LEARNERS' LEARNING WITH AUGMENTED REALITY RESOURCES

By

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DECLARATION

I, Shoueib Ibne Amine BUNNOO, declare that the thesis

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submitted to the University of KwaZulu-Natal, South Africa, for the degree of Doctor of Philosophy in Computer Science Education, has not been previously submitted by me for degree purposes at any other University.

I further declare that this thesis is my own work in design and execution, and that all the sources that I have used or quoted therein have been duly acknowledged by means of complete references.

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Shoueib Ibne Amine BUNNOO
5 February 2025

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Prof DW Govender - Supervisor
05/02/2025

DEDICATION

To the name of God, Most Gracious and Most Merciful.

To my family, for their unwavering support, patience, and love.

To my mentor, for HIS guidance and belief in my potential.

And to the dreamers, for inspiring me to keep reaching higher.

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ABSTRACT

This thesis explores the impact of Augmented Reality (AR) resources on learners' engagement, understanding, and retention of educational content, with a focus on multimodal, contextualised, and situated learning experiences. Situated within an interpretivist paradigm, this study employed qualitative methods, including focus-group interviews, art-based research, observations, and teachers' reflective journals, to investigate how AR mediates learning processes that align with diverse learner needs. The study drew upon Activity Theory**,** Situated Cognition**,** and the VARK model to examine AR's capacity to support collaborative, personalised, and contextually grounded learning.

Findings revealed that AR can serve as a transformative tool in education, bridging abstract and tangible knowledge by embedding complex content within immediate physical environments. Through the VARK model, AR was shown to accommodate diverse learning preferences, combining visual, auditory, kinaesthetic, and reading/writing modalities to create rich, holistic learning experiences. By integrating Activity Theory, this research uncovered how AR can reconfigure classroom dynamics, promoting learner-centred engagement and collaborative inquiry.

The study's methodological contributions included the novel application of art-based research, which allowed participants to express their experiences visually and emotionally, offering insights into the affective dimensions of AR. Additionally, the teachers' reflective journals provided critical insights into the pedagogical adjustments and challenges encountered when integrating AR into instructional settings. These findings contribute to educational theory by extending current understandings of how AR can foster contextualised, experiential, and multimodal learning. Practical recommendations underscore AR's potential for enhancing accessibility and inclusivity, offering a model for equitable, engaging, and adaptive learning environments.

This research also advances the literature on educational technology and digital pedagogy, proposing AR as an essential tool for 21st century education that empowers learners, enriches teachers' practices, and supports a shift towards more personalised, inclusive learning. Future research directions could include investigating the longitudinal impact of AR on knowledge retention, AR's role in differentiated instruction for neurodiverse learners, and exploring policy implications for the ethical and equitable integration of AR in education.

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LIST OF ABBREVIATIONS

3D	Three Dimensional
AR	Augmented Reality
AT	Activity Theory
EDLP	Early Digital Learning Programme
ICT	Information and Communication Technology
IT	Information Technology
IVR	Immersive Virtual Reality
MIE	Mauritius Institute of Education
STEM	Science, Technology, Engineering, Mathematics
VARK	Visual, Auditory, Reading, Kinaesthetic
VR	Virtual Reality

CHAPTER 1: INTRODUCTION

1.1 Introduction

The application of Information and Communication Technology (ICT) has a clear role in shaping the lives of young learners, as it has the potential to integrate entertainment and learning through the use of Augmented Reality (AR) tools. ICT encourages children's interest, perception and exploration. It is apparent that youngsters are fascinated by ICT and want to experiment with its many tools and applications, as well as the activities it offers them (Oojorah & Udhin, 2022; Udhin, 2019). ICT tools, applications and programmes have become more available to young learners, who now make use of them more often; and they provide excellent educational support in several areas of early-stage development, as they are among the first to attract a child's interest. Whenever ICT is incorporated into the curriculum as a necessary component of education, children gain the capacity to utilise spontaneous methods of learning, and these resources can have a beneficial impact by improving children's desire to study in a manner that meets their developmental needs. Successful ICT integration into pre- and primary school requires a concerted effort from governmental organisations and other stakeholders involved. In order to tap into contemporary technology's immense possibilities, curriculum reform would also be necessary.

Augmented Reality has garnered significant attention within educational research due to its perceived potential for fostering motivation and enhancing learning effectiveness (Akçayır & Akçayır, 2017; Dunleavy & Dede, 2014; Johnson et al., 2010). AR is gaining popularity, attributed to its favourable impact on the development of children's memory, reasoning abilities and imaginative capabilities (Akçayır & Akçayır, 2017; Dunleavy & Dede, 2014; Lee, Choi & Kang, 2017). According to Udhin (2019), AR is a revolutionary innovation that overlays computer-generated electronic data on the actual environment. In real time, the consumer may observe and interactively engage with virtual elements. A number of breakthroughs in the area of AR, ranging from research and development to the distribution of Augmented Reality/Virtual Reality hardware components to users, are also discussed in this research (Oojorah & Udhin, 2022). Compact and sophisticated hardware has been developed to have sharper visuals, smaller sizes, and more precise identification, enhancing user adoption of AR technologies. AR has been employed in almost every industry, particularly technology, entertainment and teaching. However, AR users often encounter accessibility challenges that must be addressed before this innovation can become widely accepted.

AR application poses distinct conceptual and design challenges that standard desktop programmes do not. Unlike traditional desktop education programmes, mobile-based software packages have unique challenges. Current research on the use of AR deals with technology, psychology, efficiency and hardware components, but scant work has been done on usability heuristics and customer ease. Although some existing literature offers certain principles such as simplicity, affordance and learnability, none of these studies define suitable usability principles for mobile-based AR applications for young learners (Holley & Hobbs, 2019). According to Tuli and Mantri (2020), a systematic framework should be used to determine the usability factors for building mobile-based AR applications for pre-school learners. Therefore, it was necessary to define appropriate usability principles during this study.

Contemporary AR innovations present intriguing opportunities for introducing young individuals to digital information (Billinghurst, Clark & Lee, 2015; Huang, Rauch, Liaw & Su, 2019). These advancements in AR technology have the potential to offer engaging and interactive learning experiences, allowing youngsters to seamlessly interact with and explore digital content in ways that enhance their understanding and engagement. AR can be used in a variety of contexts, from professional contexts to entertainment and recreation, as well as for teaching and learning. The use of AR in education seems particularly fruitful, as it is becoming more important to employ resources that provide a better vantage of the topic under investigation. Other uses involve the building of cooperative groups in AR, which are multi-user platforms with continuity of provision allowing every user to observe and engage with both real and digital scenarios from their respective perspectives.

This chapter presents a background to the current study by describing the problem statement, the research objectives and the research questions that guided this investigation of aspects of teaching and learning with digitised learning materials – in particular, the use of AR resources. The chapter also argues for the research premise needed to analyse learners' performance in the virtual environment. An explanation of the terminology and constructs used in this study is also provided, i.e., computerised training materials, learners’ education, and digitised classrooms. These ideas are also discussed in depth in the chapters that follow, particularly in Chapter 2. This introductory chapter further provides a concise overview of the conceptual background, in addition to the study strategy and methods. These topics will be covered in greater depth in the chapters that follow. The purpose of providing introductory information is to assist the reader in navigating the PhD report.

1.2 Background

Educators consistently seek diverse tools and resources to effectively engage and motivate learners in the delivery of instructional content (Bergmann & Sams, 2012; Daniels & Bizar, 2019). This ongoing quest for innovative strategies reflects a commitment to creating dynamic learning environments that capture learners' interest and foster a deeper understanding of the material. An emerging perspective suggests that AR has the potential to enhance the teaching-and-learning experience for learners, thereby elevating the status of this pedagogy (Dunleavy, Dede & Mitchell, 2009; Radu, 2014). This novel viewpoint underscores the positive impact of integrating AR technologies into educational practices, emphasising their ability to contribute to more effective and engaging learning environments. Educators and learners can use the applications of AR to access projection-based, recognition-based, and location-based experiences where virtual artefacts, media, and objects appear to be real and present in the classroom (Udhin, 2019). This format facilitates learner interaction with content through physical movement and proximity, enabling manipulation to attain specific learning objectives (Chen, Chang & Wang, 2014; Klopfer, Osterweil & Salen, 2009). By encouraging learners to physically engage with the material, this approach aims to enhance comprehension and skill acquisition, aligning with the broader goals of active and experiential learning. AR requires intense engagement when interacting with the virtual experience, thus providing an enhanced opportunity for concept development. During AR-enhanced classroom interactions, learners become deeply engaged with the experience, fostering understanding and significantly enhancing their learning capabilities through this active exploration of virtual objects (Akçayır & Akçayır, 2017; Cheng & Tsai, 2013). This heightened level of engagement underscores the potential of AR to create immersive learning environments, positively impacting learners' overall cognitive and experiential outcomes. AR fosters a willingness among learners to employ critical thinking, communication, and problem-solving skills as they actively engage in, and explore, educational activities or lessons (Cheng & Tsai, 2013; Klopfer & Sheldon, 2010). This increased readiness for cognitive engagement demonstrates the potential of AR to not only enhance the learning experience, but also promote the development of essential higher-order thinking abilities. Using different AR applications, learners have the capacity to develop projects that align with curriculum standards, facilitating assessment and the demonstration of their learning and competency (Johnson, Adams, Cummins, Estrada, Freeman & Ludgate, 2010; Dunleavy & Dede, 2014).

This capability not only empowers learners to actively participate in their education, but also offers a tangible means for educators to evaluate their achievements within the established academic framework.

AR can be integrated into the classroom for all grades and curricula, and a range of possibilities exist to explore different topics in, for example, biology, history and geography. Many learners do not have the opportunity to visit historical landmarks, but these can be explored through virtual reality or AR. Additionally, in biology, microscopic analysis is made possible without the use of microscopes (Garrett, Anthony & Jackson, 2018). This assists learners to engage with objects and interact with organisms in environments that would not normally be accessible to them, such as on the ocean floor. AR enables educators to deliver enriched learning experiences and opportunities, making valuable contributions to their learners' future educational endeavours (Akçayır & Akçayır, 2017; Johnson et al., 2010). By incorporating AR into educational practices, educators can foster an environment that aligns with the evolving landscape of technology-enhanced learning, equipping learners with skills and experiences that are essential for their continued academic and professional growth.

The focus of this study is on learning using AR resources and how and why these AR resources influence the learning and studying methods of Grade 1 learners aged between six and seven in Mauritian schools. This research focus is timeous, as the implementation of technology in education, particularly in primary schools, is underway in Mauritius. The ability to monitor and evaluate the implementation of AR and the impact of digital resources on both educators and learners is crucial. This assessment should specifically focus on learners' learning and studying methods, utilising structural and cognitive criteria (Chen, Chang & Wang, 2014; Akçayır & Akçayır, 2017). By employing systematic evaluation frameworks, educators and researchers can gain insights into the effectiveness of AR integration, allowing informed adjustments and improvements in the learning environment to be made. With regard to technology such as AR, the main challenges centre on problems with the current Mauritian educational system. The research goals are therefore explored in relation to the AR learning resources currently being made available in primary schools. Consequently, the research questions address the major emphasis of the research topic, i.e., learners using AR resources. A primary discussion of the research topic is presented in this chapter, together with the research context and background.

Past and contemporary contexts will be discussed as they relate to current AR learning resources. The rationale for the research will also be presented, as well as an explanation for selecting the research topic.

1.3 Problem statement

The cluster of problems that catalysed this research study were the challenges that Mauritian teachers, learners, and the nation's educational system encountered as a result of the COVID-19 pandemic. During this period, educational institutions had to rapidly transition to electronic media to provide educational continuity. This rapid transition was imposed on a largely unprepared educational sector. Learners, as well as teachers, faced many challenges while attempting to adopt these new digital methods that differed substantially from their traditional training or studying methods. Traditional methods in Mauritian schools made little use of contemporary ICT gadgets, applications, and programmes, nor did they convey knowledge to children in a tangible manner relevant to the environment in which the children lived. Additionally, educational approaches that engage emotions and experiential learning using ICT devices and applications in the pre-school level are seldom used. This issue could be resolved through the introduction and effective use of AR technologies in pre-school, while ensuring that educational goals are achieved.

The use of AR, a topic much discussed in current literature, provides teachers and learners projection-based, recognition-based, and location-based experiences that make artefacts, media, and objects virtually appear in the classroom (Garzón & Acevedo, 2019). In this system, the learners can move about and interact with specific content to develop a full understanding. In order to demonstrate their understanding of AR, and how it relates to a certain topic, learners need to fully participate. While they participate in the AR lesson and engage with the material, their capacity for learning improves as they examine the objects in class. With the use of AR, learners are more willing to explore the activity or lesson using their critical thinking, communication, and problem-solving skills. Learners are able to develop projects that demonstrate their aptitude for, and attitude towards, the lesson topic. Additionally, these projects can be assessed against curriculum standards through the use of various AR applications. This can be incorporated into the curriculum for all grades in the school and for a variety of topics, including biology, history and geography (Nielsen, Brandt & Swensen, 2018).

Primary education and the pre-schooling system in Mauritius are encountering challenges associated with the adoption of advanced technology aimed at enhancing learning methods through the utilisation of digitalised technologies. As Mauritius integrates this technology into its educational landscape, opportunities arise for improved learning experiences; however, complexities exist and adjustments are required to ensure effective implementation and integration into the educational framework. This dynamic landscape underscores the ongoing need for strategic planning, teacher training, infrastructure development, and curriculum adaptation to leverage the potential benefits of digital technologies in primary education and pre-school settings in Mauritius. AR is one type of digitised technology that can assist comprehension and conceptualisation with audio and video snippets, as well as three-dimensional (3D) models, for increased interest and motivation in kindergarten-age learners (Cook, 2019). The global pandemic, which posed a significant barrier to education, also provided a catalyst for the adoption of digitised learning in Mauritius and in many other countries globally.

