Android phones in 2020', 'best android tablets for students 2020', 'The best student laptops in 2020', 'best student laptops 2020: the best laptops for students', '10 best desktop replacement laptops in 2020', 'best Windows phone in 2020'.* Exclusion criteria were devices older than two years as of 2020, devices not specific to students, devices not available in SA, and devices costing more than R30 000. It is assumed that the average population of South African learners and instructors spend less than R30 000 on digital devices.

In accordance with the 20 device types for u-learning, the names of devices were researched that were aligned with the exclusion and inclusion criteria. The inclusion criterion was to find features of the devices that gave a quantitative matrix. Therefore, the light weight of devices, mid-price range of devices, high RAM and internal memory, high speed CPU, long battery life, large screen dimensions, thick screen to prevent screen damage, high resolution and high camera megapixels was chosen for the study. The models of the devices were restricted to 2020 versions and devices applicable to students.

In accordance to the exclusion and inclusion criteria, the following devices were chosen for the study, namely, the Dell Inspiron 3470, Samsung Galaxy Tab S5e, Samsung Galaxy A51, iPhone 11 Pro, Microsoft Surface Pro 6, Lenovo IdeaPad Flex 5 14, iPad Air 3, Samsung Galaxy Tab S6 Lite, Samsung Galaxy Tab A8 2019 Black LTE, Acer Swift 3, Samsung Galaxy Note 10 Plus, Huawei Media Pad T5 10.1-inch Black, Google Pixel 4a, Samsung Galaxy Tab S7, Acer Chromebook 314, ASUS ROG Strix Scar 17, Acer Chromebook 15.6, Dell Inspiron 14 7000, Lenovo ThinkPad X1 Carbon, and the Lumia 950 XL (Androidcentral 2020; AnySoftwareTools 2020; CNET 2020b; Creative Bloq 2020; Familyproof 2020; Gamesradar 2020; iMore 2020; Incredible Connection 2020; Laptop Study 2020; PC 2020; T3 2020; Techradar 2020; Tom's Guide 2020; Windows Central 2020).

5.3.5 DEA CCR Method (Output Oriented Model)

Step 1: Perform an Intermediate Calculation for the Normalisation Process.

In order to normalise the decision matrix, an intermediate calculation must be performed for each column. This is determined by calculating the square root of the sum of the squares for each entry in that column (Charnes, Cooper and Rhodes 1978: 435). The following formula is used (Hermoso, Latorre and Martinez-Nuñez 2019: 5):

$$\sqrt{\sum_{j=1}^{n} X_y^2} \tag{5.32}$$

Step 2: Normalise the Decision Matrix using the Normalisation Formula.

The intermediate calculation for each column of the previous step serves as the divisor in step 2. Normalisation is achieved by cancelling the units through division. The following formula is used (Hermoso, Latorre and Martinez-Nuñez 2019: 5):

$$N_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} \tag{5.33}$$

N_{ij} is the quotient

Step 3: Apply the DEA CCR Model to the Decision Matrix.

This is the minimum input and maximum output model where the maximum output is required with the least amount of input/cost criteria. For each row (DMU), in the Decision Matrix set up the 1. Objective function, 2. Constraint equations and 3. Equality equation. The equations of the DEA CCR Model are as follows (Hermoso, Latorre and Martinez-Nuñez 2019: 7):

$$g_{k=min}\left(\sum_{i=1}^{m} v_i x_{ik}\right) \tag{5.34}$$

Subject to:

$$-\sum_{r=1}^{s} u_r y_{rk} + \sum_{i=1}^{m} v_i x_{ik} \geq 0, \quad k = 1, \dots, n$$

$$\sum_{r=1}^{s} u_r y_{rk} = 1$$

$$u_r \geq 0, \quad r = 1, \dots, s$$

$$v_i \geq 0, \quad i = 1, \dots, m$$

Where:

- n is the number of DMUs/alternatives;
- m is the number of input criteria;
- s is the number of output criteria;

- x_{ik} and y_{rk} denote the values of the i^{th} input criterion and r^{th} output criterion for k^{th} alternative;
- u_r and v_i are the non-negative variable weights to be ascertained by the solution of the minimisation problem.

Step 4: Change the Signs and Inequality Signs of the Constraint Equations.

Only change the objective function and equality equation for each row of the decision matrix (Hermoso, Latorre and Martinez-Nuñez 2019: 7).

Step 5: Convert to Standard Format so that linprog Model can be Applied to Determine the Minimum Value of g_k (Hermoso, Latorre and Martinez-Nuñez 2019: 7).

Step 6: In Order to Determine the Input Weights (v_i), Output Weights (u_r), and g_k, Establish the Following 7 Matrices (Hermoso, Latorre and Martinez-Nuñez 2019: 7):

1. $f =$ Vector f is created by taking the coefficient of the objective function.
2. $A =$ Matrix A is established by taking the coefficients of $u_1, u_2, u_3, \ldots$ and $v_1, v_2 \ldots$ of the left side of constraint equation.
3. $A_{eq} =$ Vector A_{eq} is set up by taking the coefficients of $u_1, u_2, u_3, \ldots$ and $v_1, v_2 \ldots$ of the left side of the equality equation.
4. $b =$ Matrix b is obtained by taking the values of the right side of the constraint equations.
5. $b_{eq} =$ Vector b_{eq} is set up by taking the value of the right side of the equality equation.
6. $lb =$ Lower bound of variables u_1, u_2, u_3 and v_1. All values must be greater than 0.
7. $ub =$ Upper bound of u_1, u_2, u_3 and v_1. Null matrix is created for ub.

Step 7: Find the Values for g_1, $g_2, g_3, \ldots$ and $H_1, H_2, H_3, \ldots$Using the linprog Model in MATLAB R2020a (Hermoso, Latorre and Martinez-Nuñez 2019: 7):

$[x, g_k] = \text{linprog}(f, A, b, A_{eq}, b_{eq}, lb, ub]$ defines a set of lower and upper bounds on the design variables.

Set x so that the solution is always in the range $lb \leq x \leq ub$.

Set $A_{eq} = [\ ]$ and $b_{eq} = [\ ]$ if no equalities exist.

Step 8: Determine the Efficiency of the DMU using the Formula Below (Hermoso, Latorre and Martinez-Nuñez 2019: 7):

$$H_k = \frac{1}{g_k} \tag{5.35}$$

where H_k is the efficiency measure of the k^{th} DMU.

If $H_k = 1$, the DMU is efficient. The further the H_k is from 1, the more inefficient the DMU is.

5.3.6 Applying DEA in an Example Scenario

In the example scenario, the efficiency of devices for u-learning is determined by an internet search of device features. The three device alternatives also referred to as DMUs are a laptop, tablet and a smartphone which are compared using three criteria. The two benefit criteria are Internal Storage and Camera, and the cost criteria is the Price of the devices, as represented in Table 5.14.

Table 5.14: DEA Decision Matrix

Devices	Price	Internal Storage	Camera
Laptop	R15 000	256GB	12MP
Tablet	R12 000	32GB	8MP
Smart Phone	R14 000	16GB	16MP

The following DEA algorithm is applied to determine which device is efficient for u-learning.

Step 1: Perform an Intermediate Calculation for the Normalisation Process.

Table 5.15: Calculated Divisor

Devices	Price	Internal Storage	Camera
Laptop	R15 000	256GB	12MP
Tablet	R12 000	32GB	8MP
Smart Phone	R14 000	16GB	16MP
	23769,72865	258,4879107	21,54065923

Step 2: Normalise the Decision Matrix using the Normalisation Formula.

Table 5.16: Normalised Decision Matrix

Devices	**Price**	**Internal Storage**	**Camera**
Laptop	0,63105	0,99038	0,55709
Tablet	0,50484	0,12380	0,37139
Smart Phone	0,58898	0,06190	0,74278
	23769,72865	258,4879107	21,54065923

Step 3: Apply the DEA CCR Model to the Decision Matrix.

Decision Matrix Row 1: g_1 = min (0,63105v_1) **1. Objective function**

Subject to:

-0,99038u_1 -0,55709u_2 +0,63105v_1 ≥ 0 **2. Constraint equations**

-0,12380u_1 -0,37139u_2 +0,50484v_1 ≥ 0

-0,06190u_1 -0,74278u_2 +0,58898v_1 ≥ 0

Decision Matrix Row 1: 0,99038$u_1 + 0{,}55708u_2 = 1$ **3. Equality equation**

u_1, u_2, v_1 ≥ 0

Decision Matrix Row 2: g_2 = min (0,50484v_1)

Subject to:

-0,99038u_1 -0,55709u_2 +0,63105v_1 ≥ 0

-0,12380u_1 -0,37139u_2 +0,50484v_1 ≥ 0

-0.06190u_1 -0,74278u_2 +0,58898v_1 ≥ 0

Decision Matrix Row 2: 0,12380$u_1 +$ $0{,}37139u_2 = 1$

u_1, u_2, v_1 ≥ 0

Decision Matrix Row 3: g_3 = min (0,58898v_1)

Subject to:

-0,99038u_1 -0,5709u_2 +0,63105v_1 ≥ 0

-0,12380u_1 -0,37139u_2 +0,50484v_1 ≥ 0

	-0,06190u_1	-0,74278u_2	+0,58898v_1	≥ 0

Decision Matrix Row 3: $0{,}06190u_1 + 0{,}74278u_2 = 1$

$u_1, u_2, v_1 \quad \geq 0$

Step 4: Change the Signs and Inequality Signs of the Constraint Equations.

$\boldsymbol{g_1}$ **= min (0,63105**v_1**)**

Subject to:

0,99038u_1	+0,5709u_2	-0,63105v_1	≤ 0
0,12380u_1	+0,37139u_2	-0,50484v_1	≤ 0
0,06190u_1	+0,74278u_2	-0,58898v_1	≤ 0

$0{,}99038u_1 + 0{,}55708u_2 = 1$

$u_1, u_2, v_1 \quad \geq 0$

$\boldsymbol{g_2}$ **= min (0,50484**v_1**)**

Subject to:

0,99038u_1	+0,5709u_2	-0,63105v_1	≤ 0
0,12380u_1	+0,37139u_2	-0,50484v_1	≤ 0
0,06190u_1	+0,74278u_2	-0,58898v_1	≤ 0

$0{,}12380u_1 + \ 0{,}37139u_2 = 1$

$u_1, u_2, v_1 \quad \geq 0$

$\boldsymbol{g_3}$ **= min (0,58898**v_1**)**

Subject to:

0,99038u_1	+0,5709u_2	-0,63105v_1	≤ 0
0,12380u_1	+0,37139u_2	-0,50484v_1	≤ 0
0,06190u_1	+0,74278u_2	-0,58898v_1	≤ 0

$0{,}06190u_1 + 0{,}74278u_2 = 1$

$u_1, u_2, v_1 \quad \geq 0$

Step 5: Convert to Standard Format so that linprog Model can be Applied to Determine the Minimum Value of $\boldsymbol{g_k}$***.***

$\boldsymbol{g_1}$ **= min (**$\boldsymbol{0u_1 + \ 0u_2 +}$ **0,63105**v_1**)**

Subject to:

0,99038u_1	+0,5709u_2	-0,63105v_1	≤ 0
0,12380u_1	+0,37139u_2	-0,50484v_1	≤ 0
0,06190u_1	+0,74278u_2	-0,58898v_1	≤ 0

$0{,}99038u_1 + 0{,}55708u_2 + \ 0v_1 = 1$

$u_1, u_2, v_1 \quad \geq 0$

$\boldsymbol{g_2}$ **= min** $(\boldsymbol{0u_1 + 0u_2} + \mathbf{0{,}50484}v_1)$

Subject to: $0{,}99038u_1 \quad +0{,}5709u_2 \quad -0{,}63105v_1 \quad \leq 0$

$0{,}12380u_1 \quad +0{,}37139u_2 \quad -0{,}50484v_1 \quad \leq 0$

$0{,}06190u_1 \quad +0{,}74278u_2 \quad -0{,}58898v_1 \quad \leq 0$

$0{,}12380u_1 + 0{,}37139u_2 + 0v_1 = 1$

$u_1, u_2, v_1 \quad \geq 0$

$\boldsymbol{g_3}$ **= min** $(\boldsymbol{0u_1 + 0u_2} + \mathbf{0{,}58898}v_1)$

Subject to: $0{,}99038u_1 \quad +0{,}5709u_2 \quad -0{,}63105v_1 \quad \leq 0$

$0{,}12380u_1 \quad +0{,}37139u_2 \quad -0{,}50484v_1 \quad \leq 0$

$0{,}06190u_1 \quad +0{,}74278u_2 \quad -0{,}58898v_1 \quad \leq 0$

$0{,}06190u_1 + 0{,}74278u_2 + 0v_1 = 1$

$u_1, u_2, v_1 \quad \geq 0$

Step 6: In Order to Determine the Input Weights (v_i), Output Weights (u_r), and g_k Establish the following 7 Matrices.

6.1 Matrices to calculate g_1:

1. $f = [0 \quad 0 \quad 0{,}63105]$
2. $A = \begin{bmatrix} 0{,}99037 & 0{,}55708 & -0{,}63105 \\ 0{,}12379 & 0{,}37139 & -0{,}50484 \\ 0{,}06189 & 0{,}74278 & -0{,}58898 \end{bmatrix}$
3. $A_{eq} = [0{,}99037 \quad +0{,}55708 \quad +0]$
4. $b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$
5. $b_{eq} = [1]$
6. $lb = [0 \quad 0 \quad 0]$
7. $ub = [\ \ ]$

6.2 Matrices to calculate g_2:

1. $f = [0 \quad 0 \quad 0{,}50484]$
2. $A = \begin{bmatrix} 0{,}99037 & 0{,}55708 & -0{,}63105 \\ 0{,}12379 & 0{,}37139 & -0{,}50484 \\ 0{,}06189 & 0{,}74278 & -0{,}58898 \end{bmatrix}$
3. $A_{eq} = [0{,}12379 \quad +0{,}37139 \quad +0]$

4. $b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

5. $b_{eq} = [1]$

6. $lb = [0 \quad 0 \quad 0]$

7. $ub = [\quad]$

6.3 Matrices to calculate g_3:

1. $f = [0 \quad 0 \quad 0{,}58898]$

2. $A = \begin{bmatrix} 0{,}99037 & 0{,}55708 & -0{,}63105 \\ 0{,}12379 & 0{,}37139 & -0{,}50484 \\ 0{,}06189 & 0{,}74278 & -0{,}58898 \end{bmatrix}$

3. $A_{eq} = [0{,}06189 \quad +0{,}74278 \quad +0]$

4. $b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

5. $b_{eq} = [1]$

6. $lb = [0 \quad 0 \quad 0]$

7. $ub = [\quad]$

Step 7: Find the values for g_1, g_2, and g_3 using the linprog model in MATLAB R2020a.

7.1 $[x, g_1] = \text{linprog}(f, A, b, A_{eq}, b_{eq}, lb, ub]$

$x =$

1,0097 (u_1)

0 (u_2)

1,5847 (v_1)

$g_1 = 1$

$H_1 = 1$

Therefore, DMU 1 which means the Laptop is efficient.

7.2 $[x, g_2] = \text{linprog}(f, A, b, A_{eq}, b_{eq}, lb, ub]$

$x =$

0,6405

2,4791

3,1938

$g_2 = 1{,}6123$

$H_2 = 0{,}6202$

Therefore, DMU 2 which means the Tablet is inefficient.

7.3 $[x, g_3] = \text{linprog}(f, A, b, A_{eq}, b_{eq}, lb, ub]$

$x =$

0

1,3463

1,6979

$g_2 = 1{,}0000$

$H_3 = 1{,}0000$

Therefore, DMU 3 which means the Smart Phone is efficient.

Step 8: Determine the Efficiency of the DMU.

Table 5.17: Efficiency of the DMUs

Devices	g_k	H_k	Ranking order
Laptop	1,0000	1,0000	1st
Tablet	1,6123	0,6202	2nd
Smart Phone	1,0000	1,0000	1st

According to Table 5.17, the Laptop and Smart Phone are efficient and the Tablet is inefficient.

5.4 Chapter Summary

The chapter is based on strategic decision making and involves three scientific methods, namely, PCA, Fuzzy TOPSIS and DEA. The chapter begins with the discussion of PCA that was used to decrease the dimensionality of the input criteria. PCA was implemented with code statements and methods using RStudio. The PCA method was discussed together with the attributes for education requirements and technology criteria. The chapter then moved on to discuss Fuzzy TOPSIS and its role in the selection of SM application for u-learning. The chapter contained the mathematical equations involved in the Fuzzy TOPSIS selection method. The originality and value of the Fuzzy TOPSIS method in this study were also discussed. The chapter concludes with the DEA for MCDM. The DEA CCR model was chosen in the present study to establish the efficiency of devices. The originality and value of DEA in the study were discussed. The DEA steps were presented together with a scenario example to measure the efficiency of devices. Fuzzy TOPSIS and DEA were implemented in MATLAB R2020a. The next chapter presents the results of the PCA and Fuzzy TOPSIS.

CHAPTER SIX: RESULTS AND DISCUSSION OF STRATEGIC DECISION-MAKING METHODS

6.1 Introduction

The Unified Modelling Language Activity Model provides the blueprint for a software application using Intelligent Decision Support Systems. The activities in the Unified Modelling Language diagram in Figure 6.1, namely, Principal Component Analysis, Fuzzy Technique for Order Preference by Similarity to Ideal Solution, and Data Envelopment Analysis are the subjects of discussion in this chapter. The chapter is divided into three sections, that is, Section A which presents the feature survey results and the application of Principal Component Analysis, and Section B and Section C which presents and discusses the results of Fuzzy Technique for Order Preference by Similarity to Ideal Solution and Data Envelopment Analysis, respectively. The constructs and concepts of this chapter were informed by the Connectivism Theory, Decision Theory, Innovation Decision Theory, and Strategic Innovation Management Model. The construction of the Strategic Innovation Management Model is discussed in Chapter Three, Section 3.5.

A comprehensive literature review was performed on the criteria for the selection of social media applications for u-learning in Chapter Two, Section 2.5, and Section 2.6. The Principal Component Analysis was introduced, and the method was briefly outlined in Chapter Five, Section 5.1. The dimensionality reduced criteria from Principal Component Analysis were used to evaluate the chosen social media applications. Thereafter, the detailed steps of the Fuzzy Technique for Order Preference by Similarity to Ideal Solution algorithm was discussed in Chapter Five, Section 5.2. Fuzzy Technique for Order Preference by Similarity to Ideal Solution was used to rate and rank the social media applications for u-learning which were Facebook, WhatsApp, Instagram, TikTok, Viber, Facebook Messenger, QQ, QZone, WeChat, Snapchat, Reddit, Pinterest, YouTube, and Twitter as discussed in Chapter Two, Section 2.7. The Strategic Innovation Management Model was used as a paradigm for the selection of social media applications in this chapter.

The Strategic Innovation Management Model was also used as a paradigm for the efficiency scoring of the devices for u-learning that were synthesised from a detailed literature review covered in Chapter Two, Section 2.7. The Data Envelopment Analysis was the chosen scientific method to determine the efficiency of devices. Data Envelopment Analysis was introduced, and the detailed steps of this algorithm were discussed in Chapter Five, Section 5.3. The 20 devices, namely, Desktop; Gaming Tablet; Mobile Phone; iPhone Smartphone; Customised Business Tablet; 2-in-1 PC; iPad; Mini Tablet; Handheld PC; Traditional Laptop; Phablet (Phone-Tablet); Slate; Android Smartphone; Android Tablet; Notebook; Desktop Replacement Laptop; Netbook; Subnotebook/Ultraportable; Business Laptop; and Windows Phone were shortlisted. The justification for the choice of the devices were motivated with inclusion and exclusion criteria in Chapter Five, Section 5.3.4.

The results and discussion of the dimensionality reduction of u-learning features using Principal Component Analysis, the ranking of social media applications for u-learning using Fuzzy Technique for Order Preference by Similarity to Ideal Solution, and efficiency of the devices using Data Envelopment Analysis are presented in the Unified Modelling Language activity model in Figure 6.1.

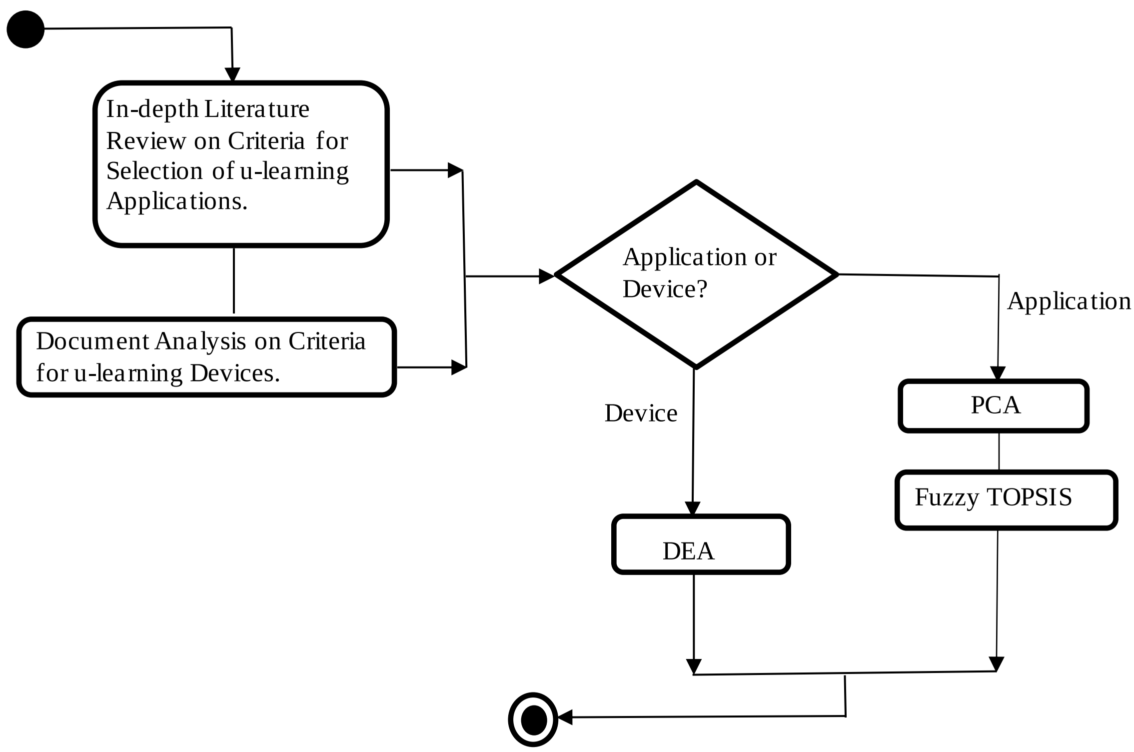

Figure 6.1: Unified Modelling Language Activity Model for Intelligent Decision Support Systems showing Chapter Six Activities

Source: Researcher's own construction

The rest of this chapter comprises Section 6.2 which describes the response rate of the feature questionnaire dataset; Section 6.3 which gives the reliability of the feature questionnaire; Section 6.4 which provides the results and discussion of the Principal Component Analysis; Section 6.5 which gives a detailed presentation of the construction of the Fuzzy Technique for Order Preference by Similarity to Ideal Solution implementation model; Section 6.6 which affords the Fuzzy Technique for Order Preference by Similarity to Ideal Solution results and analysis; Section 6.7 which gives a comprehensive presentation of the construction of the Data Envelopment Analysis implementation model; Section 6.8 which affords the Data Envelopment Analysis results and analysis; and Section 6.9 which summarises Chapter Six.

Section A: Presentation of Dimensionality Reduction Using Principal Component Analysis

6.2 Dataset

Data was purposively obtained in this study from thirty experts. The criteria employed to choose experts were, specifically, must have a teaching degree from an accredited university, must be a school-based or higher education practitioner, and must have at least three years of experience. The structure of the dataset is shown in Table 6.1.

Table 6.1: Description of Dataset (n=30)

Attributes	Categories	Frequency	Percentage
Job Description of Experts	• Higher Education Instructor	16	53%
	• School Based Instructor	11	37%
	• Higher Education e-Learning Specialist	3	10%
Sixty criteria for rating social media apps for u-learning	• Education Requirements	36	60%
	• Technology Criteria	24	40%

Three experts had 3–5 years' experience, twenty-two experts had more than 10 years' experience, and six experts had 6–10 years' experience.

6.3 Feature Questionnaire

Data was collected with a feature questionnaire forwarded via a link to the experts' mobile devices. Online questionnaires generated on Google Forms presented an economical and time-efficient data collection method. The Likert scale offered discrete values which were subsequently considered as continuous values. Education requirements and technology criteria were refined using Principal Component Analysis (PCA). The questionnaire comprised 60 items and the total Cronbach's alpha score was 0,949, verifying that the questionnaire was highly reliable. There was a 100% response rate on the feature questionnaire (Sam, Naicker and Adebiyi 2021: 4).

