Cape Peninsula
University of Technology

A user experience evaluation of the Siyavula software for mathematics education for learners with special education needs

by

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Dissertation submitted in partial fulfilment of the requirements for the degree:

Master of Information Communication Technology

in the **Faculty of Informatics and Design**

at the **Cape Peninsula University of Technology**

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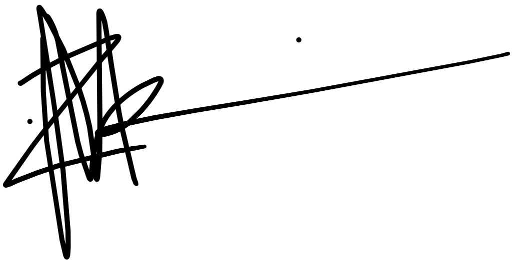
District Six, Cape Town
September 2023

DECLARATION

I, **Zandile Mboneni**, declare that the contents of this dissertation represent my unaided work and that the dissertation has not previously been submitted for academic examination towards any qualification. Furthermore, it means my opinions, not necessarily those of the Cape Peninsula University of Technology.

Signed:  **Date: 22 January 2024**

ABSTRACT

A wealth of information is available on the impact and affordances of mobile technologies in the context of ICT in education. However, the focus is now shifting to reporting on the effects and affordances of specific technologies within specific subjects. Furthermore, despite the available knowledge on mobile technologies, there is limited research focusing on special needs education and how people with disabilities use mobile phones, the services they access, and their experiences when interacting with the device. Learners with special educational needs often need help with mathematics, exhibiting challenges related to abstract information retention, delayed adoption of efficient counting strategies, and difficulties in basic number sense. Learning applications available on mobile devices have shown promising results in improving mathematics learning.

This study uses AT as a lens to explore the affordances associated with the Siyavula software for teaching mathematics to learners with special educational needs. The objectives are to explore educators' experiences when using the Siyavula software to teach mathematics to learners with special educational needs and to analyse how the Siyavula software facilitates mathematics learning for learners with special educational needs. A qualitative research method determined the potential affordances associated with the Siyavula software. Through semi-structured interviews, insights on the educators' experiences with the software while teaching maths were highlighted, and knowledge was gained on how the application facilitates learning.

The study uncovered a range of educator experiences with the Siyavula software in teaching mathematics to learners with special educational needs. These experiences encompassed positive and challenging aspects, highlighting the complexity of educator experiences when using Siyavula with learners with special educational needs. On how Siyavula facilitates learning, the study uncovered the software's potential as a valuable tool for enhancing mathematics education for learners with special educational needs (SEN).

ACKNOWLEDGEMENTS

- My deepest gratitude goes to my children for understanding when I had to spend time on my studies and not with them and for their support and encouragement.
- To my grandmother, Esther Mboneni, for consistently reminding me to be myself in whatever I do. I am grateful to have you in my life.
- I would like to acknowledge my indebtedness and render my warmest thanks to my supervisor, Professor Johannes Cronje, who made this work possible. His guidance, robust discussions and expert advice have been invaluable. I am honoured to have worked with him and grateful for all his positive words of encouragement.
- My dearest friends, you know who you are; your support and reassurance cannot go unnoticeable.
- And finally, to my employer and colleagues for allowing me time off work and for their complete and utter support.

DEDICATION

This dissertation is dedicated to my extraordinary daughter and an unwavering source of inspiration, Enya. You have shown me the true meaning of resilience, determination, and the power of the human spirit.

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LIST OF ACRONYMS

AR	Augmented Reality
AT	Activity Theory
HCI	Human-Computer Interaction
IS	Information Systems
LMS	Learning Management System
OERs	Open Educational Resources
SEN	Special Educational Needs
STEM	Science, Technology, Engineering, Mathematics
TAM	Technology Acceptance Model
UTAUT	Unified Theory of Acceptance and Use of Technology
UX	User Experience
VR	Virtual Reality

CHAPTER ONE

RESEARCH INTRODUCTION

1.1. Introduction

Siyavula is an educational organisation in South Africa that focuses on improving access to quality education through open educational resources (OERs) and digital learning materials. The word Siyavula means is "we are opening" which originates from the Nguni languages like Xhosa and Zulu. Siyavula as an organisation believes in the concept of openness where teachers and learners have access to educational resources (Siyavula, 2015). Siyavula has effectively integrated with mobile technologies to extend its reach and impact in the field of education. Siyavula has optimised its educational resources and digital content to be accessible on mobile devices. Their website and digital materials are designed to be responsive, ensuring that learners and educators can access them seamlessly on various mobile devices. This mobile friendliness aligns with the growing trend of mobile device usage for educational purposes.

Siyavula recognises that internet connectivity can be limited in certain regions. To address this challenge, they have implemented features in their mobile apps that allow users to download educational materials for offline access. Mobile technologies enable Siyavula to offer interactive and engaging learning experiences. Mobile technologies also enable Siyavula to personalise learning experiences. Mobile apps can track user progress and adapt content based on individual performance, providing tailored recommendations and support to learners.

Mobile devices are often more accessible to learners, even in remote or underserved areas than traditional computers. Siyavula's integration with mobile technologies helps bridge the digital divide by reaching learners who may not have access to desktop computers.

Scholars have investigated the use of mobile technologies, like Siyavula, in different educational environments, leading to a vast body of knowledge within the context of technology in education (Crompton & Traxler, 2019; Sharples et al., 2007; El-Hussein & Cronje, 2010). The call by Svela et al. (2019) to focus on the impact and affordances of mobile technologies within specific subjects raises interest in studying platforms like Siyavula. However, scholars (e.g., Crompton & Burke, 2017; Bano et al., 2018) examining mobile technologies in mathematics education highlight a limitation in research focusing on special needs education. Additionally, research on how people with disabilities use mobile technologies, their access services, and their experiences when interacting with such technologies is scarce (Barbareschi et al., 2019; Jahan et al., 2020; Cheng & Lai, 2020). Furthermore, research on mobile technology as an assistive tool calls for exploring various hardware and software supporting learners with special needs (Chelkowski et al., 2019). Hence, this study explores the potential affordances associated with the Siyavula software in teaching mathematics to learners with special educational needs.

1.2. Background

Educators in developing countries such as South Africa are constantly encouraged to incorporate technology into their classrooms as it offers a wide range of benefits, especially with mathematics being a national priority (Buzuzi & Chigona, 2021; Stols et al., 2015; Saal et al., 2019). A key reason for this is that many countries have a strong desire to improve teaching and learning in mathematics and science education to support innovation and build the capabilities of tomorrow's workforce, resulting in educational programmes that integrate science, technology, engineering, and maths, known as STEM curricula (Bano et al., 2018; Franklin et al., 2018; Soares et al., 2018). The National Science Foundation (NSF, 2020:7) report states that South Africa must continue to design and build a thriving innovation economy supported by a workforce invested in the STEM enterprise to remain competitive. To partake in a world whose economy is driven by innovation, learners who experience challenges with mathematics, especially those with special educational needs, need extra support to succeed in this subject.

The Collins dictionary (Collins, 2023) defines special educational needs (SEN) as “the educational requirements of pupils or learners with any of a wide range of physical disabilities, medical conditions, intellectual difficulties, or emotional or behavioural problems”. According to Kuutti et al. (2022),SEN requires additional support beyond the standard level to achieve specified educational objectives.

Mathematics is one of the areas learners with special educational needs struggle with. Learners with underlying learning disabilities in mathematics often display characteristics such as the inability to keep abstract information, delayed adoption of efficient counting strategies, and problems with many aspects of basic number sense (Gersten et al., 2008). Soares et al. (2018:48) point out that mathematics is used in the science of numbers and everyday life with number-related concepts such as calculating time and distance, managing money, and analysing data to make financial plans and decisions. However, challenges in applying such mathematical concepts impact learners' ability to perform well at school and in their personal lives (Nelson et al., 2022; Franklin et al., 2018).

Various assistive technologies, such as technical aids and technology, have been used to support the academic success of learners with special educational needs by increasing learning opportunities, enhancing communication, and promoting the seamless inclusion of these learners within educational environments (Westling et al., 2020; Hersh, 2020). The increasing number of mobile technologies and their potential use within education can offer learners with special educational needs the support needed to improve their performance both in and outside the classroom (Franklin et al., 2018; Rohizan et al., 2020).

Mobile devices provide one of the most convenient and quick ways to access educational content through the Internet or application stores where users can download unique applications (Drigas & Angelidakis, 2017). The first quarter of 2020 showed a global surge in the download of educational applications from the App Store and Google Play, with statistics showing 470 million downloads from the Apple App Store and 466 million downloads from Google Play (Ceci, 2020). Looking at the popularity of mobile technology and the rapid increase of educational applications seen today, learning applications have become one of the more influential aspects of technology in education (Uther, 2019; Balliammanda, 2021).

Some studies have shown that using mobile applications can effectively assist children in mainstream schools with acquiring maths skills (Fabian et al., 2018; Panteli & Panaoura, 2020; Prescott & Maher, 2018). Free math applications are often identified as able to assist learners with special educational needs (Singh, 2019). Maths applications have shown an ability to promote elevated levels of engagement with learning tasks and inclusive learning environments (Pitchford et al., 2018; Benavides-Varela et al., 2020). However, while mobile technologies show positive effects in education, studies are still focused on the usability aspect of mobile technologies within education (Nur et al., 2021). Additionally, most research on user experience evaluation is conducted in the USA and Europe, followed by Asia (Nur et al., 2021; Maia & Furtado, 2016).

Furthermore, research that has been conducted in developing countries shows challenges when implementing the use of mobile technologies in schools. These challenges include irregularity in power supply, lack of funds to purchase technological devices, a shortage of educators skilled with technology, lack of technical support, and a negative attitude towards their use in class (Hussain et al., 2020).

This means designers of mobile learning applications in developing countries must take note of these challenges. Schools must also consider these challenges when using mobile learning apps. By addressing these challenges through thoughtful design, designers can create more effective and accessible educational tools that cater to the specific needs of their target audience. Schools, on the other hand, can successfully integrate mobile learning applications, leading to improved access, enhanced engagement among learners, and empowerment of educators to harness the full potential of mobile technologies in the classroom. This would contribute to more equitable and effective educational experiences. Hence, more studies on evaluating user experiences with mobile learning applications are needed in developing countries as the academic environment differs from those in developed countries such as the USA and Europe.

1.3. Research problem

South Africa's poor performance in mathematics prevents many learners from entering scarce-skills-focused educational fields due to higher education programmes that require a 60% Math score (RSA, 2022). Like many other countries, South Africa must continue to design and build a thriving, innovative economy supported by a STEM-focused workforce (NSF, 2020). The South African government has invested in integrating technology into schools to improve mathematics learning. Still, studies show that many educators do not take advantage of the benefits offered by technology due to factors such as lack of technical support and limited access to technology (Buzuzi & Chigona, 2021; Mdingi & Chigona, 2021). Furthermore, many schools ban using mobile devices in class (Ng'ambi, 2020).

Learners in special needs schools are also competing to join a STEM-driven workforce. Learners with special needs and disabilities often experience various learning challenges, including challenges in mathematics. To assist these learners, additional support, such as assistive technology, is recommended (Franklin et al., 2018; Soares et al., 2018; Nelson et al., 2022). Mobile technologies have shown promise in enhancing math instruction in traditional schools (Crompton & Burke, 2017; Svela et al., 2019). Educators who incorporate these mobile applications into the mathematics classroom can leverage technological enhancements to support learners with special educational needs better. This, in turn, prepares these learners for success in a competitive job market that demands scarce skills.

Integrating educational technology, specifically the Siyavula software, in teaching mathematics to learners with special educational needs (SEN) represents an interesting area of research. While there is a growing interest in using digital learning tools to enhance the experiences of these learners, an understanding of the affordances associated with the Siyavula software in this context has not been explored. Therefore, there is a need to investigate the experiences of educators and the learning benefits perceived when using the Siyavula software for mathematics education.

1.4. Questions guiding the study

Drawn from the statement of the research problem, the research questions are as follows:

i. What are the educators' experiences using the Siyavula software to teach mathematics to learners with special educational needs?
ii. How does the Siyavula software facilitate mathematics learning for learners with special educational needs?

1.5. The study's aim and Objectives

The study aims to explore affordances associated with the Siyavula software used for teaching mathematics to learners with special educational needs. The following research objectives and questions facilitated the achievement of this aim:

i. To explore educators' experiences using the Siyavula software to teach mathematics to learners with special educational needs.
ii. To analyse how the Siyavula software facilitates mathematics learning for learners with special educational needs.

1.6. Literature review

This section provides an overview of the literature conducted for this study. Chapter two contains a more in-depth assessment of the literature review. The focus areas include mobile technology, special needs education, and user experience evaluation. A review of existing literature was also conducted on Activity Theory (AT), which underpin the study.

1.6.1. Mobile Technology

Mobile technology refers to the various technologies and services designed to be used on portable devices, like smartphones and tablets, as well as other wireless devices (El-Hussein & Cronje, 2010). These technologies enable communication, information access, entertainment, and productivity on the go (Pinchot et al., 2011). The evolution of mobile technology has reshaped how we do things.

The extensive adoption of mobile devices, especially among children and teenagers, reflects the significant role of technology in their lives (O'Dea, 2021; ChildWise, 2020; Rideout & Robb, 2019). Mobile technology offers varied functions beyond voice communication, such as text messaging, internet browsing, and online interaction (ITChronicles, 2022). This digital immersion prompts educational settings to incorporate familiar digital tools due to learners growing up amidst rapid technological advancements (Mutiaraningrum & Nugroho, 2021). Today, mobile technology facilitates learning in several ways. It aids academic achievements, enables communication between learners and educators, and supports independent learning (Shahrol et al., 2020; Gashoot et al., 2023). However, security, privacy, and connectivity issues have been experienced (Criollo-C et al., 2021; Saikat et al., 2021). Educational institutions often lack the infrastructure to support mobile learning, and the perceived disruptiveness of mobile devices during lessons leads to restrictions (Criollo-C et al., 2021; Ng'ambi, 2020). Despite these challenges, integrating mobile learning is practical and effective in enhancing learner academic achievement, knowledge sharing, and learning engagement (Alshehri & Cumming, 2020; Purwanti et al., 2019; Criollo-C et al., 2021).

Although numerous research studies have explored integrating mobile technology in education, the primary emphasis has been on its efficacy (Crompton & Burke, 2017). Furthermore, research shows a need for more investigations on its use in special needs education, flexible usage, its impact on specific subjects, and its use in developing countries (Crompton & Burke, 2017; Crompton et al., 2017; Svela et al., 2019).

In developing countries such as South Africa, research has gained momentum due to mobile device popularity, but the country's adoption of mobile devices as an educational tool remains low (Chaka, 2021; Kaisara & Bwalya, 2022). This study aligns with the call for focused investigations on the use of mobile devices within special needs settings and its impact on specific subjects like mathematics.

1.6.2. Special Needs Education

Special needs education provides adaptable pedagogical methods and additional support for learners with disabilities (Buli-Holmberg & Jeyaprathaban, 2016). Around 1.3 billion individuals, particularly children under fourteen, are affected by disabilities (WHO, 2022). These children often face challenges in educational attainment (Wodon et al., 2018). Assistive technology plays a vital role in offering additional support for these learners.

Assistive technology uses low-tech to high-tech tools to aid these learners (TechOWL, 2021). Assistive technology enhances learning for learners with disabilities, offering independence and social inclusion (Senjam et al., 2019; Dogan & Delialioglu, 2020). However, in underdeveloped countries, assistive technology's reach is limited by availability and affordability, making mobile technology an alternative learning tool (Ismaili et al., 2017; Qahmash, 2018).

Research into special needs education and mobile technology integration has gained attention, highlighting insights on how mobile technology assists learners with special needs and disabilities. Mobile technology shows a positive effect in enhancing educational outcomes for individuals with special needs and disabilities (Cumming & Draper-Rodríguez, 2017). Mobile devices, primarily iPads, support daily living, academics, and communication (Chelkowski et al., 2019). Additionally, mobile devices assist in instructional tasks, offering independence and monitoring learner progress (Chelkowski et al., 2019; Cheng & Lai, 2020). Research also explores computer-assisted tools with a focus on cognitive and skill-based learning outcomes (Cheng & Lai, 2020)

Furthermore, research highlights that mathematics is the focal point of mobile technology and special needs (Cheng & Lai, 2020). However, exploring various hardware and software use within special needs contexts has been encouraged (Chelkowski et al., 2019). Hence, a spike in research investigating specific software learners with special needs use in learning mathematics.

Various applications have been developed to support learners with special needs and disabilities in learning mathematics. Studies on mobile learning applications and mathematics illustrate a significant improvement in learning outcomes (Zhang et al., 2015; Pitchford et al., 2018; Benavides-Varela et al., 2020). However, these applications are frequently evaluated from a learner's perspective, usability, and engagement (Kay & Kwak, 2017; Pitchford et al., 2018), showing less focus on the users' feelings about the application, which are essential in the success of that system (Zarour, 2020; Mahmoud et al., 2021).

1.6.3. User Experience Evaluation

User experience (UX) evaluation is crucial in determining the success of a product, focusing on how well it meets user needs. The ISO FDIS 9241-210 standard defines UX as a person's perceptions and responses to a product, system, or service. This differentiates user experience from usability (IOS, 2018).

Usability focuses on practical elements, while user experience encompasses emotional and cognitive experiences (Norman & Nielsen, 2022). To evaluate user experience, Norman proposes three interaction levels: visceral (first impressions), behavioural (meeting needs), and reflective (past and current experiences) (Komninos, 2020). Morville's honeycomb model also highlights the significance of emotional and usability aspects in UX (Karagianni, 2018).

Research into user experience shows various trends and insights. UX research has evolved across domains (Zarour & Alharbi, 2017). Studies range from specific contexts like education to diverse applications, including websites, web interfaces, and more (Lanius et al., 2021). Research dimensions encompass UX and values, brand, user needs, development process, and technologies (Zarour & Alharbi, 2017). Questionnaires are commonly used for data collection, often in controlled environments (Maia & Furtado, 2016; Nur et al., 2021). However, self-reported measurements in non-controlled environments are needed (Nur et al., 2021).

Elements like desirability, usability, design, and value are often evaluated (Maia & Furtado, 2016). UX research has primarily been conducted in the USA, Europe, and Asia (Zuo et al., 2023; Maia & Furtado, 2016), indicating gaps in other regions. Usability, virtual reality, and HCI are the key focus areas in current research (Zuo et al., 2023). Furthermore, mobile applications have gained popularity as a critical area for research (Zuo et al., 2023).

In education, mobile applications have become popular due to widespread device adoption and high-speed internet (Ibrahim et al., 2015; Alsanousi et al., 2023). These learning apps serve various purposes. They offer opportunities for collaborative teaching, help with practice opportunities, homework assistance, lesson planning, and improved communication between educators and their learners (Hussain et al., 2020).

The use of mobile applications in education has highlighted the crucial role of user experience in promoting effective learning outcomes (Ibrahim et al., 2015; Shah et al., 2023). Thus, it is critical to understand user perspectives on the role of mobile applications on learning outcomes.

1.6.4. Theoretical framework underpinning the study

In pursuit of the study's objective, which is to explore affordances associated with the Siyavula software used for teaching mathematics to learners with special educational needs, Activity Theory was selected as the underlying theoretical framework for the research. Although other theories, such as affordance theory (Pucillo & Cascini, 2014) and sense-making theory (Andrade, 2016; Strom, 2006), have been increasingly applied in user experience evaluation, Activity Theory was deemed most suitable for this study.

Obrist et al. (2012) acknowledge that different researchers have used various theories in a broad range of studies related to user experience. Activity Theory was selected because it helps understand how users interact with artefacts in multiple environments (Engeström et al., 1999; Nardi & Kaptelin, 2006).

Initially developed for psychological studies by Engeström et al. (1999), Activity Theory is a valuable lens researchers can use to view the complexities of technology interactions and learning experiences. Activity Theory (figure 1.1) has six components: subject/subjects, object, tools, rules, community, and division of labour.

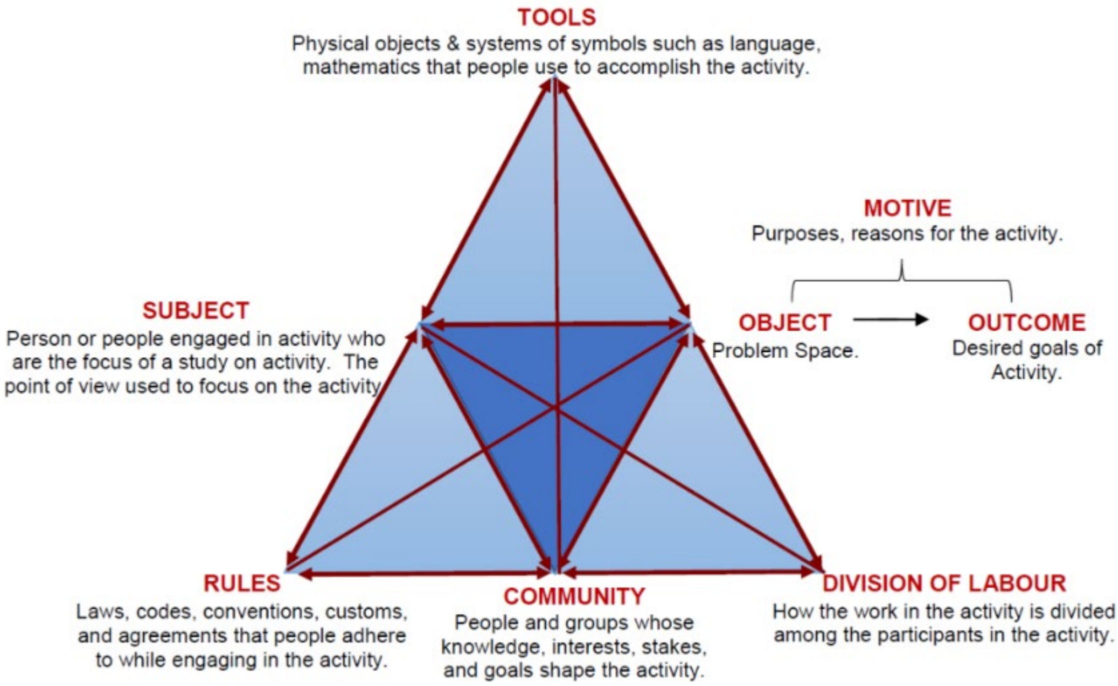

Figure 1.1: Activity Theory model (Engeström, 2015)

Any material, medium, content, artefact, instrument, or device used to mediate the relationship between the subject/subjects and the objective within an activity system are tools (Engeström et al., 1999; Chung et al., 2019). Subject/subjects refer to a person or people participating in an activity and are usually the focus of the study (Vahed et al., 2018; Chung et al., 2019). According to Kaptelinin (2005:5), the object of activity can be regarded as the purpose for various behaviours of people, groups, or organisations and characterised as "the sense-maker," which gives meaning to and sets the values of diverse entities and happenings. Rules, community, and division of labour are the terms that makeup what Engeström refers to as the social basis of the activity system, which situates the activity in a broader context that allows us to account for the influences that shape the activity (Kain & Wardle, 2014). The constraints that regulate the system's components and operations are called rules (Lee et al., 2021). The Community is the larger group to which the subject belongs, and it negotiates and mediates the rules that govern how the community operates (Kain & Wardle, 2014; Lee et al., 2021). The roles and relationships within a community that influence task division are called the division of labour (Chung et al., 2019; Lee et al., 2021; Kain & Wardle, 2014). To understand interactions and experiences, Activity Theory focuses on the interrelated nature and mutual relationships among the different components.

1.7. Research design and methodology

In alignment with the aim and objectives of the study, this study follows an exploratory research approach. This section begins by discussing the philosophical assumptions that underpin the study and subsequently elaborates on the selected research approach, methods, design, data collection methods, and data analysis strategies employed in this investigation. Additionally, it emphasises the ethical considerations that guided the research process.

1.7.1. Research philosophy

The interpretive paradigm serves as the philosophical foundation for this study. The significance of interpretation is in understanding the social world (Ormston et al., 2014), aligning with the study's focus on educators' experiences and the learning process. Interpretivists highlight the interplay between subjectivism and contextual meaning (Creswell & Plano-Clark, 2018).

As epistemology and ontology are the most common assumptions (Oates et al., 2022), this research integrates viewpoints from both, recognising Siyavula as a software existing within the domain of human-technology interaction. Additionally, it acknowledges the unexplored encounters of educators who employ Siyavula for teaching mathematics to learners with special educational needs.

1.7.2. Research Approach

The approaches commonly used in research are abductive, inductive, and deductive (O'Reilly, 2012). A deductive approach is centred on formulating a hypothesis derived from an established theory and designing a research strategy to evaluate the hypothesis (Wilson, 2014). Saunders et al. (2019) point out that the inductive approach aims to derive meaning from the collected data, discerning patterns and relationships to formulate a theory. In contrast, the abductive approach combines both the inductive and deductive approaches.

The inductive approach is a bottom-up approach to knowing mostly linked to qualitative studies (Lodico et al., 2010; Neuman, 2014). This study explores the affordances associated with the mobile learning software Siyavula used for teaching mathematics to learners with special educational needs. Based on this aim, the researcher will follow an inductive approach.

1.7.3. Research methods

There are three types of research methods: qualitative, quantitative, and mixed (Creswell, 2009). According to Leavy (2017:9), qualitative research is used to study and understand social events, figure out what people think about activities, situations, occurrences, or objects, and gain a deep understanding of different parts of social life. Quantitative research examines variables to evaluate objective theories, and these variables can be measured statistically. In contrast, mixed methods research is an investigative approach that involves collecting quantitative and qualitative data (Creswell, 2009).

To fulfil the objectives of the proposed study, which are (1) to explore educators' experiences when using the Siyavula software for teaching mathematics to learners with special educational needs; (2) to analyse ways in which Siyavula facilitates mathematics learning for learners with special educational needs, qualitative research methods were applied. This is primarily because the qualitative research method provides an extensive description of participants' feelings, opinions, and experiences and interprets the meanings of their actions (Rahman, 2017; Mohajan, 2018).

1.7.4. Research design

Research design is a procedure or a researcher's plan for collecting, analysing, interpreting, and reporting data (Creswell, 2009). Phenomenological, ethnographic, grounded theory, historical, case study, and action research represent the six prevalent qualitative research designs (Nieuwenhuis, 2020).

A case study approach was used in this study. The approach provides great insight and understanding of the dynamics of a specific situation, as well as a multi-perspective analysis for considering the voices, views, and interactions of the various groups under investigation (Yin, 2018; Schwandt & Gates, 2018). According to Yin (2018), a case can be a person, an event, or an entity. The point of this study is a special needs school in the Western Cape.

1.7.5. Study sample

A sample is a smaller selection from a larger population of individuals, objects, or items selected for measurement (Taherdoost, 2016; Sharma, 2017). To enable the generalisation of research findings to the entire population, the sample must accurately reflect that population's characteristics. Qualitative research employs non-probability sampling techniques (Higginbottom, 2004), often associated with case study research design (Taherdoost, 2016). According to Sharma (2017), various non-probability sampling methods include quota, snowball, convenience, and purposive.

This study used purposive (judgmental) sampling for participant selection. Neuman (2014) defines purposive sampling as sampling in which the researcher uses a wide range of methods to locate all possible cases of a particular difficult-to-reach population." The sampling technique is selected because it is affordable, convenient, time-efficient, and ideal for exploratory research (Taherdoost, 2016).

The key informants for the study were mathematics Educators from the selected special needs school in the Western Cape province.

1.7.6. Data collection techniques

Data collection uses techniques, instruments, and sources such as interviews, observations, surveys, oral history, or document analysis (Maree, 2016). Qualitative research's most frequently employed data collection techniques are participant observation, in-depth face-to-face interviews, and focus group discussions (Moser & Korstjens, 2018). The most used method in user experience evaluation is interviews (Pettersson et al., 2018). In qualitative research, various types of interviews are recognised, including open-ended (unstructured), semi-structured, and structured (Nieuwenhuis, 2020).

In this research, data was gathered using semi-structured interviews. This approach was chosen due to its widespread use in qualitative data collection and its effectiveness in eliciting "personal experience" narratives, as Braun et al. (2016) noted. The interviews were recorded with the interviewees' permission, and then they were transcribed.

1.7.7. Data analysis

Data analysis is a structured process employing various methods to define, evaluate, and interpret data to unveil its significance (Iyamu, 2022). Qualitative data analysis involves categorising and analysing textual (or visual) content to conclude both explicit and implicit meaning and its representation (Flick, 2014). Multiple approaches are available for analysing qualitative data, including qualitative content analysis, narrative analysis, discourse analysis, thematic analysis, grounded theory, and conversational analysis (Flick, 2014; Ngulube, 2015).