As a result, the standard method for presenting material needs to be replaced by AR presentation methods. AR methods offer the advantage of heightening interest, fostering intrigue, and enhancing enjoyment in the learning process. Additionally, they play a crucial role in integrating new knowledge into learners' existing conceptual structures, thereby facilitating a more seamless understanding and retention of information, ultimately enhancing memory (Dunleavy, Dede & Mitchell, 2009; Klopfer, Squire & Jenkins, 2002). This multi-faceted approach not only contributes to increased engagement, but also aligns with cognitive processes that promote effective learning and knowledge retention. AR technologies have the potential to empower learners, leveraging their individual talents, to acquire intellectual and behavioural competencies that may not be achieved through conventional methods (Cheng & Tsai, 2013; Klopfer & Sheldon, 2010). This personalised and dynamic approach to learning allows individuals to tap into their unique strengths, fostering a broader range of skills and competencies that align with their specific learning styles and preferences. With this in mind, the purpose of this research was to investigate the use of AR applications for literacy (languages such as English and French) and numeracy (Mathematics) education at the elementary school level in Mauritius. The research sought to understand how learners learn with AR applications and why AR resources affect learning the way they do.

Specifically, the research aimed to explore how learners engage with AR applications, focusing on the mechanisms by which AR resources influence learning outcomes in literacy (English and French) and numeracy (Mathematics) at the elementary level in Mauritius. By examining these dynamics, the study sought to uncover why AR tools impact learning as they do, particularly regarding their ability to support deeper comprehension, sustained interest, and personalised skill development.

1.4 Focus of the study

This research aimed to understand the learning process using AR resources in Grade 1 classes in Mauritian primary schools. This study focused on the current status of teaching and learning with AR resources and their implications for learning. Of specific interest was the effectiveness of learning with the use of AR resources and methods, and how it differed from traditional teaching and learning, with a focus on Grade 1 learners. The study also sought to understand how AR resources and methods are implemented in the classroom and why they influenced the learning experience for kindergarten and primary school learners. Furthermore, this analysis also aimed to assist in differentiating between the effectiveness of the traditional classroom as compared with the AR classroom (Zhang, Li, Han, Su, Li & Pan, 2021). This analysis should assist in exposing the relationship between an improved learning system and the implementation of technology. The study also explores how learners currently learn using AR tools, and how this affects their performance. Additionally, what constitutes a successful teaching process is illustrated, as well as the effectiveness of AR materials, and the enhancement of teaching and learning for primary school children.

1.5 Research objectives

There are several objectives of this study on learning with AR resources. These objectives are given below.

1. Describe what learners learn with AR resources in the Grade 1 classroom. (Descriptive)
2. Explore how learners learn with AR resources in a Grade 1 classroom. (Operational)
3. Investigate why AR resources influence learning, in the way(s) they do. (Theoretical)

1.6 Research questions

This section presents the research questions for the study, i.e., learners' learning with AR resources. The research questions attempt to cover those aspects that require a deeper understanding of the research topic. The research questions are as follows:

1. What do learners learn with Augmented Reality resources? (Descriptive)
2. How do learners learn with Augmented Reality resources? (Operational)
3. Why do learners learn the way they do with Augmented Reality resources? (Theoretical)
4. Why do Augmented Reality resources influence (enhance or undermine) learning? (Theoretical)

1.7 Context

The context is discussed here to provide a deeper understanding of the problems and issues that the Ministry of Education and other responsible authorities faced during the pandemic. These related to the extended school closures and the technological challenges needed to provide an effective learning environment for learners. With the country's adoption of the digitised classroom and digitised resources, this section also discusses requirements for delivering an improved and organised education system for all categories of learners. Digital resources can aid understanding by using cognitive and psychological or affective approaches, which are enabled by audio-video tools. Such technological advances are also described, and an argument is made for the importance and urgency of adopting such resources in the nation's primary schools.

In the wake of the Fourth Industrial Revolution, ICTs continue to have a significant influence on people's daily lives, particularly in the schooling system – a subject of interest and study (Selwyn, 2016; Voogt, Knezek, Christensen & Lai, 2018; Zhao, 2018). Many projects have been launched across the globe to incorporate the use of ICTs in education. The Mauritian National Curriculum Framework, Grades 1–6, promotes ICT inclusion in Mauritian primary schools. Mauritius recently started digitising its print-based resources as part of this endeavour. To promote teaching and learning, integrated multimedia educational materials are presented on interactive whiteboards in classrooms (Udhin, 2019). As a consequence, the training and studying procedures for most classes has had to be reconceptualised. Furthermore, because the use of technology in Mauritian primary schools is still fairly recent, there is little research on teaching and learning with digitised materials.

The current study aims to contribute to this area of research by conducting a comprehensive analysis of learners' performance in Mauritian primary schools using digitised instructional materials. Furthermore, the evaluation of learners' knowledge using digitised assessment is a critical step towards guiding policy. Accordingly, this research is grounded in a metamodern philosophy or paradigm. In this context, meta-modernism is an integrated pluralistic research paradigm. Section 1.9 discusses reasons for this choice and its influence on the methods employed.

1.7.1 Country profile

This research was carried out in Mauritius, a small island nation of 1,860 square kilometres situated in the southern Indian Ocean. Mauritius has been subjected to various waves of colonialism. The Arabs and the Portuguese first visited the island many hundreds of years ago. The Dutch became the first permanent residents in the country, arriving in 1638 and departing in 1710. According to Udhin (2019), the French gained sovereignty of the territory after the Dutch and named it Ile de France. The French occupation spanned a century until being supplanted by the British in 1810. Mauritius gained independence from the United Kingdom in 1968, becoming a republic in 1992. Following independence, the economy was based mainly on agriculture. Throughout the 1970s and 1980s, the production of textiles and garments started to make a significant contribution to the economy. Subsequent decades saw the growth of the service industry, specifically banking and tourism. The Mauritian economy changed again early in the millennium, as efforts were undertaken to transform Mauritius into a cyberspace island. The nation began to offer offshore ICT-related solutions, including commercial and intellectual endeavours. Financial diversity has become a feature of the Mauritian economy, with commercial players now involved in the ‘blue economy’ or the ocean financial system. Furthermore, these socioeconomic developments have had significant implications for the Mauritian schooling system.

1.7.2 The education system in Mauritius

Mauritius was a British colony until gaining independence in 1968. The influence of the British colonial period is evident in various systems in Mauritius, including its educational system. The Mauritian educational structure has historically been shaped by the British format, encompassing elements such as the use of English as the primary language of instruction and the incorporation of a curriculum that aligns with British educational standards. English also serves as the language for government as well as for the judiciary.

However, most of the populace converse in Mauritian Creole, which is based on French. With such diversity, and because of the need to ensure financial sustainability, an autonomous and well-resourced schooling system is required that is capable of producing knowledgeable and competent graduates. The schooling system receives a large portion of the education budget, including personnel and finances, as well as free schooling throughout the nation up to the age of 16. The Ministry of Learning and Personnel Management, Tertiary Education, and Academic Research are in charge of education and the various educational levels, including basic, intermediate, professional, and post-secondary training. The Ministry of Education is primarily charged with "creating the next generation of forward-looking and innovative leaders contributing to the transformation of the Republic of Mauritius into a high-ranking and prosperous nation" (Ministry of Education, Tertiary Education, Science and Technology, 2023). Their mission is as follows:

- To ensure that the education system fosters a knowledge-oriented, cohesive, inclusive and productive society;
- To promote a holistic and inclusive education that makes learners upholders of values and encourages them to grow into resilient and globally-minded citizens;
- To create an enabling environment for technical and higher education, science and technology development;
- To equip learners with innovative, cutting-edge knowledge and deep research skills for increased competence in a dynamic work environment; and
- To sustain existing and motivating conditions towards recognition of Mauritius as a regional and continental education hub.

Additionally, the government also aims to stimulate creativity in order to establish and maintain a schooling system capable of meeting the difficulties and expectations of a future society. The Mauritian primary schooling sector has one of the highest rates of technology adoption globally, which is aimed to meet the challenges of the 21st century. Primary institutions in Mauritius educate children aged five to ten or eleven years old. Grade 1 courses are designed for the youngest learners, while Grade 6 lessons are intended for older children. This research was carried out with Grade 1 learners aged from five to six years old, and with the majority attending classrooms resourced with interactive whiteboards.

1.7.3 Role of ICT in the Mauritian education system

Mauritius has made significant strides in integrating technology into primary education, and the Ministry of Education has prioritised the use of digital resources as part of a broader initiative to enhance digital literacy from a young age. Efforts have focussed on creating equitable access to technology in classrooms, particularly for STEM (science, technology, engineering, and mathematics) education. Initiatives such as introducing technology-based learning tools and improving infrastructure underscore the country's progressive approach to digital education (Government Information Service, Prime Minister’s Office, 2023).

Consequently, ICT currently serves a significant role in the Mauritian schooling system by enabling educators to use digital technologies in instructional activities. Furthermore, during the last several decades, educators and authorities globally have realised that ICTs offer many special characteristics or possibilities that aid in the promotion of training and studying in elementary schools. Likewise, the implementation of ICT in pre-schools can only be successful when it is supported by robust educational policy and good individual training for educators, since they are the catalysts for teaching innovation. Accordingly, it was decided that the function of ICT in the schooling system should be included in this research report.

Inspired by the Singaporean model, the Mauritian administration envisions their nation as a cyber island – a major centre in Southern Africa. The Government of Mauritius has been actively advocating for the integration of ICT since 1989. During this period, it adopted a national ICT policy inspired by the Singaporean model. The strategic approach in Mauritius involved the implementation of measures to facilitate the liberalisation of the telecommunications sector, cultivate an ICT-literate workforce, enhance the capacity of public institutions to leverage ICT, and position Mauritius as a key player in the ICT sector by fostering an enabling environment and robust infrastructure. The National Information and Communication Technology Strategic Plan was initially embraced in 1998, accompanied by the initiation of various projects focusing on policy formulation, ICT awareness, human resource development, government computerisation, and standards setting. The overarching vision of the policy aims to transform Mauritius into a cyber island, where ICT becomes the fifth pillar of the economy, following sugar, textiles, tourism, and financial services, while also establishing itself as a regional ICT hub (Isaacs, 2007).

However, Mauritius still faces challenges related to digital resource accessibility and teacher training, as technology adoption in education is relatively recent in comparison to some more advanced economies. According to the World Economic Forum Global Information Technology Report (Dutta, Geiger & Lanvin, 2015), Mauritius ranks 76th out of 134 economies in terms of its network readiness index, which measures the degree of preparation of a nation to participate in and benefit from ICT developments.

1.7.4 Schools IT project

According to the Mauritian National ICT policy, there was a stipulation that Information Technology (IT) be included as a subject and seamlessly integrated into the overall curriculum in both primary and secondary schools. However, a persistent challenge remained in advancing connectivity within schools and establishing a network conducive to information exchange within the education sector. The Schools IT Project was designed with the objective that each of the 277 primary schools in Mauritius would possess, at a minimum, a computer laboratory equipped with 21 computers, two printers (one ink-jet colour and one laser black and white), a scanner, a digital camera, and a server with a LAN connection. All these facilities were planned to be linked to a network (SchoolNet), centrally managed by a robust server located at the Ministry. This central server would facilitate internet connectivity and provide access to online educational resources. In 2003, the demand for computer laboratories surged to approximately 317 (originally planned for 222), given that 40 schools with larger populations required two laboratories instead of one. The overarching aim was to ensure that all 5,400 primary school teachers underwent ICT training to effectively incorporate ICT as a pedagogical tool, with the target set for completion by 2006. By the conclusion of 2002, the Mauritius Institute of Education (MIE) had successfully trained 330 newly recruited ICT teachers, who were subsequently deployed to primary schools.

1.7.5 Digital education

Digital education is aimed primarily at the younger generation – known as digital natives, since ICT has completely transformed their lives. These digital natives were raised in an era where technologies dominated their surroundings, whether it was smartphones, smart entertainment systems, tablets, or other devices. In summary, digital education is regarded as a significant enabler in the shift from a knowledge-based to an information-based society. There is no question that learners need to understand how to interact using technologies for future employability. It is therefore critical for learners to feel at ease using ICT technologies. This period in education provided extraordinary prospects, such as interactive projections in schools and the use of iPads to enable learners to study with technology in the school. However, it was challenging for instructors and learners to fully engage with ICT because its introduction into schooling was relatively new, with little research available to guide implementation in schools. According to Udhin (2019), most research in this area focuses on the use of technologies to improve education and training and to assist learners in developing 21st century capabilities for a technology-based future. Additionally, the Mauritian National Curriculum Framework (NCF) aims to provide learners with comprehensive education to enable them to contribute to community development as well. With this prevailing goal and purpose, the NCF is likely to support the use of technology in education. Already, some programmes carried out by the Department of Education serve as examples of Mauritian attempts to encourage the adoption of ICT as early as elementary school level. Sequentially, these efforts included the initiation of an ICT lab and curriculum in early 2000, the education of ICT instructors during the following year, and the Sankoré project, which began in 2011. The first two projects were related and centred on the necessity of modifying basic curricula in the context of the new global trading environment. The Sankoré initiative aimed to automate the elementary school curriculum to provide learners with the required skills for the world of technology. The following section provides a full overview of the Sankoré initiative, which served as the foundation of this research study.