6.4 Principal Component Analysis Results and Discussion

The results of thirty experts' grading of the sixty criteria for the assessment of social media (SM) applications for ubiquitous learning (u-learning) are presented in this section. Considering PCA, a dataset of sixty 60 dimensions was explored with comments from thirty experts (Richardson 2009).

The Table 6.2 itemises the 60 criteria mined from the existing literature for SM applications' assessment. Table 6.2 is categorised into Technology Criteria and Educational Requirements (Anstey and Watson 2018: 1-9). Criteria are represented by Column IDs.

Table 6.2: Criteria for Evaluating Social Media Application for Ubiquitous Learning

No.	Educational Requirements	Column ID	Technology Criteria	Column ID
1.	Learning Content Quality	B	Accessibility Standards	AL
2.	Presentation of Learning Content	C	Web and Course Design	AM
3.	Enjoyment Factor	D	Scalability	AN
4.	Social Interactivity	E	Ease of Use	AO
5.	Clear Instructions Provided	F	Integration/Embedding within a Learning Management System (LMS)	AP
6.	Instructor Opinion	G	Operating Systems	AQ
7.	Compatibility with Course Description	H	Browser	AR
8.	Learner Behaviour	I	No Additional Downloads Needed	AS
9.	Integrity	J	Access on the Mobile Platform	AT
10.	Suitable Technical Competences for Learning	K	Seamless Functionality Between Mobile and Desktop	AU
11.	Ownership of Learning	L	Offline Access	AV
12.	Instructional Design	M	Data Privacy and Ownership	AW
13.	Assessment of Learning	N	Downloading, Saving and Exporting Data	AX
14.	Peer Learning	O	Technical Information	AY
15.	Instructional Resources for Teaching and Learning	P	Multimedia Control	AZ
16.	Learner Support	Q	Software Characteristics Quality	BA
17.	Course Evaluation	R	User-Friendly Interface	BB
18.	Archiving/Repository	S	Functionality	BC

19.	Collaboration	T	Hypermediality	BD
20.	User Accountability	U	Facilitation of E-Content	BE
21.	Diffusion	V	Operational Stability	BF
22.	Instructor Facilitation	W	Offline Mobile Access	BG
23.	Learning Analytics	X	Security of Technology	BH
24.	Enhancement of Cognitive Task(S)	Y	Fault Tolerance of Technology	BI
25.	Higher Order Thinking	Z		
26.	Meta-Cognitive Engagement	AA		
27.	Permanency	AB		
28.	Immediacy	AC		
29.	Adaptability	AD		
30.	Management of Interactive Learning Objects	AE		
31.	u-Learning Training Factors	AF		
32.	Quality Assurance	AG		
33.	Learnability and Memorability	AH		
34.	Perceived Usefulness and Satisfaction	AI		
35.	Curriculum Management	AJ		
36.	Customisation	AK		

A load plot is utilised to reflect the original variables' impact on the principal components (PCs) (Richardson 2009). Considering the present dataset, Figure 6.2 illustrates the PC1 and PC2 load plot.

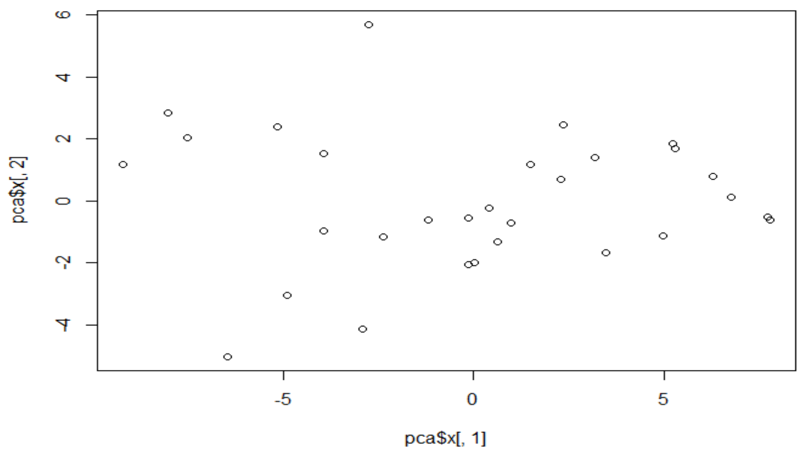

Figure 6.2: Load Plot of PC1 and PC2

The scatter plot in Figure 6.2 displays the data points PC1 and PC2 in a two-dimensional space. The column order in X dictates the axis of the data points. As PC1 is in the first column in X, it lies on the x-axis, and due to PC2 being in the second column in X, it lies on the y-axis (Ringnér 2008: 303-304).

To describe the clusters implicitly, the depth of variation accounted for by each PC in the original data is calculated by employing the squared standard deviation (STHDA 2019). The variation percentage of each PC is illustrated in the two-dimensional scree plot in Figure 6.3.

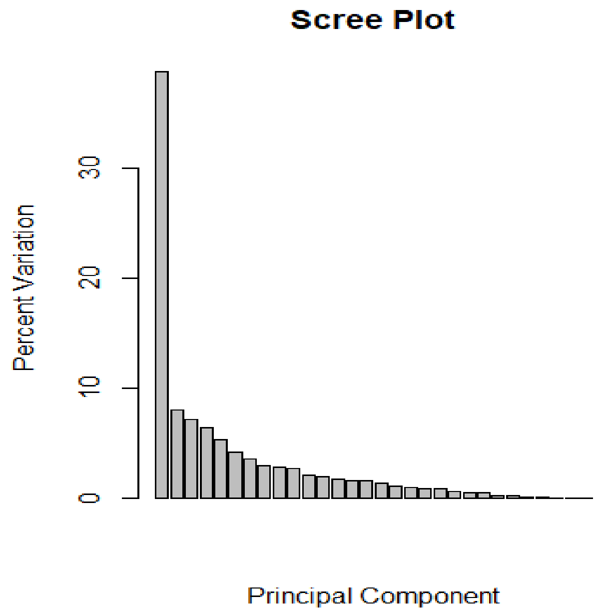

Figure 6.3: Percentage Variation of Principal Components

Figure 6.3 represents the PCs on the *x*-axis and the percentage variation on the *y*-axis. The PCA redistributes the overall variance to such an extent that the PC1 can be used to explain the total variance (Richardson 2009; Shlens 2014: 4). The largest variation in the graph is attributed to PC1, while the second largest variation is attributed to PC2 and so on. The direction along which the samples express the greatest variation is the PC1 (Ringnér 2008: 303-304; Shlens 2014: 88-89; STHDA 2019). The Scree Plot reflects that PC1 constitutes more than 38,7% of the data variation and vast variances between the clusters.

Figure 6.4 shows the percentage variation that PC1 accounts for in the original data on the *x*-axis. The percentage variation that PC2 accounts for in the original data is displayed on the *y*-axis (Richardson 2009). Dots to be plotted are replaced by criteria labels as denoted in Table 6.2 in the ‘column ID’.

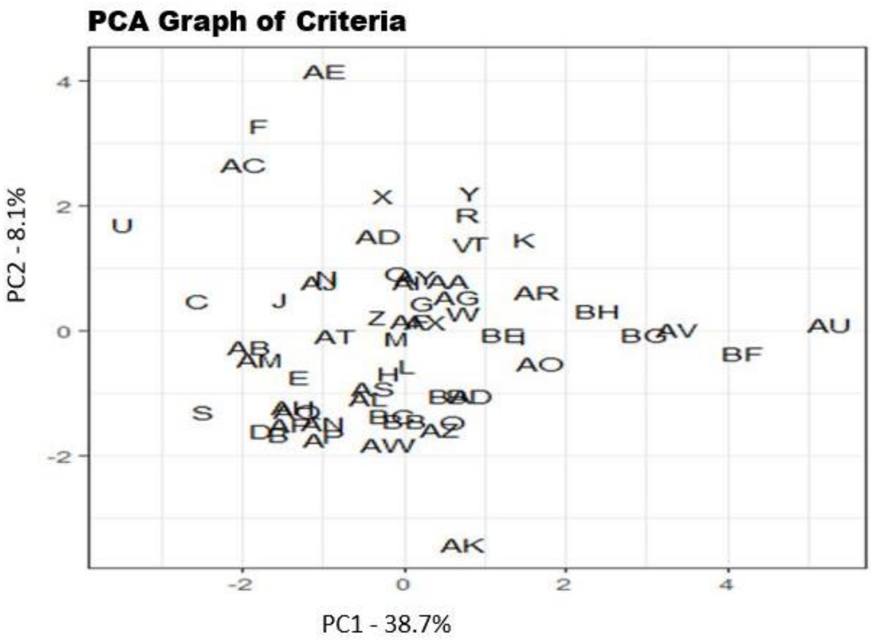

Figure 6.4: PCA Graph Detailing Location Distribution of Criteria on the Graph

Figure 6.4 illustrates that PC1 criteria have a more positive loading score and are highly ranked than criteria in PC2 which have criteria with a more negative loading score. The dimensionality of the criteria can be decreased by interpolating the data points from the PC1 (Ringnér 2008: 303-304; Richardson 2009). From the 60 criteria, 40 of the top criteria were loaded that were a factor of PC1. The top 40 features comprised 18 education requirements and 22 technology criteria. The ranking score was derived from the absolute value of the features' loading scores that were factors of PC1 (Sharma 2008: 89-90). The ranking score of the top 18 education requirements are given in Figure 6.5.

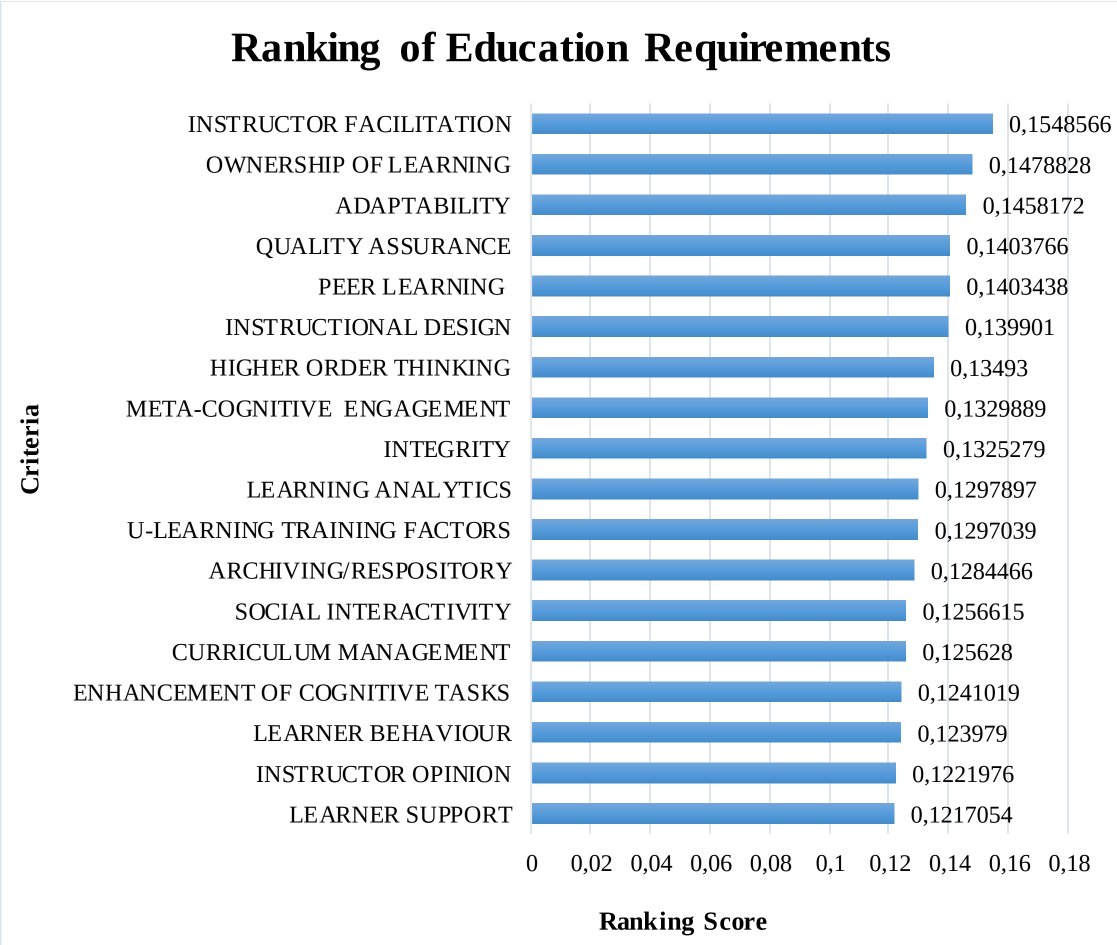

Figure 6.5: Loading Scores for the Top 18 Education Requirements

Figure 6.5 reflects that the highest ranked education requirement was Instructor Facilitation and that the lowest ranked education requirement was Learner Support. Instructor Facilitation is typified by the SM application having easy-to-use features that would enhance an instructor's management, engagement, feedback, and monitoring of learners (Debattista 2018: 100). Ownership of Learning ranked second which involves the SM application facilitating learners' endeavours to reach their own learning goals (Debattista 2018: 101). Adaptability ranked third which entails the SM application being adaptable to learners' ever-changing lives (Kanagarajan and Ramakrishnan 2018: 573).

Figure 6.6 shows the top 22 technology criteria ranking scores.

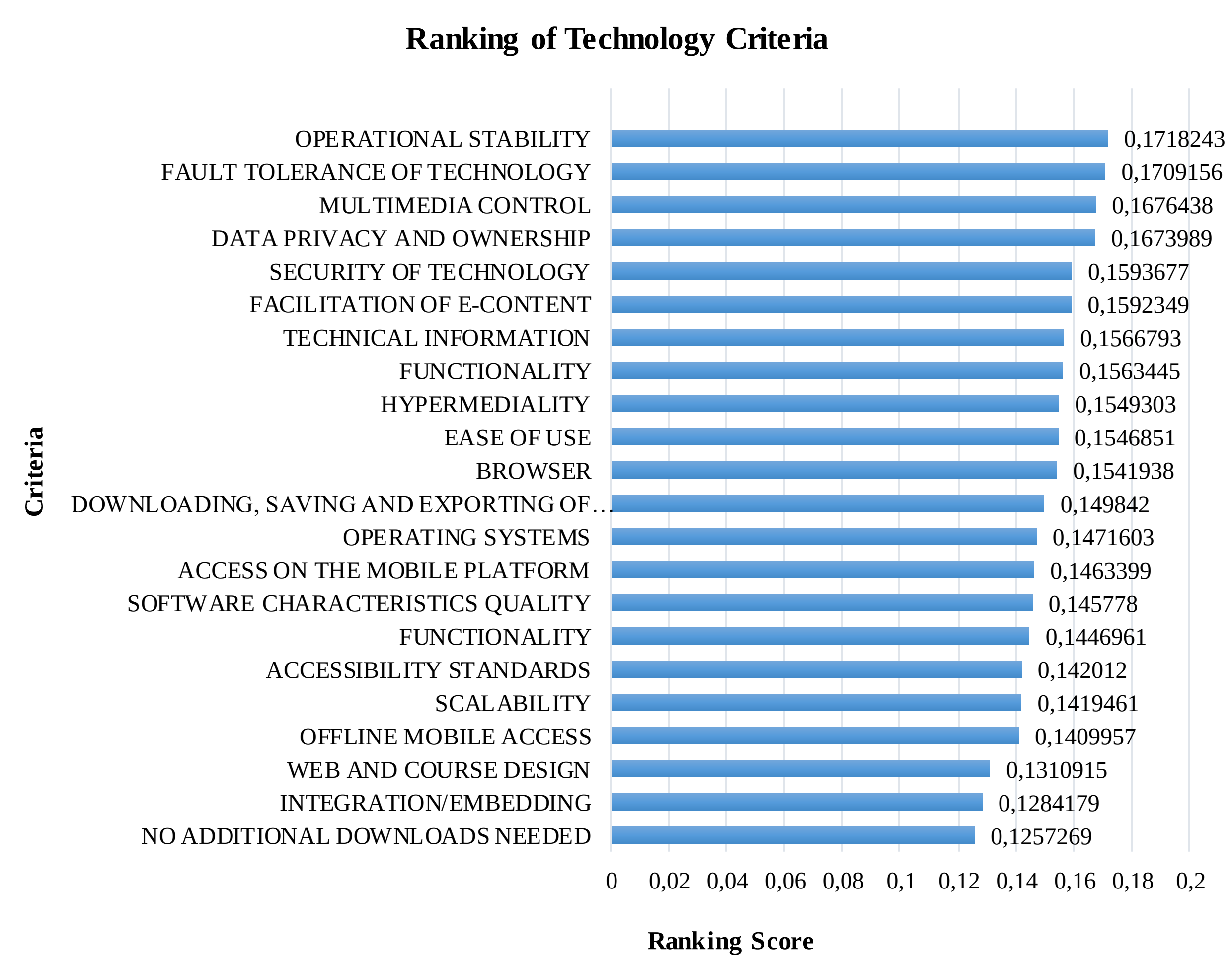

Figure 6.6: Loading Scores for the Top 22 Technology Criteria

In Figure 6.6, Operation Stability achieved the highest-ranking score from the technology criteria. Operation Stability refers to specifically designed systems that ensure the processing of daily transactions is efficiently executed and the transactional data integrity is safeguarded (Elkaseh, Wong and Fung 2016: 196-197). The second highest ranking score was Fault Tolerance of Technology which involves guaranteeing error prevention, flexibility, stability and accuracy, continuity, and interoperability (Anstey and Watson 2018: 8). The third highest ranking score was Multimedia Control which comprises sound control and audio-readings; control of video and audio clips; clarity of all graphics and images; optimisation of size for multimedia contents; and adjustment with final display process (Anstey and Watson 2018: 8).

Section B: Presentation of Fuzzy TOPSIS Findings

6.5 Fuzzy TOPSIS Results and Analysis

This section delivers the results of the ranked SM applications for u-learning using Fuzzy TOPSIS. The 260 decision makers (respondents) rated the alternatives (SM applications) and the criteria used to rank the fourteen alternatives consisted of the dimensionality reduced fifteen education requirements and fifteen technology criteria from PCA. Due to the criteria forming the top thirty education requirements and technology criteria, the linguistic scales used to classify the criteria were either Very Good (VG) or Good (G). Therefore, the criteria weightings were either (7, 9, 9) for Very Good or (5, 7, 9) for Good. Table 6.3 portrays the criteria (C) weightage.

Table 6.3: Weighted Attributes of Social Media Applications for Ubiquitous Learning

C#	Education Requirements	Weightage	C#	Technology Criteria	Weightage
1.	Ownership of Learning	(5, 7, 9)	16.	Operational Stability	(7, 9, 9)
2.	Adaptability	(5, 7, 9)	17.	Fault Tolerance of Technology	(7, 9, 9)
3.	Quality Assurance	(5, 7, 9)	18.	Hypermediality	(7, 9, 9)
4.	Peer Learning	(5, 7, 9)	19.	Multimedia Control	(7, 9, 9)
5.	Instructional Design	(5, 7, 9)	20.	Security of Technology	(7, 9, 9)
6.	Academic Integrity	(5, 7, 9)	21.	Facilitation of e-Content	(7, 9, 9)
7.	u-Learning training factors	(5, 7, 9)	22.	Technical Information	(7, 9, 9)
8.	Archiving/ Repository	(5, 7, 9)	23.	Software Characteristics Quality	(5, 7, 9)
9.	Social Interaction	(5, 7, 9)	24.	Ease of Use	(7, 9, 9)
10.	Curriculum Management	(7, 9, 9)	25.	Operating System	(5, 7, 9)
11.	Facilitation	(5, 7, 9)	26.	Browser	(7, 9, 9)
12.	Learning Analytics	(5, 7, 9)	27.	Access on a Mobile Platform	(5, 7, 9)
13.	Enhancement of Cognitive Tasks	(5, 7, 9)	28.	Data Privacy and Ownership	(7, 9, 9)
14.	Higher Order Thinking	(5, 7, 9)	29.	Downloading, Saving and Exporting Data	(5, 7, 9)
15.	Metacognitive Engagement	(5, 7, 9)	30.	Additional Download	(5, 7, 9)

The SM applications were identified as the following on MATLAB R2020a code:

Table 6.4: Labelled Social Media Applications

Social Media Application	Alternative (A)	Social Media Application	Alternative (A)
Facebook	1	QZone	8
WhatsApp	2	Reddit	9
YouTube	3	Pinterest	10
Facebook Messenger	4	WeChat	11
Instagram	5	Snapchat	12
TikTok	6	Twitter	13
QQ	7	Viber	14

Table 6.5 shows a synopsis of the combined decision matrix of Facebook, which was referred to as A1 on MATLAB.

Table 6.5: Assignment of Ratings to Facebook by Decision Makers

Criteria	FACEBOOK (A1)								
	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8…	DM260
C1	N	P	N	N	N	F	G	G	G
C2	F	P	VP	N	N	G	F	G	G
C3	F	P	N	N	N	F	F	F	VG
C4	N	P	N	N	N	F	G	G	F
C5	N	P	F	N	N	F	VG	G	F
C6	F	P	N	N	N	G	F	G	VG
C7	N	P	N	N	N	F	N	G	G
C8	N	P	F	VP	VP	G	VG	VG	VG
C9	N	P	N	N	N	F	G	G	F
C10…	N	N	F	N	N	G	G	VG	F
C26	G	N	VG	N	VP	G	VG	G	F
C27	G	N	VP	N	N	VG	VG	G	G
C28	G	N	G	N	F	VG	VG	VG	VG
C29	G	N	N	N	N	VG	VG	VG	VG
C30	G	N	N	N	N	VG	VG	VG	VG

The linguistic scales were allocated fuzzy numbers. A zero-rating was given to the "Not Sure" option labelled "N" as it is not a distinguishable linguistic term on fuzzy TOPSIS. The criteria and alternatives' aggregated fuzzy ratings were computed. The weighted normalised fuzzy decision matrix was attained after the normalisation of the combined decision matrix and its subsequent multiplication by the criteria weightage. The FNIS (A^{-}) and FPIS (A^{+}) were established and the A^{+} and A^{-} matrix was derived from calculating each alternative's distance. Table 6.6 presents the Facebook A^{+} and A^{-} matrix.

Table 6.6: The FPIS (A^+) and FNIS (A^-) of Facebook

Criteria	FPIS (A^+)	FNIS (A^-)	Criteria	FPIS (A^+)	FNIS (A^-)
C1	1,4887	0,5526	C16	1,2538	0,5993
C2	1,5578	0,5285	C17	0,7616	0,4110
C3	1,4645	0,5008	C18	0,9930	1,0621
C4	1,2866	0,8221	C19	0,8342	1,0293
C5	1,5405	0,5077	C20	0,6425	0,6597
C6	1,0949	0,4680	C21	1,0621	0,6425
C7	1,4300	0,6701	C22	0,7236	0,6459
C8	1,9274	0,0000	C23	0,7461	0,6822
C9	1,4922	0,8894	C24	0,9067	0,9153
C10	1,4783	0,0846	C25	0,6580	0,9205
C11	1,0138	0,5526	C26	0,7443	0,8894
C12	0,9032	0,5665	C27	0,4473	0,9792
C13	1,1312	0,6079	C28	0,4628	0,6908
C14	1,3246	0,4197	C29	0,7098	0,8583
C15	0,8894	0,5526	C30	0,6217	0,7910

Utilising the formulae (5.29) and (5.30), each weighted alternative's sum distance was calculated. Using formula (5.31) the CC_i was computed. Table 6.7 shows the CC_i of each alternative and its ranking.

Table 6.7: Closeness Coefficient (CC_i) and Ranking of Alternatives

Ranking #	Alternative	(CC_i)
1	YouTube	0,9188
2	WhatsApp	0,8691
3	Instagram	0,4835
4	TikTok	0,3877
5	Facebook	0,3817
6	Facebook Messenger	0,3249
7	Pinterest	0,2801
8	Snapchat	0,2484
9	Twitter	0,2108
10	Reddit	0,1601
11	WeChat	0,1379
12	QQ	0,0720
13	QZone	0,0344
14	Viber	0,0165

Since $CC_{YouTube} > CC_{WhatsApp} > CC_{Instagram} > CC_{TikTok} > CC_{Facebook} \dots$, the favoured SM application for u-learning is YouTube, bearing in mind the given criteria.