Data from the interviews was subjected to thematic analysis for examination and interpretation. According to Guest et al. (2012), thematic analysis is the most common method for analysing semi-structured interviews by identifying themes in the interview data. There are two different approaches used when conducting thematic analysis. An inductive approach begins with specific data and progresses to a broad or abstract conceptualisation of the phenomenon, and a deductive approach begins with general, abstract concepts and progresses to specific, observable, and measurable data (Terry et al., 2017; Kiger & Varpio, 2020). This study used an inductive approach to identify themes from collected data.

The unit of analysis for this study centred on the activity system. Within Activity Theory, the activity system comprises a complex network of activities, tools, and social relationships to accomplish specific goals. In this study, the activity system includes educators, the Siyavula software, and learners, all within the context of teaching mathematics to learners with special educational needs.

1.8. Delineation of the research

Several applications can be used for teaching mathematics to learners with special educational needs. This study only focuses on evaluating educator experiences with the Siyavula software.

1.9. Significance of the research

This study is significant in three ways:

i. Theoretical perspective: while numerous studies have focused on evaluating user experiences with mathematical software, a significant gap exists in understanding how mathematical software facilitates learning within special needs environments. Consequently, this study aims to contribute to the academic discourse by expanding the existing literature in this field.
ii. Methodological perspective: Activity Theory provides systems-level insights into the interactions of various factors that underpin educators' teaching experiences with mobile technologies.
iii. Practical perspective: the study provides valuable insights for application designers and developers on understanding educators' specific challenges, preferences, and needs while using the software. These insights allow designers to make informed enhancements that foster a more seamless and practical user experience. The results of this study can also benefit educators by shedding light on the strengths and limitations of Siyavula as a teaching tool.

1.10. Ethical considerations

When conducting a scholarly study, it is critical to consider ethics. Ethics refers to the methods, procedures, or perspectives that guide researchers' behaviour when analysing complex problems and issues. Ethical principles should guide resolving ongoing research challenges that may emerge during qualitative research, ensuring that these issues align with the research objectives while safeguarding the rights of all participants involved in the study (Leedy & Ormrod, 2015).

The researcher ensured that the participants were not mistreated and did not suffer harmful consequences from research activities. The participants were informed about the nature of the study, and formal consent was obtained. The participants were informed that participation is voluntary, and they could withdraw at any time without any negative consequences. Confidentiality and anonymity were guaranteed to adhere to research principles and protect participants' rights and values. According to Vanclay et al. (2013), the researcher must uphold a stringent code of ethics when conducting human subjects research. This code should encompass fundamental principles such as fairness, honesty, transparency of intentions, disclosure of research methods, the objectives behind the study, and the utmost respect for the integrity of the individuals involved, all of which should be guided by established ethical guidelines. This study was carried out per the CPUT research code of ethics.

1.11. Structure of the thesis

Chapter One serves as the introductory section of the study, where the research problem, questions, and objectives are introduced. Additionally, this chapter provides a concise overview of the literature reviewed, the research methodology, and the underlying theories that guide the study.

Chapter two delves deeper into the literature review and offers an in-depth exploration of the underpinning theories.

Chapter three encompasses the research methodology, including discussions on research philosophies, paradigms, approaches, methods, and data collection and analysis techniques.

Chapter four is centred on the analysis of data.

Chapter five is dedicated to presenting the interpretation of the findings from the data analysis.

1.12. Summary

User experience evaluation is a strategic investment that directly impacts business success by creating products and services that meet user needs, foster positive emotions, and drive user engagement. Neglecting user experience evaluation can negatively impact user satisfaction and the overall effectiveness of products and services.

In this chapter, the researcher outlines the scope of the study undertaken. The research problem is clearly defined, formulating research questions and establishing the study's aim and objectives. The primary goal of this research is to investigate the potential benefits of using the Siyavula software in teaching mathematics to learners with special educational needs.

Moreover, the chapter provides a summary of the research design and methodology. Given the exploratory nature of this study, it aligns with an interpretive paradigm. Qualitative research methods were chosen, specifically employing an inductive approach. The data collection method used was semi-structured interviews, and data analysis was conducted through the lens of Activity Theory.

Additionally, the chapter emphasises the significance of this research in contributing to the body of knowledge. Ethical considerations are outlined following the ethical standards set forth by the university’s research code of ethics. Finally, the chapter offers a structural overview of the dissertation, previewing the forthcoming chapters within the study.

CHAPTER TWO
LITERATURE REVIEW

2.1. Introduction

This chapter presents a comprehensive literature review focusing on critical areas relevant to the present study, including mobile technology, special needs education, mobile learning applications, and user experience. Activity Theory underpins the study, also discussed in this chapter.

The chapter is divided into four main sections. The first section explores mobile technology and its utilisation in education, especially in mathematics education. The second section examines special needs education and explores mobile mathematics applications used as assistive tools for learners with special needs. The third section investigates user experience evaluation and contextualises these concepts within the study's framework. Finally, the fourth section presents the underlying theory, Activity Theory, and its application in user experience research. The chapter concludes with a summary of the key points.

2.2. Mobile Technology

Mobile technology has revolutionised communication and internet access (Pinchot et al., 2011). Previously, internet access was confined to stationary computers in educational institutions, internet cafes, or a few households with computer connections.

Mobile technology refers to handheld information technology artefacts encompassing hardware (devices), software (interface, applications), and communication (network services) (El-Hussein & Cronje, 2010). It has evolved from handheld radio transceivers used in the military to mobile phones that enable voice telephony and text messaging and further progressed to smartphones and tablet computers that offer a wide range of services previously limited to stationary personal computers (Middleton et al., 2014; West, 2014; Harpur & De Villiers, 2015). West (2014) asserts that mobile technology reshapes society, communication, and the global economy. Mobile communication extends beyond voice, encompassing text messaging, internet browsing, photography, and online interaction (ITChronicles, 2022).

The global population of mobile device users exceeds seven billion, and many children now own smartphones (O'Dea, 2021; ChildWise, 2020). Teenagers extensively utilise smartphones for various purposes, including learning (ChildWise, 2020; Rideout & Robb, 2019). This attachment of young individuals to digital devices reflects the substantial role of technology in their lives. Consequently, educational settings in the mobile age should integrate familiar digital tools, considering that digital learners grow up surrounded by rapid technological advancements (Mutiaraningrum & Nugroho, 2021).The widespread availability and use of mobile devices and applications in education have sparked interest in understanding their adoption (Kumar & Chand, 2019), usage patterns (Kumar & Mohite, 2018; Rohizan et al., 2020), and user experiences (Kumar & Mohite, 2018). Consequently, this study aims to explore the experiences with mobile applications for teaching mathematics to learners with special educational needs. To gain a comprehensive understanding, the following section examines mobile technology as a learning tool, specifically its use in promoting mathematics learning.

2.2.1. Mobile technology and learning

Utilising mobile technology for learning is not new; it was initially conceptualised in the 1970s by computer scientist Alan Kay, who represented the concept of a portable computing device (Crompton, 2013). However, technological limitations at the time hindered the realisation of his idea (Maxwell, 2006; Crompton, 2013; Crompton & Traxler, 2019). Although Alan Kay's vision was never realised, rapid technological advancements now support his concept of a portable, mobile, and educational device (Crompton, 2013).

Mobile technology in various learning environments demonstrates multiple ways it facilitates learning. For instance, Kuimova et al. (2018) study on the effects of mobile learning on foreign language learning using WhatsApp found that mobile learning enabled effective learning, collaboration, and communication during the learning process. Additionally, using mobile technology helped learners achieve better academic results. Similarly, Shahrol et al. (2020) study revealed that it enabled communication between learners and their peers, including educators. Furthermore, it enabled independent learning (Gashoot et al., 2023).

Nevertheless, mobile technologies can impede the learning process. Reviews by Criollo-C et al. (2021) and Saikat et al. (2021) revealed technological challenges such as security, privacy, connectivity restrictions, internet access, and data availability. Educators found mobile learning challenging to understand and apply (Criollo-C et al., 2021). Additionally, educational institutions lack the technological infrastructure to support mobile learning and implementation strategies (Criollo-C et al., 2021; Kaliisa & Picard, 2017). Furthermore, most institutions prohibit using mobile devices at school due to perceived disruptiveness during lessons (Criollo-C et al., 2021; Ngesi et al., 2018; Ng'ambi, 2020).

Despite these challenges, researchers agree that integrating mobile learning effectively increases learner academic achievement (Ustun, 2019). For instance, Alshehri and Cumming (2020) stated that learning through mobile devices promotes knowledge creation and sharing. In addition, it promotes increased learning engagement (Purwanti et al., 2019; Shahrol et al., 2020). Furthermore, Criollo-C et al. (2021) point out that mobile learning technologies create an enjoyable and motivating learning environment leading to academic achievement.

These studies demonstrate the positive effect of using mobile technology in education. This is consistent with findings by Crompton & Burke (2017), indicating that most studies on mobile technology and learning focus on effectiveness. Most studies on mobile technology and learning also illustrate that mathematics, science, and English are popular research topics (Crompton & Burke, 2017; Crompton et al., 2017). Most research has been conducted within higher education and elementary school levels, with limited research on special needs (Crompton et al., 2017; Crompton & Burke, 2017). Furthermore, smartphones are reported to be the most used device and research was conducted mainly in America, Asia, and Europe, with only 3 % of studies being conducted in Africa (Crompton & Burke, 2017).

Despite limited research in Africa, there is a growing body of knowledge on mobile technology and learning in developing countries like South Africa (e.g., Traxler & Leach, 2006; Foko, 2009; Imtinan et al., 2012; O'Hagan, 2013; Jantjies & Joy, 2015; Aluko, 2017). The upsurge in research on mobile learning is due to the popularity of mobile devices in these countries (Lamptey & Boateng, 2017; Kaliisa & Picard, 2017).

South Africa has approximately twenty-four million smartphone users (figure 2.1), which is expected to increase to more than twenty-six million by 2023 (O'Dea, 2021). Due to the ubiquity of mobile devices, studies have been conducted to understand their impact and affordances within the South African context. For example, Chaka's(2021) study on mobile learning projects completed at secondary schools in South Africa revealed that studies focused on various concepts, such as school uptake and use of mobile learning, mobile applications as learning tools, and mobile learning as support tools. Unlike in other countries, Chaka's (2021) findings revealed low adoption and use of mobile technologies as a learning tool within South African schools.

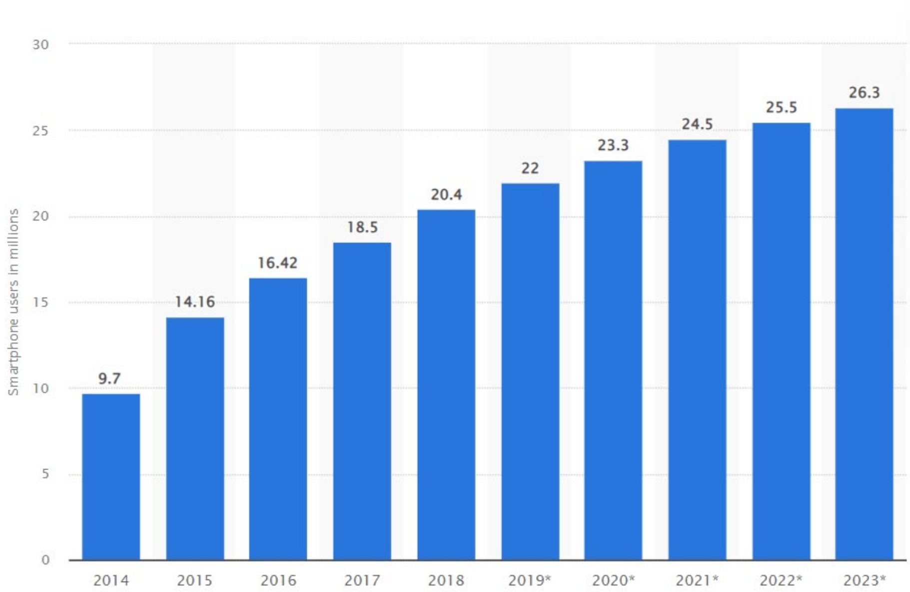

Figure 2.1: Number of smartphone users in South Africa (O'Dea, 2021)

Kaisara and Bwalya's (2022) study on trends in mobile learning research in Sub-Saharan Africa revealed that research was conducted in South Africa and Nigeria. Furthermore, most studies were quantitative, did not use a theoretical framework, and focused on learners as the target population.

Due to the vast knowledge of mobile technologies and learning, authors like Svela et al. (2019) called for a shift in investigations by changing the focus to look at the impact and affordances of specific mobile devices on particular subjects. Following the recommendation by Svela et al. (2019), this study explores the use of mobile devices in mathematics education. The following section will examine the research on using mobile technology to promote mathematics education.

2.2.2. Mobile technology in mathematics education

Mathematics and reading outcomes are a global priority, emphasising the sustainable development goals, which state that countries should ensure inclusive and equitable education and promote opportunities for lifelong learning (Isaacs et al., 2019). World organisations such as the United Nations (UN) and World Bank have expressed concern about the poor quality of education in schools, noting that children in the primary and secondary school achieve only a basic level of proficiency in mathematics and reading (Hunt, 2020). Mobile technology is a catalyst for providing learners with access to education opportunities.

Studies in various learning environments were conducted to understand better how mobile technology improves mathematics education. Fabian et al. (2018) found that using mobile technology improved achievement in mathematics. However, they found no notable change in attitudes toward the subject. Similarly, Etcuban and Pantinople (2018) discovered an improvement in learners' achievement and learning when they investigated the effects of mobile applications in math teaching among grade 8 learners.

A study by Fabian and Topping (2019) examining grade 5 and 6 learners' perceptions of using mobile technology and their impact on mathematics achievement also showed positive perceptions. According to the authors, the novelty effect is the most common theme in mobile learning because using mobile technology for learning always results in positive perceptions. The study found no significant difference in achievement between the experimental and control groups, as both performed well. However, Hwang et al. (2021), on the effects of a mobile learning application on learning angles and polygons, found that the experimental group outperformed the control group regarding learner achievement.

Although using mobile devices to learn mathematics facilitated contextual learning, visualisation of abstract mathematical concepts, and promoted active learning (Fabian & Topping, 2019), it also represents issues. Fabian and Topping (2019) identified application stability, activity design, and environmental issues. Despite these issues, these studies illustrate that learners perceive using mobile technology to learn math as applicable.

A low pass rate in mathematics has been a problem in Sub-Saharan Africa, promoting the implementation of various mobile learning initiatives to help with learner achievement. The Nokia mobile math project was one of the most popular projects in South Africa, providing free access to math content for grade 10 to 12 learners (O'Hagan, 2013; Roberts & Vänskä, 2011; Isaacs et al., 2019).

Studies have been conducted in South Africa to understand better the impact and benefits of mobile technology for learning mathematics. For instance, Isaacs et al. (2019) compared four African mobile learning pilots, including the Nokia mobile math initiative. The results showed that all programmes provided access to digital resources and were cost-effective because there were no licensing or subscription fees. This highlights the frequently mentioned challenges in mobile learning research, "internet access and data availability" (Criollo-C et al., 2021; Saikat et al., 2021).

Roberts (2021), on the JumpStart pilot programme implemented in the Ekurhuleni district of South Africa's Gauteng Province, assessed the programme's impact on learners' mathematical outcomes. The findings revealed a significant improvement in learners' achievement. Additionally, even though 80% of South African schools have access to appropriate technological infrastructure, the study showed that educators are still not using mobile technology for teaching. This highlights the often-discussed issue of no mobile phone use in schools (Ngesi et al., 2018; Criollo-C et al., 2021; Ng'ambi, 2020).

To summarise, mobile learning reviews cite a vast body of knowledge on the implementation, design, and effectiveness of mobile technologies in mathematics education over the last two decades, demonstrating positive learning outcomes (Crompton & Burke, 2017; Bano et al., 2018; Svela et al., 2019; Chaka, 2021). However, gaps have been identified, such as research conducted outside the classroom using the flexibility provided by mobile devices (Bano et al., 2018).

Most research in South Africa is quantitative, indicating a need for more qualitative studies (Chaka, 2021; Kaisara & Bwalya, 2022). Furthermore, research in special needs education is scarce (Crompton & Burke, 2017). Similarly, Barbareschi et al. (2019) pointed out limited research into how people with disabilities use mobile devices, the services they use, and their experiences. Hence, the following section investigates the role of technology, especially mobile technology, and its role as a support tool for individuals with special needs.

2.3. Special Needs Education

Disabilities affect about 1.3 billion individuals, particularly children under fourteen (WHO, 2022). These children face challenges such as educational attainment (Wodon et al., 2018). Recognising education as a fundamental human right for all, regardless of disability, international organisations like the United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2015) have advocated for inclusive education policies. In line with these efforts, special needs education has been developed to provide additional support and adaptable pedagogical methods to learners with disabilities, including those with specific learning disorders, behavioural or emotional disorders (Buli-Holmberg & Jeyaprathaban, 2016; Hornby, 2014; National Center for Education Statistics, 2022).

Various methods, including assistive technology, have assisted these learners. Assistive technology is a tool that supports learning needs (Qahmash, 2018). The Global Report on Assistive Technology points out that "assistive technology" is an umbrella term for assistive products, including the systems and services that support these products (WHO & UNICEF, 2022).

A wide range of assistive technology is available (figure 2.2), ranging from low-tech to high-tech (TechOWL, 2021). Fernández-Batanero et al. (2022) highlight web 2.0, mobile learning, hardware or software as tools that are used as assistive tools. Assistive technology is critical in increasing access to education and improving learning outcomes for learners with special needs and disabilities (Lynch et al., 2022; Coflan & Kaye, 2020). Assistive technology enhances teaching and learning and offers these learners independence and social inclusion (Senjam et al., 2019; Dogan & Delialioglu, 2020).

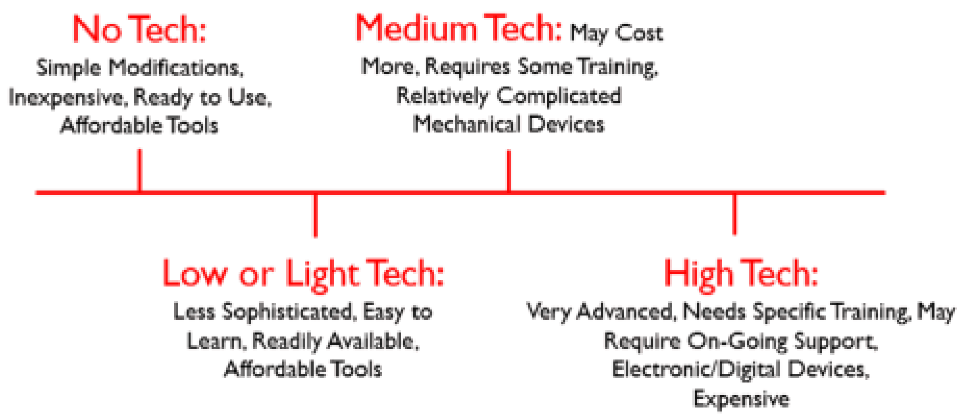

Figure 2.2: Range of assistive technology (TechOWL, 2021)

While assistive technology has significantly transformed the learning experience for learners with special needs, it remains largely inaccessible in underdeveloped and developing nations due to limited availability and affordability, resulting in mobile learning being seen as a viable alternative solution to address these challenges. (Ismaili et al., 2017; Qahmash, 2018). Hence, the following section investigates the use of mobile technology for individuals with special needs.

2.3.1. Mobile technology as an assistive tool

Research on special needs education and the integration of mobile technology has gathered substantial attention in research over the past decade. An exploration of relevant studies reveals several notable trends and patterns.

Cumming and Draper Rodríguez (2017) explored the research landscape from 2007 to 2016, focusing on the efficacy of mobile technology as an intervention for individuals with disabilities. The findings show a moderate effectiveness of mobile technology in enhancing educational outcomes. The employment of mobile technology was primarily used to support daily living and life skills, followed closely by the facilitation of academic and communicative proficiencies. Among the range of mobile devices used, iPads emerged as the predominant choice. The authors strongly recommend the need for additional research to explore the influence and efficacy of mobile technology in facilitating learning and fostering independence among individuals with disabilities.

Building upon the insightful recommendations offered by Cumming and Draper Rodríguez (2017), Chelkowski et al. (2019) effectively incorporated these guidelines. They conducted a comprehensive investigation into using mobile devices to assist learners with disabilities in educational settings; a study spanned the period since 2006. Their investigations illustrated the prevalence of mobile device adoption among learners with autism spectrum disorder, intellectual disabilities, and learning disabilities. A concentration of research efforts within primary and high school contexts was apparent, focusing on learner-centred investigations. Mobile phones and iPads stood out as the typical devices employed. The main view of these studies remained rooted in accessibility issues.

A recurring theme showed that mobile devices were used for various instructional tasks, such as management, planning, and assessment. The combination of direct instruction and personalised exercises has proven to be a highly effective teaching approach for nurturing academic skills. Mobile devices have been pivotal in managing learners' varied needs and behaviours. Additionally, research reported that mobile devices allowed for the seamless monitoring of learner progress.

Given their comprehensive study, Chelkowski et al. (2019) offered several insightful recommendations. They advocated for a broader scope encompassing disabilities beyond autism spectrum disorder and intellectual and learning disabilities. The exploration of varied hardware and software was also encouraged. They further advised a shift of focus towards using mobile devices for mobile-based teaching and learning once foundational accessibility concerns are addressed. Moreover, they highlighted the need to closely observe the development and impact of emerging devices on learners with disabilities.

In another facet of technology-enhanced special education, Cheng and Lai (2020) reviewed studies from 2008 to 2017, illustrating the role of computer-assisted tools in facilitating learning for learners with special needs. Their finding showed a significant preference distribution among personal computers, tablets, and notebooks. The software used included open-source software and learning platforms created by researchers. Guided learning strategies emerged as the most used, offering educators quick insights into learner progress. Writing, mathematics, and social skills proficiency emerged as the critical focal points. Significantly, most investigations concentrated on cognitive and skill-based learning accomplishments, with little focus on satisfaction, causal analysis, learning experience, learning-related anxiety, and cognitive load. Furthermore, primary schools constituted the immediate study area; most research emanated from the United States.

Considering these findings, Cheng and Lai (2020) called for future research to analyse the interactive or behavioural patterns exhibited by learners with special needs in technology-enhanced learning processes, stating that such insights hold the potential to inform the development of enhanced educational tools. Additionally, the authors advocated for exploring several technology-enhanced strategies, including peer assessments, issue-based discussions, computerised cognitive tools, project-based learning, and inquiry-based approaches. Moreover, there is a call for in-depth exploration of less-explored facets of special education, including examining how technology-enhanced learning tools influence learners' cognitive load and learning-related anxiety. Additionally, it is suggested that researchers should investigate the correlations and causative relationships among various factors that influence learners' performance and perceptions within special education. Lastly, the potential of extending learning contexts from classroom settings to field-based or after-class activities through technology was highlighted as a promising avenue for future exploration.

The research on special needs education and mobile technology integration has given important insights into how mobile technology helps people with disabilities learn better and become more independent. Cheng and Lai (2020) highlighted that mathematics is one of the focal points for research on mobile technology and special needs. Chelkowski et al. (2019) encouraged exploring various hardware and software uses within the special needs context. Due to these insights and recommendations, the following section will explore how mobile learning software impacts mathematics learning for learners with special needs.

2.3.2. Mobile applications as an assistive tool for learning mathematics

Over five million software applications are available worldwide, with more than 750,000 being educational (Ceci, 2020). Mathematics applications are thought to assist learners with basic mathematic skills effectively. Some studies have explored the efficacy and impact of mobile learning software as an assistive tool for enhancing mathematical learning experiences. For example, a study by Zhang et al. (2015) assessed the effectiveness of selected mathematics applications in improving the learning outcomes of elementary school learners with various disabilities, such as autism, emotional disorders, and learning disabilities. The study focused on three math applications: Splash Math, Motion Math Zoom, and Long Multiplication. Learners engaged with Splash Math for 40 minutes, while Long Multiplication was utilised for an hour. The findings of this investigation illustrated a significant improvement in learner performance when comparing pre-test and post-test scores after using the applications. Additionally, classroom observations showed general learner engagement during interaction with the applications.

Although the findings showed significant improvement in learning outcomes with the applications, the authors recommended possibilities for app design refinement. For instance, the Motion Math Zoom app could improve by adding customisation features, allowing users a tailored learning experience. Furthermore, the Long Multiplication app could benefit from integrating some gaming elements, enhancing its overall user experience.

Pitchford et al. (2018) explored whether educational apps can be used effectively by learners with special educational needs. The study results showed that learners could interact with the apps without additional assistive technology aids. Additionally, they made progress in learning basic maths. However, they took longer to complete tasks as compared to learners in the mainstream.

Benavides-Varela et al. (2020) conducted a meta-analysis encompassing studies between 2003 and 2019. Their analysis focused on evaluating the effectiveness of digital-based interventions for learners grappling with mathematical learning difficulties. Insights from the analysis showed a moderate but significant positive effect. Furthermore, the study found that the different school levels (preschool, elementary, and high school) did not significantly impact, as digital-based interventions yielded promising outcomes across all these levels. Additionally, the research results indicated the advantages of integrating gaming elements to enhance mathematical interventions for learners struggling with mathematical learning difficulties.

These studies offer valuable insights into the potential of mobile learning software as an assistive tool for mathematics education. However, research shows that math apps are frequently evaluated using learner perceptions, usability, and engagement (Kay & Kwak, 2017). The focus on usability shows that researchers do not consider the user's feelings while using learning software. Researchers (e.g., Maia & Furtado, 2016; Zarour & Alharbi, 2017; Zarour, 2020; Mahmoud et al., 2021) point out that the success of a system is not only determined by its usability but also by the emotions that users experience while using it. Hence, the following section explores user experience evaluation.

2.4. User experience evaluation

A product or system's success hinges upon its users' experiences, prompting the exploration of various approaches to understanding this phenomenon. User experience evaluation assesses whether a product or system effectively fulfils the needs of its users. Coined by Don Norman in the 1990s, the term "user experience" has gained widespread recognition and acceptance within the human-computer interaction (HCI) community (Berni & Borgianni, 2021).

Diverse perspectives on the definition of UX exist due to variances between academic and design viewpoints (Law et al., 2009; Berni & Borgianni, 2021). Law et al. (2009) state that the challenge in defining UX stems from determining its unit of analysis. The ISO FDIS 9241-210 standard, widely embraced as the most accepted definition, characterises user experience as "a person's perceptions and responses to a product, system, or service" (Law et al., 2009; Vermeeren et al., 2010; Sauer et al., 2020).

Garrett (2011) emphasised the necessity of breaking down user experience into distinct elements to consider user actions during system interactions. These elements highlight UX and usability differences (Bargas-Avila & Hornbæk, 2011; Basri et al., 2016; Pettersson et al., 2018; Guo, 2012).

According to Nielsen (2012), usability focuses on five distinct elements (figure 2.3):

i. Learnability: how easy is it for first-time users to complete basic tasks?
ii. Efficiency: how fast can users complete tasks after learning the system?
iii. Memorability: how easily can users recall system competency after inactivity?
iv. Errors: how many errors do users make, how serious are they, and how do they recover?
v. Satisfaction: how satisfying is using the system?

Figure 2.3: Jakob Nielsen's usability attributes (Sippola, 2017)

Although the system functionality is essential, recognising the significance of understanding users' cognitive and affective experiences is crucial for user experience evaluation (Morville, 2004; Norman & Nielsen, 2022; Karagianni, 2018). Norman & Nielsen (2022) state that users' emotions during interactions with a system hold significance in assessing user experience, encompassing usability factors. Norman proposed three levels of interaction (figure 2.4) when users interact with a system: first impressions of a system (visceral), how well the system functions in meeting the user's needs (behavioural), and the product's interactivity and aesthetic qualities, including past and current experiences (reflective) (Komninos, 2020).

Figure 2.4: Levels of design appeal (Interaction Design Foundation, 2020)

Similarly, Morville's (2004) seven-facet honeycomb (figure 2.5) and subsequent enhancements by Karagianni (2018) highlight the importance of considering both emotional and usability aspects within the realm of user experience.

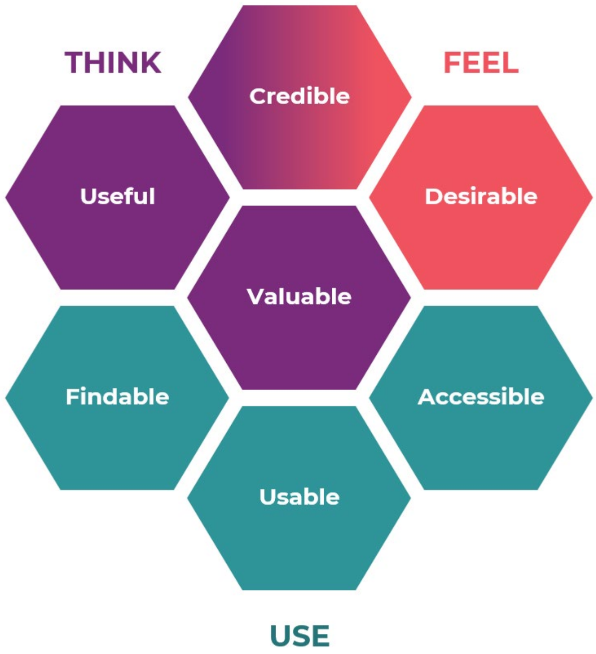

Figure 2.5: UX honeycomb (Karagianni, 2018)

Understanding how users perceive a system, their emotional responses, and their usage patterns in fulfilling their needs holds significant importance for designers and brands (Hassenzahl et al., 2010; Vaidya & Kalita, 2021). Positive user experiences with a system foster loyalty among users (Gangadharan, 2019), which is highly advantageous for the system's success as loyal customers share their positive experiences, leading to future sales and adoption (Maia & Furtado, 2016; Gangadharan, 2019). To gain further insight into this phenomenon, the following section delves into the dynamics of user experience research.