1.7.6 Early Digital Learning Programme (EDLP)

The Ministry of Education, Tertiary Education, Science, and Technology launched the Early Digital Learning Programme (EDLP) in 2017 (Oojorah & Udhin, 2022). The goal of EDLP was to change the conventional teaching and learning environment in all Mauritian primary schools by introducing the use of tablets and projectors into the curriculum. The tablets have dynamic learning tools and programmes that enable learners to generate and exchange information. The MIE has been tasked with developing interactive teaching materials, training various stakeholders in schools to use the tablets systematically, and to provide technical assistance. According to Oojorah and Udhin (2022), teachers are supported via educational trips during which MIE staff from the Centre for Open and Distance Learning address technical and educational concerns. Curriculum requirements for the use of iPads, projectors, and related devices have spurred the MIE to provide training courses to equip instructors with ICT competencies.

1.8 Research rationale

This section discusses the research rationale, which explains and justifies the choice of the research topic in the context of the use of AR learning resources in Mauritian primary schools. Teachers are frequently in search of fresh approaches and resources to engage learner interest in the content they are teaching. Currently, the literature reflects much enthusiastic discussion on the use of AR to improve teaching and learning. With the use of AR applications, instructors and learners can engage in projection-based, recognition-based, and location-based experiences that digitally bring artefacts, media, and objects into the classroom (Templeton, 2020). With AR, learners can walk about and interact with the information and develop a sense of achievement. Additionally, manipulation for research and learning can be more specialised. In order to demonstrate understanding of AR and how it connects to a certain standard or topic, learners have to become engaged. By viewing the artefacts while using AR in class, learners interact with the material and enhance their ability to learn. With the use of AR, learners tend to be more willing to investigate the task or lesson by applying their abilities in communication, problem-solving, and critical thinking. By connecting their projects with curriculum standards via the various AR applications, learners are able to show their aptitude for, and attitude towards, learning. These approaches can be implemented into the curriculum for all grade levels at school, and for many topics. AR also provides learners with virtual opportunities to visit historical locations, or to examine the microscopic world or deep-sea environments – opportunities that would not normally be available to them (Templeton, 2020). Such virtual engagement with the natural world enhances enthusiasm and motivation. Additionally, being able to provide such almost authentic learning experiences is an invaluable tool for teachers, as well as crucial for learners' present and future academic performance.

The ground-breaking technology known as AR overlays computer-generated electronic data on the actual surroundings. The consumer can watch and interact with Virtual Reality (VR) in real time. Several innovations are available in the field of AR, from research and development to the provision of AR/VR devices to users. With better graphics, smaller size, and more accurate identification, compact and sophisticated hardware has developed, improving user acceptance of AR technologies. Almost every industry has used AR, including technology, entertainment, and education. However, before this invention is widely embraced by all user types, fundamental accessibility issues that AR users face must be resolved. Using AR applications requires different ideas and greater creativity than using desktop programmes (Vuta, 2020).

Contrary to conventional desktop education programmes, mobile-based software solutions present special difficulties. There are currently few studies on usability heuristics and customer ease, despite the fact that current AR studies involve technology, psychology, efficiency, and hardware components. In order to identify the usability considerations that should be made while developing mobile-based AR apps for pre-schoolers, researchers have to use a systematic methodology. Innovations of today create intriguing new channels for exposing children to digital knowledge. There are several uses for AR, from more professional uses to entertainment and enjoyment. Since it is often necessary to use resources that provide a better vantage point of the object under study, the process of seeing and controlling virtual elements that simulate real-world situations has tremendous potential for teaching and learning (Garrett et al., 2018).

With regard to the formation of cooperative groups in AR, this can be facilitated through a multi-user platform, providing continuous service in a synchronous manner. In this setup, each user has the opportunity to view and interact with both real and digital objects from their individual perspectives. This research aims to understand learning using digital learning materials, and creates the backdrop for the inquiry by summarising the issues. This study poses the argument that it is vital to evaluate learners' work in some type of virtual environment, which concurs with Vuta (2020). The readers will have a better understanding of the concepts used in the study after reading a description of the key terms and concepts that are contextualised in this study (computerised training materials, learners' education, and digitised classrooms). The next chapters, especially Chapter 2, which examines the research assessment, go into greater detail on these concepts. The conceptual backdrop, study plan, and methodologies are briefly summarised in the introduction section. The later chapters will go into greater detail on these subjects.

ICTs have had an enormous impact on people’s daily lives, notably in education, as the Fourth Industrial Revolution approaches. Many projects globally have been initiated using ICTs in teaching and learning. ICT inclusion in Mauritian elementary institutions is encouraged under the Mauritian National Curriculum Framework for Grades 1–6. Using interactive whiteboards in schools, integrated multimedia educational materials are displayed to encourage both teaching and learning. As a result, training and learning methods – primarily those used in classrooms – have been reconceptualised. Furthermore, there is little research on the use of digitised learning materials in Mauritian elementary schools, since this innovation is still relatively new (Nielsen & Brandt, 2019).

Consequently, there is an urgent need for such research to be conducted and reported on. This study aims to contribute to fulfilling this need. Furthermore, assessing learners' understanding of using digital resources is a crucial step that is needed to ultimately inform policy. Results and recommendations from the current study are intended to contribute to these issues.

1.9 Research paradigm

Meta-modernism as a research paradigm encourages a dynamic, pluralistic approach, bridging modernist notions of structured inquiry with post-modern openness to complexity and subjective interpretation (Vermeulen & Van den Akker, 2010). This makes it particularly effective for qualitative research on digital transformation in education, where researchers must navigate the nuanced, evolving interplay between technology, policy and educational practice. By embracing both structure and fluidity, meta-modernism supports a framework where qualitative methods can reveal deeper contextual understandings of how digitisation influences learning environments, learner engagement and policy implications.

In the context of Mauritius' recent shifts towards digital classrooms and resources, meta-modernism provides a foundation to explore educational challenges and opportunities in an emergent, holistic manner. This aligns with the paradigm's tenet of capturing the oscillating needs between traditional education methods and innovative, tech-driven approaches (Turner, 2011). It also allows the researcher to employ qualitative techniques such as interviews, thematic analysis, and case studies to gain insights into the experiences and perspectives of educators and learners within this digital transition.

1.10 Influence on research methods and processes

With a meta-modernist approach, the qualitative methods used in this study are designed to adapt and respond to new findings, allowing the researcher to iteratively refine questions and techniques based on initial observations. For instance, Moraru (2019) emphasises that meta-modernism's adaptability is particularly suited for studies on technological adoption in education, as it accounts for varying educational settings, socio-cultural contexts, and participant needs. This iterative flexibility is crucial for exploring how digitised materials influence learning processes in Mauritian primary schools, where the integration of technology is still evolving and unique challenges exist.

Moreover, the paradigm's pluralistic nature justifies the selection of methods that allow for deep contextual exploration, such as narrative analysis and in-depth interviews. These methods capture the nuances of cognitive and psychological shifts in learners as they interact with multimedia content, aligning well with the affective and cognitive considerations central to the study's context.

1.11 Theoretical framework

The theoretical framework provides an explanation of the theoretical and philosophical underpinnings of the current study. Additionally, choices regarding the research objectives and research questions, as well as research methodology and data analysis techniques, are all framed according to these underpinnings. Three major theories frame the current research: Activity Theory by Yrjö Engeström (1987); Situated Cognition by Brown, Collins and Duguid (1989); and Neil Fleming's VARK model (1987). Additionally, these three theories are used to evaluate the effectiveness, validity and reliability of the research, as well as the implementation of AR curricula for teaching and learning in primary schools throughout Mauritius. These three theories will be briefly explained in the literature review to clarify research concepts about what, how, and why AR resources influence teaching and learning. Additionally, a detailed discussion and contextualisation of the theoretical frameworks is provided in Chapter 3.

1.12 Research methodology

The research process and methodological choices are discussed in detail in Chapter 4. That discussion includes choices deemed most appropriate to the investigation of the research questions posed for this study. Background on the current AR teaching-and-learning situation in Mauritius is also provided, with a focus on how this current situation can be informed by results from this research. Research methodology includes the different processes of data collection and data analysis, and the interpretation of the data. A qualitative methodology was followed using semi-structured interviews as the data collecting instrument. Qualitative methods are most commonly used to interrogate human behaviour and human motives, and to assess views and opinions. These social inquiry methods were applied to both traditional classroom settings and classrooms in which AR lessons were implemented for the improvement of the learning experience. Using semi-structured interviewing techniques, the researcher has attempted to capture, analyse, and present accurate and truthful interpretations of learners' beliefs regarding their learning process and their level of engagement in the different classroom settings. A case study method was used with face-to-face interviews conducted with learners from four zones. Public and private primary schools located in urban and rural locations can be found in each of the country's four educational zones. Data was gathered from three primary schools in Zone 2 due to the similarity in the types of schools in each of the four zones; three one-stream schools close to the researcher's place of employment were used. Interviews were conducted with learners from the first grade classes. On the basis of convenience sampling, a participant group of 45 learners in Grade 1 were chosen for the study. The three schools (School A, B and C) selected were found in zone 2. Purposive sampling was used to select participants. These schools were intentionally selected as they are in close proximity, allowing for more convenient data collection, and because they are representative of certain characteristics relevant to the research:

Geographical Diversity: Zone 2 encompasses a diverse geographical area, ensuring representation of various environments within Mauritius.

Socioeconomic Factors: Zone 2 includes schools serving diverse socioeconomic populations, offering a range of perspectives relevant to the study.

Cultural Diversity: Different schools in Zone 2 cater to learners from various cultural backgrounds, contributing to the overall representativeness of the sample.

Educational Policies: Zone 2 schools reflect broader educational policies and trends in Mauritius.

1.13 Scope and limitation of the study

This section deals with the scope and limitations of the study. This study focusses on how learners are currently learning with AR tools and how this has impacted their learning. The study also focusses on the effectiveness of AR resources, and distinctions between conventional learning and augmented learning. Broadly, therefore, the study focusses on the effectiveness of AR materials for the enhancement of the teaching and learning process for primary school children in Mauritius. Additionally, a successful AR teaching process will be illustrated.

The study aims to interrogate the present traditional learning process and its efficacy, as well as learning situations where AR resources are used in the classroom, and their impact on improving the learning experience for the learners (Cook, 2019). The results of the study will compare the effectiveness of the conventional classroom with that of the AR classroom.

This study aims to advance knowledge of AR as a tool for enhancing the educational process in the classroom, as well as to assist in determining the connection between an enhanced learning system and the use of AR.

There are a number of limitations to the study, which revolve around subjectivity and reduced opportunity to collect contradictory evidence. Chapter 4, the methodology chapter, provides discussion on the measures taken to address subjectivity in qualitative case study research. This involved a thorough examination of the validity and reliability concerns inherent in case study research and a detailed explanation of how these concerns were mitigated in the present study. Also discussed is the use of multiple sources of data, triangulation methods, and the researcher's reflexivity to acknowledge and manage subjectivity.

Additionally, the research design precluded opportunity to collect data on the disadvantages of AR implementation in the classroom. An explanation for the absence of such data is also dealt with in Chapter 4, including the potential impact of this limitation on the study's comprehensiveness, with suggested areas for future research to address the identified gap.

1.14 Research ethics

Research involving young learners (in this study, five- and six-year-old children) involves ethical considerations at every stage of the investigation. These were considered throughout the research project as a continual and reflective component of the research process. Secondly, schools can request that no study be conducted during class hours and only allow researchers to interact with the children during recesses. The ethical implications of using children's recreational time at school also had to be taken into consideration. These contextual constraints imposed on researchers were used to guide the data collection process.

1.15 Key elements

The key elements of this research are those associated with the digitised classroom, AR resources, and learners’ learning ability with the use of those resources.

1.15.1 The digitised classroom

Digitised classrooms continue to play a significant role in teaching and learning, enabling learners to study more effectively and intuitively.

Setting up the classroom environment with the likes of 3D, AR and VR resources can help the teachers demonstrate learning materials, class problems, 3D models, etc., more precisely. It is hoped that findings from this research will help with the redesign of traditional classrooms into digitised classrooms with more effective training and teaching methodologies.

1.15.2 AR resources

Smartphones have become an important device for learning in the 21st century through the use of different applications. These applications can help learners identify with real-time experiences in the virtual media and make learning more interesting, engaging, and relevant. For example, when learners learn about volcanic eruptions, digitised application-based learning can be used to explain the mechanism of the eruption, with audio-visual content for better understanding.

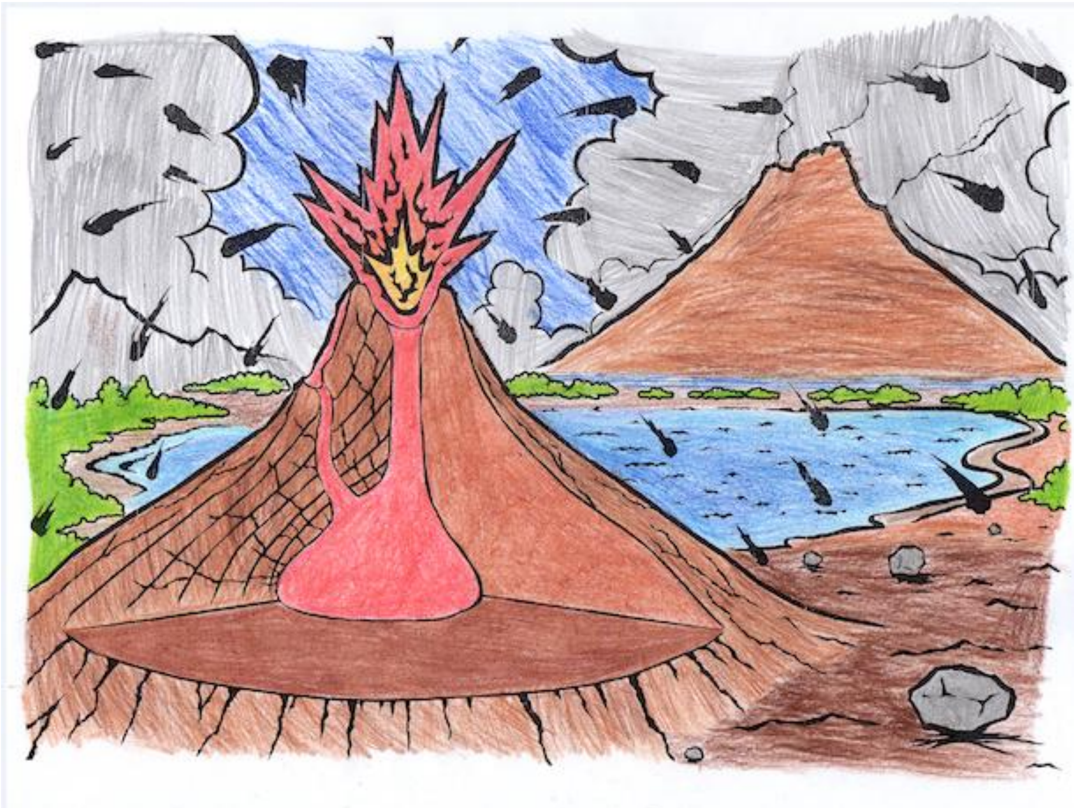

Figure 1.1: Demonstration of a volcanic eruption with the help of AR resources

(Source: quivervision.com)

1.15.3 Learners' learning

Our understanding of the learning process is undergoing a fundamental shift due to the ICT-enabled classroom environment. Digital literacy, digital training, distance learning, artificial intelligence, as well as VR are all examples of ICT-enabled learning (Zhang et al., 2021).