The results in Table 6.7 are relatively consistent with the report by HelloYes (2020), which stated that the most employed SM applications in SA in numerical order were: WhatsApp, YouTube, Facebook, Facebook Messenger, Instagram, Twitter, Pinterest, LinkedIn, Snapchat, Skype, Reddit, TikTok, Tumbler, WeChat, Twitch, and Viber. In the current study, YouTube and WhatsApp were given high priority with CC_i values of 0,9188 and 0,8691, respectively. Viber was shown to have the lowest preference with a CC_i value of 0,0165. However, in contrast to the report by HelloYes (2020), the current study showed TikTok ranked in the top 5 of SM applications with Facebook Messenger being shifted further down in preference.

Table 6.8 shows the ranking and CC_i of SM application used by instructors.

Table 6.8: Closeness Coefficient (CC_i) and Ranking of Alternatives by Instructors

Ranking #	Alternative	(CC_i)
1	YouTube	0,9354
2	WhatsApp	0,8658
3	Facebook	0,7509
4	Facebook Messenger	0,6901
5	Instagram	0,6284
6	TikTok	0,4362
7	Twitter	0,3141
8	Snapchat	0,3139
9	WeChat	0,2732
10	Pinterest	0,2663
11	Reddit	0,1756
12	QQ	0,1725
13	QZone	0,1178
14	Viber	0,0797

Table 6.8 revealed that YouTube was the SM application most commonly employed by instructors for u-learning with a CC_i of 0,9354 and that the least employed SM application was Viber with a CC_i of $0,0797$. These CC_i values align with the overall ranking presented in Table 6.7, with the exception of Facebook and Facebook Messenger that have moved up two ranking positions in Table 6.8. Table 6.9 shows the ranking and CC_i of SM application by learners.

Table 6.9: Closeness Coefficient (CC_i) and Ranking of Alternatives by Learners

Ranking #	Alternative	(CC_i)
1	YouTube	0,9161
2	WhatsApp	0,8772
3	Instagram	0,4761
4	TikTok	0,3911
5	Facebook	0,3446
6	Pinterest	0,2885
7	Facebook Messenger	0,2797
8	Snapchat	0,2505
9	Twitter	0,2096
10	Reddit	0,1668
11	WeChat	0,1257
12	QQ	0,0677
13	QZone	0,0337
14	Viber	0,0160

Table 6.9 exhibits that YouTube was the preferred SM application for u-learning ($CC_i =$ 0,9161) and that Viber was the least popular SM application with a CC_i of 0,0160. These values align with the overall rankings of SM applications in Table 6.7 as the majority of respondents were learners.

Section C: Results and Discussion on efficiency of devices using Data Envelopment Analysis

6.6 DEA Results and Analysis

The DEA Model used for the presentation of results is the DEA CCR Method represented in Equation (5.34). This model minimises input criteria and maximises output criteria. The calculation using DEA was based on the devices gathered from the research. This is represented in Table 2.3 in Chapter Two. The results are generated from the DEA simulation (program code) disclosed in Section 6.8.

6.6.1 Normalised Decision Matrix

Table 6.10 presents the results of the DEA Normalised Decision Matrix.

Table 6.10: DEA Normalised Decision Matrix

0,1544	0,1653	0,2973	0,3014	0,4007	0,0407	0,6954	0,0266	0,0141	0,2554
0,2059	0,0827	0,2001	0,1674	0,0197	0,0577	0,0579	0,1039	0,2038	0,0949
0,1029	0,1240	0,1239	0,1507	0,0256	0,5517	0,0249	0,0658	0,7524	0,1363
0,2917	0,0827	0,1105	0,3181	0,1026	0,0449	0,0272	0,0695	0,1881	0,1432
0,3346	0,3306	0,2344	0,3181	0,2052	0,0866	0,1116	0,1266	0,1254	0,1467
0,2231	0,3306	0,2668	0,2093	0,2052	0,0770	0,2318	0,0526	0,0141	0,1363
0,3123	0,0620	0,2001	0,2085	0,0256	0,0642	0,0672	0,9391	0,1254	0,1052
0,1115	0,0827	0,1982	0,1926	0,0004	0,0834	0,0677	0,0609	0,1254	0,1208
0,0343	0,0413	0,1524	0,1674	0,0128	0,0642	0,0519	0,1279	0,2038	0,1380
0,2207	0,1653	0,2668	0,1507	0,2052	0,1091	0,1738	0,0526	0,0000	0,3106
0,1887	0,2480	0,1296	0,2286	0,1026	0,7743	0,0284	0,1111	0,2508	0,1363
0,0738	0,0413	0,1925	0,1976	0,0064	0,1091	0,0666	0,0585	0,0784	0,1346
0,1716	0,1240	0,1107	0,1842	0,0513	0,0449	0,0207	0,0641	0,1912	0,1415
0,3260	0,1240	0,2363	0,2587	0,0513	0,0449	0,0833	0,1245	0,2038	0,1087
0,0651	0,0827	0,2668	0,0921	0,0128	0,0802	0,2463	0,0266	0,0141	0,3451
0,5148	0,6612	0,3297	0,2009	0,8014	0,0340	0,4143	0,0526	0,0784	0,3796
0,0372	0,0827	0,2973	0,0921	0,0128	0,0585	0,2825	0,0526	0,0141	0,3796
0,1757	0,3306	0,2668	0,2009	0,2052	0,0577	0,2318	0,0526	0,0157	0,3796
0,1860	0,1653	0,2668	0,4102	0,0064	0,1155	0,1565	0,0526	0,1254	0,2571
0,0597	0,0620	0,1086	0,1507	0,0128	0,0706	0,0239	0,0935	0,3135	0,1398

Normalisation of the decision matrix is achieved using Equation (5.32) and Equation (5.33) from Chapter Five.

6.6.2 DEA Equations

The objective function, constraint equations and equality equations are displayed below using Equation (5.34). **Objective function:**

$$g_{20} = \min\ (0u_1 + 0u_2 + 0u_3 + 0u_4 + 0u_5 + 0u_6 + 0u_7 + 0u_8 + 3477v_1 + 165v_2)$$

Constraint Matrix A

Table 6.11: DEA Constraint Matrix A

8,0	15,6	3,6	1000,0	381,0	1 049 088,0	0,9	14,8	-8 999,0	-4 800,0
4,0	10,5	2,0	49,1	540,0	4 096 000,0	13,0	5,5	-11 999,0	-400,0
6,0	6,5	1,8	64,0	5160,0	2 592 000,0	48,0	7,9	-5 999,0	-172,0
4,0	5,8	3,8	256,0	420,0	2 740 500,0	12,0	8,3	-16 999,0	-188,0
16,0	12,3	3,8	512,0	810,0	4 990 464,0	8,0	8,5	-19 499,0	-770,0
16,0	14,0	2,5	512,0	720,0	2 073 600,0	0,9	7,9	-12 999,0	-1 600,0
3,0	10,5	2,5	64,0	600,0	37 009 632,0	8,0	6,1	-18 199,0	-464,0
4,0	10,4	2,3	1,0	780,0	2 400 000,0	8,0	7,0	-6 499,0	-467,0
2,0	8,0	2,0	32,0	600,0	5 038 848,0	13,0	8,0	-1 999,0	-358,0
8,0	14,0	1,8	512,0	1020,0	2 073 600,0	0,0	18,0	-12 859,0	-1 200,0
12,0	6,8	2,7	256,0	7242,0	4 377 600,0	16,0	7,9	-10 999,0	-196,0
2,0	10,1	2,4	16,0	1020,0	2 304 000,0	5,0	7,8	-4 299,0	-460,0
6,0	5,8	2,2	128,0	420,0	2 527 200,0	12,2	8,2	-9 999,0	-143,0
6,0	12,4	3,1	128,0	420,0	4 905 600,0	13,0	6,3	-18 999,0	-575,0
4,0	14,0	1,1	32,0	750,0	1 049 088,0	0,9	20,0	-3 794,0	-1 700,0
32,0	17,3	2,4	2000,0	318,0	2 073 600,0	5,0	22,0	-29 999,0	-2 860,0
4,0	15,6	1,1	32,0	547,0	2 073 600,0	0,9	22,0	-2 168,0	-1 950,0
16,0	14,0	2,4	512,0	540,0	2 073 600,0	1,0	22,0	-10 240,0	-1 600,0
8,0	14,0	4,9	16,0	1080,0	2 073 600,0	8,0	14,9	-10 840,0	-1 080,0
3,0	5,7	1,8	32,0	660,0	3 686 400,0	20,0	8,1	-3 477,0	-165,0

In Table 6.11 the input values are given in the last two columns. These values take on a negative sign when the inequality changes to bring to standard format.

6.6.3 Efficiency of the DMUs

The efficiency of devices is calculated using Equation (5.3.5). Table 6.12 shows the efficiency of the u-learning devices.

Equality equation:

$$3u_1 + 5{,}7_{u2} + 1{,}8u_3 + 32u_4 + 660u_5 + 3686400u_6 + 20u_7 + 8{,}1u_8 + 0v_1 + 0v_2 = 1$$

Table 6.12: The efficiency of u-learning devices

#	Devices	Type	g_k	H_k	Ranking Order
1	Desktop	Dell Inspiron	1,0000	1,0000	1st
2	Gaming Tablet	Samsung Galaxy Tab S5e	1,3322	0,7506	8th
3	Mobile Phone	Samsung Galaxy A51	1,0000	1,0000	1st
4	iPhone Smartphone	iPhone 11 Pro	1,0000	1,0000	1st
5	Customised Business Tablet	Microsoft Surface Pro 6	1,1069	0,9035	2nd
6	2-in-1 PC	Lenovo IdeaPad Flex 5 14	1,1399	0,8773	4th
7	iPad	iPad Air 3	1,0000	1,0000	1st
8	Mini Tablet	Samsung Galaxy Tab S6 Lite	1,2981	0,7703	7th
9	Handheld PC	Samsung Galaxy Tab A8 2019 Black LTE	1,0000	1,0000	1st
10	Traditional Laptop	Acer Swift 3	1,1269	0,8874	3rd
11	Phablet (Phone-Tablet)	Samsung Galaxy Note 10 Plus	1,0000	1,0000	1st
12	Slate	Huawei MediaPad T5 10.1-inch Black	1,1483	0,8709	5th
13	Android Smartphone	Google Pixel 4a	1,0000	1,0000	1st
14	Android Tablet	Samsung Galaxy Tab S7	1,6728	0,5978	10th
15	Notebook	Acer Chromebook 314	1,1945	0,8372	6th
16	Desktop Replacement Laptop	ASUS ROG Strix Scar 17	1,0000	1,0000	1st
17	Netbook	ACER CHROMEBOOK 15.6	1,0000	1,0000	1st
18	Subnotebook /Ultraportable	Dell Inspiron 14 7000	1,0000	1,0000	1st
19	Business Laptop	Lenovo ThinkPad X1 Carbon	1,4048	0,7118	9th
20	Windows Phone	Lumia 950 XL	1,0000	1,0000	1st

Table 6.12 provides the g_k and H_k values which denote the devices' efficiency. An H_k value of 1,000 infers the device is efficient. The smaller the H_k value, the less efficient the device. The Desktop, Mobile Phone, iPhone Smartphone, iPad, Handheld PC, Phablet, Android Smartphone, Desktop Replacement Laptop, Netbook, Subnotebook/Ultraportable, and Windows Phone proved to be efficient with a H_k value of 1,000. This result is corroborated by Te Kete Ipurangi (2020) which identified laptops, desktops, and hybrids as efficient devices for e-learning and Ivec (2014) who listed desktops, laptops, phablets and smartphones as efficient devices for e-learning. In contrast, the paper by Te Kete Ipurangi (2020) identified tablets as efficient devices for e-learning but in the current study, the least efficient device is the Android Tablet, specifically the Samsung Galaxy Tab S7 with an H_k value of 0,5978. According to CNET (2020c), Android Tablets usually have midrange hardware, update extremely slowly, have a short lifespan and do not come with the latest Android version resulting in its inefficiency.

6.7 Chapter Summary

Chapter Six is based on the results and discussion of use of scientific methods which manage the diffusion of social computing for school-based u-learning. The chapter began with the outline of the UML Activity Model and the description of the dataset of the 30 experts who rated the 60 criteria in the feature questionnaire in Section A. The feature questionnaire showed a Cronbach's alpha score of 0,949 which demonstrates a high reliability to evaluate the SM applications. The dimensionality of the criteria was reduced using PCA which presented the top 18 education requirements and the top 22 technology criteria for SM application ranking. Instructor Facilitation and Operational Stability had the highest loading scores in their categories with 0,1548566 and 0,1718243, respectively. In Section B, Fuzzy TOPSIS was implemented using the reduced attributes from PCA and the results showed that YouTube had the highest ranking with a closeness coefficient of 0,9188. This was followed by WhatsApp, Instagram, TikTok and Facebook which formed the top five SM applications whose Likert scale responses were discussed in the section analysis. In Section C, DEA was implemented using the quantitative devices' features to determine the efficiency of devices for u-learning. Eleven of the twenty devices were found to be efficient for u-learning with an H_k value of 1,000. The Android Tablet was found to be the least efficient. The next chapter provides the results and discussion of the survey questionnaire and presents the blueprint for an IDSS.

CHAPTER SEVEN: RESULTS AND DISCUSSION OF SURVEY AND BLUEPRINT FOR AN AUTOMATED EVIDENCE-BASED APPLICATION

7.1 Introduction

Chapter Seven is represented in two sections. Section A discusses the results of the main study survey questionnaire conducted on social media applications for ubiquitous learning. The survey data was probed using the Statistical Package for the Social Sciences Version 4. Inferential and descriptive data are presented in the form of tables and graphs. The results are synthesised using current literature on social media applications. This section begins with reliability testing and concludes with hypothesis testing. Section B presents the blueprint for an intelligent decision support system of social computing diffusion for school-based ubiquitous learning. Mock-ups of the user interface as well as an entity relationship diagram are presented. The chapter concludes with a summary.

Section A: Survey Results

7.2 Survey Sample

Considering the guidelines placed by Sekaran and Bougie (2016: 233), the sample size was 384 respondents as the approximate size of the population of the present study was 129 421 (Department of Basic Education 2020). However, 260 learners and instructors responded to the questionnaire which inferred a 67,71% response rate. This is an acceptable response rate as extant literature states that the aim of researchers conducting a survey questionnaire should be a response rate of approximately 60% (Fincham 2008: 1-3; Sekaran and Bougie 2016: 239).

7.3 Survey Questionnaire

The dataset was collected via a survey questionnaire forwarded on a link to respondents' devices. Online survey questionnaires on Google Forms offered a cost-effective and time-efficient data collection method that had an interface that was user-friendly in all forms of digital access. The questions investigated technology criteria and education requirements resulting from the existent literature that is important for the management of social media (SM) diffusion in ubiquitous learning (u-learning) in schools. The thirty most frequently occurring technology criteria (fifteen) and education requirements (fifteen) were selected. Refer to Annexure K for the Survey Questionnaire.

7.4 Reliability Statistics

Table 7.1 presents the Cronbach's Alpha reliability scores for all items on the survey questionnaire.

Table 7.1: The Cronbach's Alpha score for all the items on the survey questionnaire

Question No.	Section	No. of Items	Cronbach's Alpha
Q1 – Q15	Education Requirements	210	0,946
Q16 – Q30	Technology Criteria	210	0,934
Overall		420	0,932

Table 7.1 shows that the reliability scores are more than the recommended score of 0,7 for 'Education Requirements', 'Technology Criteria' and 'Overall' categories in the survey questionnaire. This indicates a degree of high consistency of the scoring of the items, hence, a high degree of reliability of the research instrument.

7.5 Survey Results: Section A - Biographical Data

Biographical data was analysed to understand the characteristics of the respondents in the study. The biographical data is presented in this study in tables and graphs.

7.5.1 Gender

Table 7.2 represents the gender distribution in the study.

Table 7.2: Gender distribution of respondents

	Learners		Instructors	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Male	101	43,50	12	42,90
Female	128	55,20	16	57,10
Other	3	1,30	0	0,00
Total	232	100,00	28	100,00

The percentage of female learners (55,20%) and female instructors (57,10%) was much higher than their male counterparts. This is aligned with the report by Statista (2020b) which stated that the female population in SA in 2019 was around 29,7 million and the male population was roughly 28,86 million. Another study revealed that in 2012, the school enrolment rate in SA for girls was 90,9% whereas for boys it was 89,7% (The Borgen Project 2018). These statistics are further corroborated by the study at Stellenbosch University in SA which investigated the "Martha Effect". In this study it was found that females are more likely than their male counterparts to attend school, to matriculate and to complete an undergraduate degree (van Broekhuizen and Spaull 2017: 1).

7.5.2 Age

Figure 7.1 displays the ages of the respondents in the sample.

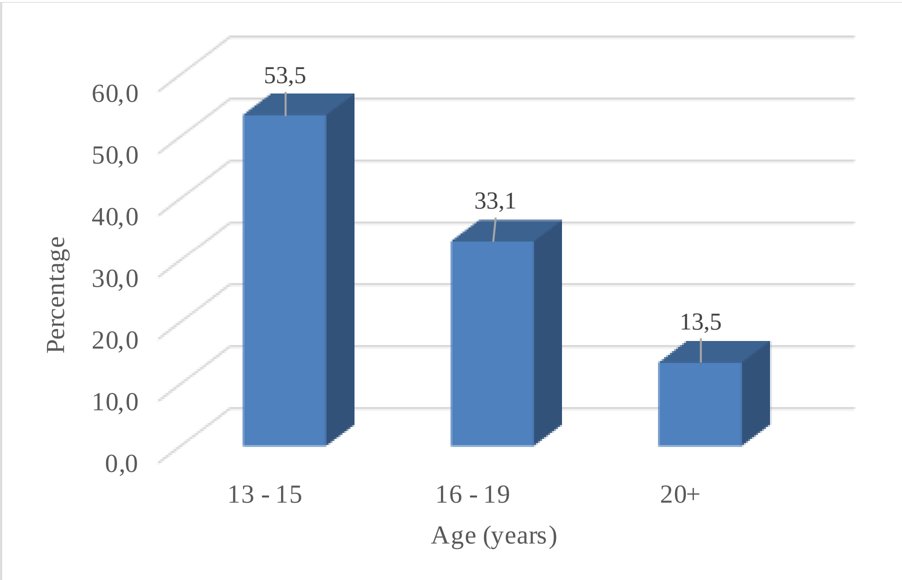

Figure 7.1: Age of respondents

Most respondents were in the age category 13–15 years. The age category of 20+ years included learners and instructors; they comprised 13,5% of the sample. Statistics in SA have revealed that the average number of years of schooling for individuals in 2016 was 10,5 years inferring that South African learners generally only reach Grade 10 of schooling which is within the age category of 13–15 years (Lehohla 2016: 43). This explains the trend in Figure 7.1.

7.5.3 Respondent Status

Figure 7.2 illustrates the distribution of respondents in terms of their status.

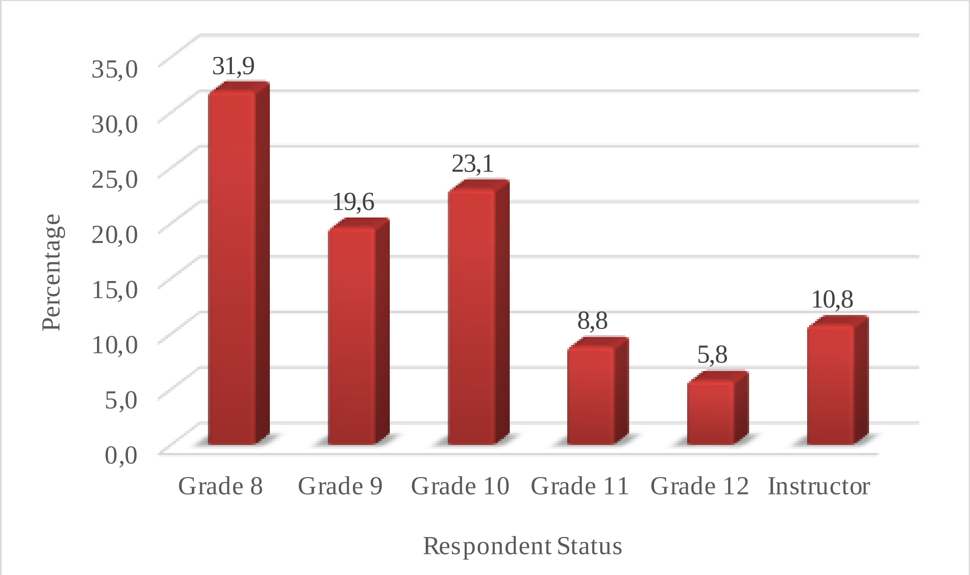

Figure 7.2: Status of respondents

Grade 8 learners comprised the majority of the sample (31,9%). The smallest group in the sample was Grade 12 learners which comprised 5,8% of the sample. This could have been due to the fact that Grade 12 learners were preparing to start their final examinations in the month of October 2020 during the data collection period. Instructors comprised 10,8% of the sample.

7.5.4 Devices Used for Ubiquitous Learning

Table 7.3 shows a count of devices used for u-learning.

Table 7.3: Count of devices used by respondents for u-learning

	No		Yes	
Device	Count	Row N %	Count	Row N %
iPhone Smartphone	175	67,31	85	32,69
Desktop	185	71,15	75	28,85
Mobile Phone	146	56,15	114	43,85
Traditional Laptop	195	75,00	65	25,00
Android Smartphone	227	87,31	33	12,69
iPad	212	81,54	48	18,46
Android Tablet	202	77,69	58	22,31
2-in-1 PC	228	87,69	32	12,31
Gaming Tablet	228	87,69	32	12,31
Windows Phone	254	97,69	6	2,31
MacBook	229	88,08	31	11,92
Business Laptop	248	95,38	12	4,62
Handheld PC	229	88,08	31	11,92
Mini Tablet	251	96,54	9	3,46
Gaming PC	230	88,46	30	11,54

Table 7.3 shows that mobile phones were generally utilised (43,85%) for u-learning, followed by iPhone Smartphone use at 32,69% and desktops at 28,85%. It is important to note that these three devices were shown to be efficient for u-learning with an H_k value of 1,000 in Chapter Six, Section 6.8, Table 6.11. In Table 7.3, the least popular device used for u-learning is a Windows Phone at 2,31%; however, it has an H_k value of 1,000 which denotes the device is highly efficient. This is probably due to the fact that the active development of Windows Phones was discontinued by Microsoft in 2017 and that by January 2020, Windows Phones had reached the end of their product lifecycle (Tung 2019).

7.5.5 Type of Internet Connectivity

Table 7.4 presents the type of internet connectivity used by learners and instructors in school-based u-learning.

Table 7.4: Type of internet connectivity used by respondents

	No		Yes	
	Count	Row N %	Count	Row N %
Wireless Internet	104	40,00	156	60,00
Fibre Internet	174	66,92	86	33,08
Cellular Network	212	81,54	48	18,46
Mobile Hotspot	202	77,69	58	22,31
Cellular Network	245	94,23	15	5,77
Cable Internet	242	93,08	18	6,92
DSL (Digital Subscriber Line)	248	95,38	12	4,62

Table 7.4 revealed that Wireless Internet was the most common choice of internet connectivity for u-learning at 60,00% and that Digital Subscriber Line (DSL) was the least popular (4,62%). The high count for wireless internet can be explained by the substantial increase in internet traffic since the COVID-19 lockdown (SEACOM 2020). This is probably due to well-resourced schools moving to online platforms for teaching and learning, businesses having to operate remotely, and the surge in streaming of series, movies and videos in households on platforms like Netflix (SEACOM 2020). The use of DSL has become unpopular to most internet users as it is prone to congestion and has poor bandwidth when compared to fibre optics (Ellis 2020).
7.5.6 Data Options

Table 7.5 shows the data options of learners and instructors for school-based u-learning.

Table 7.5: Data options of respondents

	No		Yes	
	Count	Row N %	Count	Row N %
Capped	187	71,92	73	28,08
Uncapped	111	42,69	149	57,31
Prepaid Once-off Data bundles (valid for 30 days)	217	83,46	43	16,54
Prepaid (Hourly/Weekly/Fortnightly)	219	84,23	41	15,77
Other	259	99,62	1	0,38

In Table 7.5 the most infrequently used data option for u-learning was Other (0,38%), followed by Prepaid (Hourly/Weekly/Fortnightly) at 15,77%. The most popular data option was Uncapped at 57,31%. Working remotely, online learning, movie and video streaming and gaming require uninterrupted and fast internet connectivity. Such activities have increased substantially over the COVID-19 lockdown which has prompted the need for and use of uncapped data (Ogilvy 2020), as is evident in the Table 7.5 results.