2.4.1. Trends and insights in user experience research

User experience research is crucial in understanding user interactions between digital systems, products, or services. Over the past two decades, numerous studies have been conducted to explore various aspects of user experience. This section synthesises and analyses findings from several review papers that examined user experience studies conducted between 2000 and 2021. This section provides valuable insights into the field by delving into the methodologies and trends employed in UX research.

User experience research demonstrated various application domains (Zarour & Alharbi, 2017). While some studies focused on specific areas such as education (Nur et al., 2021) and mobile phones (Pettersson et al., 2018), others explored diverse application domains, encompassing services, websites, and web interfaces (Robinson et al., 2017). This diversity reflects the evolving nature of user experience research, wherein researchers explore different contexts to gain comprehensive insights into user behaviour and preferences.

Several dimensions emerged as focal points in the reviewed studies. These encompass UX and values, UX and brand, UX and users' needs, UX and development process, and UX and technologies (Zarour & Alharbi, 2017).

The methodologies used for data collection and evaluation revealed a consistent pattern. Questionnaires were widespread, allowing for the collection of quantitative data (Maia & Furtado, 2016; Petterson et al., 2018; Nur et al., 2021). Self-reported methods are popular, enabling users to express their experiences without evaluator intervention (Rivero & Conte, 2017; Nur et al., 2021). Despite a wealth of data collected during or after user interactions, most studies conducted their assessments in controlled environments (Maia and Furtado, 2016; Robinson et al., 2017; Nur et al., 2021). Nur et al. (2021) point out that there is a need for self-reported measurements in non-controlled environments. Additionally, Nur et al. (2021) highlight convenience sampling as the most used sampling technique, followed by purposive and random sampling.

Furthermore, the most cited elements in UX evaluation are desirability, usability, attractive design, and value (Maia & Furtado, 2016). Additionally, most UX evaluation research has been conducted in the USA, Europe, and Asia (Maia & Furtado, 2016), indicating a gap in UX evaluation within the African context.

A recent bibliometric analysis by Zuo et al. (2023) between 2011 and 2021 exhibited a remarkable growth in global UX research. This growth occurred between 2016 and 2021, indicating a heightened interest and focus on UX research.

Similarly, in alignment with Maia and Furtado (2016), the analysis emphasised the United States as the most prolific country in UX research, with China and the United Kingdom following closely. Computer science information systems was the primary area accounting for UX research, followed by electrical engineering and telecommunications.

The study also highlighted usability, virtual reality, and HCI as key research foci. At the same time, mobile applications became a critical area for academia and industries, forecasting future research trends.

This section highlights the dynamic evolution of UX research across diverse domains and its increasing global importance. It also highlights the need for more diverse geographic representation and research in real-world settings for a comprehensive understanding of user experience. Additionally, the UX evaluation of mobile applications is an area of interest. Given the imperative for research conducted in real-world settings to enhance our understanding of user experience and interest in a mobile application evaluation, the subsequent section will examine user experience evaluation of mobile applications within the educational environment.

2.4.2. User experience evaluation of mobile applications in education

The prominence of mobile learning applications has been significantly pushed by the widespread adoption of mobile devices and the availability of high-speed internet connectivity (Ibrahim et al., 2015; Alsanousi et al., 2023). Their use has offered educators and learners several benefits. In education, several applications are used to enhance learning experiences, facilitate communication, and provide educational resources. Mobile and web applications such as learning management systems (LMS), eLearning apps, language learning apps, math and science apps, virtual reality (VR) and augmented reality (AR) apps, and educational games supplement traditional classroom instruction (Khaddage & Lattemann, 2013; Drigas & Angelidakis, 2017; Nur et al., 2021).

The use of these applications has offered educators and learners several benefits. Mobile applications provide opportunities for collaborative teaching, aid learners with practice opportunities and assistance with homework and classwork, assist educators in planning and preparing their lessons, and improve communication between educators and parents (Hussain et al., 2020). Despite these opportunities, Hussain et al. (2020) highlight numerous developing nations' challenges. These challenges encompass irregular power supply, limited financial resources to acquire necessary educational devices, a shortage of educators proficient in practical application usage, the need for technical support, and prevailing negative social attitudes towards integrating these technologies within the classroom.

The use of mobile applications has not only extended access to learning resources but also highlighted the crucial role of UX in promoting effective learning outcomes (Ibrahim et al., 2015; Shah et al., 2023). As Zuo et al. (2023) pointed out, there is a growing interest in studying user experience across various applications, including educational applications.

Studies show a variety of elements that are evaluated by researchers when conducting UX research. Wang et al. (2021) conducted a quantitative investigation into the strengths and weaknesses of two mathematics software, NetPad and Geometer's Sketchpad. Using their constructed evaluation model CCEMS, they assessed five core elements: clarity, credibility, efficiency, motivation, and subject attributes. The results revealed NetPad's high motivation score, particularly in offering valuable services, tools, resource packs, and support. NetPad also excelled in the subject aspect as a professional mathematics education software. In contrast, Geometer's Sketchpad had a clarity advantage, while both applications scored low in fault tolerance due to inadequate feedback and error correction mechanisms. This evaluation framework contributes to refining the evaluative model in future studies.

Mohamad and Hashim's (2021) quantitative study tested two learning applications (KoTBam and Learning Fakih) for learners with hearing impairment in Malaysia. The study adopted a set of questionnaires (UEQ, meCue, and usability evaluation model for hearing impaired) to develop an instrument for evaluating UX for learners with hearing impairments. The UX evaluation focused on five dimensions: satisfaction, deaf accessibility, efficiency, effectiveness, and emotion. The study results revealed that learners had a more positive experience with the KoTBam application as it scored highly on all dimensions except satisfaction. Both applications had a low score value for satisfaction, which included items such as sustainability of the content for learners with hearing impairments, following the syllabus for the learners, repetition of using the app and feeling to use the app daily. The study highlighted that the dimensions used are not generalisable to evaluating other disabilities. Future research will focus on testing the UX dimensions on other mobile learning applications for learners with hearing impairments.

An explorative, interpretive, qualitative study by Kohnke (2020) investigated undergraduate students' perceptions of an in-house language application to assist with vocabulary learning. The study's focus was on students' attitudes towards using mobile apps and the understanding of which features of the application motivated students to build their vocabulary. The study results show that the learners were satisfied with the application and used the app to complete coursework. The findings also illustrate that students felt the app made their learning process efficient and highlighted the flexibility of learning anywhere and at any time as a strength of the application. Additionally, students reported that example sentences and opportunities to practice pronunciation were the most beneficial features, including the gamified nature of the app, which allowed them to compete against each other and the application. The study called for future large-scale studies using mixed methods.

These studies highlight various elements in evaluating user experiences with multiple learning applications. These elements are based on various evaluation tools and models. For instance, to understand the different tools used to assess UX, a review conducted by Papadakis (2021) provided an overview of UX evaluation tools for educational applications. The review examined studies conducted between 2010 and 2018. The research focused on an array of tools employed for assessing educational apps, examining the specific criteria or elements that these tools scrutinised and assessing their suitability for the task. The findings reveal that rubrics and checklists emerged as the prevailing tools for appraising educational applications. Furthermore, the study underscores that these tools employ distinct sets of criteria for evaluating educational apps, contingent upon the specific framework being utilised. The study identified the following elements as the most estimated: the value of error/feedback, personal preferences/customisation, screen design, learner control, content appropriateness, high-order thinking skills, ease of use, cultural sensitivity, levelling, feedback to educator/parent, cooperative/social learning, learner performance, ability to save progress, accommodation of individual differences. The study identified Lee and Cherner's (2015) evaluation rubric for educational apps and Lee & Kim's (2015) checklist as adequate tools for evaluating educational apps. The study indicates a need for a more standardised app evaluation tool within education.

Additionally, a review conducted by Yasin et al. (2022) identified several elements when exploring how researchers in mobile games, educational games, and mobile educational UX use UX frameworks for evaluation. The study results illustrated fourteen significant elements based on 24 different UX frameworks (e.g., MEEGA+ model questionnaire, SkillVille, User experience questionnaires, mGBL heuristic evaluation, UCALGok, etc.). The elements included learning, challenge, usability, immersion, social, gameplay, feedback, satisfaction, content, playability, mobility, behaviour, emotions, and motivation. Similarly, Razami et al. (2022) review identified several elements based on five models and scales (e.g., User experience questionnaire, EDUGXG, EDUGX model, and MEEGA+). The elements measured included aesthetics, positive and negative affect, competence, immersion, challenge, flow, tension, usability/playability, narrative, social connectivity, learnability, concentration, goal clarity, feedback, and knowledge improvement.

These articles collectively highlight the diversity of elements considered when evaluating user experience in educational applications and the utilisation of different tools and frameworks. UX frameworks and tools ensure users have a positive and meaningful experience when interacting with a digital system (Papadakis, 2021; Razami et al., 2022). They incorporate design elements, usability considerations, interaction patterns, and user preferences to enhance the overall user experience (Vermeeren et al., 2010). However, it is essential to note that while UX frameworks and tools provide valuable design principles for creating user-friendly interfaces, they do not serve as a theoretical framework through which researchers can analyse data, formulate research questions, and develop hypotheses (Kuutti, 2010; Obrist et al., 2012). The following section examines theoretical frameworks used as a lens in UX research.

2.5. Underpinning theory

During data analysis, theories guide frameworks to analyse and explain a phenomenon (Iyamu & Shaanika, 2019; Iyamu, 2022). The use of theories is essential because they aid in understanding the underlying reasons behind the occurrence of events (Collins & Stockton, 2018). In their work, Obrist et al. (2012) identified seven categories of theories that pertain to user experience. These categories encompass theories centred on the human/user, theories related to the product/artefact, theories involving user/artefact/environment relationships, theories addressing the social aspects of user experience, design theories, frameworks encompassing various themes, and broader frameworks that relate to human existence.

Theories focused on the human/user, such as Herzberg's 2-factor theory, Maslow's theory, and self-determination theory, have been used as a lens to understand users' UX needs (Mkpojiogu et al., 2022). Theories such as the Technology Acceptance Model (TAM) focus on product/artefact acceptance (Marikyan & Papagiannidis, 2022; Hornbæk & Hertzum, 2017) and Unified Theory of Acceptance and Use of Technology (UTAUT) extends TAM by incorporating factors like social influence ad facilitating conditions have been used on studies and social influences and facilitating conditions (Marikyan & Papagiannidis, 2022). To understand how users interact with artefacts in various environments and how these interactions shape their experiences, theories such as Activity Theory (Clemmensen et al., 2016; Good & Omisade, 2019), affordance theory (Pucillo & Cascini, 2013), and sense-making theory (Andrade, 2016; Strom, 2006) have been used.

To understand the social nature of UX, theories such as actor-network theory (Hung, 2016), diffusion of innovation (Lu & Hsiao, 2022), and social learning theory (Deaton, 2015) have been used to provide valuable insights into how social interactions, group dynamics, and shared contexts influence user experiences. Design theories such as design thinking have been used to help UX designers create interfaces that are functional, intuitive, visually appealing, and aligned with user needs and expectations (Nedeltcheva & Shoikova, 2017).

These theories have provided researchers with critical lenses to analyse, understand, and enhance user interactions and digital artefacts. As this study seeks to understand how users interact with artefacts in a specific environment, the following section examines the use of AT as a lens in user experience, especially for research on mobile learning applications.

2.5.1. Activity theory in user experience research

Activity Theory, initially developed by Russian psychologists Vygotsky and Leont'ev in the 1920s and 1930s (Engeström et al., 1999; Nardi & Kaptelinin, 2006), gained popularity through the work of Engström in the 1980s (Nardi & Kaptelinin, 2006; Hasan & Kazlauskas, 2014). Engström's activity (figure 2.6) considers the intricate interconnections among the individual, the community, historical factors, the context, and the interaction within the specific situation and activity (Batiibwe, 2019).

Individuals or groups involved in the activity are called subject/subjects. As defined by Kaptelinin (2005:5), the object of activity is the entity that gives meaning to various elements and events, establishing their values. A tool refers to any material, medium, content, artefact, instrument, or device used to mediate the relationship between the subject and the objective within an activity system (Chung et al., 2019b; Engeström et al., 1999). Rules, community, and division of labour comprise what Engström refers to as the social basis of the activity system, which situates the activity in a broader context and allows accounting for the influences that shape the activity (Kain & Wardle, 2014). Rules can be understood as constraints that regulate the components and operations within the system, while the community represents the larger group to which the subject belongs, negotiating and mediating the governing rules (Lee et al., 2021; Kain & Wardle, 2014). The roles and relationships within the community that influence task allocation are called the division of labour (Chung et al., 2019b; Lee et al., 2021; Kain & Wardle, 2014).

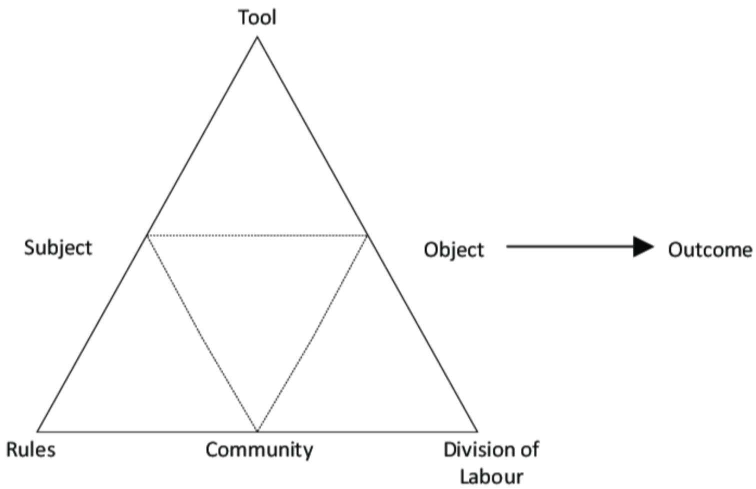

Figure 2.6: AT model (Engeström et al., 1999)

The interrelated nature and mutual reliance among the different components of AT give rise to a collection of fundamental principles that constitute a comprehensive conceptual framework that centres on foundational aspects around a hierarchical structure (figure 2.7) of activities, object-oriented focus, processes of internalisation and externalisation, tool mediation, and developmental factors (Kaptelinin & Nardi, 1997).

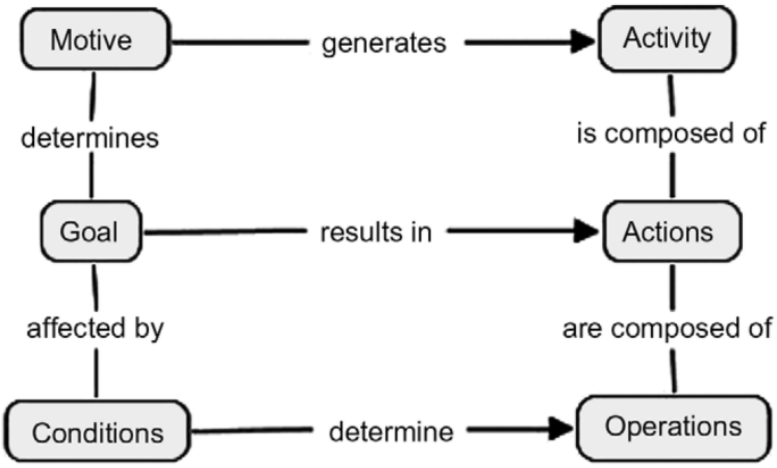

Figure 2.7: Hierarchical structure of AT (Batiibwe, 2019)

Engeström's AT model has garnered extensive utilisation in examining the impact of interactions among different components on systems and evaluating activity systems by identifying tensions or contradictions among these components that may contribute to system failure (Murphy & Rodriguez-Manzanares, 2008; DeVane & Squire, 2012). Nardi (1996) highlights that AT challenges established norms in HCI research while presenting an inquiry-driven approach. Additionally, Nardi (1996) emphasised that combining cognitive science and participatory design principles within AT provides a unified approach to understanding user experiences.

A growing body of research has turned to AT as a valuable lens to analyse and understand the complexities of user interactions with technology and environments. For instance, Lin et al. (2020) conducted a review applying AT to analyse studies from 2008 to 2018 focused on mobile-assisted reading development. The study aimed to understand how the elements of AT contribute to reading development in mobile-assisted language learning and identify conducive facilitation processes and guidelines for reading improvement. The study revealed that most subjects engaging in mobile-assisted language learning were tertiary students, followed by junior and high school learners. The mediating tools included mobile devices, e-readers, and personal digital assistants. The object of these studies was divided into technologically enhanced reading environments or activities, utilisation of reading strategies, and instructional methods.

The findings indicated that the rules component encompassed course design, teaching strategies, and learning methods. The community component typically consisted of administrators, instructors, learners, and system developers who collaboratively shaped the learning technology. In mobile-assisted language learning, the division of labour was distributed among learning system developers, instructors, and learners. Learning system developers communicated with course designers and instructors to create well-designed and user-friendly learning software. Instructors or educators were responsible for providing instruction on m-learning tasks, monitoring learner progress, and offering relevant feedback. Learners' roles encompassed cognitive learning levels, individual and collaborative learning, self-directed, self-regulated, and self-paced learning.

Positive outcomes identified in the reviewed studies highlighted three critical benefits of mobile-assisted language learning. Firstly, the effectiveness of mobile-assisted language learning tools in enhancing reading competence was demonstrated through increased reading proficiency, greater reading frequency and quantity, shared annotations, heightened sustained attention, and improved decoding skills. Secondly, self-regulated learning was evident, with learners engaging in more self-practice outside of class, independent learning, and self-paced learning. Lastly, attitudes and perceptions towards language learning were positively influenced.

A study conducted by Tan et al. (2021) explored the effectiveness of a mobile peer tutoring application by analysing the activity system involved in its use. The activity aimed to facilitate effective peer tutoring through MENTOR to Subjects who were university learners. The tool component consisted of MENTOR, a mobile application developed for peer tutoring. The application allowed asynchronous and synchronous communication tools, like text, voice, and annotation within a canvas interface. Rules were established to enhance productive tutoring interactions by asking learners to indicate their cognitive processing levels when seeking help and using Bloom's taxonomy to encourage self-regulation. The community included tutors and tutees interacting through the application. Tutors offered explanations and guidance while the tutees sought help and engaged in co-annotation to enhance understanding.

Tan et al. (2021) highlighted several contradictions which provided insights into challenges and areas for improvement, offering a nuanced understanding of the user experience. At the primary contradiction level, the study illustrated that participants lacked prior experience with mobile peer tutoring, leading to a preference for face-to-face interactions. The secondary contradiction level showed participant appreciation of MENTOR's canvas interface but suggested improvements, such as stylus support for legible annotations and videos for non-verbal cues. The tertiary contradiction levels showed that the community faced teething issues due to the need for a larger pool of available tutors. The intended affordance of indicating cognitive processing levels encountered resistance from some participants who questioned its purpose. This misalignment between the intended design and users' understanding highlighted quaternary contradiction within the study.

Another study by (Tlili et al., 2022) employed AT to analyse game-based learning for learners with disabilities. This review study aimed to identify features related to the design, implementation, and outcomes of game-based learning for learners with disabilities. The findings show that the subjects included learners with autism spectrum disorder, intellectual disability, specific learning disorders, cerebral palsy, visual impairment, and hearing impairment. The learning objectives encompassed motor skills, cognitive skills, engagement, social interaction, and academic learning outcomes (including STEM subjects, reading, music, and languages). The tools component included technologies such as eye-gaze tracking, web-based platforms, augmented reality, virtual reality, 3D simulation, and Kinect. Factors like accessibility, engagement, and learning outcomes influenced the choice of technology. The rules component included examining intervention procedures and performance measures. The community component included special education professionals, principals, game designers, parents, sign language specialists, and learners with disabilities. Learners participated in assessments, experiments, and post-test examinations within the division of labour component. At the same time, special education professionals facilitated experiments, conducted meetings with other experts such as game designers and sign language specialists, provided instructions to trainers and learners, and evaluated learners. Parents' roles varied from giving consent to researchers to being involved in the learning process with their children. Other experts such as neuroscientists, game designers, and artists contributed to recommendations, sharing experiences in designing educational games based on learners' disabilities, examining the games, and observing learner performance during the game experience.

Furthermore, Tlili et al. (2022) highlighted contradictions and challenges, such as catering to diverse disabilities. The challenge of limited compatibility with different operating systems was noted. Lengthy experiments were seen as a challenge that might discourage learner engagement. While most studies involved special education professionals, the authors noted limited inclusivity in applying general educators in designing inclusive games. Ensuring learners; enjoyment and engagement during gameplay remained a significant concern. Additionally, the study highlighted that many studies had a small sample size, which could impact the generalizability of findings.

These studies prove AT to be a useful and valuable lens through which researchers can view the complexities of technological interactions and learning experiences that might otherwise go unnoticed. As technology and human interactions evolve, AT remains a practical theory for unravelling the intricacies of these interactions and driving the refinement and enhancement of user experiences and learning outcomes.

2.6. Summary

A literature review focusing on critical areas relevant to the research was conducted. Specifically, this study aims to investigate the experiences related to mobile applications for teaching mathematics to learners with special educational needs, particularly emphasising their utilisation and promotion within the classroom setting.

The literature review reveals that mobile technology has been extensively examined in various educational contexts, demonstrating its potential to facilitate learning through diverse mechanisms. Most studies on mobile learning report positive outcomes. However, they also identify challenges that hinder the learning process. Even though South Africa currently has approximately twenty-four million smartphone users, research indicates low adoption and usage of mobile technologies as educational tools within South African schools. Furthermore, limited research exists regarding the utilisation of mobile devices, the services accessed, and the experiences of individuals with disabilities when interacting with these devices.

Mathematical applications have proven effective in supporting the development of fundamental mathematical skills among learners in mainstream educational settings. Moreover, the affordances provided by these applications make them valuable assistive tools for learners with special needs and disabilities. Nevertheless, existing studies primarily focus on evaluating math apps from a design, development, and usability perspective. Therefore, this study aims to assess the application's practical and experiential dimensions, encompassing pragmatic and hedonic aspects.

The study adopts AT as a theoretical lens to explore the affordances associated with math software for teaching mathematics to learners with special educational needs. The research objectives are to investigate educators' experiences with the Siyavula software and analyse how the software facilitates learning.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1. Introduction

This chapter thoroughly examines and discusses the research methodology employed in the study. The methodological choice was guided by the main aim and objectives of the study, which are:

Study Aim: Exploring the affordances associated with the Siyavula software for teaching mathematics to learners with special educational needs.

Study objectives:

- To explore educators' experiences using the Siyavula software to teach mathematics to learners with special educational needs.
- To analyse how the Siyavula software facilitates mathematics learning for learners with special educational needs.

Adopting Saunders et al. (2019), this chapter explains the rationale behind the philosophical assumptions, the research approach, methods, and design used in the study. The chapter also discusses the data collection and analysis techniques employed in the study, including the research ethics that served as guiding principles throughout the process. Lastly, a summary of the chapter is provided.

3.2. Philosophical assumption

This study adopts an interpretive paradigm, emphasising the importance of interpretation in understanding the social world (Ormston et al., 2014). Interpretive research aims to understand the social context of an information system and its interrelated factors (Oates et al., 2022). Unlike positivists and pragmatists, interpretivists focus on subjectivism and contextual meaning (Tharsika & Pratheepkanth, 2020; Kelly & Cordeiro, 2020; Creswell & Plano-Clark, 2018).

Epistemology and ontology are the two common assumptions in information systems research (Ormston et al., 2014; Oates et al., 2022). Epistemology deals with human knowledge, while ontology concerns the existence of realities (Coghlan & Brydon-Miller, 2014; Ormston et al., 2014; Saunders et al., 2019). Both assumptions are interconnected and complex due to their association with distinct value systems (Furlong & Marsh, 2010).

Thus, this study incorporates epistemological and ontological perspectives, acknowledging Siyavula as software within humans and technology while recognising educators' unknown experiences for mathematics instruction with learners with special educational needs.

3.3. Research Approach

The primary objective of this study was to answer the 'what' and how questions. To achieve this, an inductive approach was deemed appropriate, as explained by Saunders et al. (2019:157), who state that the interpretive paradigm informs an inductive approach. The approach is commonly employed in qualitative research (Azungah, 2018).

Inductive research aims to generate new insights and understanding based on collected data (Lodico et al., 2010; Babbie, 2020; Saunders et al., 2019). Unlike deductive research, which starts with pre-existing theories or hypotheses, inductive research allows the data to guide the development of theories or hypotheses (DeCarlo, 2018). The inductive approach is regarded as flexible and open-ended, facilitating the discovery of new and unexpected findings (Azungah, 2018).

3.4. Research methods

This study followed the qualitative research method. In information systems research, qualitative methods help researchers understand the perspectives and experiences of information system users and enable the collection of rich, detailed data that can be used to identify patterns, themes, and relationships (Myers, 1997; Kaplan & Maxwell, 2005; B. Oates et al., 2022).

Qualitative measures are considered appropriate for studying subjective experiences and perspectives, which can be difficult to understand using quantifiable measurements (Strydom & Bezuidenhout, 2021). Leavy (2017) agrees that non-numerical data helps explore, investigate, and learn about a social phenomenon. It allows for unpacking the meanings people ascribe to activities, situations, events, or artefacts. This means it allows for a deeper understanding of social life. Qualitative research methods include interviews, focus groups, ethnography, case studies, and content analysis (Creswell & Creswell, 2018; Leedy & Ormrod, 2015).

Quantitative research entails collecting and analysing numerical data using statistical methods and techniques (Babbie, 2020; Creswell & Creswell, 2018). Mertler (2021) states that the quantitative research method is based on the philosophy that our world is stable and uniform, allowing us to measure, understand, and generalise it. This method is helpful for testing hypotheses, making predictions, and determining cause-and-effect relationships (Eyesi, 2016; Apuke, 2017). Hence, it was not selected for this study.

The mixed methods approach allows researchers to gain a more complete and nuanced understanding by collecting and analysing numerical and non-numerical data (Creswell & Plano-Clark, 2018). Dawadi et al. (2021) explain that by collecting numerical and non-numerical data, mixed methods research can provide generalisable findings that can be applied to a larger population. This method would have been appropriate for the study. However, due to the scope and focus of the research questions, the qualitative method alone is sufficient.

The qualitative approach is not a distinct research method; instead, it encompasses a range of research designs that have emerged from diverse perspectives. The subsequent section then explores the research designs selected for this study.

3.5. Research design

For this study, the selected research design is the case study approach. This is due to its usefulness for understanding the interactions between information systems (IS) and organisational contexts, such as how information systems are used, adopted and implemented and how they affect organisational processes and outcomes (Shanks & Bekmamedova, 2017). Additionally, case study research design allows researchers to investigate a specific case in-depth within its real-world context (Yin, 2018; Nieuwenhuis, 2020).

Swanborn (2010) states that answering the research question is central to case study research. Rule and John (2011) point out that it allows for an in-depth examination of a phenomenon and is often selected for its flexibility and versatility. It is, however, criticised for its lack of generalizability, not being rigorous enough, for being frequently confused with non-research case studies, for potentially taking too long, for having an unclear comparative advantage when compared to other research methods and being subject to researcher's bias (Yin, 2018).

Despite these limitations, evaluation case studies can emphasise multiple perspectives and represent various participants' voices, situate what is being evaluated within its specific and temporal context, and investigate the potentially complex relationship between case and context (Rule & John, 2011). Hence, a special needs school in the Western Cape was selected as a case to investigate the affordances of the software for teaching mathematics to learners with special educational needs. The decision to focus on a special needs context in this study was informed by the review of relevant literature (e.g., Crompton & Burke, 2017; Barbareschi et al., 2019), which highlights the need to investigate the use of mobile technology in special needs settings and how people with disabilities use mobile devices, the services they access, and their experiences.

3.5.1. Study Sample

The four educators who participated in the study were deliberately chosen through purposive sampling, one of the non-probability sampling techniques commonly associated with the case study research design. Other non-probability sampling techniques often used in case study research design include convenience, snowball, and quota (Higginbottom, 2004; Taherdoost, 2016; Sharma 2017).