In contrast to the past, when studying was achieved via knowledge drilling and practices, learning nowadays is more creative and authentic. Consequently, there has been a movement towards project-based or problem-based education, inquiry-based studying, and experiential learning that precisely meet the needs of modern society and emphasise personal capacity building (Vuta, 2020).

1.16 Thesis structure

To address the aforementioned research inquiries, this research report has been structured into five parts contained in the various chapters (see Figure 1.2). These are:

1. Setting up the scene
2. Conceptualisation and contexts of learning
3. Researching learners with AR resources
4. Analysing learners' learning through AR resources
5. Learners' learning with AR resources in the metamodern era.

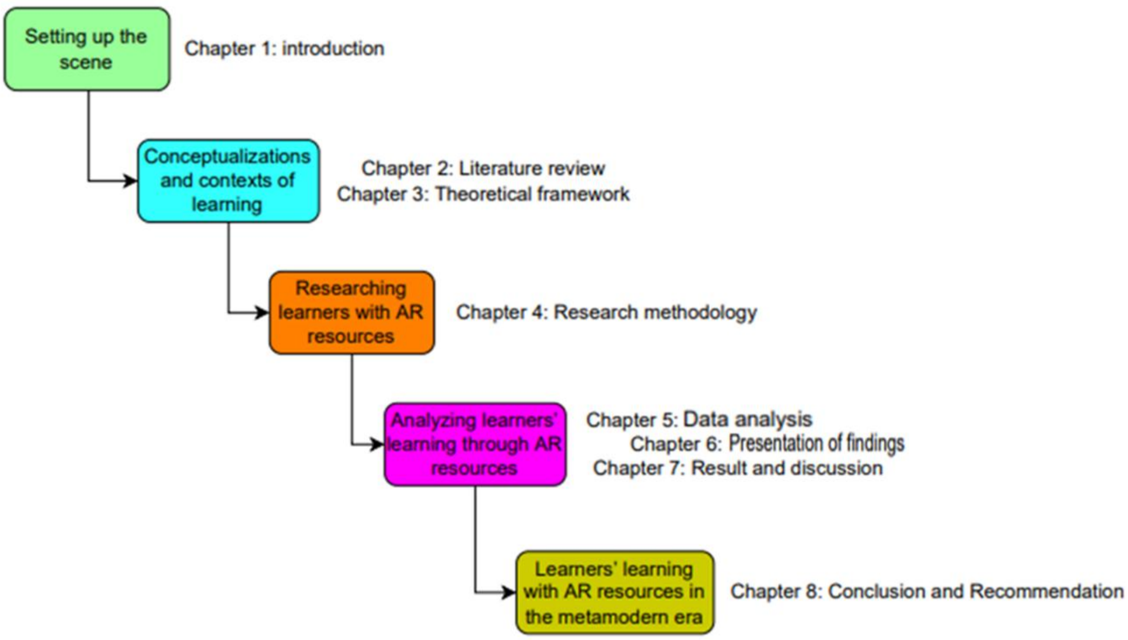

Figure 1.2: Thesis structure

(Source: Self-created at draw.io)

1.17 Chapter outlines

Chapter 1 provides the background to the study, including the problem statement, focus of the study, research objectives and research questions. The context of the study is articulated from which the research rationale is derived. The chosen research paradigm is explained, as well as theoretical frameworks and methodology. Scope and limitations are discussed, followed by research ethics and key elements of the study.

Chapter 2 reviews the literature relevant to the study. The main sections deal with AR and its role in digital education, including the advantages and disadvantages of learning with AR. The focus is then narrowed to the application of AR in the learning and development in children.

Chapter 3 deals with the theoretical principals guiding the study. Connectivism and enactivism provide the learning theories. The three theoretical frameworks used in the analysis and the interpretation of data are discussed in detail, namely: Activity Theory, Situated Cognition and the VARK model.

Chapter 4 deals with research design and methodology, including their epistemological and ontological basis. Sampling, as well as data collection and data analysis are explained and justified. Reliability, validity and ethics are revisited in greater detail.

Chapter 5 presents results from the analysis of the various data sources. These results are triangulated to produce initial findings, which are discussed against relevant literature.

Chapter 6 provides the final synthesis of results to address the research questions. This final synthesis provides the findings of the study. In-depth discussions and critical reflections are offered, as well as a constructive analysis of limitations. Conclusions and contributions close the chapter, as well as implications for future research.

1.18 Conclusion

This chapter has established the defining aspects of the research study – both theoretical and pragmatic. Background and context lead to the rationale, objectives and research questions. Selected literature explains AR and digital education and its relevance to Mauritian primary education.

The paradigm within which the study is located, as well as the theoretical frameworks that influence the methodology are justified. Finally, more pragmatic concerns related to process and methods are dealt with.

Central to the discussions in this chapter is that little research has been done in Mauritius on how digital materials influence learning in elementary schools, since the use of technology at this level is relatively new. Furthermore, assessing learners' understanding of using digital resources is a critical step towards determining policy to replace outdated teaching methods with tools and strategies to keep pace with the current digital revolution while fulfilling the educational needs of Mauritian elementary school learners.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The literature review chapter is of great significance for any research report or academic work, as it helps to situate the study in the relevant academic discourse. The literature reviewed also serves to support or challenge the findings of any study in order to advance knowledge in that area. This introductory section provides an overview of this chapter and summarises the topics dealt with.

The main research analysis is concerned with Augmented Reality (AR) resources as one of the most important digital resources to be used in the education sector in recent years. It is also supported by ancient traditions of teachers using puppet shows, dramas, or models to assist learners with conceptualisation through visualisation. Augmented learning, and other types of digital learning, include audio-visual representations that have been shown to be very effective for cognitive learning. This research study included a wide range of different types of digital aids to support pre-school learners or primary school learners in their education in Mauritian primary schools.

Firstly, literature dealing with the concept of AR resources is reviewed, followed by how AR resources could be used in education, especially for Grade 1 learners. The advantages and disadvantages are discussed in detail in order to clearly delineate the benefits as well as the drawbacks of AR in the classroom. Children's learning development is also examined using different models from the literature as applied to digital settings. The demographic influence is elaborated on as well in the section on learning and learning styles. A literature gap is identified and discussed in relation to research choices made in the current study.

2.2 What is Augmented Reality?

Augmented Reality is a technology that overlays virtual items including 3D computer-generated items, messages, and sounds on real-time photos and videos. AR is defined and classified in a variety of ways. Cascales, Pérez-López and Contero (2013) define AR as a form of Virtual Reality (VR), a technique that involves completely immersing a viewer in an artificial world. The user cannot observe the adjacent actual environment in VR, but it is observable with AR. In this regard, AR differs from VR because it inserts artificial information into actuality while not concealing the actual surrounding environment.

AR has already been hailed as one of the most intriguing emerging innovations for learning (Sotiriou & Bogner, 2008), and as a strong motivational tool that engages the learner's many senses with the correct mix of interactive audio and visual stimuli (Zhang et al., 2021). The use of AR technologies in teaching is in its initial stages, particularly with young learners. AR supports the teaching and learning experience in a variety of ways, including engaging learners' perceptions in collaborative exercises using manipulated materials. Furthermore, pleasurable edutainment via user-friendly interfaces promotes self-learning. In terms of technology acceptance, recent research has shown that learners, as well as their families, have expressed favourable attitudes towards AR (Gün & Atasoy, 2017; Cascales et al., 2013).

AR can be combined with VR, but these two technologies remain distinct. To illustrate the distinction, learners can experience real-time experiences with virtual objects in the AR environment, whereas VR provides only virtual-world experiences, shutting down real-world encounters. Both are 3D assets, but AR can help to distinguish between real-world and the virtual-world settings, whereas VR resources fail to differentiate between them. According to Kesim and Ozarslan (2012), AR must have three attributes: it must combine the actual and artificial environments; it must engage with the viewer in real time; and it needs to be represented in 3D space. AR enables users to observe the actual world while supplementing reality without entirely submerging them in an artificial setting. With the invention of the first head-mounted display device by Ivan Sutherland in 1968, AR technology was established. Tom Caudell, a Boeing scientist, coined the term Augmented Reality (Wang, Zargar & Yuan, 2021). AR demonstrates the capacity to uphold the verisimilitude of the user's perceptual experience within the authentic physical realm, achieved through the simulation of virtual objects that furnish pertinent supplementary information. This engenders a state of partial immersion wherein the user remains connected to the real world. Azuma (1997) delineates three defining characteristics of AR: firstly, the provision of a concurrent view encompassing both real and virtual objects for the user; secondly, interactivity that spans both the real and augmented domains; and thirdly, the ability to register entities in 3D space through the precise alignment of real and virtual objects in relation to one another. The contextualisation of AR within broader environmental paradigms is elucidated by the Reality–Virtuality Continuum, posited by Milgram and Kishino (1994), as depicted in Figure 2.1. This continuum delineates the spectrum between the physical and virtual worlds, with Mixed Reality positioned centrally, constituting augmented realms. AR enhances the real environment by incorporating virtual objects, while Augmented Virtuality employs real-world entities to augment the virtual environment.

The continuum presented in Figure 2.1 underscores the multifaceted nature of AR and its nuanced relationships with diverse immersive environments.

Figure 2.1: Reality–Virtuality continuum (Milgram & Kishino, 1994)

AR resources are those digital assets that can support effective digital learning using audio-video concepts with real-time experience in virtual media. An important educational consideration related to ICT, especially AR, is that the household environment influences a child’s ICT adoption. There is a generally held belief that learners' academic successes have always been encouraged by their households, which is one of the research interests in this study. Parents who desire their children to succeed are among the most enthusiastic supporters of ICT for education. Parents typically link ICT with academic accomplishment and distinguishing achievements. To summarise, available research (e.g., Aydogdu & Kelpšiene, 2021; Bailey & Bailenson, 2017; Udhin, 2019; Yilmaz & Goktas, 2017; Zhang et al., 2021) indicates that family context, particularly parental involvement, has an effect on children’s ICT use overall, which would consequently have an effect on their performance at school. However, there is no research that describes the cluster of parental characteristics that impact children who only use AR as a teaching aid in pre-school. Thus, this poses a promising area of study on the potential relationship between parental characteristics and children's use of AR for academic reasons. The current study aims to add to understanding in this area.

AR has been characterised in a variety of ways by computer scientists and educators. Milgram, Takemura, Utsumi and Kishino (1994) characterised AR as having two strategies: wide and confined. In a wider sense, AR relates to supplementing natural input to the controller with artificial signals. In a confined sense, the technical component is stressed, hence describing AR as a sort of simulated realism in which the user's head-mounted screen remains transparent, enabling a better sight of something resembling the actual world. Additional studies define AR based on its own properties.

According to Wu, Lee, Chang and Liang (2013), AR may be characterised as a system that combines actual and simulated worlds, and allows for real-time collaboration, and precise 3D registration of digital and physical items. Furthermore, Wu et al. (2013) state that the concept of AR should not be interpreted narrowly, i.e., that AR could refer to almost any technique that meaningfully combines actual and digital information. According to Klopfer and Squire (2007), AR might be roughly characterised as a scenario that occurs when an actual world setting is continuously superimposed on a cohesive position or environment-sensitive digital environment. In this case, AR gives consumers technology-mediated interactive encounters wherein real and simulated environments are mixed, and consumers' connections and involvements are enhanced (Klopfer & Sheldon, 2010).

As mentioned, virtual realism is not identical to augmented realism. One of these primary distinctions is that VR can completely submerge the user and prevent them from seeing the actual environment surrounding them. According to Azuma (1997), AR allows individuals to observe a genuine environment that has been enriched by digital features. AR features are comparable to those shown in the movie *Who Framed Roger Rabbit?* in the sense that the spectator can see both the actual environment and the additional virtual features simultaneously. AR settings also provide real-time 3D interaction. Traditionally, AR has proven especially useful for educating or training individuals in possibly dangerous circumstances where real-world knowledge is required, but where a real-world encounter might pose an unacceptable amount of risk. For example, in clinical training it is crucial to experience the texture and sensation of human limbs as well as their resistance to biopsy needles. However, because the danger of using genuine limbs is considerable, combining synthetic limbs with an ultrasonographic picture of a genuine limb is advantageous in teaching doctors about real-world treatments. AR has additionally been used in construction, aircraft production, printer maintenance, and combat experience. AR devices can also be made transportable inside a backpack for outdoor work.