7.6 Survey Results: Section Analysis

The tables that follow reflect the responses to the 30 questions in the Survey Questionnaire that relate to education requirements (B1–B15) and technology criteria (C16–C30) of SM applications. Explanations of the results in each table were provided. Only the results of the top five SM applications are presented in the tables that follow. The top five SM applications in rank order were: YouTube, WhatsApp, Instagram, TikTok and Facebook, as observed in Chapter Six, Section 6.6, Table 6.7.

7.6.1 Ownership of Learning

This item refers to the user being motivated, engaged and self-directed. The SM application allows the user to monitor their own progress where they are able to reflect on their learning based on mastery of content (Debattista 2018: 98). The table below presents the results for question B1 of the survey questionnaire.

Table 7.6: Ownership of Learning

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	38,85%	4,62%	13,08%	16,92%	18,85%	7,69%
WhatsApp	7,69%	28,85%	27,69%	23,85%	8,85%	3,08%
YouTube	7,69%	38,85%	28,08%	9,62%	8,85%	6,92%
Instagram	16,92%	10,77%	10,00%	23,85%	26,54%	11,92%
TikTok	21,15%	7,69%	10,77%	18,46%	26,54%	15,38%

In Table 7.6, the results show that YouTube is the most popular SM application with regard to **ownership of learning**. By combining the percentages in the 'Very Good' and 'Good' column, the results show that from the top five SM applications, Facebook is the least popular for ownership of learning with a percentage of 17,7% in agreement. Husain *et al.* (2012: 3), stated that YouTube lets learners and teachers acquire skills from guided videos made by experts in their field and that these videos can be replayed until the individual fully understands the concept. This gives teachers and learners a form of ownership of their learning. YouTube supports flipped classrooms whereby learners take ownership of their learning in a fair and free manner (Learn From Blogs 2021). Furthermore, teachers and learners can create videos to showcase their talents and skills. This keeps learners motivated, engaged and allows for self-directed learning (Husain *et al.* 2012: 3).

7.6.2 Adaptability

This education requirement involves the SM application providing learning that is personalised and which endeavours to provide effective, efficient, and customised learning paths to encourage every learner (Kanagarajan and Ramakrishnan 2018: 571). The table below presents the results for question B2 of the survey questionnaire.

Table 7.7: Adaptability

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	31,15%	5,77%	9,62%	16,54%	23,08%	13,85%
WhatsApp	10,38%	21,92%	31,15%	28,46%	3,08%	5,00%
YouTube	10,00%	40,00%	27,31%	16,92%	3,08%	2,69%
Instagram	27,69%	10,77%	10,77%	17,31%	22,69%	10,77%
TikTok	31,92%	7,31%	11,92%	15,00%	23,08%	10,77%

The results in Table 7.7 indicate that YouTube is the most favourable SM application for **adaptability** in u-learning with a combined score of 8,77% for 'Poor' and 'Very Poor'. Facebook is the most unfavourable from the top five SM applications for **adaptability** in u-learning with a collective percentage of 36,93% for 'Poor' and 'Very Poor'. According to Husain *et al.* (2012: 4), YouTube can be easily incorporated into any Learning Management System (LMS) and can be used on any up-to-date digital device. It creates a community by encouraging online discussions, giving learners a voice and allowing learners to create and share content and comment on topics. Teachers and learners can search for videos that are specific to their learning and teaching styles and they can use material that accommodates their bandwidth or the amount of time available to them (The Conversation 2015).

7.6.3 Quality Assurance

Quality assurance in the context of the study means that the SM application is devised to prove and improve the quality of a school's academic programmes, learning materials, services and support, and standards (Kaplan and Haenlein 2016: 446). Table 7.8 displays the results for question B3 of the survey questionnaire.

Table 7.8: Quality Assurance

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	31,54%	5,77%	7,69%	23,46%	19,23%	12,31%
WhatsApp	12,31%	20,00%	30,00%	28,46%	5,00%	4,23%
YouTube	11,92%	38,46%	26,15%	17,69%	3,08%	2,69%
Instagram	26,15%	7,69%	11,54%	21,15%	21,54%	11,92%
TikTok	28,85%	6,15%	10,38%	21,15%	20,77%	12,69%

With regards to the combination of percentages in the ‘Very Good’ and ‘Good’ column in Table 7.8, YouTube is the most popular (64,61%) and Facebook is the least popular (13,46%) SM application for **quality assurance** in u-learning. Corresponding to several papers, Facebook does not use a panel of testers for quality assurance but rather uses automated testing solutions (Mei and Yeo 2014: 57). Facebook acknowledged the significant flaws in its quality assurance but opted to spend their resources on essential works. Facebook commonly employs "canary" releases and a gradual rollout approach to test new features, updates and fixes in production (Dijkstra 2015).

7.6.4 Peer Learning

This item in the survey questionnaire refers to the SM application allowing learners and teachers to support each other to achieve educational goals (Virtanen *et al.* 2018: 990). Table 7.9 displays the results from question B4 in the survey questionnaire.

Table 7.9: Peer Learning

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	27,69%	8,08%	17,31%	19,23%	18,46%	9,23%
WhatsApp	9,62%	35,77%	38,08%	12,31%	1,54%	2,69%
YouTube	16,54%	31,15%	30,77%	12,69%	6,92%	1,92%
Instagram	24,62%	11,92%	18,08%	14,62%	21,15%	9,62%
TikTok	31,15%	7,31%	9,23%	15,77%	23,08%	13,46%

The joined percentages of the ‘Poor’ and ‘Very Poor’ columns in Table 7.9 reveal that TikTok is the most unfavourable (36,54%) and that WhatsApp is the least unfavourable (4,23%) SM application for **peer learning**. The study by La Hanisi *et al.* (2018), revealed that WhatsApp allowed learners to ask each other for help and to share solutions for concepts taught in class. With the teacher’s guidance, WhatsApp provided a supportive atmosphere and a learning community to inspire dialogue, share knowledge and to encourage peer learning.

7.6.5 Instructional Design

In u-learning, instructional design refers to the SM application being designed to meet the learning aims, needs and outcomes structure of the educational programme (Debattista 2018: 97). Table 7.10 reflects the results of question B5 in the survey questionnaire.

Table 7.10: Instructional Design

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	33,85%	3,08%	10,00%	18,85%	21,92%	12,31%
WhatsApp	13,08%	21,15%	25,00%	28,08%	6,92%	5,77%
YouTube	11,92%	41,15%	21,15%	16,54%	6,54%	2,69%
Instagram	27,69%	6,15%	13,85%	18,08%	21,15%	13,08%
TikTok	29,62%	3,85%	9,62%	15,77%	26,92%	14,23%

The merging of the columns ‘Very Good’ and ‘Good’ in Table 7.10 indicate that YouTube is the most preferred (62,30%) and that Facebook is the least preferred (13,08%) SM application for **instructional design**. According to Babu, Rajendra and Gujjarappa (2019: 68), YouTube facilitates the creation of materials and learning experiences in a way that promotes the application and acquisition of skills and knowledge. It also affords a systematic and practical process for successfully designing applicable curricula.

7.6.6 Academic Integrity

This item in u-learning means putting values into practice by being honest in the academic work users do at school. The SM application uses best practices, academic research/writing practices, and anti-plagiarism practices. It allows learners to take responsibility for their learning (Anstey and Watson 2018: 4). Table 7.11 presents the results of question B6 in the survey questionnaire.

Table 7.11: Academic Integrity

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	33,08%	7,69%	7,69%	15,38%	20,00%	16,15%
WhatsApp	19,62%	15,77%	11,54%	21,54%	16,54%	15,00%
YouTube	15,77%	24,23%	22,69%	24,23%	7,69%	5,38%
Instagram	28,46%	6,54%	10,77%	18,46%	22,69%	13,08%
TikTok	30,00%	5,38%	8,85%	17,31%	22,31%	16,15%

The results in Table 7.11 indicate that YouTube is the least unfavourable SM application for **academic integrity** in u-learning with a combined score of 13,07% for ‘Poor’ and ‘Very Poor’.

TikTok is the most unfavourable from the top five SM applications for **academic integrity** in u-learning, with a collective percentage of 38,46% for 'Poor' and 'Very Poor'. Dilon (2020) discussed how TikTok promoted inappropriate conduct within the learning environment and advocated for the loss/theft of intellectual property. As a plethora of original videos are produced daily on TikTok, an exponential amount of copycat videos are made in 'TikTok challenges' which promote plagiarism and negate academic integrity (Dilon 2020). In particular, there was a video created on TikTok on how to commit plagiarism without detection (Campbell 2019).

7.6.7 u-Learning Training Factors

u-Learning training factors refers to the SM application increasing and developing the skills and knowledge of teachers and learners in u-learning. It improves the attitudes of learners and teachers towards u-learning (Anstey and Watson 2018: 5).

The Table 7.12 reflects the results of question B7 in the survey questionnaire.

Table 7.12: u-Learning Training Factors

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	32,31%	9,23%	14,62%	15,38%	18,46%	10,00%
WhatsApp	13,46%	20,38%	24,23%	27,69%	8,08%	6,15%
YouTube	12,31%	43,85%	26,54%	13,46%	2,69%	1,15%
Instagram	21,15%	10,38%	15,00%	27,69%	15,00%	10,77%
TikTok	20,38%	12,69%	10,77%	21,54%	20,38%	14,23%

The combination of the columns 'Very Good' and 'Good' in Table 7.12 indicate that YouTube is the most preferred (70,39%) and that TikTok is the least preferred (23,46%) SM application for **u-Learning training factors** from the top five SM applications. DeWitt *et al.* (2013: 1122) conducted a survey with performing art teachers and learners in Malaysia which confirmed that YouTube can be used to generate knowledge via social interactions and observation. The study also showed that YouTube could enhance and develop teachers and learners' skills and therefore change their attitude towards the use of IT and Web 2.0 tools in education.

7.6.8 Archiving/Repository

Considering the context of the study, archiving or repository means that the SM application has a storage system used to collect, store and manage learning content (Islas-Perez *et al.* 2015: 31). The results of question B8 in the survey questionnaire are presented in Table 7.13.

Table 7.13: Archiving/Repository

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	49,62%	4,62%	4,23%	10,77%	21,15%	9,62%
WhatsApp	30,38%	11,92%	16,54%	14,23%	14,23%	12,69%
YouTube	15,38%	28,08%	28,85%	19,62%	4,23%	3,85%
Instagram	40,77%	3,46%	12,31%	17,31%	14,23%	11,92%
TikTok	23,08%	10,00%	12,69%	26,15%	16,15%	11,92%

The joined percentages of the 'Poor' and 'Very Poor' columns in Table 7.13 reveal that Facebook is the most unfavourable (30,77%) and that YouTube is the least unfavourable (8,08%) SM application for **archiving or repository** from the top five SM applications in the study. For this item on the questionnaire, a large proportion of respondents answered as 'Not Sure' as in the cases of Facebook, WhatsApp, Instagram and TikTok. According to literature, WhatsApp automatically archives content to Google Drive and to the end-user's device. Data is backed-up automatically on the application as per the end-user's discretion (Ganjoo 2019). Instagram automatically archives content to the end-user's device and Instasave can be downloaded from Google Play stores to back up content (Brown 2019). Content on TikTok has to be downloaded manually from the settings on TikTok (Ramamoorthy 2020). YouTube automatically archives videos less than 12 hours in duration but to archive videos longer than 12 hours or other content, YouTube Studio must be accessed to manually download data (Ease Online Biz Solutions 2018). Facebook has a manual backup tool that is part of the Facebook software (Handy Backup 2021). Hence, a possible reason for the high rate of 'Not Sure' responses could be that additional applications have to be researched and then downloaded for most of these platforms to archive effectively.

7.6.9 Social Interactivity

Social activity involves the SM application helping teaching and learning by allowing communication in an educational context between learners, their peers, and their teachers

(Virtanen *et al.* 2018: 991). Table 7.14 presents the results of question B9 in the survey questionnaire.

Table 7.14: Social Interactivity

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	23,85%	14,23%	16,54%	16,92%	13,85%	14,62%
WhatsApp	4,62%	53,46%	26,15%	13,85%	0,38%	1,54%
YouTube	17,31%	22,69%	18,46%	21,15%	12,31%	8,08%
Instagram	21,54%	10,00%	22,69%	21,15%	15,38%	9,23%
TikTok	28,85%	6,15%	8,85%	15,38%	25,38%	15,38%

In Table 7.14 the results regarding the combination of percentages in the 'Very Good' and 'Good' column show that WhatsApp is the most popular (79,61%) and TikTok is the least popular (15%) SM application for **social interactivity** in u-learning. The study by Robles *et al.* (2019: 246) reflected that the employment of WhatsApp improved student communication, closed the social distance between students and teachers, facilitated direct and open communication with all concerned parties, developed students' understanding in an active and dynamic way, empowered students in online discussions, and positively impacted the learning process.

7.6.10 Curriculum Management

This item relates to the SM application developing, maintaining, and improving teaching and learning by managing each subjects' content, structure, organisation, assessment of learning, and instruction (Debattista 2018: 97). Table 7.15 shows the results of question B10 in the survey questionnaire.

Table 7.15: Curriculum Management

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	48,85%	5,38%	5,38%	10,77%	21,92%	7,69%
WhatsApp	38,46%	6,92%	9,23%	18,08%	13,08%	14,23%
YouTube	13,85%	18,08%	30,00%	17,69%	8,46%	11,92%
Instagram	35,38%	5,00%	8,08%	21,15%	14,23%	16,15%
TikTok	29,23%	6,15%	11,54%	16,15%	23,46%	13,46%

The results in Table 7.15 indicate that YouTube is the least unfavourable SM application for **curriculum management** in u-learning with a combined score of 20,38% for 'Poor' and 'Very Poor'. TikTok is the most unfavourable from the top five SM applications for curriculum management in u-learning with a collective percentage of 36,92% for 'Poor' and 'Very Poor'. Instructors and learners can download YouTubeEdu which allows users to search for educational content from subject experts and add favourite videos to their playlist which helps them manage their educational resources and plan for future lessons (ReelnReel 2020). The results also show that a large percentage of responses were 'Not Sure'. While SM applications can be used for managing each subjects' content, structure, organisation, formative and summative assessment, and instruction (Zdravkova 2016: 18-20), literature suggests that the majority of instructors feel uncomfortable with the educational use of SM applications in their classrooms. Murire and Cilliers (2017: 5) also advocated for instructors being trained in educational networking to better manage the delivery of the curriculum using SM applications.

7.6.11 Facilitation

Facilitation refers to the SM application having easy-to-use features that would improve one's ability to manage, monitor and engage with content and provide feedback (Zgheib and Dabbagh 2020: 53). The Table 7.16 below reflects the results of question B11 in the survey questionnaire.

Table 7.16: Facilitation

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	31,54%	6,54%	16,15%	17,69%	15,77%	12,31%
WhatsApp	11,92%	28,85%	21,15%	21,54%	11,15%	5,38%
YouTube	20,38%	29,62%	20,38%	13,08%	8,85%	7,69%
Instagram	29,62%	6,15%	9,62%	23,85%	20,00%	10,77%
TikTok	29,23%	5,38%	9,62%	17,31%	22,69%	15,77%

The combination of the columns 'Very Good' and 'Good' in Table 7.16 indicate that WhatsApp and YouTube are the most popular (50%) and that TikTok is the least popular (15%) SM application for **facilitation**. According to literature, WhatsApp has easy-to-use features which efficiently facilitate knowledge and information construction (Barhoumi 2015: 223). Babu, Rajendra and Gujjarappa (2019: 60) affirmed that YouTube has step-by-step tutorials on how to use any of its features such that individuals can easily create, manage and engage with their materials.

7.6.12 Learning Analytics

Learning analytics involves teachers monitoring learners' performance on many responsive measures on a user-friendly dashboard/tab bar of the SM application (Sadiku, Adebo and Sarhan 2018: 74). Table 7.17 displays the results for question B12 of the survey questionnaire.

Table 7.17: Learning Analytics

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	31,54%	5,77%	16,15%	15,38%	18,85%	12,31%
WhatsApp	16,15%	25,00%	24,23%	17,31%	8,85%	8,46%
YouTube	21,92%	16,54%	13,85%	21,54%	15,38%	10,77%
Instagram	30,00%	6,92%	16,15%	15,00%	21,15%	10,77%
TikTok	30,77%	5,77%	8,46%	14,23%	25,77%	15,00%

In Table 7.17 the results show that WhatsApp was the most popular SM application (49,23%) with regard to **learning analytics**. By combining the percentages in the 'Very Good' and 'Good' column, the results show that from the top five SM applications, Facebook is the least popular with only a percentage of 14,23% in agreement. Due to WhatsApp's Hypermediality, studies have reflected that learning progress can be monitored by learners forwarding videos, voice notes, images and documents of them performing a task. Therefore, WhatsApp has a user-friendly dashboard for monitoring learner performance (Amry 2014: 132).

7.6.13 Enhancement of Cognitive Task(s)

Enhancement of cognitive task(s) encompasses using SM applications to increase the engagement in task(s) that were once very difficult to imagine through other ways (Anstey and Watson 2018: 5). Table 7.18 presents the results for question B13 of the survey questionnaire.

Table 7.18: Enhancement of Cognitive Task(s)

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	32,69%	12,69%	10,00%	13,46%	18,08%	13,08%
WhatsApp	12,31%	30,00%	8,08%	19,62%	4,62%	5,38%
YouTube	15,00%	35,00%	23,85%	13,46%	6,54%	6,15%
Instagram	22,31%	12,69%	11,92%	21,15%	20,77%	11,15%
TikTok	24,62%	6,15%	13,08%	19,23%	23,08%	13,85%

The results in Table 7.18 indicate that WhatsApp is the least unfavourable SM application for **enhancement of cognitive task(s)** in u-learning with a combined score of 10% for 'Poor' and 'Very Poor'. TikTok is the most unfavourable of the top five SM applications for enhancement of cognitive task(s) with a collective percentage of 36,93% for 'Poor' and 'Very Poor'. Barhoumi (2015: 222) discussed that the educational use of WhatsApp enhanced learners' attitudinal and cognitive levels in traditional classes.

7.6.14 Higher Order Thinking

The item involves the use of the SM applications to help learners practise higher order thinking skills (Anstey and Watson 2018: 5). Table 7.19 shows the results for question B14 of the survey questionnaire.

Table 7.19: Higher Order Thinking

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	32,31%	7,69%	8,46%	15,38%	20,38%	15,77%
WhatsApp	16,92%	18,46%	14,62%	23,08%	16,15%	10,77%
YouTube	13,08%	32,69%	26,54%	15,38%	7,69%	4,62%
Instagram	27,31%	8,46%	8,08%	25,77%	14,23%	16,15%
TikTok	28,08%	6,54%	8,85%	19,23%	24,62%	12,69%

The combination of the columns 'Very Good' and 'Good' in Table 7.19 indicate that WhatsApp and YouTube are the most popular (59,23%) and that TikTok is the least preferred (15,39%) SM application for **higher order thinking**. DeWitt *et al.* (2013: 1119) identified that YouTube can be used for higher order thinking skills like problem solving and decision making.

7.6.15 Metacognitive Engagement

Metacognitive engagement relates to learners regularly tracking their performance, monitoring their improvement, testing their knowledge on the SM application (Anstey and Watson 2018: 6). The results of question B15 are displayed in Table 7.20.

Table 7.20: Metacognitive Engagement

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	31,54%	9,23%	9,62%	12,69%	21,15%	15,77%
WhatsApp	14,62%	22,69%	18,85%	15,77%	15,77%	12,31%
YouTube	18,08%	25,77%	15,77%	23,08%	10,00%	7,31%
Instagram	26,92%	9,23%	10,38%	18,85%	20,38%	14,23%
TikTok	31,92%	8,08%	10,00%	12,69%	21,15%	16,15%

The combined percentages of the 'Very Poor' and 'Poor' column reflect that TikTok is the most unfavourable SM application and that YouTube is the least unfavourable SM application for **metacognitive enhancemen**t with percentages of 37,30% and 17,31%, respectively. Instructors can create their own YouTube channels where their learners can make videos and the audience/instructor can rate the video and leave comments to assess learning. The videos can be added to a playlist so that learners can track their performance and monitor their progress. Flipped classrooms can be implemented whereby instructors give learners a video to watch and the learners can be tested on their understanding the next day (ReelnReel 2020).

7.6.16 Operational Stability

Operational stability involves the degree that a SM application is ready for use or its degree of performance during use. It refers to the predictability of all the processes in the SM application without special variations in the system (Mishra, Yadav and Choudhary 2013: 66). Table 7.21 presents the results generated from question C16.

Table 7.21: Operational Stability

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	36,54%	12,69%	10,38%	14,23%	16,54%	9,62%
WhatsApp	11,15%	32,69%	18,85%	23,46%	10,00%	3,85%
YouTube	13,08%	36,92%	25,38%	15,38%	8,08%	1,15%
Instagram	29,62%	13,46%	11,15%	16,15%	17,69%	11,92%
TikTok	31,54%	8,46%	7,69%	14,23%	21,92%	16,15%

Table 7.21 shows that YouTube is the preferred SM application for **operational stability** with a combined 'Very Good' and 'Good' score of 62,30%. TikTok is the least preferred SM application with a 'Very Poor' and 'Poor' score of 38,07%. TikTok has been shown to have operational stability issues in the past which was fixed through updates. Most recently users have complained about the application freezing during video play and glitching while clips are being streamed. However, TikTok developers have not resolved the issue (Alonzo 2021).

7.6.17 Fault Tolerance of Technology

This item relates to the ability of a SM application to continue operating without interruption when one or more of its components fail (Zgheib and Dabbagh 2020: 54). The table below is illustrative of responses to question C17.

Table 7.22: Fault Tolerance of Technology

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	34,62%	11,15%	7,69%	20,00%	16,54%	10,00%
WhatsApp	18,85%	20,00%	24,23%	22,69%	9,23%	5,00%
YouTube	20,00%	18,08%	19,62%	28,46%	8,85%	5,00%
Instagram	28,08%	11,54%	12,31%	16,92%	22,69%	8,46%
TikTok	30,38%	10,38%	8,46%	12,69%	26,15%	11,92%

Table 7.22 denotes that WhatsApp is the favoured SM application for **fault tolerance of technology** with a total percentage of 44,23% for 'Very Good' and 'Good'. TikTok is the least ideal SM application with a combined 'Poor' and 'Very Poor' score of 38,07%. According to Mohsin *et al.* (2017: 70) when compared to Viber and Skype, WhatsApp is more fault tolerant as its time to failure (time when the first fault occurs from start-up) is more, time to repair (time taken to repair the fault) is less, uptime (percentage of the application that did not crash) is moderate, downtime (percentage of the application that crashed) is less and response time (time taken by the application to run compared to expectation) is also less.

7.6.18 Hypermediality

Hypermediality refers to the SM application permitting users to communicate through various channels (visual, audio and textual) and allowing for adaptive participation with the learning material. It is the database format comparable to hypertext where sound, images, video or text associated to the display can be directly accessed from the display (Anstey and Watson 2018: 7). The results of question C18 are displayed in Table 7.23.

Table 7.23: Hypermediality

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	28,08%	29,23%	14,23%	14,23%	8,46%	5,77%
WhatsApp	9,23%	51,15%	25,00%	12,31%	0,77%	1,54%
YouTube	16,92%	24,62%	19,23%	26,54%	8,85%	3,85%
Instagram	19,62%	36,54%	18,46%	11,92%	10,38%	3,08%
TikTok	23,85%	21,92%	13,85%	21,54%	13,08%	5,77%

The combined percentages of the 'Very Poor' and 'Poor' column reflect that TikTok is the most unfavourable SM application and that WhatsApp is the least unfavourable SM application for **Hypermediality** with percentages of 18,85% and 2,31%, respectively. Contrary to the results, TikTok has extensive Hypermediality features such as hashtags that link the display to other texts, videos, sounds, images on other users' feeds. Users can create and view 15 second videos based on various themes categorised by hyperlinks. When creating videos, special effects and music can be added using simple tools on the application (Wade and Shan 2018).

7.6.19 Multimedia Control

This item relates to the multimedia being controlled on the SM application. Multimedia refers to audio, videos, text, images and animation (Kimwise, Benjamin and Mugabirwe 2019: 405). Table 7.24 reflects the results for question C19.