Purposive sampling is a technique in which the researcher selects participants with specific characteristics or experiences relevant to the research questions (Neuman, 2014). The technique was chosen because the four educators teach mathematics at a special needs school. Taherdoost (2016) also points out that the method is affordable, convenient, time-efficient and ideal for exploratory research. Furthermore, purposive sampling is a frequently used sampling technique in UX research (Nur et al., 2021).

3.6. Data collection

This study used interviews as the primary method for collecting data. Qualitative research commonly employs various data collection techniques, including participant observation, interviews, focus group discussions, or sometimes a combination of these methods, depending on the research objectives and context (Moser & Korstjens, 2018).

The decision to use interviews as the data collection method for this study was based on their capacity to yield a high level of depth and detail regarding each participant's perspective and experiences. Interviews are a data collection method in which a researcher has a conversation with an individual or a group to collect data on their attitudes, beliefs, experiences, and behaviours (Strydom & Bezuidenhout, 2021). Yin (2018) points out that interviews are one of the most important sources of case study evidence.

Interviews are in-person, over the phone or online and can be structured, semi-structured or unstructured (Roulson & Choi, 2018; Silverman, 2019). Structured interviews ask predetermined questions in a standardised manner. Unstructured interviews are loosely formatted, while unstructured interviews allow the conversation to flow naturally and enable the interviewer to ask follow-up questions based on the interviewee's responses (Roulson & Choi, 2018).

Data was collected using semi-structured interviews to explore experiences with the Siyavula software. Semi-structured interviews are great for gathering subjective experiences (Silverman, 2019) and conducting evaluations (Adams, 2015). Furthermore, self-reported measures are the most popular data collection method in user experience studies (Rivero & Conte, 2017; Nur et al., 2021). Using semi-structured interviews to collect data involves participants self-reporting their experiences and viewpoints, making it a form of self-reported measurement within the qualitative research context. This approach enhances the validity of the study by directly addressing participants' perspectives and subjective accounts.

The interview protocols were formulated in alignment with the research questions. This means that semi-structured interviews afforded for probing during the interviews, allowing the interviewer to seek clarification where desired. This allowed me to gain more insights into the educators' perceptions of the software, including its usability, functionality, and effectiveness in supporting mathematics learning. This intentional interview protocol alignment not only ensured a focused inquiry, but it also contributed to the study's validity by directly addressing the research objectives and generating rich, relevant data.

The targeted participants were selected based on work experience and their use of the Siyavula software as a teaching tool. Data collection occurred in March 2023. Two group interviews were conducted online using Microsoft Teams, each with two educators. The interviews were recorded and then transcribed. During transcription, the participants were given pseudonyms to protect their identities. The meticulous approach to participant selection and data handling further strengthens the study's validity by ensuring the inclusion of relevant perspectives and the ethical treatment of participant information.

3.7. Data analysis

This study used thematic analysis to analyse the data. Thematic analysis is the most frequently used method for analysing semi-structured interviews (Guest et al., 2012). Two approaches are used when performing thematic analysis. An inductive approach begins with specific data and progresses to a broad or abstract conceptualisation of the phenomenon, and a deductive approach begins with general, abstract concepts and progresses to specific, observable, and measurable data (Terry et al., 2017; Kiger & Varpio, 2020). This study used an inductive approach to identify themes from the collected data.

The reliability of the analysis was improved by using interpretation-focused coding approach, which effectively structured and simplified the complex data, transforming it into meaningful and manageable codes, categories, and overarching themes. Adu (2019b) explains that the interpretation-focus coding approach is practical when the study aims to explore, explain, or understand specific behaviours, settings, experiences, or events. It is also used when research questions begin with the words "what" or "how" (Adu, 2019b). This study investigated the affordances associated with the Siyavula software educators use to teach mathematics to learners with special educational needs. Two research questions were posed to investigate this phenomenon: what are the educators' experiences with using the Siyavula software to teach mathematics to learners with special educational needs, and how does the Siyavula software facilitate mathematics learning for learners with special educational needs? Hence, interpretation-focused coding was considered appropriate. The main feature of interpretation-focused coding is meaning creation, which entails finding significant information in the data and creating a code that stands for our understanding of the data (Adu, 2019b).

Adu (2019b) points out that Interpretation-focused coding involves selecting relevant excerpts from the transcripts, understanding the passages, determining their meaning, assigning codes, and putting each code under their respective research questions. Building on Adu (2019a), the following steps were taken to code the data:

Step 1: Anchor codes

Table 3.1: Labelling research questions with anchor codes

Research Questions	Anchor code
What are the educators' experiences using the Siyavula software to teach learners with special needs mathematics?	Educator experiences
How does the Siyavula software facilitate mathematics learning for learners with special needs?	Facilitation of learning

Step 2: Identify relevant excerpts and assign a code:

Using Taguette, excerpts were selected from the interview transcripts. The sections were then assigned codes depending on the meaning or the participant's exact phrase. The first round of coding produced thirty-two codes, and after refinement, as illustrated in Figure 3.1, a codebook with twenty-two codes was created. The code book (table 3.2) includes the description of each code and the anchor code each excerpt belongs to. The transparency of the coding process and sharing of the codebook further contributes to the reliability of the analysis.

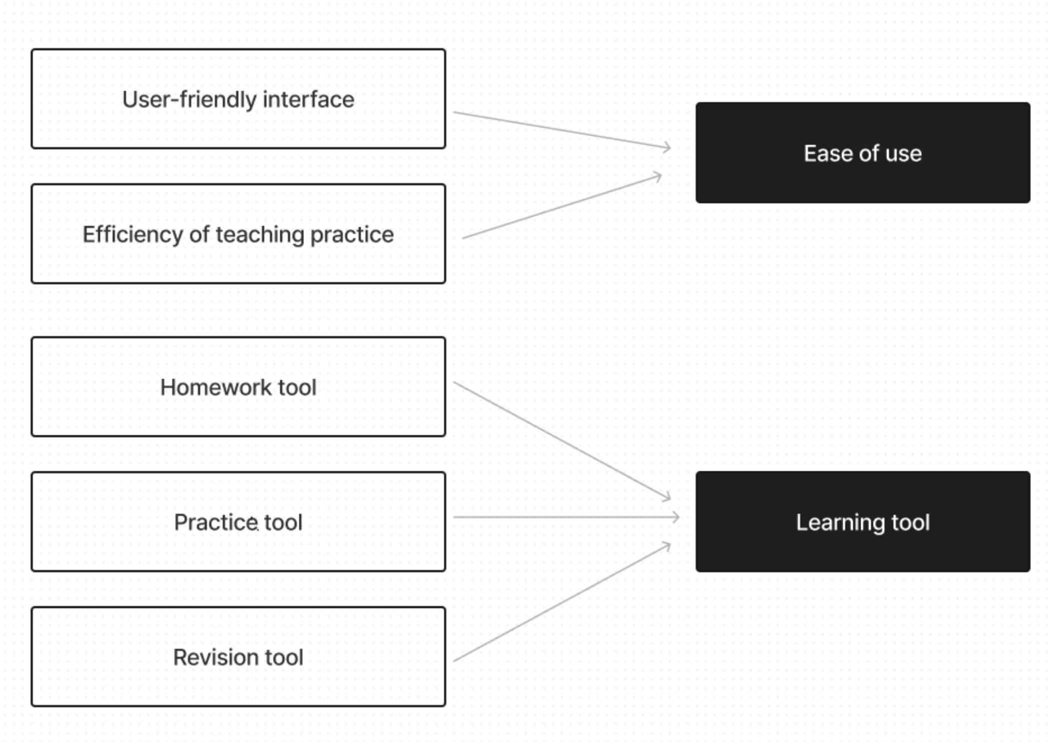

Figure 3.1: Diagram showing code refinement

Table 3.2: Generated code book

Code	Description & Corresponding research question	Excerpts
Assessment and feedback	**Facilitation of learning:** The educator is using the software to assess learners' understanding and provide feedback on their performance, which can guide further learning and revision	3
Comparison with other software	**Educator experiences**: Participants share their experiences with other software	3
Content coverage	**Educator experiences**: Siyavula software covers everything in the curriculum	1
Ease of use	**Educator experiences**	4
Flexible learning	**Facilitation of learning**: Siyavula software allows learners to access the information and learning materials at their own pace and schedule, a key affordance of digital learning technologies.	7
Individualised assignments	**Facilitation of learning:** The educator considers each learner's strengths and weaknesses and tailors the activities to each learner's needs and preferences.	3
Instant feedback	**Facilitation of learning**: affordance of the software for learners' learning process	4
Internet reliance	**Educator experiences**: the acknowledgement that the Siyavula software requires an internet connection to function correctly.	2

Issues with software	**Educator experiences**: observations and opinions on the software's features and functionality	12
Lack of adequate support	**Educator experiences:** Participants described their experience using the Siyavula software and how they had to figure it out independently without training.	2
Learning tool	**Facilitation of learning:** highlights how the tool can be used for practice and can be motivating for learners	4
Monitoring learner progress	**Educator experiences:** the ability to track learners' progress and educator's preferences and opinions about using the platform	6
No support for differentiated learning	**Facilitation of learning:** the software does not support differentiated learning, which can create a challenge in accommodating the diverse learning needs of learners with special educational needs.	3
Personalised learning	**Facilitation of learning**: By allowing learners who excel to move to more advanced content, the software facilitates individualised learning experiences tailored to each learner's needs and abilities.	2
Software improvement suggestion	**Facilitation of learning** suggests a potential improvement to the Siyavula software that could benefit learners who are struggling with mathematics	6
Software usage experience	**Educator experiences**: reflects the fact that the educator has been using the Siyavula software for a significant period, indicating that they have developed a deep familiarity with the tool and its capabilities and had opportunities to integrate it into their teaching practice	4
Learner engagement	**Facilitation of learning** highlights the positive impact the software has on motivation	11
Learner feedback	**Educator experiences**: The educator finds the software to be beneficial for the learners	5
Supportive learning environment	**Facilitation of learning:** the software offers a safe and supportive environment for learning.	2
Teaching experience	**Educator Experiences:** how long the educator has been teaching mathematics	4
The technology used for accessing software	**Facilitation of learning**: specific tools and devices used for teaching and learning with the Siyavula software.	6

Step 3: Organising codes into themes:

The codes generated were then organised into clusters (tables 3.3 & 3.4) based on meaning similarities. These clusters were then assigned themes that represented the codes within each group. Five themes emerged under each research question; Figure 3.2 illustrates the relationship between these themes, interview questions and the research objectives.

Table 3.3: Research questions one's themes

Cluster 1: **Technical Challenges** (14)	Cluster 2: **Ease of Use** (10)	Cluster 3: **Teaching and usage background** (8)	Cluster 4: **Progress tracking** (6)	Cluster 5: **Learner Perception** (5)
Issues with software (12) Lack of adequate support (2)	Comparison with other software (3) Ease of Use (4) Internet reliance (2) Content coverage (1)	Software usage experience (4) Teaching experience (4)	Monitoring learner progress (6)	Learner Feedback (5)

Table 3.4: Research questions two's themes

Cluster 1: **Learning environment** (13)	Cluster 2: **Customised learning experience** (12)	Cluster 3: **Accessing tools** (10)	Cluster 4: **Limitations and suggestions** (9)	Cluster 5: **Assessment and Feedback** (7)
Learner engagement (11) Supportive learning environment (2)	Flexible learning (7) Individualised assignments (3) Personalised learning (2)	Learning tools (4) Technology used for accessing software (6)	No support for differentiated learning (3) Software improvement suggestions (6)	Assessment and feedback (3) Instant feedback (4)

The themes were then characterised and analysed to see any relationships among them.

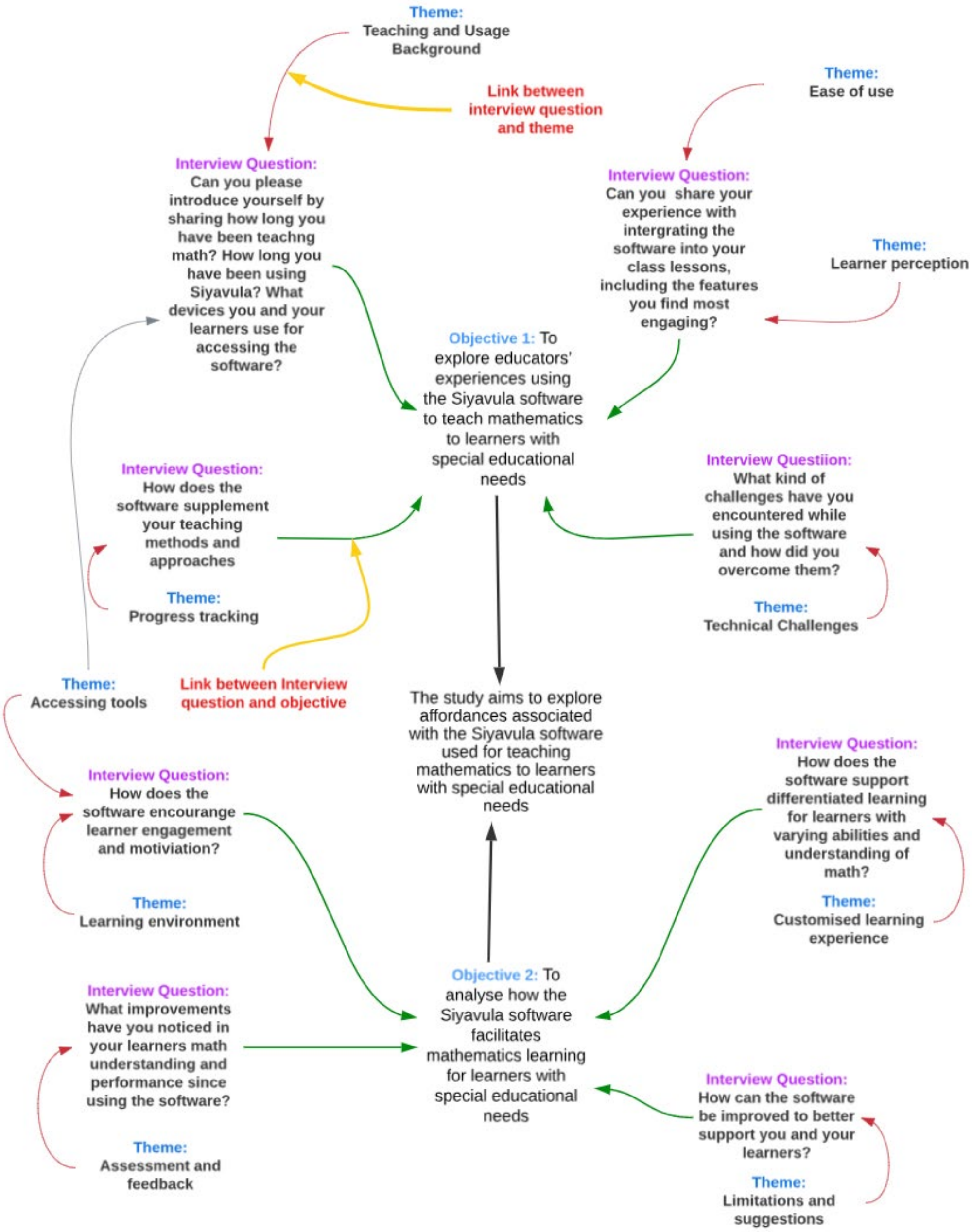

Figure 3.2: Relationship between research objectives, interview questions, and themes

The data was then interpreted in accordance with the six tenets of Activity Theory. The theory was applied to:

i. Identify educators' activities when teaching mathematics to learners with special educational needs using the Siyavula software.
ii. identify the actors who participate in these activities.
iii. Identify the various tools used.
iv. Identify the objectives educators hope to achieve using the Siyavula software.
v. Analyse the components of the activity system by examining how they interact with each other.
vi. Identifying areas where the software meets or fails to meet the user's needs.

Using AT to interpret data allows a better understanding of the complex interactions between educators, learners, and software tools during mathematics teaching and learning.

In this study, the activity system served as the unit of analysis. The central concept in Activity Theory is the activity system, which refers to the complex and interconnected system of activities, tools, and social relationships people engage in to accomplish a specific goal (Engeström & Sannino, 2020). The activity system in this study includes educators, the software, and the learners in teaching mathematics.

Analysing theme relationships and the use of AT not only improved data interpretation, but also ensured a comprehensive and triangulated examination of the educators' experiences using the Siyavula software to teach mathematics to learners with special educational needs.

3.8. Ethical considerations

While conducting scholarly research, it is of paramount importance to give due consideration to ethical implications. Ethical principles should not only guide the resolution of any ongoing research issues that may arise during qualitative research but also ensure that these resolutions align with the research objectives while safeguarding the rights and well-being of all research participants (Leedy & Ormrod, 2015).

Given the sensitive nature of the special needs' education environment, obtaining ethical approval was paramount. To uphold principles like voluntary participation, non-harm, anonymity, and confidentiality, and to ensure the absence of any risks to participants, this study diligently pursued approval from the Research Ethics Committee at the Faculty of Informatics and Design, Cape Peninsula University of Technology (CPUT) (see Appendix one). Data collection permission was also obtained from the selected special needs school (see Appendix two).

Vanclay et al. (2013) discuss ethical principles that apply when conducting social research, and the following ethical considerations have been used when gathering data:

i. Informed consent: before responses in the study were recorded, a form that delineates each participant's right to participate and right to withdraw.
ii. Voluntary participation: participation in the research was entirely voluntary, and they were informed that they could opt out at any time without repercussions.
iii. Harmlessness: participants were not harmed for participating in the research, as it did not require any experiments.
iv. Anonymity and confidentiality: participants' identity must be protected in a scientific study to defend their interests and integrity. The researcher treated all participants anonymously, and the participants' identities were not revealed.
v. Disclosure: before data collection, participants were provided with information about the study to help them decide whether to or not participate. The participants were given information about who was conducting the study, what the study's purpose was, and what outcomes were expected.

3.9. Summary

This chapter provided a comprehensive overview of the research methodology and design implemented in the study. It aimed to ensure the achievement of the study's objectives by clearly identifying the philosophical assumptions, research strategy, and methodology employed.

The thesis incorporated epistemological and ontological assumptions and is grounded in the interpretive approach. In addressing the research questions concerning educator experiences with the Siyavula software and its impact on learning, an exploratory qualitative research method employing an inductive approach was used.

A single-case study was selected as the research approach to investigate the user experience with the mathematics software, with a private special needs school in the Western Cape chosen as the case. Four mathematics educators were purposively selected as participants in the study, and data was gathered from them through semi-structured interviews.

Thematic analysis was employed to analyse the collected data, with the lens of Activity Theory serving as a framework for interpreting the data. Lastly, this chapter also discussed the ethical considerations that were crucial in guiding the research process.

CHAPTER FOUR

DATA ANALYSIS AND FINDINGS

4.1. Introduction

The analysis was conducted to achieve the study's aim to explore the affordances associated with the Siyavula software used for teaching mathematics to learners with special educational needs and to achieve the study objectives. The chapter is divided into three sections. An overview of the primary data analysis process is provided first. Secondly, the data is interpreted through the lens of Activity Theory, and lastly, the chapter is summarised.

4.2. Primary data analysis process overview

A special needs school in the Western Cape was selected as a case for this study. Data analysis was conducted to achieve the objectives of the study, which are:

- To explore the educators' experiences with the Siyavula software for teaching mathematics to learners with special educational needs.
- To understand how the software facilitates mathematics learning for learners with special educational needs.

The analysis process was conducted from an interpretive perspective to achieve these objectives.

In Chapter Three, Section 3.5.1, the criteria employed for selecting the interviewees are thoroughly addressed, while Section 3.6 provides a comprehensive account of the data collection process. To safeguard the anonymity and confidentiality of the participants, pseudonyms were adopted to represent them. This practice aligns with ethical standards in research, where the primary focus is understanding individuals' experiences and behaviours rather than divulging their identities. (Bos, 2020).

The four interviewees were assigned codenames for easy referencing during the analysis process. This was done for identification purposes and to protect the participants' identities. Page and line numbers were used to identify extracts from interviewees' responses. The following serves as an example of how the codes were employed for citations: G1P01:10: 274-279, meaning that the extract is from the first group interview, Participant One, on page 10 of the transcription document, and lines 274 to 279 of that page.

As previously outlined in Chapters One and Three, Activity Theory served as the guiding framework for the data analysis process. Based on the objectives of this study, the analysis focus was: (1) identifying how different components of the activity system model interact with one another and (2) how these interactions influence the experiences of educators in using the software for teaching mathematics.

The following section offers a comprehensive analysis and interpretation of emerging data from the semi-structured interviews and thematic analysis. The findings have been organised under specific themes based on the collected data.

4.2.1. Emerging themes

The themes were identified and subsequently analysed to explore potential relationships among them. By the (Adu, 2019a) recommendations, researchers can examine whether the themes exhibit causal, concurrent, chronological, exploratory, embedded, or overlapping relationships. This examination aids in determining the nature of the connections between the identified themes.

4.2.1.1. Research question 1: emerging themes and relationships

This section explores the relationship between various themes connected to the first research question: what are the experiences of educators when using the Siyavula software for teaching mathematics to learners with special educational needs? The emerging themes include technical challenges, ease of use, teaching and usage background, progress tracking, and learners' feedback. Table 4.1 presents the theme characteristics and the codes associated with each theme, with Figure 4.1 presenting the empirical evidence connected to each code. A detailed analysis of the observed indicators aims to uncover the nature of these relationships and gain insights into how these themes intersect and influence each other.

Table 4.1: Research question one: emerging themes and connected codes

Themes	Characteristics	Codes connected to the theme	Example empirical indicator
Technical Challenges	The theme encompasses the challenges that educators encounter when using the software. It focuses on identifying and understanding specific technical difficulties that are faced when using Siyavula.	• Issues with software • Lack of adequate support	"…for me the challenge is for me being a new user to Siyavula. It's kind of, it's not as user-friendly as one would expect in terms of navigating the site…" (G2P02:4:123-124)
Ease of use	The theme looks at how educators navigate and use the features and functionalities of the software.	• Comparison with other software • Ease of Use • Internet reliance • Content coverage	"…I particularly like it because I can use it. You know, there's some programmes that I'm pretty useless at manoeuvring through, but this is very easy, pretty intuitive…" (G1P02:3:81-82)
Progress tracking	The theme encompasses the educators' use of the software for assessing and tracking learners' progress.	• Monitoring learner progress	"…Mm, and it's helped me like that because then I can also hone in on specific problems that the learners have and remedy that because you know they will say I don't understand this particular section, whereas normally they'll be like I don't understand anything and you have to start at 1+1, but it's like that because they can now pinpoint where their weaker areas are…"(G2P02:3:89-92)
Teaching and Usage Background	The theme includes educators' teaching and usage background in terms of using the software to teach mathematics.	• Software usage experience • Teaching experience	"…So, I've been teaching math for the last 25 years and have been using Siyavula over the last five to six years…" (G1P01:1:24-25)
Learner perception	The theme focuses on understanding how learners perceive the software	• Learner feedback	"…the "are you sure" little feature, because I asked the kids, I got the kids just to tell me what they liked and disliked about the programme, and that was the first thing they said they liked, they liked that second stab of "are you sure" feature…" (G1P02:3:86-88)

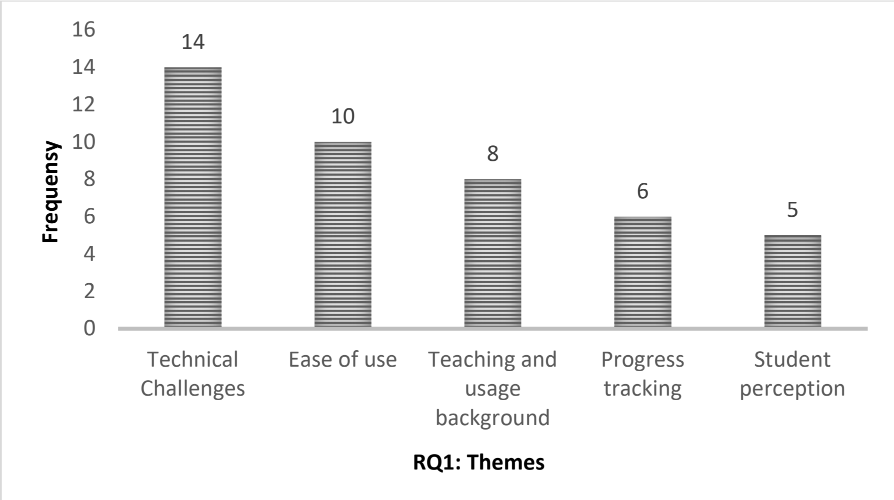

Figure 4.1: RQ1- number of excerpts per theme

The empirical indicators indicated more technical challenges (table 4.2) experienced with the software than the other themes. Although there were more technical challenges and experiences, this theme is closely followed by the theme "ease of use." This indicates that the educators also experienced several positive aspects when using Siyavula.

Table 4.2: The Positive and challenging aspects of Siyavula

Positive experiences	**Challenges with software**
• The "Are you sure" feature offers learners a second chance to get answers right. • The software is intuitive and user-friendly. • It is easy to navigate. • Save time when preparing lessons. • Accessible on various devices • Offers downloading options to do exercises offline. • Covers the curriculum. • Progress tracking feature allows the tracking of learner progress	• Repetitive • Complicated entry type methods • Glitches with learners getting stars and advancing to the next level. • Not intuitive • Does not allow creativity. • Issues with getting support via the help option. • Overwhelming learning content as all topics are presented at once. • Does not allow viewing of previous sessions. • Has a lot of tabs. • Not user-friendly in terms of navigation. • No training support for new educators.

The relationship analysis among the themes revealed various patterns. Firstly, the relationship between technical challenges and ease of use is concurrent, with empirical indicators showing that both themes were experienced simultaneously. Furthermore, within these themes, the codes demonstrate a causal relationship (figure 4.2), with technical challenges impacting educators' perceptions of ease of use.

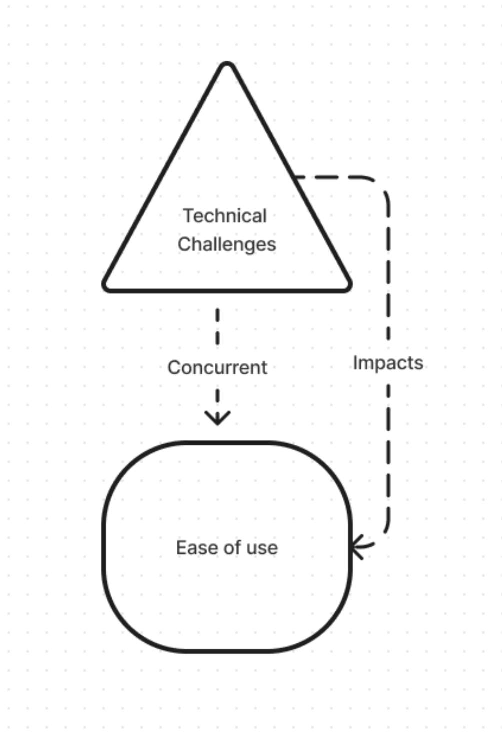

Figure 4.2: Concurrent and causal relationship between concepts

The relationship between technical challenges and the theme of teaching and usage background is found to be explanatory (figure 4.3). Educators' years of teaching experience and familiarity with Siyavula contribute to their encounters with technical challenges or ability to navigate the software effectively. However, the relationship between ease of use and teaching and usage background is concurrent (figure 4.3). The excerpts highlight how educators' years of teaching experience and adoption of Siyavula can influence their perceptions of the software's ease of use.

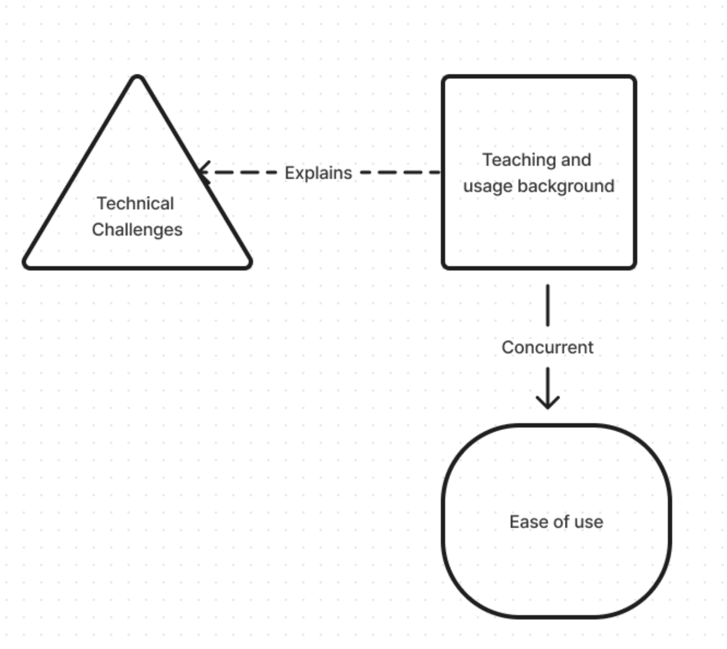

Figure 4.3: Explanatory and concurrent relationship between concepts

While there is no meaningful relationship between technical challenges and progress tracking, a causal relationship is identified between ease of use and progress tracking. The user-friendly nature of Siyavula enhances educators' ability to navigate and access the progress-tracking feature, thereby contributing to their positive perceptions of the software's effectiveness. Educators' teaching and usage background and progress-tracking features coexist concurrently. Educators appreciate the ability to monitor learner progress, such as tracking assignments and checking the leaderboard, aligning with their interest in understanding learner motivation and engagement.