2.3 AR in education

Many applications exist that attempt to teach learners how to competently use ICT, predicated upon the notion that the advantages of ICT for learning are significant (Safar, Al-Jafar & Al-Yousefi, 2016). In recent years, a significant portion of work in the academic ICT field has been used to tackle issues of fairness and equality.

There has been a growing body of research on the application of ICT to schooling, as well as to outdoor education or informal learning (Goswami & Bryant, 2007). ICT-mediated schooling should be regarded holistically, considering broader societal or cultural contexts, including aspects of home and community.

AR is still in its infancy within formal schooling. In 2010, Klopfer and Sheldon (2010) started looking into its potential use as an academic training tool. They discovered that AR was particularly beneficial for teaching about phenomena that learners could not readily encounter in their environment. Goswami and Bryant (2007), for instance, have investigated the application of AR to educating learners about Earth–Sun interactions regarding tilt angle and solstices. The learners who obtained the greatest increases in comprehension moved the digital picture in a pattern of 'move, analyse, then move again'. According to this study, learners used both bodily encounters with the AR display, and spoken interactions with their instructor. They were able to spin the picture and observe it from various angles, allowing them to challenge their beliefs and develop new knowledge. Wang et al. (2021) contend that the 3D quality of the encounter, as well as the greater choice participants had during the encounter, enhanced learners' understanding of the interconnections between the Sun and the Earth. O'Shea et al. (2009) have shown that, in contrast to traditional computer interfaces, the AR approach delivers a higher degree of cognitive accessibility to complicated infographics. In the course of their investigation, the researchers expanded upon prior studies by furnishing educators and learners with an interactive virtual representation depicting a revolving celestial body alongside a sun, modelling the correlation between sunlight, nocturnal periods, and diurnal phases. The Earth (or the celestial body) can be observed as if sitting in the sunlight (the viewable half of the globe in daylight) or from interstellar space (the dark side of the globe at night). Various studies have investigated how the learners, and their instructors, make use of such capabilities. These studies have revealed that, by offering an immersive and manipulable model of celestial movements, AR not only deepens learners' comprehension of complex astronomical concepts, but also fosters critical thinking as they question, analyse and reconstruct their understanding through direct interaction with dynamic visualisations (Goswami & Bryant, 2007; Wang et al., 2021; O'Shea et al., 2009). This hands-on, exploratory learning experience uniquely positions AR as a transformative tool – one that surpasses traditional methods in making abstract, interdependent phenomena cognitively accessible and personally engaging for learners (Klopfer & Sheldon, 2010).

Previous research has evaluated the efficiency of AR in teaching about various topics, including chemical structure for adult learners and in narratives for younger learners (Zhang et al., 2021). Recently, AR has been used to support informal education in galleries and instructional exhibitions. It is noteworthy that in the majority of contemporary research endeavours, participants have been required to use a transparent helmet-mounted display system. These helmet displays are costly and inconvenient, and can result in spatial discomfort. To address these issues, the ‘virtual mirror’ approach employs a computer monitor or whiteboard rather than head-mounted screens (Moser, 2020). This provides the added benefit of providing content accessible to more than one user at a time. As a result, it is better suited to use in schools with bigger classes of younger children, as well as to encourage cooperative and modularised teaching. The technical research department of the *BBC*, BBC Creative Research & Development, conducted research on the usage of such an interaction in 2003, which served as the foundation for the present study (Wang et al., 2021; Yilmaz & Goktas, 2017). The virtual mirror interface application with big class groupings is yet to be properly investigated. The study with children using headsets has demonstrated that AR is highly entertaining for this age group, with some instructors stating that technology has the ability to, for example, enhance higher-level cognitive abilities and allow children to envision a goal they want to achieve. Further, Lee et al. (2017) stated that there are numerous unresolved questions about the possible advantages of AR in schooling, and they have recommended further research into the advantages of AR over more conventional learning methods. Wu et al. (2013) compared the application of AR with simulated mirrored interaction to teach 10-year-olds about the interconnections between the Earth, Sun, and (in the conventional lessons only) the Moon. According to Wu et al. (2013), the application of AR in education, characterised by its mixed and enhanced reality features, presents compelling advantages. The full potential and affordances of AR can be maximised through the strategic integration of various technologies in the design of AR systems.

2.3.1 Advantages and disadvantages

This section looks at the advantages as well as the disadvantages of AR resource use in pre-school, which might assist in the effective implementation of AR resources in Mauritian primary schools. It is evident that AR resources have an array of benefits for primary, as well as higher education for purposes of clearly defining concepts. For primary learners, especially Grade 1 learners, it is one of the most effective learning tools for integrating VR with the learners' senses.

It has numerous advantages for study problems, models, or materials, for a better and more effective understanding of the content. However, it also has challenges for learners not familiar with the digital setting of the educational environment. The section below discusses some of the pros and cons of AR resources for Grade 1 learners.

2.3.1.1 Advantages

Although AR has received much interest in current decades, various scholars have given the concept diverse interpretations. This section begins with an outline of AR terminology, taxonomies, and technology. This research contends that understanding AR as a concept rather than a type of technology could be more beneficial to teachers, scientists, and architects. This section therefore defines the specific properties and attributes of AR devices and implementations. These properties, however, are not limited to AR solutions and might be encountered in other technical systems or educational contexts (for example, ubiquitous as well as mobile learning settings). When using AR, the integration of technological design, educational strategy, and experiential learning becomes increasingly significant (Wu et al., 2013). While AR provides new educational possibilities, it also presents new obstacles for teachers. In this section, the technical, methodological, and learning difficulties associated with the use of AR in teaching are discussed. Learners in AR contexts, for instance, may well be intellectually overwhelmed because of the huge quantity of data they receive, the many technological tools they must use, as well as the complicated activities they must perform. This section explains themes and difficulties for future studies as well as possible solutions to some of the obstacles.

AR produces an experience that is enriched by bridging the divide between digital and actual realities. AR's opportunities for instructing and training are rapidly being acknowledged by educational academics. The combination of simulated artefacts and true environments enables learners to visualise complicated spatial connections and abstract ideas, encounter phenomena that are not realistically possible, communicate with two- and three-dimensional artefacts in blended situations, as well as develop critical practical and information literacy that may not develop in many other technology-enhanced educational experiences. Because of these pedagogical advantages, AR has emerged as one of the most important developing innovations for teaching in the next five years. Although AR has received much interest in recent years, academics have given it varied interpretations.

Furthermore, AR can be built up by combining and linking several innovative technologies (e.g., mobile devices, laptops, iPads, tablets, computers, and other immersed technologies). However, as with many other advancements, the instructional merits of AR resources are intimately tied to how AR is being developed, executed, and incorporated into both official and unofficial learning situations. The objective of this thesis is to explain the existing state, potential, and problems of AR in schooling in order to present new perspectives on the possibilities provided by AR.

2.3.1.2 Disadvantages

There are many disadvantages of AR resources that can be presented alongside its numerous advantages. The disadvantages are described below under three headings: technology issues, pedagogical issues, and learning issues.

2.3.1.2.1 Technology issues

According to literature, one version of AR technology involves a head-mounted screen and/or an extra backpack containing computing equipment (Cercenelli et al., 2022). This design is cumbersome and costly and may cause discomfort as well as poor spatial awareness. To circumvent such issues, contemporary AR device research recommends transportable techniques that are less invasive and increase a feeling of reality. However, because these solutions incorporate various devices and application components, they can cause challenges when interfacing and with device reliability. Learners may struggle to distinguish between cues provided by the devices and the actual surroundings, recognise knowledge transfer from one gadget to another, and effectively navigate between imagination and actuality due to poor control or behavioural guidelines. Furthermore, the more instruments that are utilised, the higher the danger of equipment damage. It is therefore vital to understand how to keep these numerous devices stable. Instructors identified GPS inaccuracies, for example, as very problematic during studies conducted by Wu et al. (2013). The current rapid rate of progress in this area may be able to resolve the challenges of equipment compatibility and reliability. A laptop, PC or smartphone may feature a range of features, such as a built-in video recorder, GPS, wireless transmitter, speedier CPU, and substantial hard drive storage as well as a number of programmes. Mobile gadgets in AR technology are expected to become more compatible and dependable while performing simulations, gaming, films, and even GPS services. An additional problem appears to be the maintenance of a technological balance between geographical reliance and independence (Klopfer & Sheldon, 2010).

While location-specific techniques contextualise learners' knowledge, provide position and orientation, and assist learners in giving new significance to familiar destinations, the location-independent format has the benefits of adaptability and adjustability since it does not require educators and learners to be present in exact locations, thus saving significant transportation costs. To strike a compromise between these two methods, teachers and architects may create a layout that not only links to real-world locales, but also contains key elements present in those less-accessible places (Klopfer & Sheldon, 2010). TimeLab 2100 integrates mobility with geographical awareness, offering tangible real-world settings such as classrooms and bus terminals. In these environments, learners can identify local alternatives for specific educational requirements.

2.3.1.2.2 Pedagogical issues

Whenever AR devices are utilised in schools, there are additional pedagogical difficulties that must be addressed. Firstly, as with much previous educational advancement, the adoption of AR resources in classes may face institutional limitations and instructor reluctance. AR-enhanced learning processes often employ novel methodologies such as interactive simulations and studio-based teaching. The essence of such instructional techniques differs significantly from the teacher-centred and delivery-based emphasis of traditional learning techniques. Institutional limitations, including having to present a specific quantity of information within a specific time period, also make it harder to adopt innovations. As a result, there could be a disconnect between the conventional instruction and training methods employed in universities, and the learner-centred and experimental-style education enabled by AR technologies. Developers of AR educational experiences must recognise the differences and provide whatever assistance is needed to enable instructors and learners to overcome this ‘disconnect’. The second problem is one of curriculum development, as discussed below.

How might knowledge be transmitted and flow across two environments, and across multiple pieces of equipment, when designing educational exercises and AR frameworks? According to Klopfer and Squire (2008), combining opposing demands for uniqueness, together with dissemination using decentralised data streams (as well as with directed instructional initiatives), might constitute platform conflicts. To reconcile this contradiction, teachers and architects might benefit from a collection of architectural standards centred on cognitive concepts (e.g., dispersed cognitive and contextual knowledge) and experimental data.

Another educational concern with AR applications appears to be the lack of adaptability of the material (Folke, Carpenter, Walker, Scheffer, Chapin & Rockström, 2010).

Certain AR technologies have predefined material and learning sequences, and instructors are unable to modify these to fit learners' requirements or achieve other educational goals. Composing technologies, which enable instructors and learners to modify and build AR events and programmes, might help to address this problem (Ansari & Baby, 2023).

2.3.1.2.3 Learning challenges

There are additional issues concerning learners and their educational experiences. Learners inside an AR educational environment may experience intellectual overload due to the enormous quantity of data and material they receive, the various technical gadgets they must utilise, as well as the complex activities they must complete. What this means is that learners within AR settings have to multi-task. According to Wu et al. (2013), learners frequently experienced a sense of being overwhelmed and bewildered when participating in a multi-user AR scenario, as they have to cope with unfamiliar technology along with demanding tasks. Furthermore, for assignments in AR settings, learners may need to use and integrate a range of specialised skills such as spatial working memory, cooperation, problem resolution, technological control, and quantitative estimation. An earlier study has suggested that a dearth of such critical skills is among the causes of learning problems in AR settings (Oberhuber, Kothe, Schneegass & Alt, 2017). Supplementary scaffolding, especially for younger learners, is required to assist them to generate appropriate problem-solving strategies, according to the cues supplied by the technological tools, and appropriate to real-world situations. Additionally, AR creates an environment in which reality and imagination are intermingled, which may cause confusion for some learners. Some children lose perspective on where the simulation ends and reality begins (Klopfer, 2008). Although this issue exemplifies the realism of AR applications, losing touch with the actual surroundings can be counterproductive to education and might even endanger learners' safety and security.

2.3.2 Literature gap

This section highlights some of the core concepts needed for this area of research, which are not covered sufficiently in the literature. Thus, it also helps to identify insights needed for future research. The literature gap is that portion of additional research needed to assist in the analysis of future research findings.

This research study focusses on learning with digitised resources, such as AR, where a gap exists in current literature regarding how learners learn with such resources, as well as their attitudes towards learning with these resources. One gap within the literature is research on feelings, ideas, sentiments, goals, or thought processes, as indicated by behaviour. An additional gap is that other studies have not used actual data from real-world classroom situations. This deficiency is because the majority of these studies were conducted on either animals or adults. There has been no extensive investigation into how children acquire knowledge using AR tools. An additional vacuum in the research is that it centres mainly on the use of technologies, as well as their consequences, rather than on how learners learn using these technologies. Another major deficit in the research is that personality development, which does not remain constant, has not been considered.

One of the initial shortcomings in this research is that, currently, no concept exists to effectively describe young learners' performance in school curricula using computerised educational materials. The second shortcoming is the fact that teaching theories, as dealt with in the previous section, do not directly address the mixed character of 21st century classrooms (nor in the Mauritian context of this study). In this study, the intricacies of education have been explored through an examination of various learning patterns. These insights were supported by two well-known constructivist learning theories, which provided an analytical framework. Research limitations were also identified and are discussed below.

2.4 Children’s learning and development

Children's education is an extremely complex phenomenon and the researcher used the various developmental stages children undergo to help analyse learning using computerised learning tools. The intermediate or micro concepts that are discussed in this section are derived mainly from the work of Yilmaz (2016), Safar et al. (2016), Moser (2020), Cook (2019), and Nielsen and Brandt (2019), with a focus on the first three articles, as these three thinkers provided useful insights regarding learning among children from Grade 1 and of ages six to seven. Furthermore, Yilmaz (2016), Safar et al. (2016), and Moser’s (2020) view on children’s education and development are essential works.