Table 7.24: Multimedia Control

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	28,08%	20,77%	21,54%	13,85%	11,92%	3,85%
WhatsApp	10,77%	36,54%	33,46%	12,31%	4,23%	2,69%
YouTube	15,00%	33,85%	25,77%	16,15%	7,69%	1,54%
Instagram	22,69%	24,62%	23,08%	13,08%	12,69%	3,85%
TikTok	24,62%	19,23%	10,38%	21,92%	16,54%	7,31%

The combination of the columns ‘Very Good’ and ‘Good’ in Table 7.24 indicate that WhatsApp is the most preferred (70%) and that TikTok is the least preferred (29,61%) SM application for **multimedia control** from the top five SM applications. Exchanging Graphics Interchange Format files (GIFs), memes, songs, documents and others can be expensive if one’s internet connectivity or data option is not uncapped and it can consume a large amount of a phone’s memory. WhatsApp allows users to disable autosaving multimedia onto their phone’s galleries by selecting ‘No’ on the ‘Media Visibility’ option. Users have options of auto-downloading media when using mobile data, when connected to WiFi and when roaming. Users can screen which media they wish to download. WhatsApp has a ‘Disappearing Messages’ function that can be activated for specific conversations such that messages on that chat will disappear after seven days. Chats can be exported with the option of not attaching media and texts can be typed in bold, italics or strikethrough to emphasise the message (CNET 2020a).

7.6.20 Security of Technology

Security of technology refers to the SM application’s defence which includes the identification, deterrence and reaction to threats via software tools, security policies, and IT services (Zare *et al.* 2016: 110). The responses to question C20 are portrayed in Table 7.25.

Table 7.25: Security of Technology

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	36,92%	19,23%	7,31%	17,69%	10,77%	8,08%
WhatsApp	18,08%	26,54%	16,54%	23,85%	9,23%	5,77%
YouTube	19,62%	18,46%	24,62%	25,38%	9,23%	2,69%
Instagram	27,31%	17,69%	15,77%	22,69%	12,31%	4,23%
TikTok	28,46%	16,54%	11,15%	20,00%	17,31%	6,54%

Table 7.25 shows that WhatsApp and YouTube are the preferred SM application for **security of technology** with a combined ‘Very Good’ and ‘Good’ score of 43,08%. TikTok is the most unfavourable SM application with a ‘Very Poor’ and ‘Poor’ score of 23,58%. On WhatsApp, users have the option of blocking and/or reporting individuals; certain chats can be muted for eight hours, one week or always; a user’s ‘Last Seen’ can be hidden; and one can customise notifications so that the user can identify the message sender without looking at their phone (CNET 2020a). YouTube has a Community Guidelines Policy where harassment or bullying can be reported and after investigation, the content can be removed. Policy violation leads to

penalties which upon the third penalty, the YouTube channel is terminated (YouTube Help 2021).

7.6.21 Facilitation of e-Content

This item involves the use of the SM application to facilitate learning through electronic means (Debattista 2018: 99). Table 7.26 presents the results of question C21.

Table 7.26: Facilitation of e-Content

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	32,31%	9,23%	13,08%	25,77%	9,23%	10,38%
WhatsApp	12,31%	21,54%	26,54%	30,77%	4,62%	4,23%
YouTube	12,69%	33,46%	25,38%	20,38%	4,23%	3,85%
Instagram	27,69%	10,77%	14,62%	28,85%	9,62%	8,46%
TikTok	28,85%	8,08%	10,38%	25,00%	17,31%	10,38%

In Table 7.26 the results from most favoured SM application for **facilitation of e-content** to least favoured are: YouTube (58,84%), WhatsApp (48,08%), Instagram (25,39%), Facebook (22,31%), and TikTok (18,46%). The study by Wiechetek (2018) revealed how YouTube is essential for improving skills and knowledge and creating positive attitudes in students. YouTube presents real-life examples which tends to be lacking in traditional classes. As Generation Z are supporters of modern technologies, applying YouTube or YouTubeEdu to lessons facilitates better understanding of concepts where learners can take responsibility for their own learning. Learners can research the content on which they need clarity and can find numerous means of understanding concepts in ways that best suit their cognition from subject experts globally. The same notion can be applied to instructors (Wiechetek 2018: 2069).

7.6.22 Technical Information

Technical information is information that correlates to evaluation, development, research, engineering, testing, production, maintenance, operation, and use of the SM application (Kimwise, Benjamin and Mugabirwe 2019: 406). The responses to question C22 are presented in Table 7.27.

Table 7.27: Technical Information

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	33,08%	8,08%	20,77%	20,38%	13,85%	3,85%
WhatsApp	22,31%	15,38%	24,23%	22,69%	11,54%	3,85%
YouTube	17,69%	25,38%	24,23%	21,92%	8,85%	1,92%
Instagram	29,62%	10,77%	15,77%	26,54%	12,31%	5,00%
TikTok	27,31%	9,62%	14,62%	30,38%	15,00%	3,08%

The combination of the columns 'Very Good' and 'Good' in Table 7.27 indicate that YouTube is the most preferred (49,61%) and that TikTok is the least preferred (24,24%) SM application for **technical information** from the top five SM applications. However, most of TikTok's popularity stems from the user-centric theory and its technical information which is its diverse functions, immersive interactive design and fragmentation propagation. TikTok enhances the user experience with personalised service, innovation and content production based on user-centric design. It accomplishes the users' goals and fulfils their needs. TikTok enriches users' experiences and optimises their loyalty with interface design; recommended algorithm technology derived from big data; human-computer interactivity; content micro narrative modules which help groups or individuals understand their relationship with the world; user generated content, professionally generated content, and an occupationally generated content production model (Yu 2019: 29-31).

7.6.23 Software Characteristics' Quality

This item includes the functional and structural quality of the SM application. This means the ability of the application to perform, be reliable without system failure, be maintained, give high outputs, be used to a high degree, to adjust and adapt as is required (Debattista 2018: 100). Table 7.28 presents the results to question C23.

Table 7.28: Software Characteristics Quality

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	27,69%	12,31%	16,15%	25,38%	13,46%	5,00%
WhatsApp	14,23%	27,69%	23,46%	25,00%	5,77%	3,85%
YouTube	14,23%	28,46%	28,85%	15,77%	10,00%	2,69%
Instagram	23,08%	13,46%	19,62%	27,31%	11,54%	5,00%
TikTok	23,85%	13,85%	13,08%	28,46%	13,85%	6,92%

Table 7.28 shows that YouTube is the preferred SM application for **software characteristics quality** with a combined 'Very Good' and 'Good' score of 57,31%. TikTok is the least preferred SM application with a 'Very Poor' and 'Poor' score of 26,93%. For an application to exude high quality its software characteristics should comprise functionality, usability, efficiency, reliability, maintainability and portability (Vaníček 2006: 180). As was discussed in 7.6.16 of this section, the TikTok application glitched and froze during use which was not rectified by developers. This means that TikTok lacked reliability and maintainability which corresponds to it being rated as the least preferred application for software characteristics' quality (Alonzo 2021).

7.6.24 Ease of Use

This criterion relates to the SM application having an easy interface for teachers and learners to use (Pishtari *et al.* 2020: 1083). The results of question C24 are shown in Table 7.29.

Table 7.29: Ease of Use

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	30,00%	21,15%	22,69%	13,08%	8,85%	4,23%
WhatsApp	11,54%	40,00%	32,31%	13,46%	2,31%	0,38%
YouTube	13,46%	38,46%	30,38%	13,46%	4,23%	0,00%
Instagram	23,08%	26,15%	25,00%	15,38%	7,31%	3,08%
TikTok	22,69%	24,62%	18,08%	21,15%	8,85%	4,62%

In Table 7.29 by aggregating the 'Very Good' and 'Good' columns, the results from most popular to least popular SM applications for **ease of use** are as follows: WhatsApp (72,31%), YouTube (68,84%), Instagram (51,15%), Facebook (43,84%) and TikTok (42,70%).

According to Barhoumi (2015: 223), WhatsApp automatically performs most functions, therefore it has a simple interface with easily accessible tabs in basic terminology for users to customise its functions (Dove and Beaton 2021).

7.6.25 Operating System

Operating system refers to teachers and learners successfully using the SM application with any operating system (e.g. Apple MacOS, Microsoft Windows, Android, Linux and Apple's iOS) (Anstey and Watson 2018: 7). The results to question C25 are reflected in Table 7.30.

Table 7.30: Operating System

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	31,15%	25,77%	19,62%	12,69%	6,92%	3,85%
WhatsApp	17,31%	38,08%	22,69%	16,92%	1,54%	3,46%
YouTube	18,08%	41,15%	23,46%	12,31%	3,46%	1,54%
Instagram	23,85%	26,92%	21,54%	20,00%	5,00%	2,69%
TikTok	26,15%	23,46%	20,00%	23,08%	4,62%	2,69%

Table 7.30 indicates that YouTube is the favoured SM application for **operating system** with a total percentage of 64,61% for ‘Very Good’ and ‘Good’. Facebook is the least ideal SM application with a combined ‘Poor’ and ‘Very Poor’ score of 10,77%. Currently, Facebook’s hardware depends on Google’s operating system for users’ accessibility. As Google is a competitor, Facebook is working towards developing their own operating system to improve their product offering to users without hindrance from Google. Using Google’s operating system (Android-based) has negatively impacted the security and social interactions of Facebook (Koksal 2020).

7.6.26 Browser

This criterion relates to teachers and learners successfully using the SM application with any browser (Google Chrome, Internet Explorer, Safari, Mozilla Firefox, Opera, etc.) (Anstey and Watson 2018: 7). Table 7.31 shows the responses to question C26.

Table 7.31: Browser

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	28,85%	28,08%	21,15%	10,77%	6,92%	4,23%
WhatsApp	16,15%	34,62%	22,31%	17,31%	6,15%	3,46%
YouTube	12,69%	45,77%	20,77%	16,54%	3,46%	0,77%
Instagram	20,38%	30,00%	23,08%	14,62%	4,62%	7,31%
TikTok	21,15%	27,69%	19,23%	17,31%	6,92%	7,69%

The combination of the columns ‘Very Good’ and ‘Good’ in Table 7.31 indicate that YouTube is the most popular (66,54%) and that TikTok is the least popular (48,84%) SM application for **browser**. To ensure fast browsing speed, customised and enhanced playback and support of Hypertext Mark-up Language (HTML) 5 audio codecs and video, chromium-based browsers have to be adopted. Thus, YouTube is specific to updated browsers such as Chrome, Microsoft Edge, Opera, and Mozilla Firefox (Adams 2021).

7.6.27 Access on Mobile Platform

Access on mobile platform means that the SM application is accessed with an application download or using a mobile browser. It can be accessed on any device or mobile operating system (Anstey and Watson 2018: 7). Table 7.32 shows the responses to question C27.

Table 7.32: Access on Mobile Platform

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	26,54%	31,92%	20,38%	11,54%	5,00%	4,62%
WhatsApp	18,08%	38,46%	19,23%	16,54%	3,46%	4,23%
YouTube	17,31%	45,00%	16,54%	15,77%	4,62%	0,77%
Instagram	22,31%	33,46%	19,62%	14,62%	8,46%	1,54%
TikTok	25,00%	30,77%	17,69%	16,15%	7,69%	2,69%

The results in Table 7.32 indicate that YouTube is the least unfavourable SM application for **access on mobile platform** with a combined score of 5,39% for ‘Poor’ and ‘Very Poor’. TikTok is the most unfavourable with a collective percentage of 10,38% for ‘Poor’ and ‘Very

Poor'. Contrary to the results, TikTok operates optimally on smartphones (Figliola 2020: 1). All five SM applications are fully functional on smartphones.

7.6.28 Data Privacy and Ownership

Data privacy and ownership relates to learners and teachers maintaining copyright and ownership of their intellectual property/information. They can keep information private and choose if/how information is to be exchanged (Anstey and Watson 2018: 8). The results of question C28 are presented in Table 7.33.

Table 7.33: Data Privacy and Ownership

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	30,38%	23,08%	16,92%	13,46%	8,08%	8,08%
WhatsApp	19,62%	31,92%	18,46%	18,08%	5,77%	6,15%
YouTube	19,23%	26,15%	23,08%	20,38%	6,92%	4,23%
Instagram	23,08%	28,46%	18,46%	15,38%	6,15%	8,46%
TikTok	22,69%	22,69%	18,08%	18,85%	8,85%	8,85%

The combined percentages of the 'Very Poor' and 'Poor' column reflect that TikTok is the most unfavourable SM application and that YouTube is the most favourable SM application for **data privacy and ownership** with percentages of 17,70% and 11,15%, respectively. On YouTube, videos can be created for targeted users only whereby a privacy setting on YouTube can be used to upload a school community publicly, privately or unlisted. Parental controls can also be setup on YouTube through restricted mode (ReelnReel 2020).

7.6.29 Downloading, Saving, Importing and Exporting Data

This item means that teachers and learners can save, download, or export and import content in many different formats (Anstey and Watson 2018: 8). The responses to question C29 are relayed in Table 7.34.

Table 7.34: Downloading, Saving, Importing and Exporting Data

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	31,92%	23,08%	20,00%	11,92%	8,08%	5,00%
WhatsApp	18,08%	40,38%	21,54%	13,08%	3,85%	3,08%
YouTube	19,23%	29,23%	21,15%	19,62%	6,92%	3,85%
Instagram	28,08%	25,00%	18,85%	18,08%	6,92%	3,08%
TikTok	26,15%	23,85%	16,54%	17,31%	11,54%	4,62%

Table 7.34 indicates that WhatsApp is the most favoured SM application for **downloading, saving, importing, and exporting data** with a total percentage of 61,92% for 'Very Good' and 'Good'. TikTok is the most unfavourable SM application with a combined 'Poor' and 'Very Poor' score of 16,16%. On WhatsApp, users can import all forms multimedia within the application and from other applications. The same can be done for exporting data where multimedia can be saved. Messages can be starred and archived for convenient retrieval of content. Additionally, data can be cleared from storage (CNET 2020a).

7.6.30 Additional Downloads

Additional downloads refer to teachers and learners not needing to download more software or browser extensions to use the SM application (Anstey and Watson 2018: 8). The results of question C30 are presented in Table 7.35.

Table 7.35: Additional Downloads

	Not Sure	Very Good	Good	Fair	Poor	Very Poor
Facebook	34,62%	30,00%	11,54%	8,46%	9,23%	6,15%
WhatsApp	23,08%	40,77%	20,38%	13,08%	1,15%	1,54%
YouTube	22,69%	41,92%	17,31%	12,31%	5,38%	0,38%
Instagram	27,69%	34,23%	15,38%	12,31%	6,15%	4,23%
TikTok	27,31%	33,08%	15,77%	14,62%	6,15%	3,08%

In Table 7.35, the aggregated results for **additional downloads** for the columns 'Very Good' and 'Good' in ascending order are: Facebook (41,54%), TikTok (48,85%), Instagram (49,61%), YouTube (59,23%), WhatsApp (61,15%). A host of add-ons need to be downloaded for Facebook to offer users an enjoyable, advertisement-free, recommendations-free and notification-free experience. To avoid activating the ‘message read’ notification, Screen Blocker must be downloader. For users to efficiently view photos in full size on their news feeds, Photo Zoom must be installed. To bulk remove posts, multimedia and people from Facebook, Friends Feed, Image Cleaner and Friend Convert must be downloaded, respectively (Price 2020). While YouTube is a superior application, users complain about the layout having too much white space, being distracting, and having too many advertisements that usurp the video viewing time. These problems can be avoided by downloading ImprovedTube – YouTube extension, Audio only YouTube, Video Preview, YouTube Plus and YouTube Control Centre (Haider 2020). The built-in functionality of WhatsApp has most of the tools required to cover advanced messaging needs (SunshineKelly.com 2017). Instagram Downloader needs to be installed for images and videos to be download into the user’s device (Adams 2021). To download and save TikTok content, the Video Downloader Pro (VDP) extension needs to be downloaded and installed from the add-on store (Video Downloader Pro 2020).

7.7 Hypothesis Testing

Pearson’s Chi-Square Statistical Test

A Pearson’s Chi-square statistical test was used to assist in concluding the significance of the results. Pearson's chi-squared test can be used to evaluate how probable it is that there is an observed difference between the sets of categorical data in the study. The null hypothesis means that there is no significant difference between the sets of categorical data and that any observed difference is owed to experimental or sampling error (Pearson 1901: 559).

Table 7.36 shows the results of the significance testing using Gender and Ownership of Learning.

Table 7.36: Pearson’s Chi-square of Gender versus Ownership of Learning

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	21,135	11,481	11,205	5,439	17,729
Df	10	10	10	10	10
Sig.	0,020*	0,321	0,342	0,860	0,060

The results show a statistically significant relationship between ‘Gender’ and ‘Ownership of Learning’ for Facebook as the table reports a p-value of 0,02 which is less than 0,05. The relationship suggests that it is likely that gender will play a role in deciding the importance of the feature ‘Ownership of Learning’ in the selection of this SM application for u-learning. In WhatsApp, YouTube, Instagram and TikTok the null hypothesis will apply.

Table 7.37 reflects the results of the correlation between Gender and Quality Assurance.

Table 7.37: Pearson’s Chi-square of Gender versus Quality Assurance

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	15,891	6,129	21,468	17,278	11,574
Df	10	10	10	10	10
Sig.	0,103	0,804	0,018*	0,068	0,315

Table 7.37 shows that ‘Gender’ versus ‘Quality Assurance’ is statistically significant only for YouTube with a p-value of 0,018 (p-value< 0,05). This means that gender will play a role on whether the feature ‘Quality Assurance’ is important for u-learning. WhatsApp has a p-value of 0,814 which reflects that it is not statistically significant for ‘Gender’ versus ‘Quality Assurance’. Therefore, the null hypothesis applies. This implies that ‘Gender’ has no influence on whether ‘Quality Assurance’ is important to u-learning for WhatsApp.

Table 7.38 reflects the results of the correlation between Gender and Hypermediality.

Table 7.38: Pearson’s Chi-square of Gender versus Hypermediality

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	14,531	6,516	8,311	20,000	2,984
Df	10	10	10	10	10
Sig.	0,150	0,770	0,598	0,029*	0,982

Table 7.38 shows a statically significant relationship between ‘Gender’ and ‘Hypermediality’ for Instagram. The table above shows a p-value of 0,029 which is less than 0,05. Therefore,

‘Gender’ will play a role in deciding the importance of ‘Hypermediality’ for Instagram only. The null hypothesis will apply to Facebook, WhatsApp, YouTube and TikTok.

In relation to the results of Tables 7.36 to 7.38, Gender appears to be irrelevant when respondents rated the importance of the thirty criteria for SM applications selection as the null hypothesis was applied to most of the SM applications.

Table 7.39 shows the results of Peer Learning versus Age.

Table 7.39: Pearson’s Chi-square of Peer Learning versus Age

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	23,158	11,350	19,396	12,597	40,946
Df	10	10	10	10	10
Sig.	0,010*	0,331	0,036*	0,247	0,000*

Table 7.39 shows a statistically significant relationship of ‘Age’ versus ‘Peer Learning’ for Facebook (p-value = 0,010), YouTube (p-value = 0,036) and TikTok (p-value = 0,000) as the table reports p-values less than 0,05. The relationship suggests that it is likely that age will play a role in deciding the importance of the feature ‘Peer Learning’ in the selection of these SM applications for u-learning. For WhatsApp and Instagram, the null hypothesis will apply.

Table 7.40 shows the results of Operational Stability versus Age.

Table 7.40: Pearson’s Chi-square of Operational Stability versus Age

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	24,755	19,904	17,323	18,569	24,277
Df	10	10	10	10	10
Sig.	0.006*	0.030*	0,068	0.046*	0.007*

The results show that ‘Age’ versus ‘Operational Stability’ is only not statistically significant for YouTube with a p-value of 0,068 (p-value> 0,05). This means that age will not play a role in whether the feature ‘Operational Stability’ is important for u-learning with YouTube. The p-values of Facebook, WhatsApp, Instagram and TikTok show that 'Age' does influence whether the feature 'Operation Stability' is important for u-learning with these SM applications.

Table 7.41 shows the results of Fault Tolerance of Technology versus Age.

Table 7.41: Pearson's Chi-square of Fault Tolerance of Technology versus Age

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	32,502	16,664	33,271	19,470	12,441
Df	10	10	10	10	10
Sig.	0,000*	0,082	0,000*	0,035*	0,257

Table 7.41 shows a statically significant relationship between 'Fault Tolerance of Technology' and 'Age' for Facebook, YouTube and Instagram as their p-values are less than 0,05. Therefore, 'Age' will play a role in deciding the importance of 'Fault Tolerance of Technology' for these SM applications. The null hypothesis will apply to WhatsApp and TikTok as their p-values are 0,082 and 0,257, respectively.

Relating to the results of Tables 7.39 to 7.41, Age appears to be relevant when respondents rated the importance of the thirty criteria for SM applications selection as the null hypothesis could not be applied to most of the SM applications.

Table 7.42 reflects the results of Academic Integrity versus Status.

Table 7.42: Pearson's Chi-square of Academic Integrity versus Status

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	81,321	90,227	55,895	53,173	40,372
Df	20	20	20	20	20
Sig.	0.000*	0.000*	.000*	.000*	.004*

The results reveal that all of the top five SM applications have a statistically significant relationship between 'Academic Integrity' versus 'Status' as their respective p-values are less than 0,05. This means that ‘Status’ does influence the importance of ‘Academic Integrity’ for all of these SM applications.

Table 7.43 shows the results of u-Learning Training Factors versus Status.

Table 7.43: Pearson’s Chi-square of u-Learning Training Factors versus Status

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	45,213	43,640	57,324	79,427	52,220
Df	20	20	20	20	20
Sig.	0.001*	0.002*	0.000*	0.000*	0.000*

Table 7.43 reflects that all the top five SM applications have a statistically significant relationship between ‘u-Learning Training Factors’ versus ‘Status’ as their respective p-values are less than 0,05. This means that ‘Status’ does influence the importance of ‘u-Learning Training Factors’ for all these SM applications.

Table 7.44 presents the results of Technical Information versus Status.

Table 7.44: Pearson’s Chi-square of Technical Information versus Status

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	36,278	35,347	28,496	33,177	28,958
Df	20	20	20	20	20
Sig.	0.014*	0.018*	0,098	0.032*	0,089

Table 7.44 shows a statistically significant relationship of ‘Status’ versus ‘Technical Information’ for Facebook (p-value = 0,014), WhatsApp (p-value = 0,018) and Instagram (p-value = 0,032) as the table reports p-values less than 0,05. The relationship suggests that it is likely that status will play a role in deciding the importance of the feature ‘Technical Information’ in the selection of these SM applications for u-learning. For YouTube and TikTok the null hypothesis will apply.

Table 7.45 shows the results of Data Privacy and Ownership versus Status.

Table 7.45: Pearson's Chi-square of Data Privacy and Ownership versus Status

	Facebook	WhatsApp	YouTube	Instagram	TikTok
Chi-square	51,107	46,121	51,044	52,489	43,797
Df	20	20	20	20	20
Sig.	0,000*	0,001*	0,000*	0,000*	0,002*

Table 7.45 shows that 'Status' versus 'Data Privacy and Ownership' is statistically significant for Facebook, WhatsApp, YouTube, Instagram, and TikTok as the associated p-values are less than 0,05. This means that status will play a role in whether the feature 'Data Privacy and Ownership' is important for u-learning with these five SM applications.

Relating to the results of Tables 7.42 to 7.45, Status appears to be relevant when respondents rated the importance of the thirty criteria for SM applications selection as the alternative hypothesis applied to most of the SM applications.

Section B: Blueprint for an Evidence-Based Automated Application using Intelligent Decision Support Systems (IDSSs)

7.8 Entity Relationship Diagram for the Automated Software Application

An Entity Relationship Diagram (ERD) is a structural diagram implemented for system analysis and database design. It consists of various connectors and symbols that envision the major entities contained by the scope of the system and interrelationships between these entities (Song, Evans and Park 1995: 429). Figure 7.3 displays the ERD which incorporates two IDSSs into one application for managing the social computing diffusion in school-based u-learning.