Insights into learners' experiences with the software were gained through their feedback to the educators. These insights revealed an explanatory relationship between learners' perception theme and technical challenge's theme. Learners shared their perspectives on the software, including finding it daunting and facing challenges in navigation, which helped in understanding the specific technical difficulties encountered.

Learners also provided valuable feedback regarding the ease of use of the software. Both educators and learners appreciate features like the "Are you sure" prompt, which positively impacted their overall experience with the software. This feedback reinforced the educator's perception of the software's user-friendly nature. An embedded relationship (figure 4.4) between the learner perception theme and the teaching and usage background theme is revealed. By effectively using the software, educators found that it influenced perceptions, shaping their feedback and facilitating a more tailored approach to teaching mathematics to learners with special educational needs.

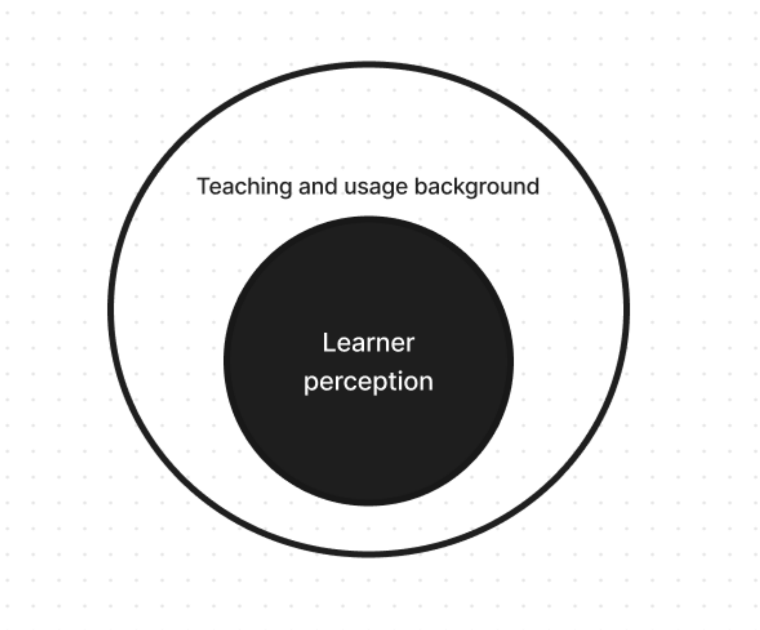

Figure 4.4: Embedded relationship between concepts

Lastly, a concurrent relationship exists between learners' feedback and progress tracking. The excerpts mention learners' improvement in accuracy and marks due to the dedicated usage of Siyavula, indicating that learners' feedback and progress tracking were aligned.

4.2.1.2. Research question 2: emerging themes and relationships

This section explores the relationship between various themes connected to the second research question: how does the Siyavula software facilitate mathematics learning for learners with special educational needs? The themes analysed include learning environment, assessment and feedback, customised learning experience, accessing tools, and limitations and suggestions. Table 4.2 presents the theme characteristics and the codes associated with each theme, and Figure 4.5 shows the empirical evidence connected to each code. Through an examination of the empirical evidence, the section investigates the connections and interactions among these themes, providing insights into the dynamics of the Siyavula software in facilitating mathematics learning for learners with special educational needs.

Table 4.3: Research question two: emerging themes and connected codes

Themes	Characteristics	Codes connected to the theme	Example empirical indicator
Learning environment	This theme encompasses how the software facilitates a conducive learning environment.	• Learner engagement • Supportive learning environment	"…So, for me, it's made my learners more engaged in the subject because it works on the confidence, and I think math is a confidence subject…" (G2P02:3:84-85)
Assessment and feedback	This theme highlights the importance of timely and targeted feedback.	• Assessment and feedback • Instant feedback	"…One of the benefits that I see is the instantaneous feedback…" (G1P01:2:56)
Customised learning experience	The theme focuses on the individualised aspects of learning facilitated by the Siyavula software.	• Flexible learning • Individualised assignments • Personalised learning	"…the advantage as well from my side, and one of the pluses is that actually you can use any device to connect to this program because it's web-based…" (G1P01:6:218-220)
Accessing tools	The theme looks at how users access the software for learning math. It examines various devices used to interact with the software.	• Learning tool • Technology used for accessing software	"…Luckily, because the school has constant Wi-Fi access, and all learners bring their devices to school every day…" (G2P01:2:41-42)
Limitations and suggestions	The theme highlights the shortcomings associated with the software in supporting mathematics learning for learners with SEN. It also includes the recommendations provided by educators to address these limitations and enhance the software's effectiveness.	• No support for differentiated learning • Software improvement suggestions	"…in order to support me, the software would need to allow me to amend some of the questions because I know the students that are in my class. So, if I was able to amend the questions and make them relatable to a specific child or, yeah, to make the questions more unique for each individual, then that would help…" (G2P01:6:198-201)

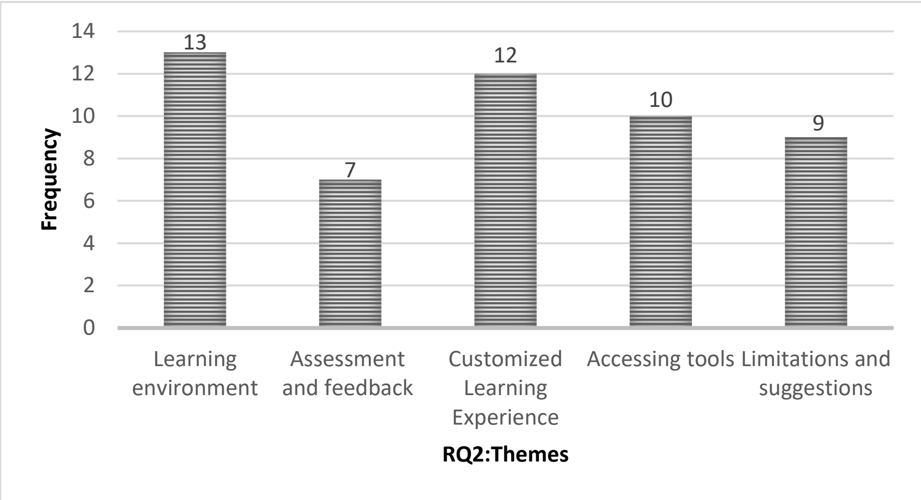

Figure 4.5: RQ2-number of excerpts per theme

The interview data has revealed two prominent themes that shed light on this matter. The first prevailing theme revolves around the learning environment provided by Siyavula. Empirical evidence indicates that learners experience a sense of empowerment when using the software. They show positive attitudes towards the subject of mathematics. The presence of achievement-based incentives such as stars and leaderboards serve as a motivating factor for learners.

Consequently, learners become more engaged in the learning process, fostering a sense of confidence in their mathematical abilities. Furthermore, Siyavula fosters a more interactive and collaborative environment between educators and learners. The competitive element introduced through the leaderboard encourages healthy competition among learners. Notably, the software also creates a stress-free learning environment where learners feel comfortable making mistakes, contributing to learning.

The second prevailing theme highlights Siyavula's ability to tailor the learning experience to individual learners. Siyavula's flexibility in accommodating various mathematical proficiency levels is a crucial feature. It allows educators to assign specific tasks to learners, ensuring their unique needs are met. Moreover, Siyavula offers a variety of questions suited to different skill levels within a given topic, thereby alleviating the anxiety often associated with learning mathematics in a traditional classroom setting. The accessibility of Siyavula from various devices makes it a useful tool, enabling learners to engage with mathematics at their convenience from any location.

The analysis of the themes reveals a significant relationship between them. The learning environment and customised learning experience themes demonstrate an overlapping relationship (figure 4.6), with Siyavula creating a positive learning environment that aligns with the customised learning experience offered by the software.

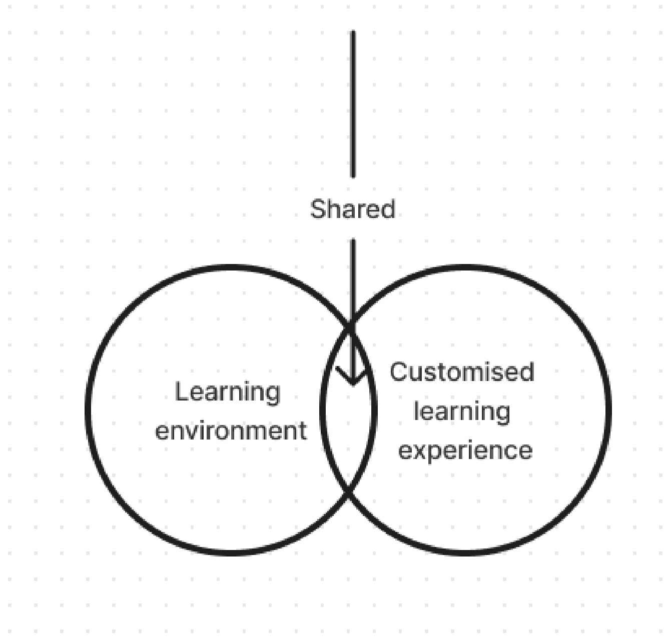

Figure 4.6: Overlapping relationship between concepts

The concurrent and overlapping nature of the themes is noticed in the relationship between the learning environment, customised learning experience, and access tools. The theme accessing tools emphasises using Siyavula as a tool for various learning purposes, including practice, homework, revision, and extension. It highlights the features and resources Siyavula provides, such as the practice tab, that support learning. This theme concurrently exists with the other two, as using Siyavula as a tool is integral to creating a supportive learning environment and delivering a customised learning experience. The excerpts also mention the devices used to access Siyavula and the reliance on internet connectivity, emphasising the practical aspect of accessing the necessary tools and technology to utilise Siyavula effectively.

Furthermore, the themes of learning environment, customised learning experience, and accessing tools are embedded within the theme of assessment and feedback. These interconnected themes contribute to the assessment process by fostering learner motivation, enabling tailored assessments, and providing tools for practice, instant feedback, and analysis. Effectively integrating these themes enhances the assessment and feedback process, improving the overall learning experience.

Lastly, the relationship between the limitations and suggestion's theme and the other themes is characterised as explanatory and concurrent. It highlights the identified shortcomings within the learning environment and customised learning experience, prompting suggestions for improvement. These suggestions include creating a more inclusive and supportive learning environment through differentiated instructional strategies, incorporating explanatory videos, improving the user interface, and providing additional guidance.

4.3. Data analysis with Activity Theory

Activity Theory was used as a theoretical framework to analyse the context of teaching mathematics in this study, which involves interactions among educators, the Siyavula software, and learners with special educational needs. This section aims to interpret the components of this study's activity system and explore its inherent dynamics and tensions.

4.3.1. Activity system components

As Figure 2.6 of Chapter 2 depicts, the activity system model comprises seven components: subject, object, tools, community, rules, division of labour and outcomes. The analysis process commenced by identifying the activity and its diverse elements within the activity system.

In this study, the activity refers to educators' collective efforts and interactions as they utilise the Siyavula software for teaching mathematics. This encompasses their use of the software features and resources, instructional practices, and learner interactions. The activity involves various actions such as planning and preparation, integrating the software into teaching, facilitating, guiding learners, and seeking support.

The subject plays the leading role in the activity system, representing the main actors involved (Engeström, 2015; Hasan & Kazlauskas, 2014). In the context of this study, the educators who use the Siyavula software to teach mathematics are the subjects and the primary focus of investigation as they drive the activity.

An activity is driven by the pursuit of an object, which signifies the goal or purpose of the activity (Kaptelinin, 2005). The present study aims to use the Siyavula software to teach mathematics to learners with special educational needs. Engeström (2015) emphasises the distinction between an activity's object and its outcomes. This study's desired outcome is the successful use of the software to facilitate mathematics learning for learners with special educational needs.

There is an interactive relationship between the activity, tools, and social context (Hasan & Kazlauskas, 2014). The movement within the system is mutually influenced by the means employed and impacted by the social context. It highlights the reciprocal relationship that reveals the dynamic nature of the activity system and the interplay among its components in shaping human behaviour and achieving goals (Adamides, 2023). In this study, the Siyavula software is a crucial tool as the research investigates the affordances associated with its use for teaching mathematics to learners with special educational needs. The data collected also revealed additional tools for effectively utilising the software, such as laptops, Chromebooks, and internet access. For instance, one participant mentioned using the internet and specific devices to access Siyavula.

"…So, the fact that the speed of the Internet has increased over the last five years meant that it's become more viable to use it in the classroom, and the device that I use is a Microsoft laptop, but the students are all on a Chromebook, and they access the Siyavula software via a Chromebook.…" (G1P01:1:25-28)

According to AT, the community refers to the individuals involved in the activity system who share common goals and interests (Hasan & Kazlauskas, 2014). This study's community component includes learners, parents, a software administrator, and Siyavula support personnel. Learners actively use the Siyavula software for practice, completing assigned homework, and acquiring mathematical knowledge and skills. Parents play a crucial role in supporting their children's education by monitoring their progress, offering encouragement, and ensuring the completion of assigned tasks (e.g., G1P02:7:238-242). The software administrator oversees the implementation and operation of the software. At the same time, the Siyavula support team provides technical assistance to educators and learners, addressing technical issues and ensuring optimal software functioning.

"…We can also, quite frequently, communicate with our parents as well. If we find that, you know, we suggest a certain amount of time the kids could spend every day, not being spent? Then we can go back to the parents and say, we did mention that in our comment. In a report comment, it doesn't seem as if our advice is being heeded. Maybe have a chat, have a chat with your child…" (G1P02:7:238-242)

The influence of the community on activities is facilitated through the establishment of rules, as indicated by Iyamu and Shaanika (2019). Furthermore, subjects involved in the activities are bound by these rules, as Iyamu (2020) noted. Explicit and implicit rules were observed from the data provided by participants. Detailed rules such as the "bring your own device" (BYOD) policy require learners to bring the prescribed Chromebooks. Restricting access to specific websites and apps is explicitly stated to ensure a safe learning environment. Additionally, using the software as a practice and homework tool is expressly mentioned, indicating that it is part of the expected instructional practice. Furthermore, the alignment of the software with the South African curriculum reinforces the expectation that it should be used to support the teaching and learning of mathematics following the prescribed curriculum.

Promoting learners' usage of the software as a practice tool for a designated duration is an implicit rule within the activity system, as the educators do not explicitly mention it. An illustration of these rules can be observed through the account of one of the participants, who highlighted the practice of learners bringing their devices to school and the encouragement for them to engage in a 10-minute practice session on Siyavula.

"…I'm able to use all the features that Siyavula has, but the one that I've been using the most is the practice tab, and I use it mostly as a homework tool. So, instead of giving questions from a textbook, I just asked them to do 10 minutes of practice on Siyavula, which is for all the grades 8 to 12.…" (G2P01:2:41-45)

Iyamu (2020) indicates that each participant assumes specific responsibilities and tasks in the activity system. The division of labour defines the allocation of duties, task distribution, and the organisation of roles and power hierarchies, as highlighted by Adamides (2023). The data collected in this study provides insights into the distinct roles and responsibilities of educators, learners, parents, school administration, school software administrators, and software support personnel within the activity system.

Educators hold responsibilities such as lesson planning and preparation, incorporating the Siyavula software into their teaching, facilitating learner engagement with the software, monitoring learner progress, and providing guidance. On the other hand, learners are expected to utilise the software as a practice tool, complete assigned homework, actively participate in classroom activities and share feedback on their experiences with the software. Parents play a vital role in supporting their children's education by encouraging the use of Siyavula software, ensuring task completion, and collaborating with educators to monitor and support their children's progress.

The school administration is responsible for ensuring the overall implementation and usage of Siyavula software within the school, ensuring that the school subscription is paid up to date, and providing general oversight of the software's integration and effectiveness. The school's software administrator's role and responsibilities encompass providing technical support to educators, learners, and the school administration, ensuring the software's functionality, addressing any arising technical issues, and coordinating with the Siyavula support team if necessary. Notably, the first participant in the initial interview also serves as the school's software administrator, as exemplified below:

"…Maybe just from a back-end point of view. So, as an administrator of the school with the Siyavula app, I get to make sure that the back end, so assigning kids into classes, getting the right code…" (G1P01:11:407-408)

The Siyavula support team plays a crucial role in assisting educators and learners by addressing technical challenges and ensuring the smooth operation of the software. During discussions about software challenges and how educators overcame them. One participant mentioned contacting Siyavula through the help option:

"…I've tried to go to Siyavula and asked them about it. I've encouraged the students to send, so there's a help option, so I've encouraged students to send or use the help option whenever they encounter the problems…" (G2P01:4:114-116)

Following identifying various components through empirical evidence, a conceptualised activity system (Figure 4.7) was developed to represent the components relevant to this study.

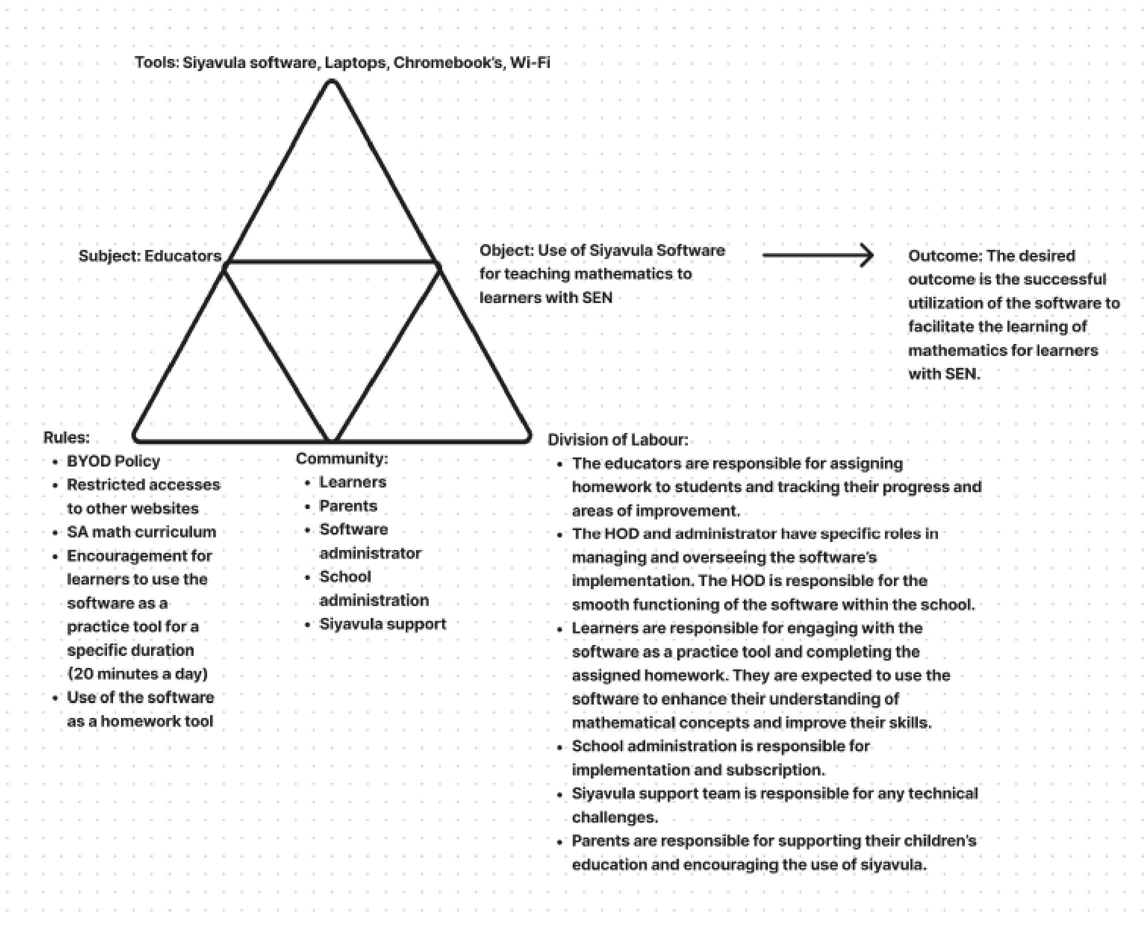

Figure 4.7: Conceptualised activity system

Identifying the components and understanding interdependencies among them provides insights into how the different parts of the activity system interact and influence each other, helping identify constraints and limitations. The following section will investigate the restrictions and limitations inherent within the recognised activity system.

4.3.2. Dynamics and tensions within the activity system

Engeström et al. (1999) identify four sources of tension within an activity system, namely primary, secondary, tertiary, and quaternary contradictions. These provide critical information for understanding the dynamics and tensions within an activity system (Hasan & Kazlauskas, 2014). This section will investigate the various levels of contradictions within the activity system of this study.

4.3.2.1. Examination of tools to understand challenges and tensions

This section will explore the tools used within the activity system by analysing their function, usability, and impact on the activity system. Analysing how tools facilitate or hinder the achievement of goals can reveal contradictions between the desired outcome and the constraints imposed by the tools used. The examination of the tools assists in understanding the core challenges and tensions in using the Siyavula software to facilitate mathematic learning for learners with special educational needs. To identify constraints and limitations associated with using the Siyavula software and other tools, excerpts from participants were examined. By examining the empirical evidence, insights would be gained into specific issues.

Based on the empirical evidence, the constraints and limitations identified include (figure 4.8):

i. New user difficulties: One participant mentioned that the Siyavula software was less user-friendly for new users, and they had to familiarise themselves with the navigation (G2P02:4:124-125).
ii. Complexity in the entry method for specific mathematical notations: Another participant highlights the complexity of the entry method, mentioning the need for using particular keys and symbols to input detailed mathematical notes (G1P02:5:176-178).
iii. Inability to review previous sessions or content: A participant stated that learners found checking old sessions or accessing previous content challenging, suggesting a limitation in the software's functionality (G1P02:5:1085-186).
iv. Overwhelming presentation of all topics and sub-chapters upfront: One participant points out that the upfront display of all the issues and sub-chapters for the entire year can be overwhelming for learners, especially those who already have a negative perception of mathematics (G1P01:4:148-156).
v. Limited options for customisation or personalisation: A participant mentioned that the software does not allow creativity for individual learners, suggesting a constraint in personalisation or customisation options (G2P01:6:200-203).

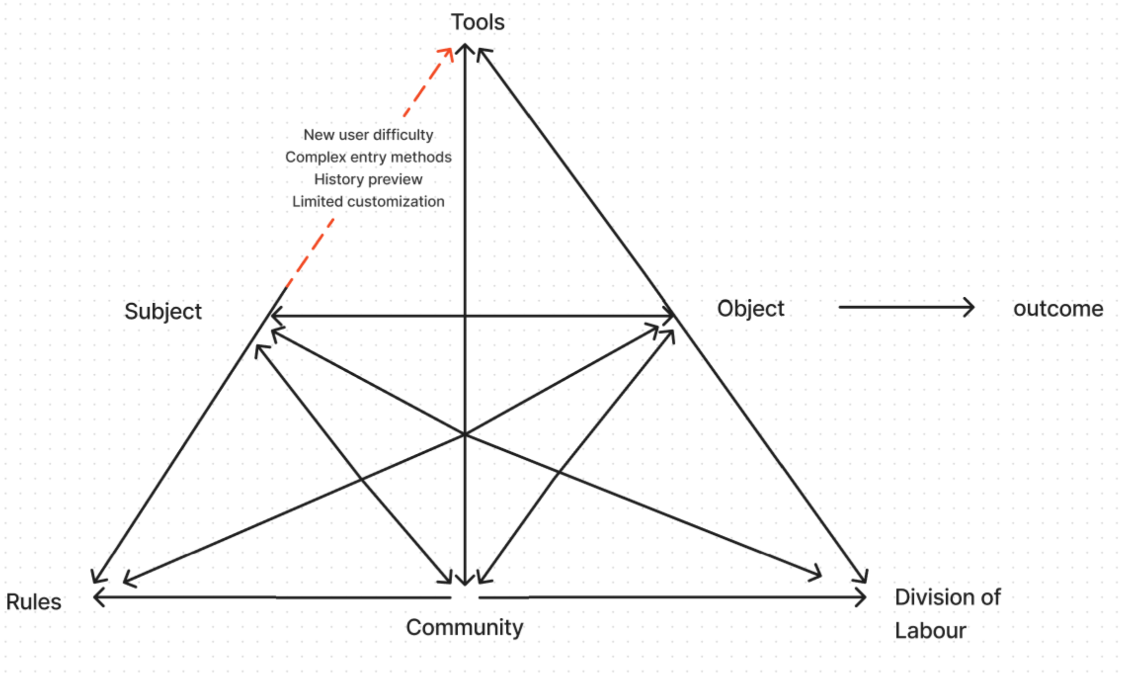

Figure 4.8: Primary contradiction level

Despite these limitations, there are also positive aspects such as intuitive navigation, timesaving, device compatibility, and comprehensive syllabus coverage. The constraints and limitations were then further examined and considered within the broader context of the activity system to understand their impact on the effective use of the software for teaching mathematics to learners with special educational needs.

The constraint relating to new user difficulties is interconnected with educators' roles and responsibilities within the activity system. Educators, as subjects, are expected to use the software effectively for teaching mathematics to learners. However, new user difficulties can hinder their ability to engage fully and benefit from the software, impacting their instructional practices and learner interactions.

The complexity of the entry method can impact how educators and learners interact with the software and use its features. It influences the ease of use and may require additional time or effort to input specific mathematical notations accurately, potentially affecting the flow of instructional activities.

The inability to review previous sessions or content restricts the ability of learners to revisit and consolidate their learning. It can hinder the progress of learners who may require reinforcement and revision of previously covered material.

The overwhelming presentation of all topics and sub-chapters upfront can impact the motivation and engagement of learners. It creates a sense of being overwhelmed and makes it challenging for them to focus and navigate through the material effectively.

The limited options for customisation or personalisation can impact the ability of educators to tailor the software to meet the diverse needs and learning styles of learners with special educational needs. It restricts their ability to adapt the software to individual learner requirements.

Challenges in receiving timely support are associated with the community component and the support provided by the Siyavula support team. Challenges in receiving timely support can hinder educators' ability to address technical issues or seek assistance when needed. This can lead to frustration and potential delays in resolving problems, impacting the effective utilisation of the software.

The observed contradictions and tensions may hinder the desired outcome of successfully using the software and facilitating mathematics learning for learners with special educational needs.

4.3.2.2. Analysis of interactions, communication, and rules

This section will examine the secondary-level contradiction by examining the nature and patterns of interaction and communication among participants within the activity system. Analysing the interactions and communication among participants will help uncover tensions within the activity system due to differing perspectives and interests. Furthermore, the section will analyse the rules and guidelines to identify conflicts or tensions arising from discrepancies between rules and actual practice within the activity system.

Effective communication and interaction among stakeholders contribute to a positive learning environment and the successful use of Siyavula for teaching mathematics to learners with special educational needs. Based on the empirical evidence, educators use Siyavula to give instruction and provide learner feedback. They analyse learner performance, identify areas of weakness, and use the software as a tool for revision and reinforcement. This interaction fosters learner engagement, motivation, and personalised learning. Additionally, the educators encourage learners to ask questions, inquire about concepts, and seek clarification, which promotes interactive learning and creates opportunities for deeper mathematical understanding. Furthermore, educators employ various strategies to engage learners and address their needs. They use software features such as personalised assignments, stars, leaderboards, as shown in the example below, and differentiated tasks to motivate and challenge learners.

"…the fact that there's a scoreboard, there's a leaderboard. They can rate themselves against their peers and see if they can. So, it's not just that, within inter-schools, you can rate yourself between other schools. There's an internal leaderboard amongst the students, and they can rank themselves within that leaderboard on things and work on that. So, it's not a punishment to say to them, go on to Siyavula, and now that you've finished your homework, spend some time on Siyavula because they're keen to climb that leaderboard…" (G1P01:7-8:268-274)

The communication and interaction between educators and parents happen through various channels, such as parent-educator meetings and progress reports. This interaction provides opportunities for educators to share information about learners' progress, address concerns, and involve parents in the education process. One participant mentions how they communicate and interact with parents.

"…we quite frequently communicate with our parents as well. If we find that, you know, we suggest a certain amount of time the kids could spend every day, not being spent? Then we can go back to the parents and say, we did mention that in our comment. In a report comment, it doesn't seem our advice is being heeded. Maybe have a chat, have a chat with your child…" (G1P02:7:238-242).

The interaction between educators, the software administrator, and the Siyavula support team helps resolve problems and improve the software experience for educators and learners. The effectiveness and responsiveness of Siyavula support play a crucial role in enhancing the overall user experience.