2.4.1 Digital learning and identity development

Many researchers discuss how AR influences children's learning abilities and how to improve effective engagement through better management of the AR resources in science modelling, music practice and others (Garzón & Acevedo, 2019; Nielsen & Brandt, 2019; Cook, 2019). This research supports extra-curricular activities for personal skills-building and identity improvement, and the development of skills for future application. Additionally, Oojorah and Udhin (2022) have discussed how these Early Digital Learning Programmes or EDLPs help to improve children's cognition and skills development.

Masmuzidin and Aziz (2018), who are known for their contributions to psycho-social theories for children, have argued that 'identity' is formed at a very early age when the infant is recognised as a distinct person. As infants develop, significant characteristics of their parents are adopted; however, the youngster finally begins the act of personality development. This ‘sense of identification' has long been accorded high significance, as authenticity is thought to be closely related to the growth and development of the child, combined with education (Wu et al., 2013). These authors have posited a hypothesis of how children construct a ‘feeling of identity’ in the context of a post-modernist age. It is posited that identity has three components: the ego, self-identity and socio-cultural identity. These authors believe that identity development begins at pre-school and serves to provide a connection to prior experience, while offering guidance for the future.

2.4.2 Psycho-social development

Nielsen and Brandt (2019) have claimed that temperament development occurs sequentially through a series of phases of psycho-social growth. It is believed that the psychological crises that people may experience at various times in their life can have an impact on their psychological growth, either favourably or adversely. Bullying, for instance, can have an impact on a child's individual growth. An important finding from this research is that identity development does not remain constant, as people ‘reinvent’ themselves at various phases.

Moreover, Masmuzidin, Aziz and Suhaimi (2022) believe that a child's interpersonal communication and experiences are not formed as a consequence of romantic arousal, as Freud asserted. Rather, socio-cultural influences play a crucial role in shaping identity, with early identifications contributing significantly to social integration during adolescence. This is alluded to as the 'method of recognition' by Koca, Yüzgeç and Çubukçu (2024). Because identity development and training are inextricably intertwined, the investigator considered it worthwhile to incorporate concepts from Gün and Atasoy (2017) to include the influence of digital materials.

Research by Goswami and Bryant (2007), while not directly addressing early identity formation, provides insights into the later stages of adolescent identity building, which is an essential component of overall social development. By understanding these later identity constructs, a broader perspective can be gained on how foundational experiences and influences can scaffold into adolescent self-concept and social integration. This study attempted to fill a void in the research by assessing learners aged five to six who were studying with AR resources. This approach aimed to provide greater insight into assertions regarding how digital educational materials influence identity and socio-cultural development (Fan, Antle & Warren, 2020). Furthermore, this research added to the corpus of knowledge on education and identity building.

2.4.3 Active learning

The discussion of Dünser and Hornecker (2007) on styles of teaching, which centre on self-directed activities, hands-on acquisition, and participatory play, presents an alternative perspective on children's learning. Their work suggests that engaging children in active, exploratory learning can foster deeper understanding and retention of knowledge by encouraging children to learn through doing and playing. This approach contrasts with traditional, more passive teaching methods, emphasising the value of experiences that allow children to construct knowledge independently and collaboratively.

Dunleavy and Dede (2014) conducted experimental work that shed light on the concept of pre-school education and learning. The project was later expanded to include learners of all ages, allowing researchers to observe how interactive and immersive approaches can benefit diverse age groups. This broader scope helped demonstrate the adaptability of their educational strategies and their potential to support lifelong learning across developmental stages. As the current study focussed on children in the age range of early infancy to age six years old, the investigator chose to employ the research of Safar et al. (2016) and Chen et al. (2017).

Freitas and Campos (2008) suggest that for effective education to occur, children need to make innovative decisions and select suitable tasks to guide their learning experiences. By empowering children to engage actively in decision-making and task selection, educators can foster a sense of agency and autonomy in learners, which research shows is essential for meaningful learning. This approach aligns with constructivist theories, where children learn best when they are actively involved in shaping their educational journeys.

Lee et al. (2019) have argued that, at the age of six, children transition from being less inactive to more responsive. It is proposed that the intellectual development of a six-year-old child extends beyond mere reception of information, marking the initiation of active participation in thinking and meaning-making. This transition leads to stability and progress with relatively minimal fluctuation. Lin et al. (2013) defined this as conscious education, which is highly engaging and vital for the child. These authors argue that youngsters from the ages of six to twelve can create judgments using their own creative thinking skills.

2.4.4 Socio-cultural influences

Markamah, Subiyanto and Murnomo (2018) have proposed that when adolescents connect with their personal cohort of peers, they improve. Liu et al. (2007) demonstrated this by displaying learners collaborating in teams in school. Montessori's (1967) ideas on training were relatively similar to Vygotsky's (1978) thoughts on teaching because they both emphasised the role of social economic elements in facilitating education (Udhin, 2019). Although both Yilmaz (2016) and Woolley and Jarvis (2007) agree that education is important for infant growth, their theories vary greatly.

Holton (2010) claims that even a six-year-old child creates knowledge based on their inherent natural curiosity through study, which indicates that even if children are left to follow their instincts, they would still be inspired to continually investigate their world. It has been suggested that, when the setting is well-designed, children may learn via their innate interests. On the contrary, Maiese (2017) claims that there is not anything fundamental or physiological in operation, arguing that children develop knowledge via encounters with socio-cultural settings. Wilson (2012) concurs, stating that even a common cultural domain shapes a child’s personality and cognitive functioning.

While Montessori saw education as exploration depending upon that child's preparedness and motivation (Jeong, Franchett, Ramos de Oliveira, Rehmani & Yousafzai, 2021; Fleming, Culclasure, Warren & Riga, 2023), Vygotsky (1978) saw education as guided exploration with curricula and instructions (Udhin, 2019). The learners in this research used digital learning materials in a structured classroom where the atmosphere was not previously conducive to fostering interest and knowledge construction through social interactions. Training could be exploratory, as stated by Montessori (Kamil & Asriyani, 2023; Demangeon, Claudel-Valentin & Tazouti, 2023), or guided discovery, as asserted by Vygotsky (1978), or it may represent an approach on the continuum between the two approaches to education. Montessori and Vygotsky's theories do reflect two ends of a continuum regarding child-centred versus guided learning approaches, though they are not necessarily in strict opposition. Montessori's approach emphasises child-led, exploratory learning, believing that children are naturally motivated to explore and learn independently as their readiness allows (Montessori, 1967). In contrast, Vygotsky's theory stresses the importance of guided instruction, where learning is scaffolded through interaction with knowledgeable others, such as teachers, who help learners achieve tasks they could not accomplish alone (Vygotsky, 1978).

2.4.5 Development of intellectual skills

Mental tools may also assist in education. Holton (2010) defined thinking skills as tools which accompany a person during their integration into society. This statement was made in reference to ideas on acquisition proposed by Duke et al. (2013). Duke et al. (2013) have suggested that individuals acquire five distinct knowledge types or intellectual skills as they mature, which reflect behavioural, epistemic and societal dimensions (Amhar, Sabrina, Sulasmi & Saragih, 2022). Originally, they identified four foundational intellectual tools: somatic, mythic, romantic and philosophical understanding, to which ironic comprehension was later added. These tools represent varied ways of understanding the world, each with unique cognitive and affective processes that contribute to holistic intellectual development. Each intellectual skill or knowledge emerges at a given age or stage in the development of the person.

Because this dissertation was written for young learners, the romanticist intellectual skill was emphasised, as supported by Wu et al. (2013). The basic elements of romanticist knowledge involve proficiency in literature and reading, along with the development of refined sight and reasoning skills. Certain thinking capacities, for example, can be employed to create tales, fantasies or metaphors. Children can gain numerous skills, such as creating metaphors instead of merely absorbing them (Yilmaz, 2016). According to Pearson (1990), several studies have contended that pre-schoolers can complete a metaphorical phrase more readily than older children. The pre-schoolers may be better at metaphors since they relate to their interests and surroundings. Children can gain numerous skills by creating metaphors instead of merely absorbing them (Yilmaz, 2016).

In the 21st century, cognition development frequently relates to technologies employed as training aids (Herrington & Parker, 2013). The relationship between learners and digital materials was investigated during this research to ascertain how and when the learners developed innovative problem-solving skills.

The opinions of Gardner (2006) match those of Montessori education, i.e., a child's curiosity is considered essential for learning to take place (Kamil & Asriyani, 2023). This aligns with the idea that curiosity-driven exploration plays a crucial role in self-supervised prediction, as discussed by Pathak, Agrawal, Efros and Darrell (2017). This was also noted by Vygotsky (1978), who proposed that a learner's desire to learn must be recognised by classmates or culture. In this PhD research, the educational theories of Montessori and Gardner were explored in relation to learners aged six to seven years, with a particular focus on contexts where technology integration was emphasised. The study aimed to compare how these theories, which advocate for individualised and holistic learning, align with the experiences of children in today's digital age. This interpretivist approach enabled a deeper understanding of how these educational paradigms manifest in the classroom, especially in environments where technology is encouraged as part of the learning process (Montessori, 1967; Gardner, 1983).

According to Udhin (2019), whenever ideas are translated into visuals, feelings are engaged. Udhin argues that creating one's own visuals from words may boost the depth of knowledge development. Udhin’s (2019) observation is rooted in how visual engagement can deepen cognitive processing and comprehension. By translating abstract ideas into visuals, learners activate emotional and sensory areas of the brain, which supports stronger memory formation and enhances conceptual understanding. This connection is particularly valuable in educational settings because it encourages learners to interact actively with the material. When learners create their own visuals based on textual information, it fosters a more profound level of engagement, helping them not only retain but also personalise the knowledge, potentially leading to improved critical thinking and long-term retention. These ideas are of particular relevance to learning with AR resources.

2.5 Learning and learning styles

2.5.1 Evaluation of learning with technology

2.5.1.1 Learning in the pre-modern era

Belief in a certain type of divinity was how people in the pre-modern age typically conveyed their feeling of identity and mission. Pre-modern societies did not consider the development of separate identities (Garrett et al., 2018). Learning was seen as the foundation of every country's progress (UNICEF, 2023).

Socrates, Plato, and Aristotle, three giants of ancient thought, were frequently described as members of the 'wisdom-loving disciplines', and the information they provided remains relevant in a post-modern era. Despite the opinions of his predecessors (Plato and Aristotle), Socrates felt that schooling was not a method of learning, and therefore maintained that we should teach ourselves to recall our lost wisdom. Socrates' focus was not on instructing, but on reminding people of the reality that exists within them. He proposed that a question-and-response method, held in informal outdoor settings, would awaken the truth within people (Mares, 2018). Plato later developed a more organised idea of learning that was intimately tied to the many virtues that a person should achieve (Mares, 2018). Plato saw schooling as educating individuals in groups on how to keep the equilibrium associated with specific qualities. He used politicians as models of caution and warriors as demonstrations of valour.

Plato felt that if early learners had been entitled to equal academic chances, all individuals might live together in peace. Furthermore, Plato proposed that learning was primarily for people who completed higher-level tests and that individuals who were unable to pass this assessment should be allocated employment. He did not think that learning was intended for all members of the community. Aristotle argued against this, stating that chances to learn should be available to all people who are eager to learn. His aim was to produce extraordinary intellectuals who would benefit society (Mares, 2018).

Additionally, during the Roman Catholic Age (500 AD to 1500 AD), educational paradigms were predominantly characterised by memorisation and rote learning (Bhattacharya, 2022). Udhin (2019) contends that in the pre-modern era, emphasis was placed on teacher-centred curricula, with traditional schooling heavily reliant on acquiring information from sanctioned authorities. It was considered that the origin of information was guided by a heavenly blueprint.

Learners were viewed as having no authority to question or criticise, or generate individual meaning, since information was regarded as divine and immutable (Dusil, Kannowski & Schwedler, 2024).

As a result, the primary paradigm of education was ‘transmission-based’, on the assumption that knowledge was derived from ultimate reality and truth (Austin, Orcutt & Rosso, 2001). Learners were considered inert consumers of learning, and instructors' roles were defined as teaching people rather than facilitating learning (Higgs & McCarthy, 2008). This approach, often known as a ‘transitory way of instruction’, was the sole method employed at the time (Bolgia, McKitterick & Osborne, 2011). Pre-modern thinkers never explored the different aspects that could impact the moulding of learners' knowledge, including through the use of technology.

2.5.1.2 Learning in the modern era

The modern era encompasses the early contemporary era, which spanned from roughly 1500 AD until around 1900 AD (but sometimes considered as extending up to 1945) (Spielvogel, 2011; Wiesner-Hanks, 2019). The Renaissance is an example of an earlier modern facade. The Reformation was the transitional phase between the Late Middle Ages and the Early Modern Period. Even during the Reformation (15^{th}–17^{th} century), the paradigm of education moved from memorisation to inquiry- and discovery-based education. Furthermore, with the advent of inventions, such as telescopes and microscopes, new views emerged, which expanded the boundaries of thinking and understanding. This period was referred to as the Age of Discovery and Globalisation because it saw great advancements in sciences, politics, the military, and engineering. The emergence of contemporary industrial society and the fast spread of urbanisation, accompanied by horrific responses to World War I, were some of the elements that defined modernism.

Modernism challenged Enlightenment certainties as well as religious convictions. Education as knowledge transmission was called into doubt. Educators were regarded as co-creators of information, with the authority to criticise information. The contemporary era's principal goal was to unite civilisation in order to create equal ideals and experiences across diverse civilisations. The dominant schools of thinking would have been to allow learners to build and apply diverse skills and ideas. As the learner was no longer a static recipient of information, but instead an active participant in the curriculum, the teacher–learner interaction strengthened.

There are several hypotheses that describe how people acquire knowledge. It is critical to comprehend the many learning approaches and their applications, as well as to assess and link the various viewpoints to the study topic of this research.