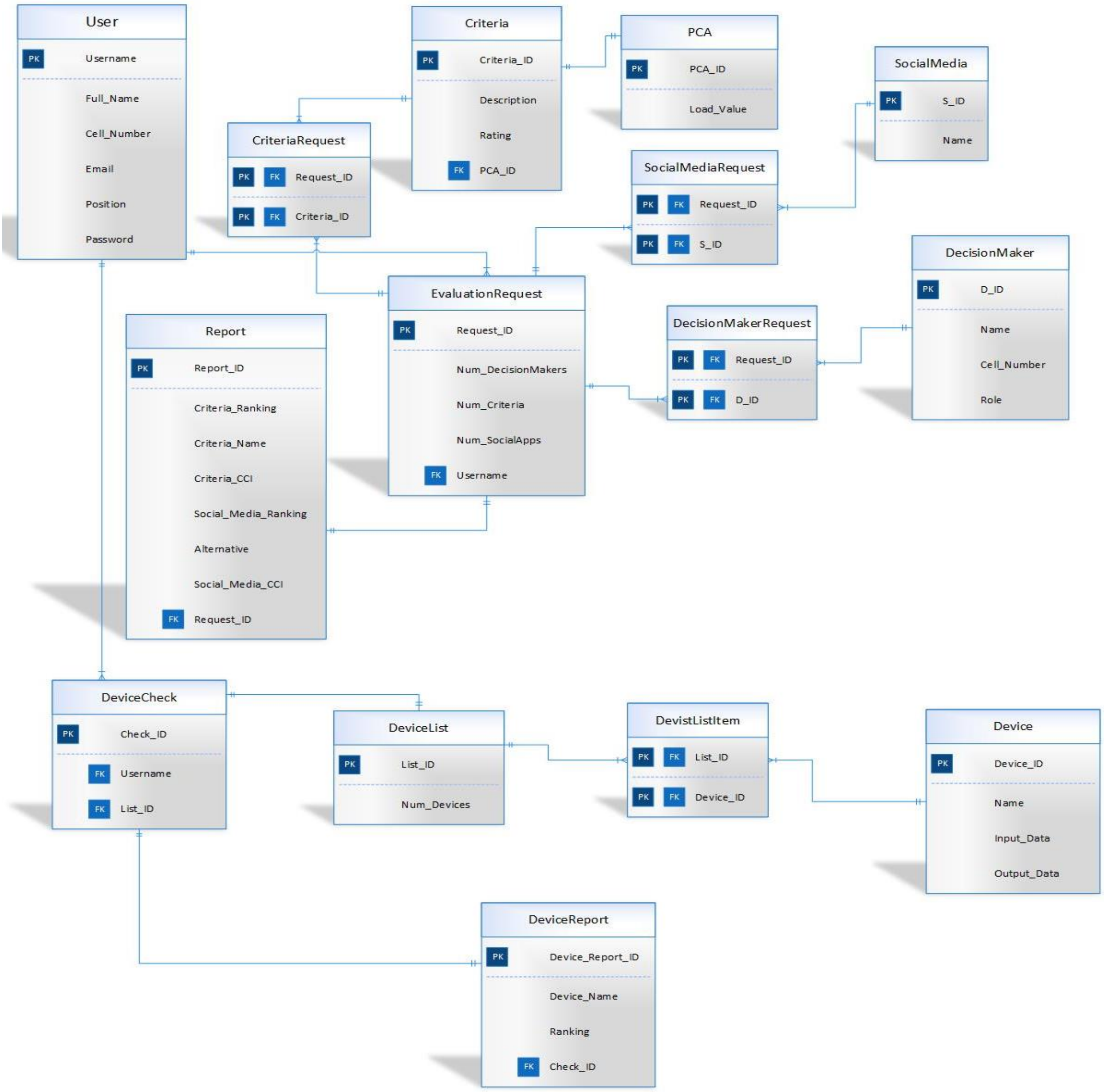

Figure 7.3: ERD diagram of the application for IDSSs

Source: Researcher's own construction

Figure 7.3 shows the structure of the new system and provides vital information for the design of the database. In Figure 7.3 the major Entities represented in rectangles are: User, Criteria, PCA, SocialMedia, CriteriaRequest, SocialMediaRequest, DecisionMakerRequest, DecisionMaker, Report, DeviceCheck, DeviceList, DeviceListItem, Device, and DeviceRequest. These Entities represent the scope of the system and the ERD shows the inter-relationships among these entities. The ERD will serve as an important source document during the requirements engineering phase of the application development process.

In Figure 7.3 the Entities are described with attributes, for example the 'Report' Entity has the following attributes, namely, Report_ID, Criteria_Ranking, Criteria_Name, Criteria_CCi, Social_Media_Ranking, Alternative, Social_Media_CCi, and Request_ID. These attributes are the entities' characteristics. The 'Report' Entity is described with a primary key that is used to uniquely identify a record in the database. The primary key attribute for this Entity is 'Report_ID' and is identified with the text label 'PK' in Figure 7.3. In the same way, the attributes and primary key attributes are represented for other Entities.

A foreign key is reference to the primary in the database table. In Figure 7.3 foreign keys are represented with the text label 'FK' as an attribute in an Entity. The following Entities have foreign keys, namely, CriteriaRequest, Criteria, SocialMediaRequest, Report, EvaluationRequest, DecisionMakerRequest, DeviceCheck, DevisListItem and DeviceReport. In the entity 'Criteria' for example the foreign key 'PCA_ID' is a reference to primary key 'PCA_ID' in the 'PCA' Entity. Using this attribute, the criteria values from the 'PCA' table now become available to the 'Criteria' table.

In Figure 7.3, Entities that are in a relationship are associated with one another through connecting lines or connectors, for example the Entity 'User' is associated with the Entity 'DeviceCheck' because a 'User' will perform a 'DeviceCheck'. Similarly, other relationships between Entities exist in Figure 7.3.

In Figure 7.3, cardinality is represented by one-to-one and one-to-many relationships. A one-to-one relationship exists between 'DeviceCheck' and 'DeviceReport'. 'DeviceCheck' can be used to represent information from 'DeviceReport' more concisely. A one-to-many relationship exists between 'User' and 'Device Checks'. One user can perform many device checks. Similarly, the cardinality between other Entities can be described. In the next section the screen mock-ups are presented.

7.9 Screen Mock-ups

In addition to the prototypes simulated by MATLAB R2020a, the design of the user interfaces for the digital IDSS application are shown below. Brief explanations accompany the screen designs. The mock-up design was implemented in HTML and JavaScript.

7.9.1 Sign-up Screen

Figure 7.4 depicts the sign-up screen for the digital IDSS application.

Figure 7.4: Sign-up screen

This screen will allow end-users to capture their account details for the application. There are fields specified for registration such as 'Username', 'Full Name', and 'Position' (role). If a user already has an account, then a link is displayed to allow the user to log into the system.

7.9.2 Login Screen

Figure 7.5 displays the design of the login screen.

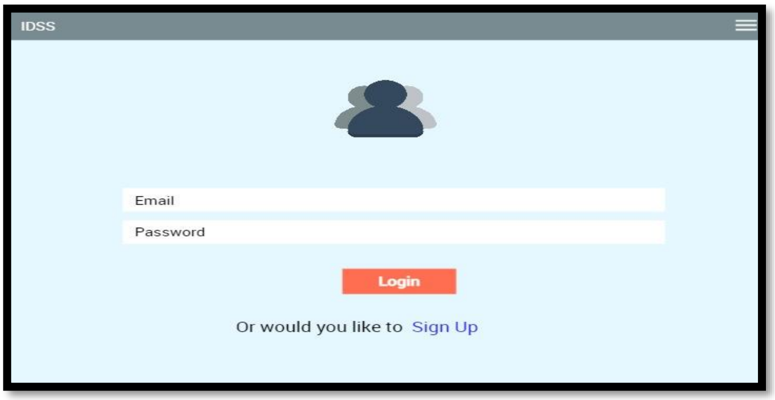

Figure 7.5: Login screen

In Figure 7.5, an email address and password is required to gain access into the system. A link is provided for users to sign-up to access the digital IDSS.

7.9.3 Setup Decision Making Parameter Screen

Figure 7.6 illustrates the setup decision making parameter screen design.

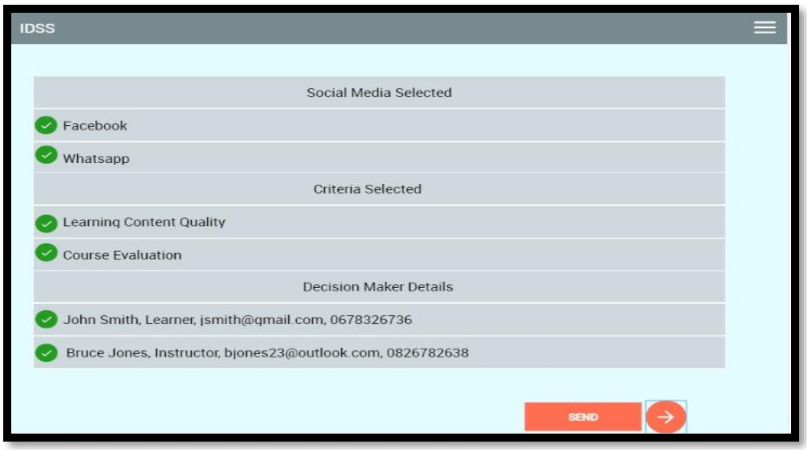

Figure 7.6: Setup decision-making parameter screen

In this interface, users can select the SM applications, the education requirements and technology criteria, as well as decision maker details. These parameters will provide input to the MCDM algorithm, namely Fuzzy TOPSIS. Once the input parameters are selected, the user can click on the send button.

7.9.4 Setup Criteria Screen

Figure 7.7 shows the design of the criteria selection screen.

Figure 7.7: Setup criteria screen

In the criteria selection screen, a predefined ranking is available for the end-user to view. The results displayed were obtained scientifically using PCA. The results are shown to advise the end-user of the importance of the criteria. However, the choice of criteria is at the discretion of the end-user. The end-user can also choose the cost and benefit criteria.

7.9.5 Output Ranking Screen for Social Media Applications

Figure 7.8 shows the design of the SM application ranking screen.

Figure 7.8: Social media ranking

Figure 7.8 presents the results of the ranking using three columns, namely, ‘Ranking #’, ‘Alternative’, and ‘Closeness Coefficient’.

7.9.6 Setup Input Parameters for Devices

Figure 7.9 shows the design of the setup input parameters for devices.

Figure 7.9: Setup input parameters for devices

This screen is used to add the details of the devices. Input features and output features are critical to the processing of results for the DEA algorithm.

7.9.7 Selection of Device's Screen

Figure 7.10 shows the design for the selection of the device's screen.

Figure 7.10: Selection of device's screen

This screen is set up to allow users to input the devices that are used for u-learning. The devices chosen for this screenshot are currently utilised for u-learning (Androidcentral 2020; AnySoftwareTools 2020; CNET 2020a; Creative Bloq 2020; Familyproof 2020; Gamesradar 2020; iMore 2020; Incredible Connection 2020; Laptop Study 2020; PC 2020; T3 2020; Techradar 2020; Tom's Guide 2020; Windows Central 2020). The users have the option to select one or more devices where they require efficiency values.

7.9.8 Output Efficiency of Devices Screen

Figure 7.11 shows the design of the device efficiency screen.

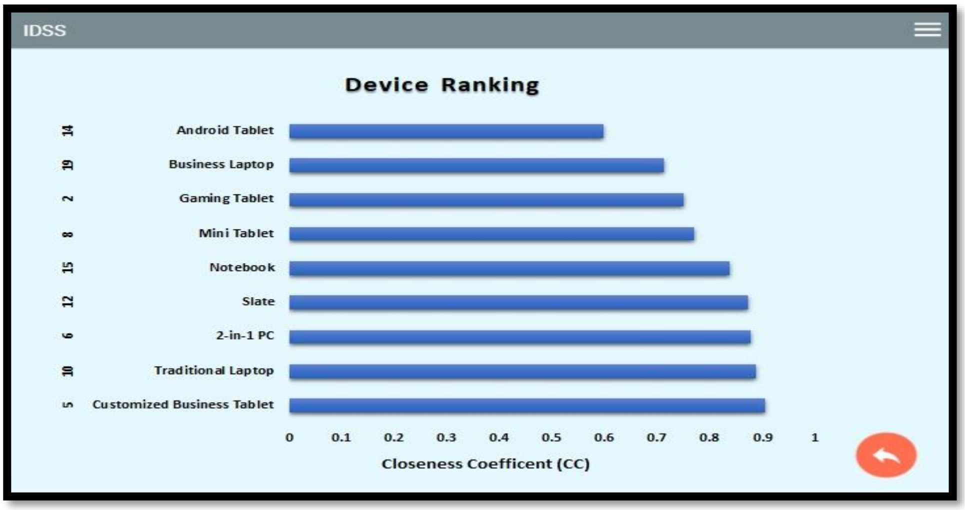

Figure 7.11: Output efficiency of device's screen

Figure 7.11 shows that the efficiency of devices will be output in a graphical form. The graphics are used to show the magnitude of the ranking.

7.10 Chapter Summary

The survey questionnaire was answered on Google Forms by 260 respondents which was generated from the dimensionality reduced SM application attributes which inferred an acceptable response rate of 67,71%. The overall Cronbach's alpha score was 0,932 which reflected a high reliability of the survey questionnaire. The analysis of the respondents' biographical data reflected that a greater percentage of respondents were female (57,10%), were in the age group 13–15 years (53,5%) and were in grade 8 (31,90%). The analysis of the biographical section showed that most respondents used mobile phones (43,85%) as u-learning devices, used wireless internet (60%) as a type of internet connectivity, and used uncapped data (57,31%) as a connectivity option. The significance of the results was verified by means of a Pearson's Chi-square statistical test for the top five SM applications. This involved testing the correlation of the education requirements and technology criteria versus the Gender, Age and Status of respondents where a p-value of less than 0,05 denoted statistical significance. The next chapter provides the summary, recommendations, and conclusions of this study.

CHAPTER EIGHT: SUMMARY, RECOMMENDATIONS, AND CONCLUSIONS

8.1 Introduction

The aim of the study was to investigate social media-driven Intelligent Decision Support Systems using live data, in order to assist instructors and learners manage the diffusion of social computing in school-based ubiquitous learning. The investigation of the Intelligent Decision Support Systems began with the collection of features regarding education requirements and technology criteria. Principal Component Analysis implemented on RStudio was employed to decrease the data dimensionality. The two simulations using live data were employed to assist with decision making of social media applications and digital access. The results were generated on MATLAB R2020a. As part of the research study, the program codes were generated 'from scratch' for both simulations. The first Intelligent Decision Support System simulation used the Fuzzy Technique of Order Preference Similarity to the Ideal Solution algorithm. This simulation provided automated intelligence on the choice of social media applications for school-based ubiquitous learning. The second Intelligent Decision Support System simulation used the Data Envelopment Analysis algorithm to provide insights into the most efficient ubiquitous devices for ubiquitous learning.

Chapter Eight provides a summary of Chapters One to Seven and discusses the conclusions from the results generated on Principal Component Analysis, Fuzzy Technique of Order Preference Similarity to the Ideal Solution, Data Envelopment Analysis and the statistical analysis. This chapter also assesses whether the aims and objectives of the research were achieved and how the findings of the study will impact and/or benefit society. Finally, the significant contributions are outlined, and the suggestions for future research are made. Annexure L provides a reference to show the alignment of the research and offers a concise summary.

8.2 Summary of the Study

The past twenty years has instituted an Information and Communications Technology (ICT) evolution. Consequently, Web 2.0 technologies and more specifically social computing has irrevocably integrated into education. Ubiquitous learning (u-learning) presents a solution for the continuance of the school syllabus in times of natural disasters or pandemics, such as, COVID-19. The plethora of social media (SM) applications, the education requirements and technology criteria of each application, as well as the numerous devices they operate on have propagated the need for Intelligent Decision Support Systems (IDSSs) to support learners and instructors at school on Multi-Criteria Decision Making (MCDM) for u-learning. Therefore, the aim of the study was to investigate SM driven IDSSs using live data to assist instructors and learners manage the diffusion of social computing in school-based u-learning.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) technique was employed to identify the extant literature on how artificial intelligence (AI) is implemented in u-learning and to uncover gaps for the current study. Sixty education requirements and technology criteria for e-learning, m-learning and u-learning were derived, the top fourteen SM applications of 2020 in SA were revealed, and the critical specifications of devices for u-learning along with the top twenty devices for u-learning were identified. On probing the various MCDM techniques it was found that Fuzzy Technique of Order Preference Similarity to the Ideal Solution (TOPSIS) and Data Envelopment Analysis (DEA) would be the most suitable techniques for selecting SM applications and ranking devices for u-learning, respectively.

Connectivism served as a theory to explain why instructors and learners chose certain SM applications and devices for u-learning. The three components of the Innovation Diffusion Theory (IDT) broadly categorised the education requirements and technology criteria of the study that arose from the literature review. The Multi-Criteria Decision Analysis Process Model of the Decision Theory served as a blueprint for the IDSSs that were to be achieved in the current study. Elements of the three discussed theories gave rise to the emergent conceptual model of the study which was called the Strategic Innovation Management Model (SIMM). The SIMM was implemented as a paradigm for the efficiency scoring of devices for u-learning.

The research paradigm of the study was positivism with a quantitative research design model being employed to collect the data in three phases. In Phase 1, the responses of thirty experts in e-learning and m-learning were solicited using the Feature Questionnaire which had a 100% response rate and a high reliability with a Cronbach's alpha score of 0,949. In Phase 2, learners and instructors comprising 384 participants were invited to take part in the Survey Questionnaire which had an acceptable response rate of 67,71% and a reliability Cronbach's alpha score of 0,932. Implementing inclusion and exclusion criteria in the study afforded the population size of 129 421 individuals from schools in the eThekwini Region. Using simple random sampling afforded a sample size of 384 respondents with a confidence level of 95% and a margin of error of 5%. In Phase 3, numerous documents were explored to determine the exact specifications of each device.

The activities in the Unified Modelling Language (UML) diagram involved the use of the Principal Component Analysis (PCA) which reduced the dimensionality of the criteria derived from the responses collected in Phase 1 in the research design model. The top fifteen education requirements in rank order were Instructor Facilitation, Ownership of Learning, Adaptability, Quality Assurance, Peer Learning, Instructional Design, Higher Order Thinking, Metacognitive Engagement, Academic Integrity, Learning Analytics, u-Learning Training Factors, Archiving/Repository, Social Interactivity, Curriculum Management, and Enhancement of Cognitive Task(s). The top fifteen technology criteria in rank order were Operational Stability, Fault Tolerance of Technology, Multimedia Control, Data Privacy and Ownership, Security of Technology, Facilitation of e-Content, Technical Information, Functionality, Hypermediality, Ease of Use, Browser, Archiving Saving Importing and Exporting Data, Operating Systems, Access on the Mobile Platform, and Software Characteristics' Quality.

In the next ULM activity, the results of 260 respondents translated on Fuzzy TOPSIS showed that YouTube had the highest CC_i of 0,9161, followed by WhatsApp, Instagram, TikTok, Facebook, Facebook Messenger, Pinterest, Snapchat, Twitter, Reddit, WeChat, QQ, QZone and Viber. A Pearson's Chi-square statistical test was conducted to deduce the significance of Age, Gender and Status on the results. P-values less than 0,05 proved statistically significant and the null hypothesis applied to p-values greater than 0,05. For example, there was a statistically significant relationship for Gender versus Ownership of Learning for Facebook (p-value= 0,02) but the null hypothesis applied to WhatsApp, TikTok, Instagram and YouTube which all had p-values greater than 0,05. There also was a statistically significant relationship between Age versus Peer Learning for Facebook, YouTube and TikTok which suggested that Age would influence deciding the importance of Peer Learning in the selection of these SM applications for u-learning. Regarding the relationship between Status versus Technical Information for YouTube and TikTok, the null hypothesis applied which suggested that Status did not play a role in deciding the importance of Technical Information in the selection of these SM applications for u-learning.

In the third ULM activity, the results of DEA CCR Model identified the benefit criteria as Screen Thickness, RAM, Battery Life, CPU, Screen Size, Resolution, Camera, and Internal Memory; and the cost criteria as Cost and Weight. The devices that proved to be efficient for u-learning with a H_k value equal to 1,000 were the Desktop, Mobile Phone, iPhone Smartphone, iPad, Handheld PC, Phablet, Android Smartphone, Desktop Replacement Laptop, Netbook, Subnotebook/Ultraportable, and Windows Phone. This was followed by the Customised Business Tablet, Traditional Laptop, 2-in-1 PC, Slate, Notebook, Mini Tablet, Gaming Tablet, Business Laptop and Android Tablet.

Lastly, the blueprint for the software application utilising IDSSs was presented using an Entity Relationship Diagram (ERD) and mock-ups of the user interface. The ERD diagram displayed the structure of the new system and provided essential information for database design.

8.3 Conclusions of Study and Recommendations

The conclusions and recommendations of the Literature Review, PCA, Fuzzy TOPSIS, DEA and IDSS are presented in this subsection.

8.3.1 Literature Review Conclusions and Recommendations

Research objective one was to determine the extent that social computing could be used for school-based u-learning. The scope of social computing includes SM applications and digital devices. In Chapter Two, fourteen of the top SM applications in SA for 2020 were identified as being WhatsApp, Facebook, Instagram, Viber, QQ, QZone, WeChat, Snapchat, Facebook Messenger, Twitter, Pinterest, YouTube, Reddit and TikTok (HelloYes 2020; SmartInsights 2020). Thereafter, a literature review was conducted reflecting the features of each application and how they can be implemented in e-learning or m-learning. There existed a gap in the studies involving SM applications for u-learning but the 'word' ubiquitous was often used in these studies to describe the nature of SM applications in learning. To determine the extent that SM applications can be implemented for u-learning, the education requirements and technology criteria had to be established. In Chapter Two, Table 2.1 presented education requirements and Table 2.2 presented the technology criteria for assessing SM applications for u-learning synthesised from the extant literature. Chapter Seven, Section 7.6 elaborated on how the top five SM applications (YouTube, WhatsApp, Instagram, TikTok and Facebook) determined in this study performed against the derived education requirements and technology criteria. For successful employment of SM applications, the digital access needs to be parallelised with the criteria of u-learning. A Document Analysis in Chapter Two revealed the top twenty devices which can be employed for e-learning and m-learning and the specifications of each device. The devices used for u-learning in Chapter Two, Table 2.3 showed the prominent features of devices for u-learning. From the literature and results of the study, it is evident how closely interrelated social computing is with u-learning. It is recommended that the education requirements, technology criteria and device specifications be prioritised when employing social computing for u-learning as SM applications and devices have a short life cycle but the essential features that were derived in this study are a significant long-term contribution.

8.3.2 PCA Conclusions and Recommendations

The results of the PCA corresponded with the research objective two which was to ascertain the most pertinent criteria of SM applications for u-learning. The sixty criteria for assessing SM applications' aptness for u-learning, were reduced to forty of the most critical criteria for u-learning in this study (Figure 6.5 and Figure 6.6, Chapter Six). The value of this result is that while SM applications will constantly change over time, the criteria employed to evaluate their suitability to education remains unchanged. Furthermore, no previous studies had identified the most influential features of SM applications for u-learning. According to the findings of the study, it is advised that school decision makers now utilise the top education requirements and technology criteria to guide their selection of SM application for u-learning, m-learning and e-learning.

8.3.3 Fuzzy TOPSIS Conclusions and Recommendations

SM applications have become integral tools for fulfilling the requirements of school-based u-learning, especially in unusual circumstances such as the COVID-19 period. According to HelloYes (2020), the most employed SM applications in SA for the year 2020 in numerical order were WhatsApp, YouTube, Facebook, Facebook Messenger, Instagram, Twitter, Pinterest, LinkedIn, Snapchat, Skype, Reddit, TikTok, Tumbler, WeChat, Twitch, and Viber. However, according to SmartInsights (2020), Generation Z individuals preferred Facebook, YouTube, WhatsApp, Facebook Messenger, WeChat, Instagram, TikTok, QQ, QZone, Reddit, Snapchat, Twitter, Pinterest, and Viber. It is important to highlight that these references did not relate social computing to u-learning. In the present study, **the research objective three involved the selection of optimal SM applications for u-learning using MCDM with live data**.

Accordingly, this study afforded the ranking of the top fourteen SM applications in 2020 using the MCDM tool Fuzzy TOPSIS with thirty u-learning SM application criteria and the 260 decision makers. The results showed that YouTube was the most optimal SM application for u-learning with a $CC_i = 0{,}9188$, followed by a $CC_i = 0{,}8691$ for WhatsApp. The least likely application applicable for u-learning with a $CC_i = 0{,}0165$ was Viber (Table 6.7, Chapter Six). It is recommended that school decision makers now apply SM applications like YouTube, WhatsApp, Instagram, TikTok and Facebook to their lessons where applicable to facilitate the proliferation of u-learning. Policy makers are advised to change school policy to allow for the use of these SM applications in a responsible and meaningful way to enrich and achieve the outcomes of lessons.