However, the participant, the school's software administrator, mentions challenges in navigating the backend system (figure 4.9), particularly in tasks such as assigning learners to classes or moving learners between groups.

"…If I want to move a kid from one class because we've, you've got different groups that we work with, so if I want to move a kid from one group to another group so that they can see that teachers' assignments and tasks. It's not intuitive in the sense of, OK, I click on the class, and I can move the kid. I've got to go; I still don't even know how to do it. I've got to find my way to, I know it's there, somewhere. To find out how to get to the kid, I've got to find the kid and then find them, move them, and tell them to the class. It's not; it's not something I can just go to the class, click on a kid, and go move. It's a bit of a rigmarole, and every time I have to move a kid it's like it takes me a minute more than it should…" (G1P01:11:415-422).

This indicates a constraint in terms of user-friendliness and efficiency in managing administrative tasks related to the software.

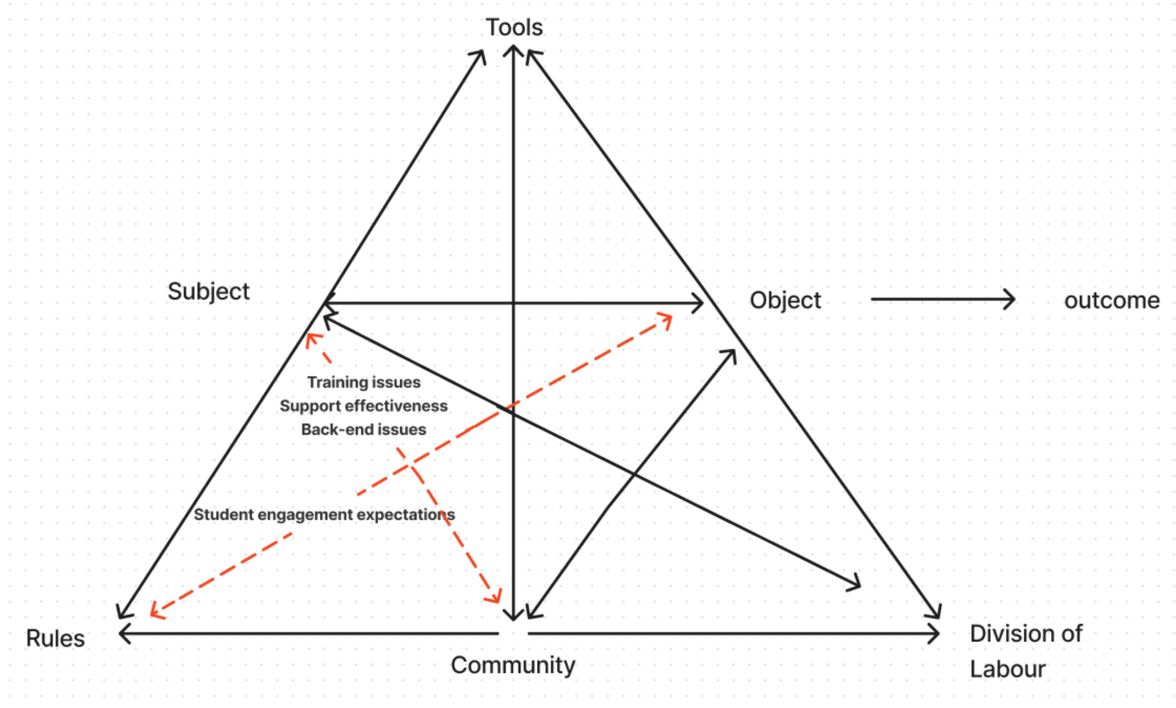

Figure 4.9: Secondary contradiction level

Constraints and tensions were identified when analysing the excerpts related to the interaction and communication between educators and Siyavula support (figure 4.9). Two participants mentioned not receiving training from Siyavula (G2P01 & P02:4-5:134-141). This indicates a constraint regarding educators' knowledge and skill in effectively using the software. While the excerpt below does not explicitly mention restrictions or tensions, the effectiveness of Siyavula's support in addressing educator concerns, providing timely assistance, and resolving technical issues could impact the overall experience.

"…So, that's the biggest challenge, the repetitive nature of the program, and they have bugs when it comes to the levelling up. I've tried to go to Siyavula, and I've asked them about it. I've encouraged the students to send, so there's a help option, so I've encouraged students to send or use the help option whenever they encounter problems. There's not much that you can do as a teacher when there is an issue with Siyavula. I've tried to approach them, and they also can only do so much every year. Also, because I use it for homework, I only find out about the issues the next day after spending hours trying to get to 3 or 4 stars…" (G2P02:4:111-118).

Delays or inadequacies in support may create frustrations or hinder the smooth utilisation of the software.

In addition to analysing the interactions and communication between participants, it is essential to consider the rules and guidelines that shape their behaviour and actions within the activity system. In the context of secondary contradiction analysis, the identified rules can be examined to determine conflicts or tensions arising from discrepancies between formal rules and actual practice within the activity system.

The software is integrated as a homework tool, suggesting an expectation of learner engagement outside the classroom. However, there might be challenges in ensuring consistent engagement with the software, leading to tension between the intended use of the software and learners' actual level of engagement. Furthermore, educators' encouragement to learners to use the software for a designated duration creates a conflict between promoting standardised software usage and accommodating individual learning requirements. Despite the alignment of the software with the South African mathematics curriculum, there is a recognised need for customisation to address the unique needs of individual learners effectively.

4.3.2.3. Analysis of roles and responsibilities

The previous section investigated the secondary contradiction level by examining the tensions that may arise due to differing perspectives and interests from the interaction and communication of participants in the activity system. It also looked at tensions that may arise from discrepancies between the rules and actual practice. This section will investigate the tertiary contradiction level by analysing the roles and responsibilities of different participants within the activity system.

The analysis began by identifying all the participants in the activity system and defining their roles and responsibilities. Role distribution was examined by looking for disparities in roles and decision-making authority distribution. Then, the defined roles were compared with actual performance to identify gaps and ambiguities or conflicts arising from the gaps.

As stated in section 4.3.1, the participants have various roles within the activity system. Educators are responsible for lesson planning and preparation, incorporating the Siyavula software into their teaching, facilitating learner engagement with the software, monitoring learner progress, and providing guidance. Learners use the software as a practice tool, complete assigned homework, actively participate in classroom activities and share feedback on their experiences with the software.

The school's software administrator provides technical support to educators and learners, ensuring the software's functionality, addressing any arising technical issues, and coordinating with the Siyavula support team if necessary. The school administration is responsible for ensuring the overall implementation and usage of the software within the school, ensuring that the school subscription is paid up to date, and providing general oversight of the software's integration and effectiveness.

The Siyavula support team is responsible for assisting educators and learners by addressing technical challenges and ensuring the smooth operation of the software. Parents are responsible for supporting their children's education by encouraging the use of the software, providing task completion, and collaborating with educators to monitor and support their child's progress.

Examining role distribution reveals that one of the educators holds multiple roles as the Head of the Senior phase, a mathematics educator in the senior grade, and the school's software administrator. This situation suggests a concentration of roles and responsibilities on a single individual.

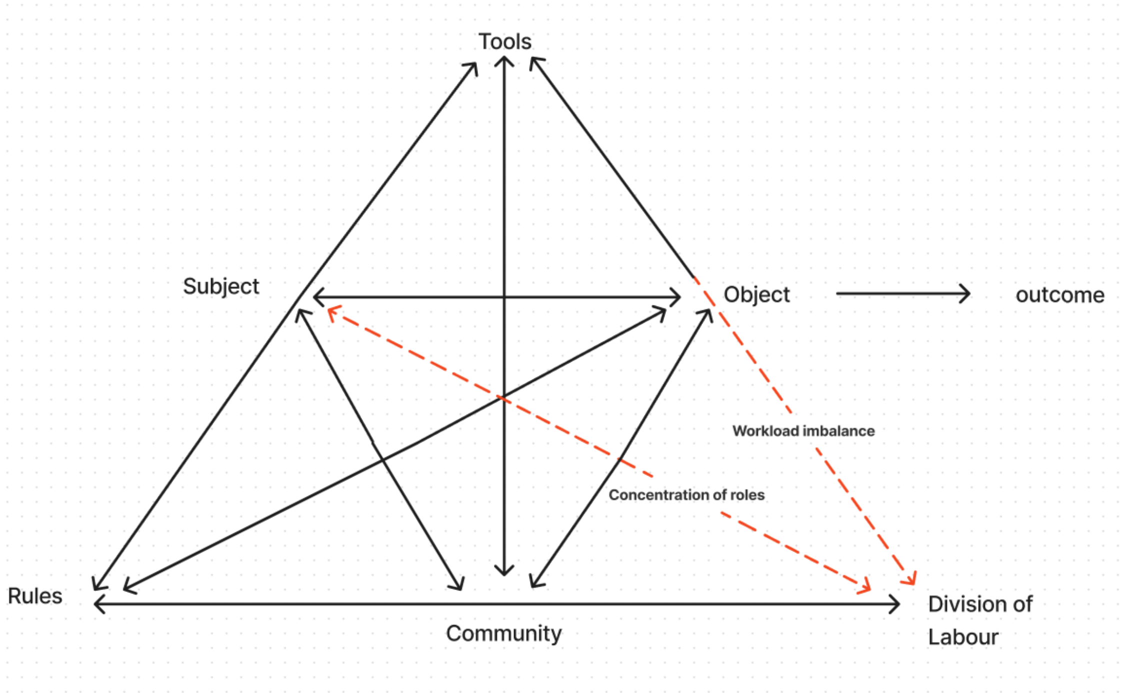

Figure 4.10: Tertiary contradiction level

The analysis of the distribution of decision-making authority shows that as the primary users of the Siyavula software in their teaching, educators have decision-making authority regarding how they incorporate the software into their lessons, which resources to use, and how to monitor learner progress using the software. The educator, the Head of the Senior phase, and the school's administration hold decision-making authority related to the overall implementation of the software. This includes decisions on the school's subscription, budget allocation for the software, and coordination of resources for effective integration.

Looking at the distribution of roles and decision-making authority, there could be a workload imbalance experienced by the educator with multiple functions. This can be a significant gap which can impact their ability to fully engage with and use the software, hindering the achievement of the expected outcome. There might be a gap between the expectations of the school and the decision-making authority given by educators.

4.3.2.4. External technological factors that may impact the activity system

The previous section focused on analysing the tertiary contradiction level by looking at the roles and responsibilities of different participants within the activity system. To further explore the contradictions within the activity system, this section investigates the quaternary contradiction level by examining external technological factors likely to impact the activity system.

Siyavula incorporates adaptive technology, data analytics, and personalised feedback. These technological factors contribute to a personalised, mastery-based learning experience for learners while providing valuable insights and support for educators in monitoring and addressing individual performance.

Based on the excerpts, various external technological factors are likely to impact the activity system facilitated by the software for mathematics. The participants mentioned using laptops and Chromebooks to access Siyavula.

"…So, I've been teaching math for the last 25 years and have been using Siyavula over the last five to six years, obviously very reliant on the fact that the Internet is used. So, the fact that the speed of the Internet has increased over the last five years means that it's become more viable to use in the classroom. The device that I use is a Microsoft laptop, but the students are all on a Chromebook, and they access the Siyavula software via a Chromebook…" (G1P01:1:24-28).

The availability of reliable internet connectivity through constant Wi-Fi access is crucial for accessing and using the Siyavula software. Technological factors related to internet connectivity and network infrastructure influence the accessibility and usage of Siyavula.

Participants expressed a desire for the software to be more user-friendly and easier to navigate.

"…how it can improve itself on the teacher end of the things if it was more user friendly and I could navigate the site from the get-go. I mean, when there's like prompts that could help us, that would be great, but unfortunately, that does not happen…" (G2P02:7:213-216).

Technological factors related to the software's interface design, intuitiveness, and usability play a significant role in shaping the experience of both educators and learners. Improved prompts, clear instructions, and intuitive navigation can enhance user experience and reduce frustration.

Participants suggest the inclusion of step-by-step explanatory videos within the software.

"…I think for the lower, for the kids that are struggling, I think if they stuck videos into their explanations. Videos that go step by step, because it's one thing to have it written and you've gotta, you've got to follow their style but to have someone explain the steps. So, their steps are there; this is how I got the answer, but if you still don't see it, have someone talk through their thinking behind why they're doing what they're doing. So, a video link where you can click on the video and someone to walk you through the problem in math, talking us through why am I doing this, why am I doing that, to get to the answer, I think that would be beneficial for those that struggle with math…" (G1P01:10:366-373)

This technological factor can provide an additional resource for learners, especially those struggling to understand written explanations. Video-based explanations can enhance comprehension and provide visual and auditory guidance to support learning.

Participants expressed a need for customisation within the software. They suggest the ability to amend or make questions more relatable to individual learners.

"…In order to support me, the software would need to allow me to amend some of the questions because I know the students that are in my class. So, if I was able to amend the questions and make them relatable to a specific child or, yeah, to make the questions more unique for each individual, then that would help…" (G2P01:6:198-201).

Technological factors that enable customisation, adaptive features, and the ability to tailor content to individual needs can enhance engagement, motivation, and personalisation within the activity system.

Analysing these external technological factors reveals potential tensions and contradictions within the activity system. While participants mention accessing Siyavula through laptops and Chromebooks, it is essential to consider the potential limitations of these devices. The software's compatibility and performance on different devices may create tensions for users with varying access capabilities.

The desire for a more user-friendly interface and improved navigation suggests a contradiction between the software's intended ease of use and users' challenges in effectively using the platform. This contradiction can impact user satisfaction and adoption. Participants highlight the need for explanatory videos to cater to different learning styles. The absence of video-based explanations may create tensions for learners who struggle with written reasons and impede their understanding of mathematical concepts.

The external technological factors discussed can exacerbate and mitigate existing contradictions within the system. Inadequate internet connectivity, network infrastructure, unintuitive interfaces, and the absence of video-based explanations may exacerbate existing tensions within the activity system, hindering compelling learning experiences and impeding the achievement of learning goals. However, Siyavula's web-based nature allows it to be accessed from any device that can connect to the internet, which mitigates these accessibility concerns. Improvements in user interface design and the integration of explanatory videos can mitigate existing tensions, enhancing usability, engagement, and understanding within the activity system.

4.4. Summary

This chapter presented the findings from the interview data. Themes related to the two research questions were analysed to understand how they intersect and influence each other. Themes related to the research question on the experiences of educators with the software exhibit concurrent, causal, explanatory, and embedded relationships. This suggests that specific themes directly influence or explain others, interwoven with the context of educators' experiences with the software.

Themes associated with the second research question on how the software facilitates learning demonstrate overlapping, concurrent, embedded, and explanatory relationships. This indicates that the themes are interconnected, with overlapping aspects and concurrent influences on each other. Furthermore, specific themes serve as explanatory factors, providing insights into learning facilitation within this study's context.

The lens of Activity Theory further provided insights into various dynamics and tensions within the activity system. Applying the theory enabled the identification of how different elements and stakeholders interact and influence each other, shedding light on the complexities and nuances of the research questions.

CHAPTER FIVE

INTERPRETATION OF FINDINGS

5.1. Introduction

Based on the study's overarching goal and specific objectives, the primary emphasis lies in investigating the affordances associated with the Siyavula software, particularly its role in teaching mathematics to learners with specific learning difficulties. The focus is on exploring the software's effectiveness, usability, and impact on teaching and learning outcomes for learners with special educational needs.

This chapter, therefore, focuses on discussing the findings presented in Chapter Four. This chapter is organised into four sections. The first and second sections discuss the results of the two research questions. The third section interprets the findings through the lens of Activity Theory. The fourth section concludes the study, limitations and recommendations are also presented.

5.2. Educator experiences: discussion of finding

In pursuit of understanding educator experiences with the Siyavula software for teaching mathematics to learners with special educational needs, the study revealed various positive and challenging aspects.

5.2.1. Positive aspects of Siyavula

Educators found the progress tracking feature most engaging. The quality is helping educators gain insights into their learners' performance in mathematics. Assessing learner progress is a fundamental aspect of education that helps educators and learners. It helps ensure learners receive the support they need to succeed while enabling educators to adapt their teaching strategies to maximise learning outcomes. This resonates with Chelkowski et al. (2019) finding that mobile technology within special needs education allows educators to monitor learner progress.

The "Are you sure" feature was also highlighted as engaging. This feature allows learners to review and correct their answers before finalising them. The finding aligns with the research of Papadakis (2021), Yasin et al. (2022), and Razami et al. (2022). These studies emphasise the importance of error feedback in the user experience (UX) evaluation of educational applications. Offering learners feedback on calculation errors enhances the usability and effectiveness of the software.

Educators have evaluated the software's interface positively, finding it intuitive, user-friendly, engaging, and easy to navigate. This suggests the software's design has created a positive educator user experience. The finding is consistent with previous research conducted by Wang et al. (2021) and Kohnke (2020). These studies emphasised the importance of usability in educational applications, and the positive evaluation of the software's interface aligns with this emphasis.

The software's ability to save time in lesson preparation was valuable for educators. The finding underscores the importance of educational technology in supporting educators in their daily responsibilities. It acknowledges that well-designed software can be helpful for educators, helping them be more effective in their roles. This finding aligns with previous research conducted by Hussain et al. (2020) and Chelkowski et al. (2019), both acknowledged the significance of learning applications in supporting educators with lesson preparation and planning.

Furthermore, the software's alignment with the curriculum was found to be a vital element. This finding is consistent with the observations made by Wang et al. (2021), which emphasised the significance of subject-aspect coverage in educational applications. Curriculum alignment assures that the software is high quality and meets set academic standards and goals, thus contributing to learning outcomes. When educational software aligns with the curriculum, it can provide learners with a seamless and coherent learning experience, as it complements what is being taught in the classroom (Chelkowski et al., 2019).

5.2.2. Challenging aspects of Siyavula

Educators have expressed concerns about the presence of content repetition. This finding is consistent with the research conducted by Mohamad and Hashim (2021), which also highlighted the potential drawbacks of excessive content repetition. The alignment with their findings reinforces that content repetition can be problematic, particularly for specific groups of learners, such as learners with special educational needs. It can lead to disengagement, frustration, or a lack of intellectual stimulation. While some repetition can be valuable for reinforcing key concepts, it is essential to strike a balance to avoid overloading learners with redundant information.

Educators mentioned challenges related to complex input methods when answering some questions. Complex input methods can create more cognitive load and task difficulty, especially for learners with special needs who may already face learning challenges. This complexity can lead to longer task completion times as users navigate the technology. The finding by Pitchford et al. (2018) that learners with special needs take longer to complete tasks is consistent with the idea that complex input methods can slow down the interaction process.

Glitches experienced with the star-rewarding feature were noted. These glitches have had a direct impact on the levelling-up process. The presence of glitches affecting this process suggests that users face obstacles in advancing through the educational content, representing a failure in error prevention. Nielsen (2012) emphasises the importance of designing systems that prevent errors whenever possible. Technical glitches can impede learning and negatively affect user engagement and motivation.

The overwhelming amount of learning content was identified as a challenge. This can lead to cognitive overload for educators and learners, affecting the effectiveness of the software. Additionally, the presence of too many tabs was mentioned. A cluttered user interface can impede user navigation and hinder the software's usability. Nedeltcheva and Shoikova (2017) highlighted the importance for designers to design interfaces that are functional, intuitive, visually appealing, and aligned with user needs and expectations. Furthermore, new users found the software not user-friendly regarding navigation, highlighting the impediment caused by a cluttered user interface.

Educators mentioned that learners were not able to review previous sessions. This is essential for tracking progress and helping learners identify areas needing attention, just as the progress tracking feature helps educators track learner progress. Allowing learners to track their progress would increase ownership of learning and motivation.

Educators have expressed a need for comprehensive technical support. This finding aligns with the observations by Hussain et al. (2020), who noted challenges related to technical support when using mobile learning applications in developing countries. Inadequate technical support can negatively affect the user experience of educators.

The software restricted users' ability to customise questions, limiting flexibility in shaping content according to learners' unique needs. This limitation aligns with the insights provided by Papadakis (2021) and Zhang et al. (2015), emphasising the importance of personalisation and customisation for tailored learning experiences. Tailoring the learning experience to individual preferences and learning styles can enhance engagement and learning outcomes.

5.2.3. Significance of the theme relationships

The study unveiled significant relationships between the themes that emerged from the data. A concurrent relationship between the themes "technical challenges" and "ease of use" suggests that the educators simultaneously experienced the positive and challenging aspects. The educators' teaching background and Siyavula usage clarified the educators' perspectives on the software. They highlight an explanatory relationship between the two themes.

The feature that educators found most engaging, progress tracking, assisted with understanding learners' mathematical capabilities. This highlighted a causal relationship between the themes "progress tracking" and "ease of use", contributing to the educators' positive perceptions regarding the software. The "Are you sure" feature also reinforced the positive perceptions about the software's user-friendliness.

In conclusion, these insights suggest that enhancing personalisation, reducing content repetition and overload, and providing robust technical support can improve the usability and effectiveness of Siyavula for learners with special educational needs, enhancing the teaching and learning experience. This bridges the gap between mobile technology and special education, offering valuable insights on aspects developers should consider when creating learning applications for learners with special educational needs.

5.3. Facilitation of learning: discussion of findings

The empirical evidence gathered in the study suggests that the Siyavula software does play a significant role in facilitating mathematics learning for learners with special educational needs.

The data revealed a positive correlation between the time spent practising math on Siyavula and improved learning outcomes. This aligns with the findings of Zhang et al. (2015), which demonstrated performance improvements when learners spent specific durations using educational applications.

Educators in the study use the software as both a practice and a homework tool. This approach aids learners in understanding mathematical concepts, echoing the observations by several authors, such as Fabian et al. (2018), Benavides-Verela et al. (2020), Roberts (2021), and Hwang et al. 2021), that mobile technologies improve mathematics achievement.

Siyavula offers a motivating and engaging learning environment that boosts learners' confidence and fosters a positive attitude toward mathematics. This aligns with the insights of authors such as Criollo-C et al. (2021), Shahrol et al. (2020), Fabian and Topping (2019), and Pitchford et al. (2019), who found that learning through mobile technologies creates an enjoyable, motivating, and engaging learning environment.

Siyavula's curriculum coverage facilitates contextual learning, allowing learners to connect mathematical concepts to real-world applications, an idea supported by Fabian (2019). Additionally, the question bank provided by Siyavula empowers educators to select questions of varying difficulty levels, providing learners with a customised learning experience. This is consistent with the idea that individualised exercises are practical, as noted by Chelkowski et al. (2019). Furthermore, Siyavula's accessibility on various devices and the option to download activities make learning flexible, enabling learners to learn anytime and anywhere. This finding aligns with Ustun (2019) regarding the effectiveness of integrating mobile learning.

Educators suggested that to be effective in supporting learners with special educational needs, Siyavula should provide differentiated instructional strategies, incorporate explanatory videos, improve the interface (referring to overwhelming content and the many tabs), provide additional guidance for the learners, and allow educators the opportunity to customise exercises. These suggestions resonate with Zhang et al. (2015) and Benavides-Verela et al. (2020).

These findings offer practical implications for educators and developers. They highlight the potential of Siyavula as a valuable tool for enhancing mathematics learning for learners with special educational needs. Educators can use Siyavula to provide personalised and engaging learning experiences. Developers should consider customisation features and gamification elements to improve the software's effectiveness.

5.3.1. Significance of the themes

The themes that emerged for the facilitation of learning to hold substantial significance in understanding how the Siyavula software facilitates mathematics learning for learners with special educational needs. The overlapping relationship between the themes " learning environment: and "customised learning experience" signifies that Siyavula provides a learning environment conducive to personalised and individualised learning experiences. This combination fosters an atmosphere where learners with varying learning needs can thrive.

The concurrent relationship between the theme's learning environment, customised learning environment, and accessing tools highlights that Siyavula leverages tools to facilitate learning. This means that the software creates an engaging learning environment and provides the necessary resources for learners to excel.

Embedding the theme assessment and feedback with the learning environment and customised learning experience themes highlights the importance of timely and targeted feedback. Siyavula's ability to offer such feedback aligns with modern pedagogical approaches and is essential for learner progress.

The explanatory and concurrent relationship between the theme "limitations and suggestions" and the other themes highlights that while Siyavula has its strengths, it is not without shortcomings. Educators' suggestions provide valuable insights into areas of improvement, which can lead to more effective support for learners with special educational needs.

These relationships demonstrate the interconnectedness of these themes, emphasising that Siyavula's success in facilitating mathematics learning for learners with special educational needs relies on creating a motivating, engaging, and customisable learning environment supported by timely feedback. The significance lies in recognising that addressing these aspects can lead to more inclusive and effective educational technology for learners with diverse learning needs.

5.4. Activity Theory: discussion of findings

This section delves into the interpretation of the findings through the lens of Activity Theory. The study examined the challenges and dynamics surrounding using the Siyavula software in mathematics education for learners with special educational needs.

The study primarily focuses on educators utilising the Siyavula software to teach mathematics, shedding light on their role in driving the educational activity system. This activity is driven by the pursuit of a clear objective: using the Siyavula software as an effective tool to facilitate mathematics learning for learners with special educational needs. Within this activity system, I identified various components, each uniquely shaping the educational experience. These components include the subjects (educators), the object (use of Siyavula for mathematics education), tools (Siyavula software, laptops, Chromebooks, and internet access), rules (course design, teaching strategies, usage guidelines), community (learners, parents, administrators, support teams), and the division of labour among stakeholders.

Activity Theory helped in highlighting specific dynamics and tensions within the activity system. At the primary contradiction level, the analysis identified five constraints and limitations in using Siyavula software, which can hinder the achievement of the desired outcome. Educators, as subjects, face navigation challenges when they are new users of the Siyavula software, which contradicts the intended user-friendliness of the interface. The study by Tan et al. (2021) highlighted a similar contradiction when exploring a peer tutoring system using AT. To address the contradiction of new user difficulties, educators must provide comprehensive training and ongoing support to ensure a smooth transition into using the software effectively.

Educators mention that learners experience difficulty entering specific mathematical notations, affecting a smooth workflow. Improvements in the software's interface design, including more explicit instructions and intuitive navigation, can mitigate the contradiction related to complex entry methods and improve user satisfaction. Additionally, the inability to review previous sessions and the overwhelming upfront display of topics and sub-topics impact the ability of learners to focus, creating anxiety. This can affect their motivation and engagement.

Furthermore, limited options for customisation within the software contrast with the diverse needs and learning styles of learners with special educational needs. Enhancing customisation options within the software can help meet the diverse needs of learners with special educational needs, aligning with the desired personalisation. Tailoring technology to meet the diverse needs of learners with disabilities has been emphasised in literature (Tlili et al., 2022).

These contradictions highlight the concurrent relationship between themes. The identified constraints and limitations demonstrate how different aspects of educator experiences and the learners’ learning experiences are interconnected and influence each other simultaneously. It also highlights the causal relationship between themes, shedding light on the cause-and-effect dynamic that affects educator experiences.

The secondary contradiction level analysis focused on interactions and communication among activity system participants. Effective communication and interaction among stakeholders, such as educators, learners, parents, software support teams, and administrators, contribute to a positive learning environment and successful software use. Educator-learner interactions with the software showed that it promoted engagement, motivation, and personalised learning. This finding highlights the overlapping relationship between the learning environment and customised learning experiences. Furthermore, interactions between educators and parents and the software support teams provide collaboration, progress monitoring, and problem-solving opportunities.

Challenges in receiving timely support can hinder the activity system's effectiveness. Tan et al.'s (2021) study on a mobile peer tutoring application revealed that effective communication within an educational technology system is vital for productive interactions. Ensuring timely support services for technical issues is crucial to maintaining effective communication and exchange within the activity system.

The analysis identified potential imbalances in role distribution and decision-making authority, such as being the head of the senior phase, senior mathematics educator, and school software administrator. Educators' multiple roles can lead to a workload imbalance, potentially affecting their ability to engage with and use the software entirely. The explanatory relationship between "Teaching Background" and "Siyavula Usage" highlights how educators' roles and backgrounds can influence their perspectives and decision-making within the system. Addressing the workload imbalance for educators with multiple functions can contribute to their full engagement with the software, benefiting both educators and learners. Lin et al. (2020) emphasised the importance of creating conducive facilitation processes and guidelines to support educators in their roles.

Furthermore, Educators have decision-making authority, but there may be a gap between school expectations and educators' decision-making authority. Bridging the gap between school expectations and educator decision-making authority is vital for effectively implementing the software within the educational context. The study by Tan et al. (2021) highlighted the importance of aligning educational technology systems with the expectations and needs of users. Ensuring that educators have a say in the decision-making process aligns with the findings of their study.

Finally, external technological factors were considered at the quaternary contradiction level. User interface design, explanatory videos, and customisation options were identified as potential sources of system tension. User interface design issues may hinder the software's practical use, while including explanatory videos and customisation features can enhance user experience and engagement. This suggests that addressing these factors can have a broad impact on the overall activity system, as indicated by the concurrent relationships between "Learning Environment," "Customized Learning Experience," and "Accessing Tools."