The cognitive process, which refers to the relationship between experiences and surroundings, represents the most basic type of studying. In summary, the ‘associative learning’ concept states that the brain generally retains knowledge when it is linked to authentic experience, rather than learned in isolation. Moreover, Garzón and Acevedo (2019) proposed the notion of 'classical and operant conditioning', which entails remembering through affiliation: that is, linking two concurrent experiences. They contend that the reaction might be contingent or unmanifested, with the only distinction being that the stimuli are varied. Moreover, Thorndike (1898) has argued that Pavlov's concept could not describe most environmental behaviours because it did not take into consideration the intricacies of varied actions in the surroundings. Hence, Thorndike invented a novel notion, which he dubbed ‘operant conditioning’. He contended that sophisticated behaviours are the result of expected results rather than prompted events. Garzón, Baldiris, Gutiérrez and Pavón (2020) expanded on the concept of 'operant conditioning', suggesting that somehow a rewarded action is likely to be replicated, but a non-rewarded action is likely to diminish and eventually vanish. He described action with rewards as positive encouragement, which could include vocal reassurance such as “that's really excellent” or “you're doing exceptionally well, continue to do so”. He claimed that removing an undesirable consequence of an activity can increase performance of that activity.

Table 2.1: Evaluation of learning with technology

Year	Learning and aspects of technology
The mid-1960s	Computers were first used in classrooms, enabling personalised drills and repetition to strengthen fundamental abilities.
The late 1970s	Microcomputers were created, allowing for experimentation-based learning.
1980s	Programmes including word processors, spreadsheets, and distant learning through two-way voice and video are introduced.
The mid-1980s	Innovative techniques using interactive multimedia elements were introduced.
1990s	With the usage of the modern internet, the World Wide Web with interactive elements to expand curricula across a wide variety of disciplines, multimedia instructional technology began to gain traction. This strong association with technology aided in addressing several educational issues.
2000s	Technology is widely used to alter how and what learners learn in school.

2.5.1.3 Learning in the late modern and post-modern era

According to Udhin (2019), late modernity (late 20th century) is simply a phrase employed by authors who do not embrace the shift to a newer social phase of post-modernism, but who nevertheless admit a drastic amplification of certain features of modernity. Many historians label current society as ‘post-modernity’, arguing that it is the outcome of the expansion and growth of certain social factors that shaped previous types of modern community interaction. His ideas focus on the decline of history, social relationships, and the disembodying of both place and time. Improvements in communications (digital communication), transportation, and societal institutions allowed time–space connections that were previously restricted in modernism and post-modernism. Unlike the pre-modern age, which was been governed by conventions, late modernisation saw tradition lose dominance. Individuals in post-modernity were more able to be reflective about their social surroundings by deciding who they wanted to ‘really be’. Max Weber, like Giddens, holds the same viewpoint, arguing that ancient and medieval civilisation was overly influenced by convention (Käsler, 2004). Late modernism was a time when people could take responsibility for themselves and consider various options. Individuals began to examine themselves rather than obey conventions.

People began to comprehend their self-identity, and they were proactively moulding and commenting on themselves. As individuals proceeded throughout existence, they were creating their individual personal tales.

The post-modern era may be construed as a characterisation of the contemporary age or as a phase dedicated to instigating educational reform. In this period, the aim of learning shifted towards empowering learners to cultivate their individual identities, assume responsibility for their own learning, and acquire knowledge at their own discretion. Practical education, proactive teaching, and learner-centred learning took precedence, consequently delineating education in the post-modern era as an emphasis on experiencing, experimenting, and building knowledge (Udhin, 2019). Learners might gain information through educational processes within post-modern classrooms. Personal diversity in education was highlighted instead of conformity in concepts and practice (Park, 2018). This was the period when different learning studies began. Variations in learners' teaching strategies were identified and emphasised.

Udhin (2019) used the notion of ‘interest’ to characterise education in the post-modernism period. Education can be characterised as a fairly persistent shift involving both observable action and interior activities such as cognition, beliefs, and feelings. The ‘reinforcement theory of education’ was enhanced with the addition of motivation, which results in the intended outcomes. It was suggested that efficient learning occurs particularly when optical or visual perception is stimulated. Oojorah and Udhin, (2022) stressed the idea that varied stimuli such as colours, sound, and motion stimulate many senses, resulting in better knowledge construction. The gap in this area of research is because the majority of the work was conducted with animals or adults. There has been no extensive investigation into how youngsters learn.

The current research aimed to comprehend how children learn by focusing on the range of stimuli that might be present in a digitised curriculum applied to a traditional setting. Similar to the pre-modern age, a traditional classroom setting promotes transmission-based education. These contradictions in conventional classroom design with the use of internet materials may affect how learners learn. This is where this research can contribute – by providing an understanding of education where technologies have become a vital element of the instruction and studying processes, but still inside the conventional classroom setting. Furthermore, Udhin (2019) highlighted the importance of the educator in addressing challenges in various studies of social constructivism.

He emphasised the importance of the instructor in scaffolding education and training by directing learning processes to elicit deep evaluation and, therefore, meaningful learning experiences. This shift in understanding can affect people's learning processes, as education is inextricably linked to people's ideas. The notion that once people gain confidence they become able to generate expertise by themselves, persisted throughout the post-modern age.

Constructivist, as well as socio-constructivist approaches have become the prominent educational philosophies in the post-modernism era (Çekiç, 2010). Constructivism stressed the creation of new learning based on prior encounters. Constructivists believed that individual action has a significant influence on the production of reality. Interpretivism exhibits a heightened sensitivity towards individual meanings and contributions, deviating from the constraints imposed by the positivist research philosophy. Nevertheless, interpretive research is not without critique, as it eschews the notion of knowledge development grounded in universally applicable laws, prompting a reassessment of its validity criteria distinct from those embraced in the positivist paradigm. Moreover, the interpretive paradigm assumes the subjectivity of reality, acknowledging its potential variability across different individuals. Consequently, this premise implies that research participants may not furnish universally applicable interpretations (Scotland, 2012; Collins, 2010). The behaviourist approach does not see learning as being intrinsic to the learner. Behaviourists contend that information is received through outside factors or resources, and that acquisition occurs through the activity of comprehension. Constructivism, on the other hand, argued that learners are not empty vessels waiting to be supplied with information. Constructivists contend that learners actively strive to generate significance from their information. Interpretivism emphasises lifelong learning and contends that the 'open-ended' nature, rather than 'fuzziness' in schools, is designed to equip learners for ongoing and continuous education. According to cognitivism, children learn depending on what is offered to them and through interactions with their surroundings. Udhin (2019) built on Dewey's position in the post-modernism age with the notion of the Zone of Proximal Development (ZPD), which he defined as the developmental stage a child can achieve with sufficient scaffolding. According to Vuta (2020), the social situation plays a pivotal role as a catalyst or guiding force for both evolution and acquisition, fostering a sense of progression and assimilation. Vygotsky integrated constructivist principles and practice with a societal view on education. He highlighted the importance of interpersonal and cultural connections for knowledge generation.

He described the ZPD as the difference between the real developmental stage, as measured by individual problem-solving, and the degree of potential development with guidance from parents, instructors, or more competent peers. Vygotsky coined the term ‘scaffolding’ to describe the assistance that a more competent individual offers learners in order to assist them to master a particular activity or ability (Shabani, 2016). He also advised that peer relationships be used to collaboratively build or co-construct knowledge. Vygotsky’s research focussed on the importance of cultural and societal variables in intelligence, and he viewed speech as the single most significant method of instruction. According to Shabani (2016), Vygotsky thought that teaching occurs through participating in the learning experience.

2.5.1.4 Learning with Augmented Reality technology

Teaching and learning using AR relies heavily on technology. This term ‘technology’ has been used in prior research to distinguish AR. Klopfer and Sheldon (2010), for instance, characterised AR as a ‘technology’ that combines actual and digital world experiences. This limited approach regards AR as simply a type of simulated environment with a head-mounted screen. This concept represents earlier applications of AR to education, which often comprised head-mounted gear for superimposing virtual content on the actual world. However, with the rapid advancement of ICT, the definition of AR can be progressively expanded as additional equipment and programming components are used to generate virtual reality. For example, advances in mobile computing provides new possibilities for augmented realism (Squire & Klopfer, 2007) and generates a subset of AR known as ‘mobile AR’.

AR techniques allow learners to participate in realistic discovery inside the actual world, while virtual features such as documents, videos, and images serve as extra materials to enable learners to examine their environment. Among the most common applications of AR entail annotating current locations with a layer of location-based data. Secondly, the usage of AR technology might include the merging of the real world with virtual learning materials. As Klopfer and Squire (2008) showed, using AR allows learners to encounter scientific events that would not be conceivable inside the actual environment (for example, chemical reactions). Liu et al. (2007) suggest many AR technologies to achieve this aim, e.g., by using AR investigations, learners were capable of seeing simulated solar panels on the lecture room tables or visualising photosynthetic activity. Furthermore, Wu et al. (2013) discovered that AR techniques have the ability to involve learners in managing virtual items from a range of viewpoints.

A 3D interactive geometric system (Construct3D) targeted at assisting mathematical and geometric teaching was created in the investigation by Kaufmann et al. (2005). Construct3D, as an AR platform, offers learners a real-world context in which to work, as well as digital 3D items for learners to control, analyse, and modify in an attempt to understand spatial connections. While high-end circuits and complex techniques are employed in AR techniques, as Wu et al. (2013) explain, such techniques really are not crucial for educational scholars. What is more essential is how technology facilitates and enables effective learning. Teachers, scientists, and architects might benefit from seeing AR as a concept rather than a specific set of equipment. To this end, the following section deals with the characteristics and attributes of AR technology for learning purposes.

2.5.2 Attributes and affordances of AR resources

Drawing on studies that employ AR for academic purposes, the characteristics and capabilities of AR technology are discussed in the five subsections below. AR can provide: (1) educational material from 3D viewpoints (Rohendi & Wihardi, 2020; Krüger, Palzer & Bodemer, 2022; İbili, Çat, Resnyansky, Şahin & Billinghurst, 2020); (2) omnipresent, cooperative, and contextual learning (Davari-Najafabadi, 2024; Grubert, Langlotz, Zollmann & Regenbrecht, 2016; Davari, Stover, Giovannelli, Ilo & Bowman, 2024); (3) learning perceptions of embodiment, intensity, and absorption (Riva, Baños, Botella, Mantovani & Gaggioli, 2016; Georgiou & Kyza, 2021); (4) visualising the unseen (Majgaard, Larsen, Lyk & Lyk, 2017; Sotiriou & Bogner 2008; Salmi, Kaasinen & Kallunki, 2012; Alrashidi, Almohammadi, Gardner & Callaghan, 2017; Vrellis, Delimitros, Chalki, Gaintatzis, Bellou & Mikropoulos, 2020); and (5) linking official and unstructured education (Holley & Hobbs, 2019; Drljević, Botički & Wong, 2022).

Firstly, AR can improve educational experiences by allowing learners to engage with 3D virtual elements. AR allows learners to supplement their visual impression of the content or surroundings by using 3D artefacts. Learners can examine the 3D item from various angles to develop a better understanding. For example, Wu et al. (2013) demonstrated how effective 3D AR is when used to teach astrophysics. AR and conventional training experiences were incorporated into the investigation. Instructors and primary school learners used a whiteboard, projector, web camera, AR tiles, and digital 3D modelling tools to view and manipulate a simulated 3D rotating world to study the Earth and the Sun, as well as daytime and night-time.

The conventional teaching approach for this topic involves reading a printed book, lecturing about the planetary system, and demonstrating these concepts using physical 3D items (e.g., a bouncing ball, a cord, and a light). The research by Wu et al. evaluated the queries instructors asked throughout the two sessions, as well as in the surveys conducted following the workshops. They discovered that educators recognised the advantages of employing 3D imaging and thought that AR may make difficult content accessible to learners. Early chemical education studies may shed light on this subject. Wu et al. (2013) discovered that learners who used both digital and practical models fared much better than learners who used only one of these models. They also claimed that both digital and analogue representations “should indeed be supplied during classroom teaching since different kids have inclinations for various kinds of modelling and symbolic sets" (pp. 41–49). However, more evidence is needed from AR studies to justify the adoption of AR-based 3D digital simulations over real-world 3D counterparts.

A second aspect of AR capabilities is the use of portable devices. The omnipresent or portable AR solution might allow widespread, cooperative, and contextual learning augmented by computational methods, simulations, modelling, and virtual elements in actual surroundings using mobile phones, wireless connections, and location-registered technologies. Accessibility, social involvement, contextual responsiveness, connectedness, and uniqueness are some of the benefits of this type of platform. Numerous smartphone AR applications, e.g., Environmental Detectives and Mad City Mystery, were created to enhance outdoor education. In Environmental Investigators, learners conduct inquiries using portable computers, obtain data specific to the site, evaluate and analyse the findings, and present solutions responsive to the setting. According to Squire and Klopfer (2007), involving learners in performing computer games in real-world settings can increase context awareness and lead to better-educated judgments that take account of all contextual elements. Furthermore, employing portable gadgets in dynamic situations may confuse learners and encourage task disruptions. These incorporated attention-aware capabilities may assist in eliminating task disruptions and controlling children’s attention, as an AR device can recognise learners' whereabouts and functioning state, send task warnings, as well as provide options to redirect learners' attention. Furthermore, social involvement increases when learners cooperate via connected portable devices along with face-to-face encounters, and scaffolding tailored to diverse avenues of study can be offered to foster originality (Klopfer, 2008).