8.3.4 DEA Conclusions and Recommendations

Devices are essential for m-learning, e-learning and u-learning to be conducted successfully (Kazaure, Matthew and Okafor 2019: 2). Devices need to have the necessary specifications for SM applications or LMS to operate optimally. **Consistent with the research objective four of the study, the efficiency of devices used for u-learning were determined using the Multi-Criteria Decision Analysis technique DEA CCR Model (output model) with live data categorised as benefit criteria and cost criteria**. The results of DEA which are displayed in Table 8.1 is an adaptation of Table 6.12 in Chapter Six. It simply states which devices are efficient and the values of the less efficient devices.

Table 8.1: The ranked efficiency of u-learning devices

#	Device	Rank Order
11	Phablet (Phone-Tablet)	Efficient
18	Subnotebook /Ultraportable	Efficient
16	Desktop Replacement Laptop	Efficient
17	Netbook	Efficient
4	iPhone Smartphone	Efficient
7	iPad	Efficient

9	Handheld PC	Efficient
13	Android Smartphone	Efficient
3	Mobile Phone	Efficient
20	Windows Phone	Efficient
1	Desktop	Efficient
5	Customised Business Tablet	0,9035
10	Traditional Laptop	0,8874
6	2-in-1 PC	0,8773
12	Slate	0,8709
15	Notebook	0,8372
8	Mini Tablet	0,7703
2	Gaming Tablet	0,7506
19	Business Laptop	0,7118
14	Android Tablet	0,5978

It is recommended that decision makers utilise the efficient devices presented in Table 8.1 to effectively employ u-learning. As per the literature review, efficient devices for 2020 were the Samsung Galaxy Note 10 Plus, Dell Inspiron 14 7000, ASUS ROG Strix Scar 17, ACER Chromebook 15.6, iPhone 11 Pro, iPad Air 3, Samsung Galaxy Tab A8 2019 Black LTE, Google Pixel 4a, Samsung Galaxy A51, Lumia 950 XL, and Dell Inspiron 3470. Due to models constantly changing, it is advised that decision makers analyse the specifications of the efficient devices in Table 2.3 (Chapter Two) and either match or better those specifications with their proposed device.

8.3.5 Intelligent Decision Support System Conclusions and Recommendations

Relating to the research objective five, an automated application was designed using IDSSs constructed research evidence and the scientific methods, namely, Principal Component Analysis, Fuzzy TOPSIS and DEA for the selection of SM applications and devices. The software application was designed based on an ERD and screen mock-up designs of the application. The designs were implemented in HTML and JavaScript (Chapter Seven, Section B). Justification for the software application design being identified as IDSSs is that it has a reasoning mechanism by simulating the thought processes of decision makers and applying related knowledge to direct decision makers to select appropriate decision models corresponding to their demands; it makes the interface between various subsystems easier and manages the models as knowledge structures; and it constructs an all-inclusive decision support system structure to make the system more adaptable to the change of the decision form and the environment. The aforementioned qualities are characteristic of IDSSs (Changlin and Yufen

2017: 203). It is recommended that for decision makers to ensure that decisions are made consistently, efficiently, effectively and expertly when uncertainty exists, that a software application constructed on IDSSs of this nature must be employed to assist instructors and learners manage the diffusion of social computing in school-based u-learning.

8.4 Recap of Significant Contributions to the Body of Knowledge

The significant contributions of this study to the body of knowledge are:

1. **An emerging theoretical framework called Strategic Innovation Management Model (SIMM) was developed**. The model comprises eight steps. It begins with analysing the decision-making problem. The criteria and alternatives must be clearly identified. Weights are allocated to the criteria and alternatives. The criteria can be categorised as Relative Advantage, Technical Compatibility, and Technical Complexity. The information is evaluated leading to a decision. The decision is in the form of a ranked list. A detailed explanation of how the model was created using the mini-Delphi method is given in Chapter Three, Section 3.5.

2. **Established dimensionality reduced features (impacting factors) of social computing that must be considered for u-learning**. The findings from conducting PCA fulfilled the gap that previously existed for the factors most impacting SM applications for u-learning by presenting the dimensionality reduced education requirements and technology criteria. It was recommended that the emphasis be placed on the derived technology criteria and education requirements of social computing for u-learning. The top fifteen education requirements in rank order were Instructor Facilitation, Ownership of Learning, Adaptability, Quality Assurance, Peer Learning, Instructional Design, Higher Order Thinking, Metacognitive Engagement, Academic Integrity, Learning Analytics, u-Learning Training Factors, Archiving/Repository, Social Interactivity, Curriculum Management, and Enhancement of Cognitive Task(s). The top fifteen technology criteria in rank order were Operational Stability, Fault Tolerance of Technology, Multimedia Control, Data Privacy and Ownership, Security of Technology, Facilitation of e-Content, Technical Information, Functionality, Hypermediality, Ease of Use, Browser, Archiving, Saving, Importing and Exporting Data, Operating Systems, Access on the Mobile Platform, and Software Characteristics Quality (Chapter Six, Section A). This will ensure cost efficiency and optimisation of SM applications for u-learning.

3. **Simulated Fuzzy TOPSIS using live data as a novel method to support intelligent decision making on countless social media applications**. It was concluded from the simulation with Fuzzy TOPSIS based on thirty u-learning application criteria and the 260 decision makers that the top fourteen SM applications for u-learning in rank order were: **YouTube, WhatsApp, Instagram, TikTok, Facebook, Facebook Messenger, Pinterest, Snapchat, Twitter, Reddit, WeChat, QQ, QZone and Viber (Chapter Six, Section B)**. It was recommended that school policy should change to accommodate the use of SM applications in u-learning and that the identified five SM applications be employed to implement successful u-learning.

4. **Simulated on MATLAB using live data, an innovative and novel IDSS utilised Data Envelopment Analysis (DEA) to ensure the use of the most efficient digital access in times when ubiquitous learning is gaining momentum**. It was concluded that using the DEA CCR Model with 8 benefit criteria and 2 cost criteria generated from the ten device specifications through Document Analysis that the most efficient devices for u-learning were **Phablet (Phone-Tablet), Subnotebook /Ultraportable, Desktop Replacement Laptop, Netbook, iPhone Smartphone, iPad, Handheld PC, Android Smartphone Mobile Phone, Windows Phone, and Desktop**. The least efficient devices for u-learning in rank order were: Customised Business Tablet, Traditional Laptop, 2-in-1 PC, Slate, Notebook, Mini Tablet, Gaming Tablet, Business Laptop, and Android Tablet (Chapter Six, Section C). It is recommended that decision makers use the aforementioned efficient devices for u-learning.

5. The IDSSs Fuzzy TOPSIS and DEA were simulated on MATLAB R2020a. **Based on the simulations the researcher designed a real-life software application using an ensemble of Fuzzy TOPSIS and DEA as IDSSs for decision makers in schools to utilise when confounded by choices for u-learning**. The design for the software application was based on the ERD and the user interface mock-ups, implemented in HTML and JavaScript (Chapter Seven, Section B). This will ensure cost efficiency and optimisation of u-learning. This system is based on impacting factors from the research to support school policy makers on preferences for u-learning. The scientific methods implemented concurrently within a single application is a significant contribution to the body of knowledge.

8.5 Implications of the Study

The new knowledge obtained from the study will be of benefit to society in various ways. This study is based on impacting factors from the research to support school decision makers in preferences of SM applications and devices for u-learning. The findings of the study could help to change school policy by advocating for the use of social computing in u-learning. Disparities of bandwidth or connectivity in South African remote teaching and learning could be resolved by implementing social computing for u-learning.

The established weightage of criteria in Figures 6.5 and 6.6 (Chapter Six), and the results and analysis of the Survey Questionnaire in Tables 7.6 to 7.34 (Chapter Seven) could inform instructors on how to implement SM applications to achieve learning outcomes in a dynamic way that will optimise pedagogy. The implications of the study are that the time it would have taken to train instructors and learners to use the e-learning applications would be reduced. The new knowledge of the study will reduce the effort and time made by instructors to choose the most favourable SM application and efficient device for u-learning. The assessment of devices by DEA (Chapter Six, Section C) will eliminate the costs that decision makers could have spent on buying inefficient devices for u-learning.

The high weighted education requirements and technology criteria could serve as a guide for SM application developers to augment their application in a way that is aimed to enhance u-learning. New SM applications could be created based on these criteria.

An implication of this study is that it added to the inadequate literature on the employment of DEA and Fuzzy TOPSIS in education. It also supplemented the literature on the DEA and Fuzzy TOPSIS application within a South African high school context. The study afforded easy to follow steps and examples for Fuzzy TOPSIS and a DEA CCR Model that can be used by other researchers. An emerging theoretical framework called SIMM was developed which can be employed by researchers who wish to explore research using the combination of Connectivism, IDT and Decision Theory. The research design presented a successfully executed electronic method for data collection which could be adopted by other researchers who are faced with unprecedented circumstances during their studies.

8.6 Future Research

Based on the limitations of the study, future studies should focus on IDSS and EDM utilising the reduced dimension criteria, thus decreasing overfitting. Dimensionality reduction will also enhance the performance of IDSS algorithms and ML algorithms. It is evident that there is a need for a larger target population which is inclusive of learners and school-based instructors from other districts, regions and provinces. This will deliver an all-inclusive view of the social computing context in SA as a whole. The study involved the responses of high school learners and school-based instructors but it would be interesting to acquire responses of primary school respondents. Future studies should manually acquire the responses from participants such that even respondents with less affordability can contribute to the body of knowledge on social computing for u-learning. Future studies can concentrate on the patenting of the software application using IDSSs presented in the current study and more testing should be conducted to measure its effectiveness and efficiency in real-life situations within a South African school context.

8.7 Chapter Summary

Chapter Eight commenced with the aim of the study and a brief description of how the aim was achieved. A summary of Chapters One to Seven was provided highlighting the essential attributes of each chapter. In the Chapter One summary a narrative of the current education and ICT situation was given along with the problem statement. The aim of the study was stated and the research objectives, significance of study, scope, delimitations and research outputs were mentioned. The Chapter Two summary provided the terminology of essential concepts in the study and outlined the structure of the literature review. It was noted that PRISMA was conducted to derive the sixty education requirements and technology criteria. The summary stated what the top fourteen SM applications were in SA in 2020, the ten essential specifications of devices for u-learning, and the top twenty digital devices for u-learning. Justifications for Fuzzy TOPSIS and DEA as MCDM techniques of the study were cited. In the Chapter Three summary, theory was defined and the three theoretical frameworks, namely, Connectivism, IDT and Decision Theory were synopsised. The emergent theoretical framework SIMM, its validation and usefulness was discussed. The Chapter Four summary outlined the research design by debunking the three phases of scientific methods which included PCA, Fuzzy TOPSIS, DEA and Document Analysis. The data collection process was discussed, making reference to the Feature Questionnaire and Survey Questionnaire. The reliability of the data collection instruments using Cronbach’s alpha, the population size, the sampling and the ethical considerations were briefly discussed. The definition, terminology, literature review, algorithm, example scenario of PCA, Fuzzy TOPSIS and DEA were reviewed in the Chapter Five summary. The Chapter Six summary explained the UML Activity diagram for the current study and gave an overview of the results and discussion of PCA, Fuzzy TOPSIS and DEA. The top fifteen education requirements, the top fifteen technology criteria, the ranked order of the SM applications, and the efficiency scores of devices were revealed. The Chapter Seven summary provided the results and discussion of the Survey Questionnaire in Section A and the design for a software application using IDSSs in Section B. Chapter Eight concluded with the implications of the study, the recap of significant contributions to the body of knowledge, and the study research.

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ANNEXURES

Annexure A: Research Project Plan

	Jan 2020	Apr 2020	May 2020	Jul 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2021	Jan 2021	Feb 2021	Mar 2021	Apr 2021	May 2021	Jun 2021
Preliminary Literature Review	■	■												
Proposal Preparation			■	■										
Literature Review				■	■									
Data Collection						■	■							
Statistical analysis								■	■	■				
Journal Publications						■	■	■	■	■				
Writing Thesis							■	■	■	■	■			
Proof reading by 2 academics												■	■	
Final editing by supervisor													■	
Intent to submit													■	■
Submit thesis for examination														■

Annexure B: Turn It In Report – Cover Page

Thesis 3 May 2021

ORIGINALITY REPORT

13%	11%	9%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	thesai.org Internet Source	3%
2	www.hindawi.com Internet Source	2%
3	Caitlin Sam, Nalindren Naicker, Marion Adebiyi. "Dimensionality Reduction of Social Media Application Attributes for Ubiquitous Learning Using Principal Component Analysis", Mobile Information Systems, 2021 Publication	1%
4	researchspace.ukzn.ac.za Internet Source	<1%
5	Caitlin Sam, Nalindren Naicker, Mogiveny Rajkoomar. "Selection of Social Media Applications for Ubiquitous Learning using Fuzzy TOPSIS", International Journal of Advanced Computer Science and Applications, 2021 Publication	<1%
6	Submitted to University of Johannsburg Student Paper	<1%

Annexure C: Consent for Learners Over 18 and Instructors

Full Title of the Study:
Intelligent Decision Support System for Managing Social Media Diffusion in School-Based Ubiquitous Learning.

Names of Researcher/s:
Caitlin Sam, PhD Candidate in Information Technology.
Dr Nalen Naicker, PhD, MSc, Hons BSc, BSc, HED (4 year).
Dr Mogiveny Rajkoomar, PhD (LIS), FCOT, PHED, BA.

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Caitlin Sam, about the nature, conduct, benefits, and risks of this study. Research Ethics Clearance Number: IREC 113/20
- I have also received, read, and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research, which may relate to my participation will be made available to me.

______________________ ___________ ______ ________________

Full Name of Participant **Date** **Time** **Signature/Right Thumbprint**

I, Caitlin Sam, hereby confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

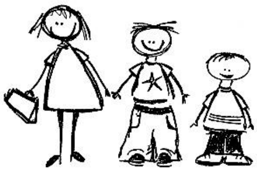
___________________ ___________ _____________________

Full Name of Researcher **Date** **Signature**

___________________ ___________ _____________________

Full Name of Witness (If applicable) **Date** **Signature**

Annexure D: Assent Form For Learners <18 Years Of Age



TITLE OF THE RESEARCH PROJECT: Intelligent Decision Support System for Managing Social Media Diffusion in School-Based Ubiquitous Learning.

RESEARCHERS' NAME(S): Caitlin Sam, PhD Candidate in Information Technology.

RESEARCHER'S CONTACT DETAILS: caitlin.s01@curro.co.za or caitsam87@gmail.com

What is RESEARCH?

Research is something we do find **NEW KNOWLEDGE** about the way things (and people) work. We use research projects or studies to help us find out more about children and teenagers and the things that affect their lives, their schools, their families, and their health. We do this to try and make the world a better place!

What is this research project all about?

The research I wish to conduct for my PhD thesis involves "Intelligent Decision Support System for managing Social Media Diffusion in School-Based Ubiquitous Learning."

Ubiquitous learning (u-learning) involves anytime and anywhere learning. The main aim of the study is to create an Intelligent Decision Support System to help teachers and learners manage social media use in school-based u-learning in the eThekwini District. The study aims to determine the level that social media applications and digital access can be used for school-based u-learning; discover the technology criteria for u-learning; establish standardised education requirements of dynamic social media applications for u-learning; design an evidence-based Intelligent Decision Support System based on the technology criteria and education requirements to support end-users (learners and school-based instructors) using scientific methods.

Why have you been invited to take part in this research project?

Your opinions on social media applications for u-learning are valuable to my study as it will help me to develop an Intelligent Decision Support System for school management to better cater for your needs.

Who is doing the research?

My name is Caitlin Sam and I am a PhD candidate in Information Technology at the Durban University of Technology. I work for a high school as a Mathematics teacher and due to our recent change to multimodal teaching and learning because of school disruptions such as Covid-19, I want to develop a system to help learners and teachers make decisions on the use of social media applications and devices for u-learning.

What will happen to me in this study?

I will approach learners and teachers (participants) from schools in the Pinetown District and Umlazi District to participate in this study. A general letter will be sent to each school principal requesting permission for the study. Once a school agrees to participate in the study, parents will be asked for informed consent and permission to approach learners for the study. Once permission is obtained, an email with a link or mobile phone link to the survey questionnaire will be sent to all participants. Remember that participation is voluntary. Participants' freedom of choice will be respected. No names will be recorded on the questionnaire. The survey will be distributed to participants starting from the 5^{th} of October 2020 until the 6^{th} of November 2020. It is estimated that participants will take 15 minutes to complete the questionnaire. I agree to follow all the ethical principles of the research.

Can anything bad happen to me?

There will be no risk or discomfort to you. If you want to stop answering the survey because a question is making you uncomfortable, you are welcome to do so.

Can anything good happen to me?

The survey will empower you on the latest social media applications that can be used for u-learning. The successful completion of this study will allow you to make intelligent decisions on countless social media applications and devices for u-learning that can shape the course of education.

Will anyone know I am in the study?

Your participation in the study will be kept confidential as names will not be recorded on the questionnaire.

Who can I talk to about the study? Your friends, family, or other teachers. Should you be confused about anything please feel free to contact the following people:

Miss Caitlin Sam on: 083 460 0896 or email: caitlin.s01@curro.co.za or caitsam87@gmail.com;

My supervisor Dr N. Naicker on: 031 373 5640 or email: naickern@dut.ac.za;

My co-supervisor Dr M. Rajkoomar on: 031 373 6776 or email: mogier@dut.ac.za;

The Institutional Research Ethics administrator on: 031 373 2900.

Complaints can be reported to the DVC: Research, Innovation and Engagement Prof. S. Moyo on: 031 373 2577 or moyos@dut.ac.za.

What if I do not want to do this?

You can refuse to take part even if your parents have agreed to your participation in the study. Participation in this study is voluntarily and you may withdraw from this study at any stage. No reasons will be required from you should wish to withdraw.

MARK THE OPTION YOU CHOOSE WITH AN (X) FOR THE QUESTIONS BELOW:

Do you understand this research study and are you willing to take part in it?

YES	NO

Has the researcher answered all your questions?

YES	NO

Do you understand that you can STOP being in the study at any time?

YES	NO

Signature of Child ____________________ Date ____________________

Annexure E: Letter to Gatekeeper – Department Of Education

Department of Accounting and Informatics
71 Ritson Road
Musgrave
Berea
4001

Att: Pinetown District Manger
41 Voortrekker Street
Ashley
Pinetown
3600

Request for Permission to Conduct Research

Dear Mr E.M. Khanye

I trust that you are keeping well and safe.

My name is Caitlin Sam, an IT PhD student at the Durban University of Technology. The research I wish to conduct for my Doctoral thesis involves “Intelligent Decision Support System for managing Social Media Diffusion in School-Based Ubiquitous Learning.”

I am hereby seeking your consent to conduct a questionnaire with high school learners and school-based instructors in the eThekwini Region, namely, Pinetown District and Umlazi District scheduled from 5 October 2020 to 6 November 2020.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the approval letter which I received from the Institutional Research Ethics Committee (IREC).

If you require any further information, please do not hesitate to contact me on 083 460 0896 or caitlin.s01@curro.co.za; my supervisor Dr N. Naicker on: 031 373 5640 or email: naickern@dut.ac.za;or my co-supervisor Dr M. Rajkoomar at 031 373 6776, email mogier@dut.ac.za

Thank you for your time and consideration in this matter.

Yours sincerely,
Cait

Durban University of Technology

Annexure F: Department Of Education Permission To Conduct Study

KWAZULU-NATAL PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE HEAD OF DEPARTMENT

Private Bag X9137, PIETERMARITZBURG, 3200
Anton Lembede Building, 247 Burger Street, Pietermaritzburg, 3201
Tel: 033 3921062 / 033-3921051
Email: Phindile.duma@kzndoe.gov.za
Buyi.ntuli@kzndoe.gov.za

Enquiries: Phindile Duma/Buyi Ntuli **Ref.**:2/4/8/7034

Ms Caitlin Sam
4 Somerset Ridge
Farningham Ridge
PINETOWN
3610

Dear Ms Sam

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"INTELLIGENT DECISION SUPPORT SYSTEM FOR MANAGING SOCIAL MEDIA DIFFUSION IN SCHOOL-BASED UBIQUITOUS LEARNING;** in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 19th October 2020 to 10TH March 2023.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma/Mrs Buyi Ntuli at the contact numbers above.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

Dr. EV Nzama
Head of Department: Education
Date: 19th October 2020

GROWING KWAZULU-NATAL TOGETHER

Annexure G: Institutional Ethical Clearance Letter

DUT DURBAN UNIVERSITY OF TECHNOLOGY

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

22 October 2020

Ms C Sam
4 Somerset Place
Farningham Ridge
Pinetown
3610

Dear Ms Sam

Intelligent Decision Support System for Managing Social Media Diffusion in School-Based Ubiquitous Learning
Ethical Clearance Number IREC 113/20

The Institutional Research Ethics Committee acknowledges receipt of your final data collection tool for review.

We are pleased to inform you that the data collection tool has been approved. Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the IREC acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely,

Professor J K Adam
Chairperson: IREC

Annexure H: Ethics Certificate

TRREE

Zertifikat

Certificat

Certificado

Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

Caitlin Sam

a complété avec succès - has successfully completed

Introduction to Research Ethics

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2020/09/18

CID : ziq4gggpcM

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

FMH Continuing Education Program (5 Credits)
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[REV : 20170310]

Annexure I: Mini-Delphi Questionnaire for the Proposed Conceptual Framework (SIMM)

The study wishes to acquire expert opinion on the following:

1. Is the model reflective of the significant concepts in the study?

YES	NO

2. Does the theoretical model provide opportunities for expressing the problem situation and evaluating the results?

YES	NO

3. Are there any additional constructs that must be added so that the model will align optimally with the study, *"Intelligent Decision Support System for Managing Social Media Diffusion in School-Based Ubiquitous Learning"*? If yes, please elaborate.

____
____
____
____
____
____
____

4. Please comment on the concepts that were added/omitted from Innovation Diffusion Theory and Decision Theory.

____
____
____
____
____
____
____

Annexure J: Feature Questionnaire – PCA

Survey: Features for Social Media Applications in Ubiquitous Learning

Dear Participant. You are invited to participate in a survey to ascertain the educational requirements and technology criteria for ubiquitous learning (u-learning). It will take approximately 15 minutes to complete the questionnaire. Answer each question as honestly as possible. Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will remain confidential. If you have questions at any time about the survey or the procedures, you may contact Caitlin Sam by email at caitlin.s01@curro.co.za. Thank you very much for your time and support.

Section A: Demographic Details

Please choose the option that applies to you in the questions that follow.

1. What is your job description?

☐	School-based instructor
☐	Higher education instructor
☐	Higher education e-learning specialist

2. What is your job experience?

☐	3-5 years
☐	6-10 years
☐	Above 10 years

Section B: Education Requirements

Please rate the following social media application features in light of their importance to promote u-learning in high schools. The rating scale is from 1 to 5 with 1 being the least important and 5 being the most important.

3. LEARNING CONTENT QUALITY: Relevance, timeliness, accuracy, comprehensiveness, and usefulness of learning content.

1	2	3	4	5

4. PRESENTATION OF LEARNING CONTENT: Simplicity, clarity, and readability of text; appropriate format with lists of topics; choice of media aligned with content; possibility to correct choices and entries; display of time required to view media.

5. ENJOYMENT FACTOR: Gratification from the use of social media application for learning.

1	2	3	4	5

6. SOCIAL INTERACTIVITY: Allows learners to share their ideas on various subjects with each other. Learner-led online discussions may be included.

1	2	3	4	5

7. CLEAR INSTRUCTIONS PROVIDED: Social media application offers clear instructions on how to access and use all elements of the online learning environment.

1	2	3	4	5

8. INSTRUCTOR OPINION: The importance of instructor opinion on the value of the social media application.

1	2	3	4	5

9. COMPATIBILITY WITH COURSE DESCRIPTION: The social media application is compatible with course description- with pre-requisites (if any); learning outcomes and what is expected of the learners.

1	2	3	4	5

10. LEARNER BEHAVIOUR: The social media application makes learners aware of regulations, policies and ethics that govern the social media application.

1	2	3	4	5

11. INTEGRITY: The social media application has academic integrity needed to facilitate learning.

1	2	3	4	5

12. SUITABLE TECHNICAL COMPETENCES FOR LEARNING: The social media application is at a suitable level for learners to display sufficient technical competences needed to successfully reach the learning outcomes.

1	2	3	4	5

13. OWNERSHIP OF LEARNING: The social media application gives learners the opportunity to meet their own learning goals.

1	2	3	4	5

14. INSTRUCTIONAL DESIGN: The social media application allows learners to use appropriate learning strategies and methods to meet learning outcomes.

1	2	3	4	5

15. ASSESSMENT OF LEARNING: The social media application provides opportunities for assessment aligned goals and objectives; clear, well-defined, and measurable assessment of learning outcomes; provides opportunities for fair and transparent grading; feedback related to grading; learners can track their learning progress.