Activity Theory provided a structured lens to understand the dynamics and contradictions within the educational activity system related to using Siyavula software in mathematics education for learners with special educational needs. It helped highlight the interconnectedness of themes, identify areas for improvement, and recognise the implications of addressing these aspects on the overall effectiveness of the technology in supporting diverse learners. This comprehensive analysis offers valuable insights for researchers and practitioners in special education and educational technology.

5.5. Conclusion

In conclusion, this section reviews the study by focusing on how the objectives were met. Furthermore, the study's contributions to the existing body of knowledge and significant stakeholders and its limitations and recommendations for future research are examined.

This study set out to explore the affordances associated with the Siyavula software in the context of teaching mathematics to learners with special educational needs. The empirical evidence has shed light on the multifaceted nature of the Siyavula software and its impact on educator experiences and learning facilitation. In doing so, the aim of the study has been successfully achieved by uncovering valuable insights that contribute to understanding Siyavula's potential in special education.

The study uncovered a range of educator experiences with the software in teaching mathematics to learners with special educational needs. These experiences encompassed positive and challenging aspects, highlighting the complexity of educator experiences when using Siyavula with learners with special educational needs. The findings emphasised the critical role of user-friendly design, progress monitoring, and curriculum alignment in creating positive experiences. Conversely, challenges such as content repetition, technical glitches, and the need for technical support must be addressed to enhance the software's usability and effectiveness.

The study also delved into how Siyavula facilitates learning, uncovering its potential to enhance mathematics education for learners with special educational needs. We found a positive correlation between the time spent practising mathematics on Siyavula and improved learning outcomes, emphasising the software's role in supporting learners' academic progress.

Educators' use of Siyavula as both a practice and homework tool was beneficial, aligning with research on the positive effects of mobile technologies in mathematics education. Siyavula's ability to create a motivating and engaging learning environment fostered a positive attitude toward mathematics among learners, echoing previous findings on mobile learning.

The software's coverage of the curriculum and provision of a question bank allowed for contextual learning and personalised experiences. Additionally, its flexibility in terms of device accessibility and downloadable exercises empowered learners to learn at their convenience.

5.5.1. Contributions of the research

The benefits of the study can be appreciated from academic and industry perspectives. Theoretically, the study provides empirical insights into using Siyavula software for learners with special educational needs in mathematics education. It adds to the growing body of knowledge on the practical application of educational technology in special needs education settings. This study bridges the gap between technology, special education, and mathematics education. It demonstrates the importance of interdisciplinary research in addressing the unique needs of diverse learners.

From an industry perspective, this study offers valuable insights into the user experiences and needs of educators in the context of educational technology, specifically Siyavula software. These insights enhance our understanding of the complex interplay between technology and special education. They can inform developers to create more user-friendly, engaging, and adaptive educational software.

5.5.2. Limitations of the study

This study has provided insights into the affordances associated with using Siyavula software for teaching mathematics to learners with special educational needs. However, it is crucial to acknowledge that this study has limitations. This section discusses some rules that have been identified.

Due to the school having only four mathematics educators in the senior phase, the first limitation of this study concerns the small sample size of educators who participated in the investigation of Siyavula software. Although the study's findings provide valuable insights within the context, they may not be easily transferrable to a large and more diverse population.

Secondly, the study's focus on Siyavula software within a special needs educational context may limit the transferability of findings to other contexts. The effectiveness and limitations of educational technology might appear differently across different educational environments.

Lastly, while the study thoroughly explores educator experiences with Siyavula, there is a limitation concerning exploring the perspectives of learners. Educator insights are crucial; however, a more extensive examination of learners' experiences could provide a more comprehensive understanding of the software's impact.

5.5.3. Recommendations

Based on the analysis and findings of the research, further studies on the affordances of the Siyavula software as a learning tool focusing on learner experiences are recommended. Future studies should undertake longitudinal research and track changes in educator experiences with Siyavula. This can reveal how these experiences evolve and whether there are long-term benefits or challenges.

In addition, further studies that involve a larger sample of educators are recommended. This can help in providing an understanding of the software's effectiveness in different contexts.

Furthermore, the Siyavula software should be compared with other open-source educational technologies to determine its relative effectiveness. This can help educators and policymakers make informed decisions about technology adoption in special education.

REFERENCES

Adamides, E.D. 2023. Activity theory for understanding and managing system innovations. International Journal of Innovation Studies, 7(2): 127–141.

Adams, W.C. 2015. Conducting semi-structured interviews. In K. E. Newcomer, H. P. Hatry, & J. S. Wholey (eds.). Handbook of practical program evaluation. Hoboken, New Jersey: John Wiley & Sons, Ltd: 492–505.

Adu, P. 2019a. connecting themes, and developing tables and diagrams. In A step-by-step guide to qualitative data coding. New York: Routledge: 158–182.

Adu, P. 2019b. Understanding the art of coding qualitative data. In A step-by-step guide to qualitative data coding. New York: Routledge: 23–58.

Alsanousi, B., Albesher, A.S., Do, H. & Ludi, S. 2023. Investigating the user experience and evaluating usability issues in AI-enabled learning mobile apps: an analysis of user reviews. International Journal of Advanced Computer Science and Applications, 14(6): 18–29.

Alshehri, A. & Cumming, T.M. 2020. Mobile technologies and knowledge management in higher education institutions: students' and educators' Perspectives. World Journal of Education, 10(1): 12–22.

Aluko, R. 2017. Applying UNESCO guidelines on mobile learning in the South African context: Creating an enabling environment through policy. International Review of Research in Open and Distance Learning, 18(7): 24–44.

Andrade, G.C. 2016. Understanding user experience through sensemaking process. Unpublished master's thesis. Indiana University, Indiana. https://scholarworks.iupui.edu/items/4d89895f-38d4-43a9-a2c9-059bd8594301 [11 September 2023].

Apuke, O.D. 2017. Quantitative research methods: a synopsis approach. Arabian Journal of Business and Management Review, 6(11): 40–47.

Azungah, T. 2018. Qualitative research: deductive and inductive approaches to data analysis. Qualitative Research Journal, 18(4): 383–400.

Babbie, E.R. 2020. The practice of social research. Boston: Cengage Learning.

Balliammanda, K. 2021. Perceptions of teachers on teaching and learning with mobile devices in higher education classrooms in Oman: a pilot study. Studies in Technology Enhanced Learning, 1(2). https://stel.pubpub.org/pub/01-02-balliammanda-2021/release/1 [9 March 2023].

Bano, M., Zowghi, D., Kearney, M., Schuck, S. & Aubusson, P. 2018. Mobile learning for science and mathematics school education: a systematic review of empirical evidence. Computers and Education, 121: 30–58.

Barbareschi, G., Aranda Jan, C., Nique, M., Ramos Barajas, F. & Holloway, C. 2019. Mobile phones as assistive technologies: gaps and opportunities. In MacLachlan, M. & Berman-Bieler, R. (eds.). Proceedings of the GReAT Summit. Geneva, Switzerland: WHO, 294–308. extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https

%3A%2F%2Fat2030.org%2Fstatic%2Fat2030_core%2Foutputs%2FMobile-phones-as-assistive-technologies.-Gaps-and_B2wSGDI.pdf [30 May 2023].

Bargas-Avila, J.A. & Hornbæk, K. 2011. Old wine in new bottles or novel challenges? A critical analysis of empirical studies of user experience. In Proceedings of the International Conference on Human Factors in Computing Systems, 7-12 May 2011. Vancouver: ACM, 2689–2698. https://dl.acm.org/doi/10.1145/1978942.1979336 [14 April 2022].

Basri, N.H., Noor, N.L.M., Adnan, W.A.W., Saman, F.M. & Baharin, A.H.A. 2016. Conceptualizing and understanding user experience. In 4th International Conference on User Science and Engineering, 23-25 August 2016. Melaka, Malaysia: IEEE, 81–84. https://ieeexplore.ieee.org/document/7857938 [14 April 2022].

Batiibwe, M.S.K. 2019. Using cultural historical activity theory to understand how emerging technologies can mediate teaching and learning in a mathematics classroom: a review of literature. Research and Practice in Technology Enhanced Learning, 14: 12. https://telrp.springeropen.com/articles/10.1186/s41039-019-0110-7 [4 September 2023].

Benavides-Varela, S., Zandonella Callegher, C., Fagiolini, B., Leo, I., Altoè, G. & Lucangeli, D. 2020. Effectiveness of digital-based interventions for children with mathematical learning difficulties: a meta-analysis. Computers and Education, 157(November): 103953. https://www.sciencedirect.com/science/article/pii/S0360131520301512 [16 April 2022].

Berni, A. & Borgianni, Y. 2021. From the definition of user experience to a framework to classify its applications in design. In International conference on engineering design, ICED2, 16-20 August 2021. Gothenburg, Sweden: Cambridge University Press, 1627–1636. https://www.cambridge.org/core/journals/proceedings-of-the-design-society/article/from-the-definition-of-user-experience-to-a-framework-to-classify-its-applications-in-design/BDA17A8DA7C4B70DF0B339B29A7C33FC [17 April 2022].

Bos, J. 2020. Confidentiality. In Research Ethics for Students in the Social Sciences. Cham: Springer International Publishing: 149–173. https://link.springer.com/10.1007/978-3-030-48415-6_7 [1 July 2023].

Buli-Holmberg, J. & Jeyaprathaban, S. 2016. Effective practice in inclusive and special needs education. International Journal of Special Education, 31(1): 119-134.

Buzuzi, A. & Chigona, A. 2021. Mathematics teachers' integration of technology for pedagogical use in a less affluent high school in the Western Cape. In Langran, E. & Archambault, L. (eds.). Society for Information Technology & Teacher Education International Conference. Waynesville: Association for Association of the Advancement of Computing in Education (AACE): 1369–1378. https://www.learntechlib.org/primary/f/219321/ [28 May 2022].

Ceci, L. 2020. Global mobile education app downloads by platforms 2020. Statista. https://www.statista.com/statistics/1128262/mobile-education-app-downloads-worldwide-platforms-millions/ [9 March 2022].

Chaka, C. 2021. Mobile learning studies conducted conducted in certain secondary schools in South Africa from 2005 to 2015: a review study. Per Linguam, 37(2): 31–49.

Chelkowski, L., Yan, Z. & Asaro-saddler, K. 2019. The use of mobile devices with students with disabilities: a literature review. Preventing School Failure: Alternative Education for Children and Youth, 63(3): 277–295.

Cheng, S.C. & Lai, C.L. 2020. Facilitating learning for students with special needs: a review of technology-supported special education studies. Journal of Computers in Education, 7(2): 131–153.

ChildWise. 2020. Childhood 2020: new independent report. extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https%3A%2F%2Fwww.childwise.co.uk%2Fuploads%2F3%2F1%2F6%2F5%2F31656353%2Fchildwise_press_release_-_monitor_2020_-_immediate_release.pdf [9 March 2022].

Chung, C.J., Hwang, G.J. & Lai, C.L. 2019a. A review of experimental mobile learning research in 2010–2016 based on the activity theory framework. Computers and Education, 129: 1–13.

Chung, C.J., Hwang, G.J. & Lai, C.L. 2019b. A review of experimental mobile learning research in 2010–2016 based on the activity theory framework. Computers & Education, 129: 1–13.

Clemmensen, T., Kaptelinin, V. & Nardi, B. 2016. Making HCI theory work: an analysis of the use of activity theory in HCI research. Behaviour and Information Technology, 35(8): 608–627.

Coflan, C.M. & Kaye, T. 2020. Using education technology to support students with special educational needs and disabilities in low- and middle-income Countries. https://docs.edtechhub.org/lib/2WY8H4WW [15 December 2022].

Coghlan, D. & Brydon-Miller, M. 2014. The sage encyclopedia of action research. London: Sage publications Ltd.

Collins. 2023. Definition of Special educational needs. Collins English Dictionary. https://www.collinsdictionary.com/dictionary/english/special-educational-needs [11 September 2023].

Collins, C.S. & Stockton, C.M. 2018. The central role of theory in qualitative research. International Journal of Qualitative Methods, 17(1). https://doi.org/10.1177/1609406918797475 [4 September 2023]

Creswell, J.W. 2009. Research design: qualitative, quantitative, and mixed methods approaches. 3rd ed. Los Angeles: Sage Publications.

Creswell, J.W. & Creswell, D.J. 2018. Research design: qualitative, quantitative, and mixed methods approaches. 5th ed. Thousand Oaks, California: Sage Publications Inc.

Creswell, J.W. & Plano-Clark, V.L. 2018. Designing and conducting mixed methods research. 3rd ed. Thousan Oaks, California: Sage Publications Inc.

Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á. & Luján-Mora, S. 2021. Mobile learning technologies for education: benefits and pending issues. Applied Sciences, 11(9): 4111. https://www.proquest.com/openview/732145fbdc0b3bcbf5d9820d229a6383/1?pq-origsite=gscholar&cbl=2032433 [13 December 2022]

Crompton, H. 2013. A historical overview of m-learning: toward learner-centered education. In Handbook of mobile learning. London: Routledge: 3–14.

Crompton, H. & Burke, D. 2017. Research trends in the use of mobile learning in mathematics. In Information Resources Management Association (ed.). Blended Learning: Concepts, Methodologies, Tools, and Applications. Hershey, Pennsylvania: IGI Global: 2090–2104.

Crompton, H., Burke, D. & Gregory, K.H. 2017. The use of mobile learning in PK-12 education: A systematic review. Computers and Education, 110: 51–63.

Crompton, H. & Traxler, J. 2019. Learning With Mobile Devices. In M. Khosrow-Pour, ed. Advances, methodologies and technologies in modern education delivery. Hershey, Pennsylvania: IGI Global: 793–808.

Cumming, T.M. & Draper Rodríguez, C. 2017. A meta-analysis of mobile technology supporting individuals with disabilities. The Journal of Special Education, 51(3): 164–176. https://journals-sagepub-com.ezproxy.cput.ac.za/doi/abs/10.1177/0022466917713983 [15 December 2022].

Dawadi, S., Shrestha, S. & Giri, R.A. 2021. Mixed methods research: a discussion on its types, challenges, and criticisms. Journal of Practical Studies in Education, 2(2): 25–36.

Deaton, S. 2015. Social learning theory in the age of social media: implications for educational practitioners. Journal of Educational Technology, 12(1): 6.

DeCarlo, M. 2018. Scientific inquiry in social work. Montreal, Canada: Pressbook.

DeVane, B. & Squire, K.D. 2012. Activity Theory in the learning technologies. In D. Jonassen & S. Land, eds. Theoretical Foundations of Learning Environments. New York: Routledge: 242–267.

Dogan, S. & Delialioglu, O. 2020. A systematic review on the use of technology in learning disabilities. Ankara University Faculty of Educational Sciences Journal of Special Education, 21(3): 611–638.

Drigas, A.S. & Angelidakis, P. 2017. Mobile applications within education: An overview of application paradigms in specific categories. International Journal of Interactive Mobile Technologies, 11(4): 17–29.

El-hussein, M.O.M. & Cronje, J.C. 2010. Defining mobile learning in the higher education landscape. Educational Technology & Society, 13(3): 12–21.

Engeström, Y. 2015. Learning by expanding: an activity-theoretical approach to developmental research. 2nd ed. New York: Cambridge University Press.

Engeström, Y., Miettinen, R. & Punamaki, R.L. 1999. Perspectives on Activity Theory. Cambridge: Cambridge University Press.

Engeström, Y. & Sannino, A. 2020. From mediated actions to heterogenous coalitions: four generations of activity-theoretical studies of work and learning. Mind, Culture, and Activity, 28(1): 4–23. https://www.tandfonline.com/doi/abs/10.1080/10749039.2020.1806328 [14 May 2023].

Etcuban, J.O. & Pantinople, L.D. 2018. The effects of mobile application in teaching high school mathematics. International Electronic Journal of Mathematics Education, 13(3): 249–259.

Eyesi, D. 2016. The usefulness of qualitative and quantitative approaches and methods in researching problem-solving ability in science education curriculum. Journal of Education and Practice, 7(15). extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https%3A%2F%2Ffiles.eric.ed.gov%2Ffulltext%2FEJ1103224.pdf [16 April 2023].

Fabian, K. & Topping, K.J. 2019. Putting "mobile" into mathematics: results of a randomised controlled trial. Contemporary Educational Psychology, 59 (October): 101783. https://www.sciencedirect.com/science/article/abs/pii/S0361476X18303904 [14 December 2022].

Fabian, K., Topping, K.J. & Barron, I.G. 2018. Using mobile technologies for mathematics: effects on student attitudes and achievement. Educational Technology Research and Development, 66(5): 1119–1139. https://link.springer.com/article/10.1007/s11423-018-9580-3 [16 April 2022].

Fernández-Batanero, J.M., Cabero-Almenara, J., Román-Graván, P. & Palacios-Rodríguez, A. 2022. Knowledge of university teachers on the use of digital resources to assist people with disabilities: the case of Spain. Education and Information Technologies, 27(7): 9015–9029.

Flick, U. 2014. The Sage handbook of qualitative data analysis. London: Sage Publications Ltd.

Foko, T. 2009. The use of mobile technologies in enhancing learning in South Africa and the challenges of increasing digital divide. In ED-Media conference on education multimedia, 22-26 June 2009. Honolulu, Hawaii: hypermedia & telecommunications. https://researchspace.csir.co.za/dspace/handle/10204/3491 [13 March 2022]

Franklin, D., Brooks, R., Children, R.R., Power, T., Franklin, D. & Shaywitz, S.E. 2018. Helping your child with language-based learning disabilities: strategies to suceed in school and life with dyslexia, dysgraphia, dyscalculia, ADHD and processing disorders. Oakland: New Harbinger Publications, Inc.

Furlong, P. & Marsh, D. 2010. A skin not a sweater: ontology and epistemology in political science. In D. Marsh & G. Stoker, eds. Theory and methods in political science. New York: Palgrave Macmillan.

Gangadharan, P. 2019. The Importance of user experience design. UX Planet. https://uxplanet.org/the-importance-of-user-experience-design-988faf6ddca2 [19 April 2022].

Garrett, J.J. 2011. The elements of user experience. 2nd ed. Berkeley, CA: New Riders.

Gashoot, M., Eve, B. & Mohamed, T. 2023. Implementing technology for teaching: the use of a mobile/tablet approach for enhancing students' learning (design interaction) technology-enhanced learning (TEL). Journal of Education, 203(1): 230–241.

Gersten, R., Chard, D.J., Jayanthi, M., Baker, S.K., Morphy, P. & Flojo, J. 2008. Mathematics instruction for students with learning disabilities or difficulty learning mathematics: a synthesis of the intervention research. Portsmouth, NH. extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https%3A%2F%2Ffiles.eric.ed.gov%2Ffulltext%2FED521890.pdf [4 September 2023].

Good, A. & Omisade, O. 2019. Linking activity theory with user centred design: a human computer interaction framework for the design and evaluation of mHealth interventions. Studies in Health Technology and Informatics, 263: 49–63.

Guest, B.G., Macqueen, K.M. & Namey, E.E. 2012. Introduction to applied thematic analysis. In Applied Thematic Analysis. Thousand Oaks, California: Sage Publications: 3–20.

Guo, F. 2012. More than usability: the four elements of user experience, Part I. UXmatters. https://www.uxmatters.com/mt/archives/2012/04/more-than-usability-the-four-elements-of-user-experience-part-i.php [17 April 2022].

Harpur, P. & De Villiers, R. 2015. MUUX-E, a framework of criteria for evaluating the usability, user experience and educational features of m-learning environments. South African Computer Journal, 56(1). https://sacj.cs.uct.ac.za/index.php/sacj/article/view/240 [4 September 2023].

Hasan, H. & Kazlauskas, A. 2014. Activity Theory: who is doing what, why and how. In Hassan, H. (ed.). Being pactical with theory: a window into business research. Wollongong, Australia: Faculty of Business, University of Wollongong: 9–14.

Hassenzahl, M., Diefenbach, S. & Göritz, A. 2010. Needs, affect, and interactive products - facets of user experience. Interacting with Computers, 22(5): 353–362.

Hersh, M. 2020. Paper commissioned for the 2020 Global Education Monitoring Report, inclusion and education. Paris, France.

Higginbottom, G.M.A. 2004. Sampling issues in qualitative research. Nurse Research, 12(1): 7–19.

Hornbæk, K. & Hertzum, M. 2017. Technology acceptance and user experience: A review of the experiential component in HCI. ACM Transactions on Computer-Human Interaction, 24(5). https://www.researchgate.net/publication/320261224_Technology_Acceptance_and_User_Experience_A_Review_of_the_Experiential_Component_in_HCI [20 February 2023].

Hornby, G. 2014. Inclusive special education: evidence-based practices for children with special needs and disabilities. New York: Springer.

Hung, A.C.Y. 2016. Beyond the player: a user-centered approach to analyzing digital games and players using actor-network theory. E-Learning and Digital Media, 13(5–6): 227–243.

Hunt, P.F. 2020. Inclusive education: children with disabilities. https://unesdoc.unesco.org/ark:/48223/pf0000373662 [14 December 2022].

Hussain, A., Mkpojiogu, E.O.C. & Babalola, E.T. 2020. Using mobile educational apps to foster work and play in learning: a systematic review. International Journal of Interactive Mobile Technologies, 14(18): 178–194.

Hwang, W.-Y., Hariyanti, U., Abdillah, Y.A. & Chen, H.S.L. 2021. Exploring effects of geometry learning in authentic contexts using ubiquitous geometry App. Technology & Society, 24(3): 13–28.

Ibrahim, N., Fatimah, W., Ahmad, W. & Shafie, A. 2015. User experience study on folktales mobile application for children's Education. In 9th International conference on next generation mobile applications, services and technologies, 09-11 September 2015. Cambridge, UK: IEEE, 353–358. https://ieeexplore.ieee.org/document/7373268 [16 April 2022].

Imtinan, U., Chang, V. & Issa, T. 2012. Characteristics of mobile learning environments in developing countries. The international journal of learning, 18(5): 163–173.

Interaction Design Foundation. 2020. The Reflective Level of Emotional Design. https://www.interaction-design.org/literature/article/the-reflective-level-of-emotional-design [20 January 2024].

IOS. 2018. ISO 9241-11:2018, Ergonomics of human-system interaction — Part 11: Usability: definitions and concepts. International Organization of Standardization. https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en [18 April 2022].

Isaacs, S., Roberts, N. & Spencer-smith, G. 2019. Learning with mobile devices: A comparison of four mobile learning pilots in Africa. South African Journal of Education, 39(3): 1656. extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https%3A%2F%2Fwww.ajol.info%2Findex.php%2Fsaje%2Farticle%2Fdownload%2F189825%2F179043 [13 March 2022].

Ismaili, J., Houcine, E. & Ibrahimi, O. 2017. Mobile learning as alternative to assistive technology devices for special needs students. Education and Information Technologies, 22: 883–899.

ITChronicles. 2022. Mobile technologies. https://itchronicles.com/mobile-technologies/ [13 December 2022].

Iyamu, T. 2020. A case for applying activity theory in IS research. Information Resources Management Journal, 33(1): 1–15. http://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/IRMJ.2020010101 [1 July 2023].

Iyamu, T. 2022. Activity theory. In Applying Theories for Information Systems Research. New York: Taylor and Francis Inc.: 53–70.

Iyamu, T. & Shaanika, I. 2019. The use of activity theory to guide information systems research. Education and Information Technologies, 24(1): 165–180.

Jahan, N., Barbareschi, G., Jan, C.A., Mutuku, C.M., Rahman, N., Austin, V. & Holloway, C. 2020. Inclusion and independence: the impact of mobile technology on the Lives of Persons with Disabilities in Kenya and Bangladesh. In IEEE Global Humananitatian Technology Conference (GHTC). Seattle, WA: IEEE: 573–580. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9342934 [30 May 2022].

Jantjies, M. & Joy, M. 2015. Mobile enhanced learning in a South African context. Education Technology & Society, 18(1): 308–320.

Kain, D. & Wardle, Elizabeth. 2014. Activity Theory: an introduction for the writing classroom. In Wardle, E. & Downs, D. (eds.). Writing about writing: a college reader. Boston: Bedford/St. Martin's: 273–283.

Kaisara, G. & Bwalya, K.J. 2022. Trends in mobile learning research in sub-Saharan Africa: a systematic literature review. International Journal of Education and Development using Information and Communication Technology (IJEDICT), 18(2): 231–244.

Kaliisa, R. & Picard, M. 2017. A systematic review on mobile learning in higher education: The African perspective. Turkish Online Journal of Educational Technology, 16(1): 1–18.

Kaplan, B. & Maxwell, J.A. 2005. Qualitative research methods for evaluating computer information systems. In J. G. Anderson & C. E. Aydin, eds. Evaluating the Organizational Impact of Healthcare Information Systems. New York: Springer Science & Business Media Inc.: 30–55.

Kaptelinin, V. 2005. The object of activity: making sense of the sense-maker. Mind, Culture, and Activity, 12(1): 4–18.

Kaptelinin, V. & Nardi, B.A. 1997. Activity theory: basic concepts and applications. In S. Pemberton, ed. CHI '97: Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems. Atlanta Georgia: Association for Computing Machinery: 158–159.

Karagianni, K. 2018. Optimizing the UX honeycomb: a small amendment to the classic. UX Collective. https://uxdesign.cc/optimizing-the-ux-honeycomb-1d10cfb38097 [18 April 2022].

Kay, R. & Kwak, J. 2017. Do math apps help elementary school students? It depends. In Johnston, J. P. (ed.). EdMedia and Innovate Learning. Waynesville, NC: Association for the Advancement of Computing in Education (AACE): 27–32. https://www.learntechlib.org/p/178412/ [15 December 2022].

Kelly, L.M. & Cordeiro, M. 2020. Three principles of pragmatism for research on organizational processes. Methodological Innovations, 13(2): 1–10. https://journals.sagepub.com/doi/full/10.1177/2059799120937242 [1 May 2023].

Khaddage, F. & Lattemann, C. 2013. The future of mobile apps for teaching and learning. In Z. L. Berg & L. Muilenburg, eds. New York: Routledge.

Kiger, M.E. & Varpio, L. 2020. Thematic analysis of qualitative data: AMEE guide No. 131. Medical Teacher, 42(8): 846–854.

Komninos, A. 2020. Norman's three levels of design. IxDF. https://www.interaction-design.org/literature/article/norman-s-three-levels-of-design [19 February 2023].

Kuimova, M., Burleigh, D., Uzunboylu, H. & Bazhenov, R. 2018. Positive effects of mobile learning on foreign language learning. TEM Journal, 7(4): 837–841.

Kumar, B.A. & Chand, S.S. 2019. Mobile learning adoption: a systematic review. Education and Information Technologies, 24(1): 471–487.

Kumar, B.A. & Mohite, P. 2018. Usability of mobile learning applications: a systematic literature review. Journal of Computers in Education, 5(1): 1–17.

Kuutti, K. 2010. Where are the Ionians of user experience research? In Hvannberg, E., M., Larusdottir, M. K., Blandford, A. & Gulliksen, J. (eds.). NordiCHI '10 Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, 16-20 October 2010. Reykjavik, Iceland: Association for Computing Machinery, 715–718. https://dl.acm.org/doi/abs/10.1145/1868914.1869012 [12 September 2023].

Kuutti, T., Sajaniemi, N., Björn, P.M., Heiskanen, N. & Reunamo, J. 2022. Participation, involvement and peer relationships in children with special educational needs in early childhood education. European Journal of Special Needs Education, 37(4): 587–602.

Lamptey, H. K., & Boateng, R. 2017. Mobile learning in developing countries: A synthesis of the past to define the future. World academy of science, engineering and technology. International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 11(2): 443–450.

Lanius, C., Weber, R. & Robinson, J. 2021. User Experience Methods in Research and Practice. Journal of Technical Writing and Communication, 51(4): 350–379. https://doi.org/10.1177/00472816211044499.

Law, E.L.C., Roto, V., Hassenzahl, M., Vermeeren, A.P.O.S. & Kort, J. 2009. Understanding, scoping and defining user experience: a survey approach. In Preceedings of the SIGCHI conference on human factors in comuting systems. 719–728.

Leavy, P. 2017. Research design: quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches. New York: The Guilford Press.

Lee, C.B., Hanham, J., Kannangara, K. & Qi, J. 2021. Exploring user experience of digital pen and tablet technology for learning chemistry: applying an activity theory lens. Heliyon, 7(1): e06020. https://www.sciencedirect.com/science/article/pii/S2405844021001250#:~:text=Our%20participants%20showed%20that%20when,structure%20is%20critical%20to%20learning [16 April 2022].