1	**2**	**3**	**4**	**5**

16. PEER LEARNING: Fosters peer learning and engagement to meet learning outcomes and to learn skills and competences.

1	**2**	**3**	**4**	**5**

17. INSTRUCTIONAL RESOURCES FOR TEACHING AND LEARNING: Social media application provides a clear explanation of how resources are going to be applied and utilised; no unwarranted technical, financial, or administrative barriers for chosen resources; various multimedia content and multi-modal delivery channels for learners' different learning preferences.

1	**2**	**3**	**4**	**5**

18. LEARNER SUPPORT: Learners are enabled to achieve their maximum potential through instructional support, academic support, technical support, and administrative support.

1	**2**	**3**	**4**	**5**

19. COURSE EVALUATION: The social media application provides feedback to improve teaching and learning.

1	**2**	**3**	**4**	**5**

20. ARCHIVING/REPOSITORY: The social media application allows learning area resources, texts, communication, etc. to be backed-up or archived (in line with the institution's access policies) in a safe and secure way.

1	2	3	4	5

21. COLLABORATION: The social media application allows learners to be able to interact with the instructor, classmates, or experts in the field; it can be synchronous (real-time learning) or asynchronous (learning in different locations and at different times).

1	2	3	4	5

22. USER ACCOUNTABILITY: The social media application provides technical solutions for holding learners accountable for their actions.

1	2	3	4	5

23. DIFFUSION: The social media application is widely known and popular; most learners are familiar with the application and have basic technical competence with it.

1	2	3	4	5

24. INSTRUCTOR FACILITATION: The social media application has easy-to-use features that would significantly improve an instructor's ability to actively manage, monitor, engage and provide feedback to learners.

1	2	3	4	5

25. LEARNING ANALYTICS: The social media application allows instructors to monitor learners' performance on a variety of responsive measures; Measures can be accessed through a user-friendly dashboard/tab bar.

1	**2**	**3**	**4**	**5**

26. ENHANCEMENT OF COGNITIVE TASK(S): The use of the social media application increases engagement in targeted thinking process task(s) that were once very complex or difficult to imagine through other means.

1	**2**	**3**	**4**	**5**

27. HIGHER ORDER THINKING: The social media application promotes understanding facts, inferring from them, connecting them to other facts and concepts, categorising, manipulating, and applying them to seek new solutions to new problems.

1	**2**	**3**	**4**	**5**

28. META-COGNITIVE ENGAGEMENT: Through the social media application, learners can regularly receive formative feedback on learning; track their performance, monitor their improvement, test their knowledge.

1	**2**	**3**	**4**	**5**

29. PERMANENCY: Both course material and material produced by learners is never deleted on purpose.

1	**2**	**3**	**4**	**5**

30. IMMEDIACY: When using the social media application, learners should be able to get information whenever they want; it may be local, stored on their device, or stored on a server and is accessed by the learner over the internet.

1	2	3	4	5

31. ADAPTABILITY: The social media application should be able to adapt to learners' changing lives.

1	2	3	4	5

32. MANAGEMENT OF INTERACTIVE LEARNING OBJECTS: The social media application allows for adaptation of learning paths and user groups' management.

1	2	3	4	5

33. U-LEARNING TRAINING FACTORS: The social media application is a continuous training system for training content and management of trainees.

1	2	3	4	5

34. QUALITY ASSURANCE: Fitness for purpose; suitability of provided knowledge; user interface; language level; graphic approach and interaction level.

1	2	3	4	5

35. LEARNABILITY AND MEMORABILITY: Learnability; productivity level after user has learnt to use the system; memorability level by ensuring user is able to use system after a period of inactivity without having to relearn everything.

1	2	3	4	5

36. USEFULNESS AND SATISFACTION: The degree to which it is believed that using a particular system would enhance their performance and be satisfaction of using the application to complete a task.

1	**2**	**3**	**4**	**5**

37. CURRICULUM MANAGEMENT: The social media application promotes the management of the curriculum.

1	**2**	**3**	**4**	**5**

38. CUSTOMISATION: The social media application is adaptable to its environment: easily customised to suit the classroom context and targeted learning outcomes.

1	**2**	**3**	**4**	**5**

Section C: Technology Criteria

Please rate the following social media application features in light of their importance in promoting u-learning in high schools. The rating scale is from 1 to 5, with 1 being the least important and 5 being the most important.

39. ACCESSIBILITY STANDARDS: Ease of access, access time, access speed, internet access, accessibility of learning materials, user focused participation, required equipment, and cost to use.

1	**2**	**3**	**4**	**5**

40. WEB AND COURSE DESIGN: Design of user interface; display of instructional materials and display of web page; service design.

1	**2**	**3**	**4**	**5**

41. SCALABILITY: The social media application can be scaled to accommodate any class size with the flexibility to create smaller sub-groups or communities of practice.

1	**2**	**3**	**4**	**5**

42. EASE OF USE: The social media application has a user-friendly interface, and it is easy for instructors and students to become skilful in a personalised and easily understandable manner.

1	**2**	**3**	**4**	**5**

43. INTEGRATION/EMBEDDING WITHIN A LEARNING MANAGEMENT SYSTEM (LMS): The social media application can be embedded (as an object via HTML code) or fully integrated into an LMS while maintaining full functionality of the application.

1	**2**	**3**	**4**	**5**

44. OPERATING SYSTEMS: Users can effectively use the social media application with any standard, up-to-date operating system (e.g. Microsoft Windows, Apple MacOS, Linux, Android and Apple's iOS).

1	**2**	**3**	**4**	**5**

45. BROWSER: Users can effectively use the social media application with any standard, up-to-date browser.

1	**2**	**3**	**4**	**5**

46. NO ADDITIONAL DOWNLOADS NEEDED: Users do not need to download additional software or browser extensions to use the social media application.

1	**2**	**3**	**4**	**5**

47. ACCESS ON THE MOBILE PLATFORM: The social media application can be accessed, either through the download of an application via a mobile browser, regardless of the mobile operating system and device; design of the mobile application fully takes into consideration the constraints of a smaller-sized screen.

1	2	3	4	5

48. FUNCTIONALITY: There is little to no functional difference between the mobile and the desktop version, regardless of the device used to access it; no difference in functionality between applications designed for different mobile operating systems.

1	2	3	4	5

49. OFFLINE ACCESS: Offers an offline mode – core features of the social media application can be accessed and utilised even when offline, maintaining functionality and content.

1	2	3	4	5

50. DATA PRIVACY AND OWNERSHIP: Users maintain ownership and copyright of their intellectual property/data; and the user can keep data private and decide if/how data is to be shared.

1	2	3	4	5

51. DOWNLOADING, SAVING AND EXPORTING DATA: Users can archive, save, or import and export content or activity data in a variety of formats.

1	2	3	4	5

52. TECHNICAL INFORMATION: Ease of installation and uninstallation; clarity of update time and time needed during update process; availability of technical support or online help; and information about limitations.

1	2	3	4	5

53. MULTIMEDIA CONTROL: Audio-readings and sound control; clarity of all images and graphics; control of audio or video clips; adjustment with final display process; and optimised size for multimedia contents.

1	2	3	4	5

54. SOFTWARE CHARACTERISTICS QUALITY: Reliability, usability, efficiency, maintainability, and portability.

1	2	3	4	5

55. USER-FRIENDLY INTERFACE: Ease of navigation and control tools; materials are easily accessible; and utilisation of links to external websites.

1	2	3	4	5

56. FUNCTIONALITY: Scale and offline usability – synchronous and asynchronous communication tools.

1	2	3	4	5

57. HYPERMEDIALITY: The social media application allows users to communicate through different channels (audio, visual, textual) and allows for non-sequential, flexible/adaptive engagement with material, and media richness.

1	2	3	4	5

58. FACILITATION OF E-CONTENT: Use of key words, content should be printable, and self-assessment should be allowed.

1	2	3	4	5

59. OPERATIONAL STABILITY: These systems are designed in a manner that processing of day-to-day transactions is performed efficiently and the integrity of the transactional data is preserved.

1	2	3	4	5

60. OFFLINE MOBILE ACCESS: Full or partial functionality when the mobile platform is off-line.

1	2	3	4	5

61. SECURITY OF TECHNOLOGY: Secure and trustable working environment.

1	2	3	4	5

62. FAULT TOLERANCE OF TECHNOLOGY: Error prevention, stability and accuracy, flexibility, and interoperability and continuity.

1	2	3	4	5

Annexure K: Survey Questionnaire – Fuzzy TOPSIS

Hello: You are invited to participate in our survey "Intelligent Decision Support Systems for Managing Social Media Diffusion in School-Based Education for Ubiquitous Learning." Ubiquitous learning (u-learning) refers to anytime and anywhere learning. It includes e-learning, mobile learning, wireless technologies, social networking, and devices which facilitate u-learning. In this survey, you will be asked questions about Social Media Applications. It will take approximately 20 minutes to complete the questionnaire.

SECTION A: Demographic Data

1. What is your gender?
    1. Male
    2. Female
    3. Other __________

2. What is your age group (in years)?
    1. 13–15
    2. 16–19
    3. ≥20

3. What is your current status?
    1. Grade 8 Learner
    2. Grade 9 Learner
    3. Grade 10 Learner
    4. Grade 11 Learner
    5. Grade 12 Learner
    6. Instructor/Teacher

4. Select the device/s you use for e-learning (more than one answer is acceptable/ allowed).
    1. Desktop
    2. Gaming Tablet
    3. Mobile Phone
    4. iPhone Smartphone
    5. Customised Business Tablet
    6. 2-in-1 PC
    7. iPad
    8. Mini Tablet
    9. Handheld PC
    10. Traditional Laptop
    11. Phablet (Phone-Tablet)
    12. Slate
    13. Android Smartphone
    14. Android Tablet
    15. Notebook
    16. Desktop Replacement Laptop
    17. Netbook
    18. Subnotebook
    19. Business Laptop
    20. Windows Phone
    21. Other __________

5. Choose your type of internet connectivity (more than one answer is acceptable).
    1. DSL (Digital Subscriber Line)
    2. Cable Internet
    3. Fibre Internet
    4. Satellite
    5. Wireless Internet
    6. Cellular Network
    7. Mobile Hotspot

6. What is your data option? (More than one answer is acceptable.)
1. Capped Contract
2. Uncapped Contract
3. Prepaid (Hourly/Weekly/Fortnightly)
4. Prepaid Once-off Data bundles (valid for 30 days)
5. Other

SECTION B: Education Requirements

Please rate the following social media applications that best serve as u-learning tools using education requirements.

1. OWNERSHIP OF LEARNING: The user is motivated, engaged and self-directed. The social media application allows the user to monitor their own progress where they are able to reflect on their learning based on mastery of content.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

2. ADAPTABILITY: The social media application provides personalised learning, which aims to give efficient, effective, and customised learning paths to engage each learner.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

3. QUALITY ASSURANCE: The social media application is designed to prove and improve the quality of a school's learning materials, academic programs, services and support, and standards.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❏	❏	❏	❏	❏	❏
WhatsApp	❏	❏	❏	❏	❏	❏
YouTube	❏	❏	❏	❏	❏	❏
Facebook Messenger	❏	❏	❏	❏	❏	❏
Instagram	❏	❏	❏	❏	❏	❏
TikTok	❏	❏	❏	❏	❏	❏
QQ	❏	❏	❏	❏	❏	❏
QZone	❏	❏	❏	❏	❏	❏
Reddit	❏	❏	❏	❏	❏	❏
Pinterest	❏	❏	❏	❏	❏	❏
WeChat	❏	❏	❏	❏	❏	❏
Snapchat	❏	❏	❏	❏	❏	❏
Twitter	❏	❏	❏	❏	❏	❏
Viber	❏	❏	❏	❏	❏	❏

4. PEER LEARNING: The social media application allows learners and teachers to support each other to achieve educational goals.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

5. INSTRUCTIONAL DESIGN: The social media application is designed to meet the learning aims, needs and outcomes structure of the educational programme.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

6. ACADEMIC INTEGRITY: Putting values into practice by being honest in the academic work users do at school. The social media application uses best practices, academic research/writing practices, and anti-plagiarism practices. It allows learners to take responsibility for their learning.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	☐	☐	☐	☐	☐	☐
WhatsApp	☐	☐	☐	☐	☐	☐
YouTube	☐	☐	☐	☐	☐	☐
Facebook Messenger	☐	☐	☐	☐	☐	☐
Instagram	☐	☐	☐	☐	☐	☐
TikTok	☐	☐	☐	☐	☐	☐
QQ	☐	☐	☐	☐	☐	☐
QZone	☐	☐	☐	☐	☐	☐
Reddit	☐	☐	☐	☐	☐	☐
Pinterest	☐	☐	☐	☐	☐	☐
WeChat	☐	☐	☐	☐	☐	☐
Snapchat	☐	☐	☐	☐	☐	☐
Twitter	☐	☐	☐	☐	☐	☐
Viber	☐	☐	☐	☐	☐	☐

7. U-LEARNING TRAINING FACTORS: The social media application increases and develops the knowledge and skills of learners and teachers in u-learning. It improves the attitudes of learners and teachers towards u-learning.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	☐	☐	☐	☐	☐	☐
WhatsApp	☐	☐	☐	☐	☐	☐
YouTube	☐	☐	☐	☐	☐	☐
Facebook Messenger	☐	☐	☐	☐	☐	☐
Instagram	☐	☐	☐	☐	☐	☐
TikTok	☐	☐	☐	☐	☐	☐
QQ	☐	☐	☐	☐	☐	☐
QZone	☐	☐	☐	☐	☐	☐
Reddit	☐	☐	☐	☐	☐	☐
Pinterest	☐	☐	☐	☐	☐	☐
WeChat	☐	☐	☐	☐	☐	☐
Snapchat	☐	☐	☐	☐	☐	☐
Twitter	☐	☐	☐	☐	☐	☐
Viber	☐	☐	☐	☐	☐	☐

8. ARCHIVING/REPOSITORY: The social media application has a storage system used to collect, store and manage learning content.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

9. SOCIAL INTERACTIVTY: The social media application helps teaching and learning by allowing communication in an educational context between learners, their peers, and their teachers.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	☐	☐	☐	☐	☐	☐
WhatsApp	☐	☐	☐	☐	☐	☐
YouTube	☐	☐	☐	☐	☐	☐
Facebook Messenger	☐	☐	☐	☐	☐	☐
Instagram	☐	☐	☐	☐	☐	☐
TikTok	☐	☐	☐	☐	☐	☐
QQ	☐	☐	☐	☐	☐	☐
QZone	☐	☐	☐	☐	☐	☐
Reddit	☐	☐	☐	☐	☐	☐
Pinterest	☐	☐	☐	☐	☐	☐
WeChat	☐	☐	☐	☐	☐	☐
Snapchat	☐	☐	☐	☐	☐	☐
Twitter	☐	☐	☐	☐	☐	☐
Viber	☐	☐	☐	☐	☐	☐

10. CURRICULUM MANAGEMENT: The social media application develops, maintains, and improves teaching and learning by managing each subject's content, structure, organisation, assessment of learning, and instruction.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

11. FACILITATION: The social media application has easy-to-use features that would improve the user's ability to manage, monitor, engage, and provide feedback.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

12. LEARNING ANALYTICS: Teachers can monitor learners' performance on many responsive measures on a user-friendly dashboard/tab bar of the social media application.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

13. ENHANCEMENT OF COGNITIVE TASK(S): The use of the social media application increases engagement in task(s) that were once very difficult to imagine through other ways.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

14. HIGHER ORDER THINKING: Use of the social media application helps learners to practise higher order thinking skills.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instragram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

15. METACOGNITIVE ENGAGEMENT: Learners can regularly track their performance, monitor their improvement and test their knowledge on the social media application.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	☐	☐	☐	☐	☐	☐
WhatsApp	☐	☐	☐	☐	☐	☐
YouTube	☐	☐	☐	☐	☐	☐
Facebook Messenger	☐	☐	☐	☐	☐	☐
Instagram	☐	☐	☐	☐	☐	☐
TikTok	☐	☐	☐	☐	☐	☐
QQ	☐	☐	☐	☐	☐	☐
QZone	☐	☐	☐	☐	☐	☐
WeChat	☐	☐	☐	☐	☐	☐
Snapchat	☐	☐	☐	☐	☐	☐
Reddit	☐	☐	☐	☐	☐	☐
Pinterest	☐	☐	☐	☐	☐	☐
Twitter	☐	☐	☐	☐	☐	☐
Viber	☐	☐	☐	☐	☐	☐

SECTION C: Technology Criteria

Please rate the following social media applications that best serve as u-learning tools using technology criteria.

16. OPERATIONAL STABILITY: The degree that a social media application is ready for use or its degree of performance during use. It refers to the predictability of all the processes in the social media application without special variations in the system.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

17. FAULT TOLERANCE OF TECHNOLOGY: The ability of a social media application to continue operating without interruption when one or more of its components fail.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

18. HYPERMEDIALITY: The social media application allows for users to flexibly/adaptively engage with the learning material. It is the database format comparable to hypertext where sound, images, video or text associated to the display can be directly accessed from the display.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

19. MULTIMEDIA CONTROL: Multimedia (audio, images, videos) can be controlled on the social media application.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

20. SECURITY OF TECHNOLOGY: The defence of the social media application includes detection, prevention, and response to threats through the use of security policies, software tools and IT services.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

21. FACILITATION OF E-CONTENT: The social media application enables learning electronically.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

22. TECHNICAL INFORMATION: Information that relates to research, development, engineering, test, evaluation, production, operation, use, and maintenance of the social media application.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

23. SOFTWARE CHARACTERISITCS QUALITY: This means the ability of the application to: perform, be reliable without system failure, be maintained, give high outputs, be used to a high degree, to adjust and adapt as is required.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❏	❏	❏	❏	❏	❏
WhatsApp	❏	❏	❏	❏	❏	❏
YouTube	❏	❏	❏	❏	❏	❏
Facebook Messenger	❏	❏	❏	❏	❏	❏
Instagram	❏	❏	❏	❏	❏	❏
TikTok	❏	❏	❏	❏	❏	❏
QQ	❏	❏	❏	❏	❏	❏
QZone	❏	❏	❏	❏	❏	❏
WeChat	❏	❏	❏	❏	❏	❏
Snapchat	❏	❏	❏	❏	❏	❏
Reddit	❏	❏	❏	❏	❏	❏
Pinterest	❏	❏	❏	❏	❏	❏
Twitter	❏	❏	❏	❏	❏	❏
Viber	❏	❏	❏	❏	❏	❏

24. EASE OF USE: The social media application has an easy interface for teachers and learners to use.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

25. OPERATING SYSTEM: Teachers and learners can successfully use the social media application with any operating system (e.g. Microsoft Windows, Apple MacOS, Linux, Android and Apple's iOS).

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

26. BROWSER: Teachers and learners can successfully use the social media application with any browser (Internet Explorer, Google Chrome, Mozilla Firefox, Safari, Opera, etc.).

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

27. ACCESS ON MOBILE PLATFORM: The social media application can be accessed with the download of an application or using a mobile browser. It can be accessed on any device or mobile operating system.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

28. DATA PRIVACY AND OWNERSHIP: Learners and teachers maintain ownership and copyright of their intellectual property/information. They can keep information private and decide if/how information is to be shared.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

29. DOWNLOADING, SAVING, IMPORTING AND EXPORTING DATA: Teachers and learners can download, save, or import and export content in many different of formats.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❏	❏	❏	❏	❏	❏
WhatsApp	❏	❏	❏	❏	❏	❏
YouTube	❏	❏	❏	❏	❏	❏
Facebook Messenger	❏	❏	❏	❏	❏	❏
Instagram	❏	❏	❏	❏	❏	❏
TikTok	❏	❏	❏	❏	❏	❏
QQ	❏	❏	❏	❏	❏	❏
QZone	❏	❏	❏	❏	❏	❏
Reddit	❏	❏	❏	❏	❏	❏
Snapchat	❏	❏	❏	❏	❏	❏
WeChat	❏	❏	❏	❏	❏	❏
Pinterest	❏	❏	❏	❏	❏	❏
Twitter	❏	❏	❏	❏	❏	❏
Viber	❏	❏	❏	❏	❏	❏

30. ADDITIONAL DOWNLOADS: Teachers and learners do not need to download more software or browser extensions to use the social media application.

	Very Good	Good	Fair	Poor	Very Poor	Not Sure
Facebook	❑	❑	❑	❑	❑	❑
WhatsApp	❑	❑	❑	❑	❑	❑
YouTube	❑	❑	❑	❑	❑	❑
Facebook Messenger	❑	❑	❑	❑	❑	❑
Instagram	❑	❑	❑	❑	❑	❑
TikTok	❑	❑	❑	❑	❑	❑
QQ	❑	❑	❑	❑	❑	❑
QZone	❑	❑	❑	❑	❑	❑
Reddit	❑	❑	❑	❑	❑	❑
Snapchat	❑	❑	❑	❑	❑	❑
WeChat	❑	❑	❑	❑	❑	❑
Pinterest	❑	❑	❑	❑	❑	❑
Twitter	❑	❑	❑	❑	❑	❑
Viber	❑	❑	❑	❑	❑	❑

Annexure L: Alignment of the Research

<table>
<tr><td colspan="4">TITLE: Intelligent Decision Support Systems for Managing the Diffusion of Social Computing in School-Based Ubiquitous Learning.</td></tr>
<tr><td colspan="4">AIM: The aim of the study is to investigate social media-driven Intelligent Decision Support Systems using live data, in order to assist instructors and learners manage the diffusion of social computing in school-based ubiquitous learning.</td></tr>
<tr><th>Research Objectives</th><th>Theoretical Framework</th><th>Data Collection Methods/Data Sources</th><th>Data Analysis/Results</th></tr>
<tr><td>[RO 1]:
Determine the extent that social computing could be used for school-based ubiquitous learning.</td><td>Connectivism
Decision Theory
IDT
SIMM
Chapter Three</td><td>Literature Review
Chapter Two</td><td></td></tr>
<tr><td>[RO 2]:
Ascertain the most pertinent criteria of social media applications for ubiquitous learning.</td><td>Connectivism
Decision Theory
IDT
SIMM</td><td>Feature Questionnaire with Experts
Chapters Four and Five
Annexure J</td><td>Principal Component Analysis (Generated code on RStudio)
Chapter Six</td></tr>
<tr><td>[RO 3]:
Select the optimal social media applications for ubiquitous learning using multi-criteria decision making with live data.</td><td>Connectivism
Decision Theory
IDT
SIMM</td><td>Main Study Survey Questionnaire
Chapters Four and Five
Annexure K</td><td>Fuzzy TOPSIS (Generated code on MATLAB for simulation)
Chapter Six
Statistical Analysis using SPSS
Chapter Seven</td></tr>
<tr><td>[RO 4]:
Determine the efficiency of devices used for ubiquitous learning using multi-criteria decision analysis with live data.</td><td>Connectivism
Decision Theory
IDT
SIMM</td><td>Literature Review
Document Analysis
Chapter Two</td><td>Data Envelopment Analysis (Generated Code on MATLAB for simulation)
Chapter Six</td></tr>
<tr><td>[RO 5]:
Design an automated application using Intelligent Decision Support Systems based on research evidence.</td><td>Connectivism
SIMM</td><td>Simulation:
PCA, Fuzzy TOPSIS and DEA
Chapters Five and Six</td><td>ERD Design of automated IDSS with mock-ups of user interfaces.
Chapter Seven</td></tr>
<tr><td colspan="4" align="center">Consolidation of Project Work
Summary, Conclusions, Significant Contributions, Implications and Future Research
Chapter Eight</td></tr>
</table>

Annexure M: Certificate of Language Editing

Geraldine Coertze

Independent Communications Consultant

Language Practitioner -

English Language Academic Editor

Certificate of English Language Academic Editing

Author: Caitlin Sam (20507809) **Date:** 07 May 2021

Document type: Doctoral thesis

Discipline: Information and Communication Technology

Academic supervisor: Dr N. Naicker

Higher Education Institution: Durban University of Technology

Dissertation title: Intelligent Decision Support Systems for Managing the Diffusion of Social Computing in School-Based Ubiquitous Learning

This serves to certify that the above thesis was language edited and that assistance was provided with checking the citations and the format of the reference list.

The document was returned to the author with tracked changes, comments and a comprehensive academic editing report to facilitate the correction process. It was the responsibility of the author to accept or reject changes and to attend to all issues raised in the comments and in the report. The final, corrected version of the document was not proofread, although assistance was provided with generating the Table of Contents, List of Figures, List of Tables, and with certain aspects of document layout.

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Communications Consultant and Language Practitioner

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