Lee, C.-Y. & Cherner, T.S. 2015. A comprehensive evaluation rubric for assessing instructional apps. Journal of Information Technology Education: Research, 14: 21–53. http://www.jite.org/documents/Vol14/JITEV14ResearchP021-053Yuan0700.pdf. [12 September 2023]

Lee, J.S. & Kim, S.W. 2015. Validation of a tool evaluating educational apps for smart education. Journal of Educational Computing Research, 52(3): 435–450.

Leedy, P.D. & Ormrod, J.E. 2015. Practical research: planning and design. 11th ed. Essex, England: Pearson Education Limited.

Lin, C.C., Lin, V., Liu, G.Z., Kou, X., Kulikova, A. & Lin, W. 2020. Mobile-assisted reading development: a review from the activity theory perspective. Computer Assisted Language Learning, 33(8): 833–864.

Lodico, M.G., Spaulding, D.T. & Voegtle, K.H. 2010. Methods in educational research: from theory to practice. 2nd ed. San Francisco: Jossey-Bass.

Lu, X. & Hsiao, K.L. 2022. Effects of diffusion of innovations, spatial presence, and flow on virtual reality shopping. Frontiers in Psychology, 13: 941248. https://www.frontiersin.org/articles/10.3389/fpsyg.2022.941248/full [1 May 2022]

Lynch, K., An, L. & Mancenido, Z. 2022. The impact of summer programs on student mathematics achievement: a meta-analysis. Review of Educational Research, 20(10): 1–41. https://journals-sagepub-com.ezproxy.cput.ac.za/doi/10.3102/00346543221105543 [15 December 2022].

Mahmoud, M.A., Badawi, U.A., Farag, T., Hassan, W., Alomari, Y.M. & Alghamdi, F.A. 2021. Evaluation of user experience in mobile applications. International Journal of

Innovation, Creativity and Change, 15(7): 536–552. https://www.researchgate.net/publication/351935442 [11 September 2023].

Maia, C.L.B. & Furtado, E.S. 2016. A systematic review about user experience evaluation. In Marcus, A. ed. DUXU 2016: Design, User Experience, and Usability: Design Thinking and Methods. Toronto: Springer Cham: 445–455. https://link.springer.com/chapter/10.1007/978-3-319-40409-7_42 [14 December 2022].

Maree, K. 2016. Planning a research proposal. In K. Maree, ed. First steps in research. Pretoria: Van Schaik Publishers: 26–47.

Marikyan, D. & Papagiannidis, Savvas. 2022. Unified Theory of Acceptance and Use of Technology. In Papagiannidis, S. (ed.). TheoryHub book: a theory resource for students and researchers alike. Newcastle: Newcastle University.

Maxwell, J.W. 2006. Tracing the dynabook: a study of technocultural transformations. University of British Columbia.

Mdingi, X. & Chigona, A. 2021. Teachers' integration of instructional technology into curriculum delivery in disadvantaged communities: a case of Cape Flats schools in South Africa. In EdMedia and Innovate Learning. Waynesville, NC: Association for the Advancement of Computing in Education (AACE): 97–106. https://www.learntechlib.org/p/219644/ [30 May 2022].

Mertler, C.A. 2021. Introduction to educational research. 3rd ed. Thousand Oaks, California: Sage Publications Inc.

Middleton, C., Scheepers, R. & Tuunainen, V.K. 2014. When mobile is the norm: researching mobile information systems and mobility as post-adoption phenomena. European Journal of Information Systems, 23(5): 503–512.

Mkpojiogu, O.C., Okeke-Uzodike, O.E. & Omopariola, V. 2022. Understanding users' UX needs through the lenses of psychological needs theories: users' expectations and felt experiences. In International Conferences Interfaces and Human Computer Interaction. Lisbon, Portugal: IADIS: 75–83. https://www.researchgate.net/publication/365978110. [20 January 2024]

Mohajan, H.K. 2018. Qualitative research methodology in social sciences and related subjects. Journal of Economic Development, Environment and People, 7(1): 23–48.

Mohamad, N. & Hashim, N.L. 2021. UX testing for mobile learning applications of deaf children. International Journal of Advanced Computer Science and Applications, 12(11): 294–299.

Morville, P. 2004. User Experience Design. Semantic Studios. https://semanticstudios.com/user_experience_design/ [18 April 2022].

Moser, A. & Korstjens, I. 2018. Series: Practical guidance to qualitative research. Part 3: Sampling, data collection and analysis. European Journal of General Practice, 24(1): 9–18.

Murphy, E. & Rodriguez-Manzanares, M.A. 2008. Using activity theory and its principle of contradictions to guide research in educational technology. Australasian Journal of Educational Technology, 24(4): 442–457.

Mutiaraningrum, I. & Nugroho, A. 2021. Smartphone-based mobile assisted language learning application in higher vocational education in Indonesia. Journal of English Educators Society, 6(1): 26-34.

Myers, M.D. 1997. Qualitative research in information systems. MIS Quarterly: Management Information Systems, 21(2): 241–242.

Nardi, B.A. 1996. Activity theory and human-computer interactions. In Nardi, B. A. (ed.). Content and consciousness: activity theory and human-computer interactions. Massachusetts: MIT Press: 8–16.

Nardi, B.A. & Kaptelinin, V. 2006. Acting with technology: activity theory and interactive design. Cambridge, Massachusetts: MIT Press.

National Center for Education Statistics. 2022. Students with Disabilities. Condition of Education. Institute of Education Sciences. https://nces.ed.gov/programs/coe/indicator/cgg/students-with-disabilities#suggested-citation [14 December 2022].

Nedeltcheva, G.N. & Shoikova, E. 2017. Coupling design thinking, user experience design and agile: towards cooperation framework. In BDIOT2017: International Conference on Big Data and Internet of Thing. London: Association for Computing Machinery: 225–229.

Nelson, G., Crawford, A., Hunt, J., Park, S., Leckie, E., Duarte, A., Brafford, T., Ramos-Duke, M. & Zarate, K. 2022. A systematic review of research syntheses on students with mathematics learning disabilities and difficulties. Learning Disabilities Research and Practice, 37(1): 18–36.

Neuman, W.L. 2014. Social research methods: qualitative and quantitative approaches. 7th ed. Essex, England: Pearson Education Limited.

Ng'ambi, D. 2020. Empathy-driven mobile app development (MAD) without coding: a case of citizen developers. In Traxler, J. & Crompton, H. (eds.). Critical mobile pedagogy: cases of digital technologies and learners in the margins. New York: Taylor & Francis: 136–150.

Ngesi, N., Landa, N., Madikiza, N., Cekiso, M.P., Tshotsho, B. & Walters, L.M. 2018. Use of mobile phones as supplementary teaching and learning tools to learners in South Africa. Reading & Writing, 9(1): a190. https://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2308-14222018000100014#:~:text=Researchers%20in%20a%20SAIDE%20study,the%20culture%20of%20South%20Africa [14 December 2022]

Ngulube, P. 2015. Qualitative data analysis and interpretation: systematic search for meaning. In Mathipa, E.R. & M. T. Gumbo, M.T. (eds.). Addressing research challenges: making headways for developing researchers. Noordywk: Mosala-Masedi Publishers: 131–156.

Nielsen, J. 2012. Usability 101: Introduction to usability. Nielsen Norman Group. https://www.nngroup.com/articles/usability-101-introduction-to-usability/ [18 April 2022].

Nieuwenhuis, J. 2020. Qualitative research design and data-gathering techniques. In Maree, K. (ed.). First steps in research. South Africa: Van Schaik Publishers: 72–100.

Norman, D. & Nielsen, J. 2022. The definition of user experience (UX). Nielsen Norman Group. https://www.nngroup.com/articles/definition-user-experience/ [17 April 2022].

NSF. 2020. STEM education for the future: a visioning report. South Africa. extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https%3A%2F%2Fwww.nsf.gov%2Fedu%2FMaterials%2FSTEM%2520Education%2520for%2520the%2520Future%2520-%25202020%2520Visioning%2520Report.pdf [3 May 2022].

Nur, I.A., Santoso, H.B. & Putra, P.H.O. 2021. The method and metric of user experience evaluation: a systematic literature review. In 10th International Conference on Software and Computer Applications, 23-26 February 2021. Kuala Lumpur, Malaysia: ACM, 307–317. https://dl.acm.org/doi/abs/10.1145/3457784.3457832 [3 August 2023].

Oates, B.J., Griffiths, M. & McLean, R. 2022. Researching information systems and computing. 2nd ed. London: Sage Publications Ltd.

Obrist, marianna, Roto, V., Verneeren, A., Vaananen-Vainio-Mattila, K., Law, E.L.-C. & Kuutti, K. 2012. In search of theoretical foundations for UX research and practice. In CHI'12 Extended Abstracts on Human Factors in Computing Systems, 5-10 May 2012. Austin, Texas: Association for Computing Machinery, 1979–1984. https://dl.acm.org/doi/abs/10.1145/2212776.2223739 [12 September 2023].

Obrist, M., Vaananen-Vainio-Mattila, K., Roto, V., Vermeeren, A., Law, E.L.C. & Buie, E. 2012. Theories behind UX research and how they are used in practice. In CHI '12 Extended Abstracts on Human Factors in Computing Systems, 5-10 May 2012. Austin, Texas: Association for Computing Machinery, 2751–2754. https://dl.acm.org/doi/10.1145/2212776.2212712 [12 September 2023].

O'Dea, S. 2021. Forecast number of mobile users worldwide 2020-2025. Statista. https://www.statista.com/statistics/218984/number-of-global-mobile-users-since-2010/ [9 March 2022].

O'Hagan, T. 2013. Mobility in education: can mobile devices support teaching and learning in South Africa? Focus, (68): 55–59.

O'Reilly, K. 2012. Ethnographic returning, qualitative longitudinal research, and the reflexive analysis of social practice. The Sociological Review, 60(3): 518–536. https://journals.sagepub.com/doi/abs/10.1111/j.1467-954X.2012.02097.x?journalCode=sora [13 August 2022].

Ormston, R., Spencer, L., Barnard, M. & Snape, D. 2014. The foundations of qualitative research. In Ritchie, J., Lewis, J., McNaughton-Nicholls, C. & Ormston, R. (eds.). Qualitative research practice: a guide for social science students and researchers. London: Sage Publications Ltd, 1–26.

Panteli, P. & Panaoura, A. 2020. The effectiveness of using mobile learning methods in geometry for students with different initial mathematical performance. Social Education Research, 1(1): 1–10.

Papadakis, S. 2021. Tools for evaluating educational apps for young children: a systematic review of the literature. Interactive Technology and Smart Education, 18(1): 18–49.

Pettersson, I., Lachner, F., Riener, A. & Butz, A. 2018. A Bermuda triangle? A review of method application and triangulation in user experience evaluation. In Proceedings of the 2018 CHI conference on human factors in computing systems, 21-26 April 2018.

Canada: Association for Computing Machinery: 1–16. https://dl.acm.org/doi/10.1145/3173574.3174035 [3 August 2023].

Pinchot, J., Paullet, K. & Rota, D. 2011. How mobile technology is changing our culture. Journal of Information Systems Applied Research, 4(1): 39–48. www.aitp-edsig.org/www.jisar.org [16 December 2022].

Pitchford, N.J., Kamchedzera, E., Hubber, P.J. & Chigeda, A.L. 2018. Interactive apps promote learning of basic mathematics in children with special educational needs and disabilities. Frontiers in Psychology, 9(MAR): 262. https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00262/full [11 April 2022].

Prescott, A. & Maher, D. 2018. The use of mobile technologies in the primary school mathematics classroom—developing ‘Create-Alouds’. In Calder, N. & Larkin, K. eds. Using mobile technologies in the teaching and learning of mathematics. Switzerland: Springer International Publishing, 283–300.

Pucillo, F. & Cascini, G. 2014. A framework for user experience, needs and affordances. Design Studies, 35(2): 160–179.

Purwanti, Y., Imania, K.A.N., Rahadian, D., Bariah, S.H. & Muljanto, S. 2019. Mobile learning in promoting student’s engagement. Journal of Physics: Conference Series, 1402(6): 06603. https://iopscience.iop.org/article/10.1088/1742-6596/1402/6/066033 [9 March 2022].

Qahmash, A.I.M. 2018. The potentials of using mobile technology in teaching individuals with learning disabilities: a review of special education technology literature. TechTrends, 62(6): 647–653. https://link-springer-com.ezproxy.cput.ac.za/article/10.1007/s11528-018-0298-1 [15 December 2022].

Rahman, M.S. 2017. The advantages and disadvantages of using qualitative and quantitative approaches and methods in language “testing and assessment” research: a literature review. Journal of Education and Learning, 6(1): 102–112.

Razami, H.H., Ibrahim, R. & Aljuaid, N.M. 2022. A review of models and factors for digital educational games acceptance and user experience. In 2022 International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), 20-22 October 2022. Ankara, Turkey: Institute of Electrical and Electronics Engineers (IEEE), 37–42. https://ieeexplore.ieee.org/document/9932728 [14 December 2022].

Rideout, V. & Robb, M.B. 2019. The Common-Sense census: media use by tweens and teens, 2019. San Francisco, CA. extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https%3A%2F%2Fwww.commonsensemedia.org%2Fsites%2Fdefault%2Ffiles%2Fresearch%2Freport%2F2019-census-8-to-18-full-report-updated.pdf [9 March 2022].

Rivero, L. & Conte, T. 2017. A systematic mapping study on research contributions on UX evaluation technologies. In IHC 2017: Proceedings of the XVI Brazilian Symposium on Human Factors in Computing Systems, 23-27 October 2017. Joinville, Brazil: Association for Computing Machinery, 1–10. https://dl.acm.org/doi/10.1145/3160504.3160512 [12 September 2023].

Roberts, N. 2021. Assessing early grade mathematics learner outcomes using m-learning: the case of JumpStart South Africa. In Auer, M. E. & Tsiatsos, T. (eds.). Internet of things, infrastructure and mobile applications: proceedings of the 13th IMCL conference. Switzerland: Springer Cham, 136–146. https://www.researchgate.net/publication/344274878_Assessing_Early_Grade_Mathematics_Learner_Outcomes_Using_m-Learning [14 December 2022].

Roberts, N. & Vänskä, R. 2011. Challenging assumptions: mobile learning for mathematics project in South Africa. Distance Education, 32(2): 243–259.

Robinson, J., Lanius, C. & Weber, R. 2017. The past, present, and future of UX empirical research. Communication Design Quarterly, 5(3): 10–23.

Rohizan, R., Soon, L.H. & Mubin, S.A. 2020. MathFun: examining the effectiveness of calculic model in designing app for dyscalculia children. In Journal of Physics: Conference Series. Mangalore, India: IOP Publishing Ltd. https://iopscience.iop.org/article/10.1088/1742-6596/1712/1/012031 [7 April 2022].

Roulson, K. & Choi, M. 2018. Qualitative Interviews. In Flick, U. ed. The Sage handbook of qualitative research design. London: Sage Publications Ltd: 233–249.

RSA. 2022. Minister Blade Nzimande: Post-school education and training sector state of readiness for the academic year 2022. South African Government. https://www.gov.za/speeches/minister-higher-education-science-and-innovation-dr-blade-nzimande-2-feb-2022-0000 [30 May 2022].

Rule, Peter. & John, Vaughn. 2011. Your guide to case study research. Hatfield, Pretoria: Van Schaik Publishers.

Saal, P.E., Graham, M.A. & van Ryneveld, L. 2019. The Relationship between using information and communication technology in education and the mathematics achievement of students. International Journal of Instruction, 12(3): 405–424.

Saikat, S., Dhillon, J.S., Ahmad, W.F.W. & Jamaluddin, R.A. 2021. A systematic review of the benefits and challenges of mobile learning during the covid-19 pandemic. Education Sciences, 11(9): 459. https://www.mdpi.com/2227-7102/11/9/459 [14 December 2022].

Sauer, J., Sonderegger, A. & Schmutz, S. 2020. Usability, user experience and accessibility: towards an integrative model. Ergonomics, 63(10): 1207–1220.

Saunders, M., Lewis, P. & Thornhill, A. 2019. Research methods for business students. 8th ed. London: Pearson.

Schwandt, T.A. & Gates, E.F. 2018. Case study methodology. In Denzin, N. K.& Lincoln, Y. S. (eds.). The Sage handbook of qualitative research. Thousand Oaks, California: Sage Publications: 600–630.

Senjam, S.S., Foster, A., Bascaran, C., Vashist, P. & Gupta, V. 2019. Assistive technology for students with visual disability in schools for the blind in Delhi. Disability and Rehabilitation: Assistive Technology, 15(6): 663–669. https://www.tandfonline.com/doi/abs/10.1080/17483107.2019.1604829 [15 December 2022].

Shah, S.A., Iqbal, M., Hasan, M., Gul, A., Haider, M.M. & Naeem, I. 2023. Comparing the impact of online learning platforms and traditional classroom settings on student performance and satisfaction. Palarch's Journal of Archaeology of Egypt, 20(2): 1305–1319.

Shahrol, S.J.M., Sulaiman, S., Samingan, M.R. & Mohamed, H. 2020. A systematic literature review on teaching and learning english using mobile technology. International Journal of Information and Education Technology, 10(9): 709–714.

Shanks, G. & Bekmamedova, N. 2017. Case study research in information systems. In Williamson, K. & Johanson, G. (eds.). Research Methods: Information, Systems, and Contexts. Cambridge, MA: Chandos Publishing: 193–208. https://www.researchgate.net/publication/323515278_Case_study_research_in_information_systems [16 April 2023].

Sharma, G. 2017. Pros and cons of different sampling techniques. International Journal of Applied Research, 3(7): 749–752.

Sharples, M., Lonsdale, P., Meek, J., Rudman, P. & Vavoula, G.N. 2007. An evaluation of MyArtSpace: a mobile learning service for school museum trips. In Norman, A. & Pearce, J. (eds.). Proceedings of 6th Annual Conference on Mobile Learning, mLearn 2007. Melbourne, 238–244. https://figshare.le.ac.uk/articles/conference_contribution/An_Evaluation_of_MyArtSpace_a_Mobile_Learning_Service_for_School_Museum_Trips/10097393 [16 April 2022].

Silverman, D. 2019. Interpreting qualitative data. 6th ed. London: Sage Publications Ltd.

Singh, M. 2019. Top 10 Must-Have Free Apps for Dyscalculia. https://numberdyslexia.com/top-10-must-have-free-apps-for-dyscalculia-2019/ [10 April 2022].

Siyavula. 2015. Siyavula Education. extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https%3A%2F%2Fwww.siyavulaeducation.com%2Fdownloads%2FSiyavula_Education-Company_brochure.pdf [20 January 2024].

Soares, N., Evans, T. & Patel, D.R. 2018. Specific learning disability in mathematics: a comprehensive review. Translational Pediatrics, 7(1): 48–62.

Stols, G., Ferreira, R., Pelser, A., Olivier, W.A., Van der Merwe, A., De Villiers, C. & Venter, S. 2015. Perceptions and needs of South African mathematics teachers concerning their use of technology for instruction. South African journal of education, 35(4): 1–13.

Strom, G. 2006. Sense-making methodology: learn what users understand is important. In Bertelsen, O. Brynskov, M. Dalsgaard, P. Iversen, O. S. Graves-Petersen, M. & Wetterstrand, M. (eds.). Proceedings of the sixth Danish Human-Computer Interaction (HCI) Research Symposium, 15 November 2006. Aarhus, Denmark: University of Aarhus, 57–58. extension://nhppiemcomgngbgdeffdgkhnkjlgpcdi/data/pdf.js/web/viewer.html?file=https%3A%2F%2Ftidsskrift.dk%2Fdaimipb%2Farticle%2Fdownload%2F7139%2F6102%2F23017 [5 September 2023].

Strydom, A. & Bezuidenhout, R.-M. 2021. Qualitative data collection. In F. du Plooy-Cilliers, C. M. Davis, & R. Bezuidenhout, eds. Research matters. Cape Town, South Africa: Juta & Company Ltd.

Svela, A., Nouri, J., Viberg, O. & Zhang, L. 2019. A systematic review of tablet technology in mathematics education. International Journal of Interactive Mobile Technologies, 13(8): 139–158.

Swanborn, P. 2010. Case study research: what, why and how? London: Sage Publications Ltd.

Taherdoost, H. 2016. Sampling methods in research methodology; how to choose a sampling technique for research. International Journal of Academic Research in Management, 5(2): 18–27.

Tan, S.C., Looi, C.K., Cheung, Y.L., Chung, S.H., Lim, S.J. & Wong, W.H. 2021. Designing and evaluating a mobile peer tutoring application: a cultural historical activity theory approach. Interactive Learning Environments, 29. https://www.tandfonline.com/doi/full/10.1080/10494820.2021.1983608 [6 September 2023].

TechOWL. 2021. Range of assistive technology and devices. https://techowlpa.org/at-101-page-2/ [20 October 2022].

Terry, G., Hayfield, N., Clarke, V. & Braun, V. 2017. Thematic Analysis. In C. Willig & W. Stainton-Rogers, eds. The SAGE Handbook of Qualitative Research in Psychology. Thousand Oaks, California: SAGE Publications: 17–37.

Tharsika, K. & Pratheepkanth, P. 2020. A review of methodological choice: research paradigm underpins. In Research Conference on Business Studies. Sri Lanka: Faculty of Business Studies, University of Vavuniya, 298–304. http://drr.vau.ac.lk/handle/123456789/2605 [1 May 2023].

Tlili, A., Denden, M., Duan, A., Padilla-Zea, N., Huang, R., Sun, T. & Burgos, D. 2022. Game-based learning for learners with disabilities—what is next? a systematic literature review from the activity theory perspective. Frontiers in Psychology, 12. https://www.frontiersin.org/articles/10.3389/fpsyg.2021.814691/full [6 September 2023].

Traxler, J. & Leach, J. 2006. Innovative and sustainable mobile learning in Africa. In Fourth IEEE International Workshop on Wireless, Mobile and Ubiquitous Technology in Education, 16-17 November 2006. Athens, Greece: IEEE, 98–102. https://cput.primo.exlibrisgroup.com/permalink/27CPUT_INST/14nhk7s/cdi_ieee_primary_4032531 [13 March 2022].

UNESCO. 2015. Education for all 2000-2015: achievements and challenges. https://www.unesco.org/gem-report/en/efa-achievements-challenges [14 Decenber 2022].

Ustun, A.B. 2019. Effects of mobile learning in blended learning environments. Journal of Information and Communication Technologies, 1(1): 1–14.

Uther, M. 2019. Mobile learning: trends and practices. Education Sciences, 9(1): 33–35. https://www.mdpi.com/2227-7102/9/1/33/htm [9 March 2022].

Vahed, A., Ross, A., Mtapuri, O. & Searle, R. 2018. Research as transformation and transformation as research. In Bitzer, E. Frick, L. Fouriel-Malherbe, M. & Pyhälto, K. (eds.). Spaces, journeys and horizons for postgraduate supervision. Stellenbosch: African Sun Media: 315–332.

Vaidya, G. & Kalita, P.C. 2021. Understanding emotions and their role in the design of products: an integrative review. Archives of Design Research, 34(3): 5–21.

Vanclay, F., Baines, J.T. & Taylor, C.N. 2013. Principles for ethical research involving humans: ethical professional practice in impact assessment part I. Impact Assessment and Project Appraisal, 31(4): 243–253. http://dx.doi.org/10.1080/14615517.2013.850307.

Vermeeren, A.P.O.S., Law, E.L.C., Roto, V., Obrist, M., Hoonhout, J. & Väänänen-Vainio-Mattila, K. 2010. User experience evaluation methods: current state and development needs. In Proceedings of the 6th Nordic Conference on Human-Computer Interaction. 521–530.

Wang, T.H., Kao, C.H. & Wang, T.J. 2021. Implementation of mobile learning in mathematics instruction for elementary second graders. Mathematics, 9(14): 1603. https://www.mdpi.com/2227-7390/9/14/1603#:~:text=The%20MLS%20was%20used%20to,interest%20and%20mathematics%20learning%20achievement. [30 April 2022].

West, D.M. 2014. Going mobile: how wireless technology is reshaping our lives. Washington: Brookings Institution Press.

Westling, D., Fox, L., Carter, E., Kurth, J. & Da Fonte, M. 2020. Teaching students with severe disabilities. 6th ed. Upper Saddle Rive, NJ: Pearson.

WHO. 2022. Disability. https://www.who.int/news-room/fact-sheets/detail/disability-and-health [14 December 2022].

WHO & UNICEF. 2022. Global report on assistive technology. https://iris.who.int/handle/10665/354357 [20 January 2024].

Wilson, J. 2014. Essentials of business research: a guide to doing your research project. 2nd ed. London: Sage Publications Ltd.

Wodon, Q., Male, C., Montenegro, C. & Nayihouba, A. 2018. The Challenge of Inclusive Education in Sub-Saharan Africa. World Bank, Washington, DC. https://www.worldbank.org/en/topic/disability [14 December 2022].

Yasin, S.N.S., Ibrahim, R. & Yusoff, R.C.M. 2022. Mobile educational games user experience elements: a systematic literature review. In 2022 International congress on human-computer interaction, optimization and Robotic applications (HORA). Ankara, Turkey: IEEE.

Yin, R.K. 2018. Case study research and applications: design and methods. 6th ed. Thousand Oaks, California: Sage Publications.

Zarour, M. 2020. A rigorous user needs experience evaluation method based on software quality standards. Telkomnika (Telecommunication Computing Electronics and Control), 18(5): 2787–2799.

Zarour, M. & Alharbi, M. 2017. User experience framework that combines aspects, dimensions, and measurement methods. Cogent Engineering, 4(1). http://doi.org/10.1080/23311916.2017.1421006.

Zhang, M., Trussell, R.P., Gallegos, B. & Asam, R.R. 2015. Using math apps for improving student learning: an exploratory study in an inclusive fourth grade classroom. TechTrends 2015 59:2, 59(2): 32–39. https://link-springer-com.ezproxy.cput.ac.za/article/10.1007/s11528-015-0837-y [15 December 2022].

Zuo, W., Mu, B., Fang, H. & Wan, Y. 2023. User experience: a bibliometric review of the literature. IEEE Access, 11: 12662–12675.

APPENDICES

Appendix A: Ethical approval from CPUT

Cape Peninsula
University of Technology
creating futures

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Office of the Research Ethics Committee
Faculty of Informatics and Design
Room 2.09
80 Roeland Street
Cape Town
Tel: 021-469 1012
Email: ndedem@cput.ac.za
Secretary: Mziyanda Ndede

28 September 2022

Ms. Zandile Mboneni
c/o Department of Information Technology
CPUT

Reference no: 199108129/2022/25

Project title: A user-experience evaluation of prodigy software for mathematics education

Approval period: 28 September 2022 – 31 December 2023

This is to certify that the Faculty of Informatics and Design Research Ethics Committee of the Cape Peninsula University of Technology approved the methodology and ethics of Ms. Zandile Mboneni (199108129) for Master Information and Communication Technology.

Any amendments, extension or other modifications to the protocol must be submitted to the Research Ethics Committee for approval.

The Committee must be informed of any serious adverse event and/or termination of the study.

[signature]

Dr Blessing Makwambeni
Acting Chair: Research Ethics Committee
Faculty of Informatics and Design
Cape Peninsula University of Technology

Appendix B: Data collection permission letter from the Department of Education

Western Cape Government
Education

Directorate: Research

meshack.kanzi@westerncape.gov.za
Tel: +27 021 467 2350
Fax: 086 590 2282
Private Bag x9114, Cape Town, 8000
wced.wcape.gov.za

REFERENCE: 20220926-7045
ENQUIRIES: Mr M Kanzi

Ms Zandile Mboneni
7 Crescent Court
2 Station Road
Rondebosch
7700

Dear Zandile Mboneni,

RESEARCH PROPOSAL: A USER-EXPERIENCE EVALUATION OF PRODIGY SOFTWARE FOR MATHEMATICS EDUCATION.

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **26 September 2022 till 31 March 2023.**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Mr M Kanzi at the contact numbers above quoting the reference number.
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000

We wish you success in your research.

Kind regards,
Meshack Kanzi
Directorate: Research
DATE: 26 September 2022

1 North Wharf Square, 2 Lower Loop Street,
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tel: +27 21 467 2531

Private Bag X 9114, Cape Town, 8000
Safe Schools: 0800 45 46 47
wcedonline.westerncape.gov.za

Appendix C: Informed consent to participate in the study

Cape Peninsula University of Technology

Consent to participate in the research study

Full Title of the Study: A user-experience evaluation of the Siyavula application for mathematics education

Names of Researcher: Zandile Mboneni

Statement of agreement to participate in the research Study:

- I hereby confirm that I have been informed by the researcher about the nature, conduct, benefits, and risks of this study
- 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 will not include any personal information and any information regarding my identity 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 computerized 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 this research which may relate to my participation will be made available to me.

______________________	_______________	_________	____________________
Full name of participant	**Date**	**Time**	**Signature**

I, _____________________________ (Name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

______________________	_______________	_________	____________________
Full name of researcher	**Date**	**Time**	**Signature**

______________________	_______________	_________	____________________
Full name of witness	**Date**	**Time**	**Signature**