Thirdly, Wu et al. (2013) have stated that AR as well as other immersed educational modalities, including meaningful gaming and simulated worlds, provides attributes of the present, as well as proximity and engagement. AR can establish a mediated environment that enables learners to perceive themselves in a shared space with others. This feeling of engagement can aid learners to connect with their broader community of peers. AR technology can also deliver real-time feedback with vocal and behavioural signals to increase learners' feeling of urgency. Timeliness plays a crucial role in fostering emotional engagement in educational settings. AR integrates learners, digital content, and interactive elements within real-world environments, creating a sense of immediacy that can enhance learner engagement and motivation. By immersing learners in responsive, contextualised learning experiences, AR has the potential to make educational content more relatable and impactful, which is essential for emotional resonance in learning (Billinghurst & Duenser, 2012).

Interactive media, as exemplified by AR, have the potential to evoke a profound sense of immersion among users, where an immersive state is defined as the subjective impression of active participation within a detailed and authentic scenario (Algerafi, Zhou, Oubibi & Wijaya, 2023). Empirical findings underscore the nuanced nature of the AR experience, contingent upon the level of immersion experienced, whether high or low. Consequently, organisations are compelled to carefully consider methodologies for gauging AR experiences to enhance user engagement and satisfaction (Tom Dieck et al., 2023). These authors also recommended that involvement could enable learners to better understand real-world problems, difficulties, and their surroundings. Current research on a portable AR unit with attributes capable of boosting learners' sensations of existence, urgency, and engrossment has shown success in the teaching of socio-scientific issues around nuclear power and environmental damage caused by radioactivity. These issues were dealt with in relation to the fatal nuclear failures at Japan's Fukushima Daiichi Nuclear Power Plant following the earthquake. Ninth-class learners utilised Android tablet devices to gather information on radiation intensity readings at their school, which was taken to represent a site 12 kilometres from the nuclear power plant during the first day following the plant's hydrogen gas leak. The research discovered a substantial relationship between learners' impressions of AR activities and changes in their views concerning nuclear issues. These results strongly suggest that AR can potentially influence learners' emotional dispositions towards real-world concerns (Ishii et al., 2007). Another feature of these capabilities is that AR allows the depiction of unseen ideas or occurrences by projecting virtual items or data onto actual items or settings.

By utilising virtual elements such as atoms, matrices, and signs, AR technologies could assist learners to understand abstract concepts or unobservable phenomena (Zhang & Wang, 2021), such as ventilation or electromagnetic fields. Augmented biochemistry, for instance, allows learners to choose chemical components, combine them into 3D molecule structures, and flip the images. Wu et al. (2013) added 3D material to a paper-based colouring booklet and gave youngsters a pop-up reading sensation that visually represented the written material. Such augmentation provides new representations that have the ability to improve learners' comprehension of complex and unseen topics or events. A final characteristic of the affordances mentioned in the literature is the possibility for AR to provide bridging between formal and informal education (Fukuhara, Yamawaki & Kageyama, 2010). The CONNECT project, for instance, used AR as well as other technologies to create a digital scientific theme-park setting. There were two settings in the surroundings: exhibition style and classroom mode. The environmental situations comprise online and traditional field excursions to scientific institutions, pre- and post-visit educational exercises, and experimentation and modelling tasks. Thus, throughout this initiative, scientific instruction at schools was linked to teaching activities in online and traditional gallery tours, through the use of AR to supplement learners' visualisation, experimentation, and modelling. An early review of the CONNECT programme found that the atmosphere affected learners' subjective willingness to study science as well as their conceptual knowledge of the abstract concept. However, the appealing qualities and attributes highlighted throughout this subsection might not be exclusive to AR, as some of these may be encountered on other platforms or in other contexts with comparable technological advances or ideas (e.g., omnipresent and transportable learning spaces). To fully utilise the attributes of AR, it is necessary to investigate how the usage of AR might be coordinated with various teaching methodologies, in particular, to accomplish desired academic goals. The teaching and learning methodologies shown and classified here have been utilised in constructing AR training experiences and AR in various educational contexts.

2.5.3 How AR resources influence learning practices of primary learners

With the improvement of technology, learning becomes easier to understand using known models and digital resources. AR resources are digital resources that can enable users to experience real-life events or sensations through virtual media. Whenever learning occurs through examples or storytelling, it becomes easier for the learners to understand the meaningful concepts in the problem situation. For example, young learners become enthusiastic, which assists them to engage effectively in class discussion.

The swift interaction facilitated by AR allows learners to grasp new study topics more effectively, contributing to the development of cognitive learning foundations and immersive learning practices. It also enables learners to understand learning content with real-life sensations, which is one of the most effective practices for any category of learners, especially at primary level, as they can better understand real-life situations through virtual media. Hence, studying becomes more interesting to learners, which helps them to engage intuitively in class discussions. Such technological implications can help to improve learning practices in any classroom setting. Young learners are influenced to a greater extent by these types of learning practices. Cognitive and physical growth is most malleable in early years; thus, primary schools would benefit by employing these types of learning practices in their education system. Certain cognitive and intellectual foundations are laid down in younger children, and this has implications for later academic and professional performance; and ultimately nation building. Several researchers argue that augmented technology helps to bring more sophisticated insight to young learners. Technology facilitates real-life experiences through virtual objects, engaging the emotional or affective domain and enhancing deeper understanding (Yang, Cai, Diao, Liu, Liu & Xiang, 2022). In addition, it helps to clarify concepts and enhance motivation (Raposo et al., 2020).

AR resources are excellent digital resources for creating a cognitive and affective learning experience. Engaging both these domains concurrently can influence the brain’s structure and activity, which is why such learning practices are able to generate a deeper and longer-term understanding of concepts; as well as improve self-realisation (Radu et al., 2023; Fagbemi, 2023).

AR innovation has been used for a wide range of instructional and entertainment purposes. AR enables users to interact with the actual environment while immersed in computer-generated material. The user can observe and engage with the digital content concurrently. With MagicBook, a strategy to enhance a conventional format with digital material was developed. The MagicBook framework (Dünser & Hornecker, 2007) has been implemented in a variety of ways, ranging from computerised ‘pop-up books’ that enable the reader to go and see interactive 3D material and affiliated audio (e.g., the eyeMagic book) as well as booklets that permit viewers to communicate with the virtual elements, and novels where the subscriber can smoothly move between the simulated information in the books, totally absorbed in that environment (Dünser & Hornecker, 2007).

Augmented textbooks have piqued the interest of scholars and teachers alike as a way to enrich textbooks with dynamic visualisation and modelling, animations, 3D images, and music. By proactively investigating and altering the media, such functionalities introduced to a printed book can improve the participant's learning experience (Dünser & Hornecker, 2007). Utilising such tools and techniques of display could result in greater comprehension of complicated dynamics or 3D designs, as well as overcoming the limits of traditional instructional media. Aside from providing a more accurate portrayal of certain knowledge, dynamic 3D visualisations can excite learners and increase participation, hence facilitating immersed education. Rather than merely showing and engaging with text content on desktops, an AR page allows for the incorporation of actual user engagement, which can assist in education, and cooperation among users. Users may read the ebook in the same way as flipping the covers of an actual book. The incorporation of additional engagement tools might allow readers to engage with certain aspects and effectively participate in the tale. Conversation, self-directed understanding, exploration, and cooperation may all help with learning and understanding. Dünser and Hornecker (2007) contend that most instructors believe that practice is the greatest teacher. Yet, in practice, learners are rarely offered the chance to have a first-hand interaction with what they are learning. The use of new educational media could improve the reading and studying process. Dünser and Hornecker (2007) found that young learners' encounters with dynamic books were influenced by a variety of elements, ranging from technology execution to the incorporation and layout of the dynamic sections.

Augmented tale booklets can be created for particular purposes, such as allowing youngsters to construct their own original tales and illustrations utilising AR technologies. Some scholars also examined various methods of non-linear cinematic storytelling that enable the readers to choose alternative pathways in a tale or adjust the storyline based on the route chosen (Bolewski, 2012; Rothe & Hussmann, 2019). The training system under consideration here is aimed at what Dünser and Hornecker (2007) refer to as an 'explorative action', in which a learner investigates a model contained within a system. Clearly, the tale determines whether or not a text is captivating. Although Mckenzie and Darnell (2004) suggest non-linear and participatory tales and exercise textbooks as AR book possibilities, the tales utilised throughout this experiment were interactive but maintained a sequential plot thread. Readers could engage with certain aspects of the tales. The learners had to perform tasks that did not alter the storyline.

The utilisation of AR books in schools for literacy development among children aged six to seven was investigated in a study conducted by the BBC (Hornecker & Dünser, 2007). This research employed two AR books to explore how these young learners interacted with the stories, both individually and in pairs, outside of the classroom setting. The study aimed to examine the children's engagement and management of enhanced textbooks, assess the effectiveness of incorporating participatory story elements in enhancing teaching and learning, and evaluate whether writing supports cooperative learning. The researchers observed eight pairs of participants, involving six learners each, focusing on their cooperative learning activities related to the narrative and their interactions with the platform. The study began with a discussion of the technology and the overall research methodology. Subsequently, the findings were detailed and discussed, with a particular emphasis on topics related to the development of AR-based narrative books.

AR has the ability to involve and drive learners to study content from a range of different viewpoints, and it has been found to be especially beneficial for presenting academic content that learners would not be able to encounter directly in the actual world. This also allows the display of spatial connections and the interconnections between items inside a 3D area, as well as the possibility of flawless communication between the actual and digital environments. It allows instructional technology designers to work towards a particular academic outcome with a dense mix of digital equipment and applications. However, little is known about how elementary school instructors may integrate AR into their classes, or the architectural criteria that would be required. Consequently, this study also looked at the capabilities and limits afforded by AR technologies to learners and instructors in Mauritian traditional education institutes. Because of the structure of the Mauritian standard curriculum, instructors frequently have a short period, of approximately 30–45 minutes, to deliver a substantial quantity of essential content. This limits the time available for learners to investigate complex topics. AR applications may be useful in this regard. However, it is necessary to first understand the design principles used if the intention is to provide learners with a rich immersive game while also meeting the organisational standards of the standard curriculum. Throughout this study, the characteristics of AR and incorporated resources will be discussed, including the technologies employed and how they have previously been implemented in academic settings. To achieve this, the study uses an experimental investigation involving 45 children aged five to six years old and their instructors from four Mauritian primary schools.

The conversations among instructors using AR were analysed and compared with those using conventional techniques. The approach relied on two data sources: video recordings of classroom events, and voice transcripts of instructor interviews. The results showed that instructors were optimistic about the prospective advantages of AR for teaching topics such as the Earth, Sun, and Moon, and that it might render such source material approachable to learners in a way that makes it real. However, programmes must be more interactive and flexible in addition to allowing users to manage aspects of the technology, i.e., educators and learners must be able to slow down or pause animated patterns to study them, as well as examining events as the occur. The methodology was influenced by socio-cultural philosophy, particularly the idea that knowledge is constructed and disseminated within the entire teaching-and-learning context. This philosophical model takes account of the social character of education and the impact of human action on a mediating instrument that affects both the nature of the action and the actor. Under such conditions, the subject of study becomes the mediating role played by the interaction between the person and the instrument or object. Because the whole is larger than the aggregate of its parts, the study emphasis is on the investigation of persons employing technologies in contexts.

Researchers of media impacts have shown that people might react to digital content (e.g., computers, TVs, and Immersive Virtual Reality (IVR)) as though it were authentic, and that the human intellect has not developed to react to the virtual environment differently than it would to the actual environment. Adult users may understand that they are in a secure room with head-mounted displays; however, while using IVR to peer over the brink of a digital cliff, their hearts beat faster and their hands sweat. Children, on the other hand, may react differently to adults when immersed in sensory acute and engrossing media such as IVR (Bailey & Bailenson, 2017) and the encounter may appear more realistic and authentic to them. Using a head-mounted display, Bailey and Bailenson (2017) discovered that children aged 6 to 18 perceived higher degrees of involvement and authenticity in a simulated space than adults aged 19 to 65. If young people perceive IVR as being more realistic than adults do, they might be more receptive to affective learning (e.g., responsible behaviour). Additionally, multimodal depiction teaches children the symbolic character of communication, which may either enhance or impede education. This capacity starts to emerge somewhere around age three and matures with the development of the executive functions of the brain.

Even with a less engaging medium, such as a two-dimensional (2D) TV display, young children perceive the content as real, which can influence learning and behaviour. For example, a television study has demonstrated that young children are more prone than older children to perceive the information as genuine (Calvert & Kotler, 2003). If children believe the material and personalities in the media are genuine, they will use them as resources of data when making decisions. However, little is known about how learners react to IVR in comparison to less-immersive systems. IVR may produce genuine sensory-rich encounters that immerse children in the information, making it difficult for them to recognise it as a simulation. For example, a young child might believe that such an integrated entity is a real person rather than a device performance; this could have an emotional impact on the sort of choices they make. Thus, according to Safar et al. (2016), the more visible or enticing a simulation appears, the more challenging it becomes for youngsters to distinguish dual representations. Mental development may also alter how children perceive IVR in intellectual and interpersonal contexts. Children's cognitive capacities and talents grow significantly as they age, based on a neurological network of brain pathways. Because parts of the mind associated with social intelligence grow gradually, younger children might be less responsive to interpersonal signals, including isolation, than teenagers.

The comprehensive attributes of IVR are able to test younger children's instinctive reflexes, including motor or selective attention responses, as well as cognitive capacities. Considering its technical capabilities, IVR could induce mental absorption, a state in which the brain, as well as the body, becomes merged with the virtual world. IVR, in particular, links sensory perceptions with technologies, producing the impression of being immersed in the information. IVR has the capacity to influence how ideas are developed by simulating genuine and enticing settings. Even in non-immersive surroundings such as television, young children will prioritise knowledge from a culturally relevant virtual figure; they consider the online avatar as a living individual and that the figure can actually see them.

2.5.4 Learning style models

It is argued in the preceding section that learning is facilitated by the relationships that learners have within and beyond the school. However, educational conceptualisations are more than mere exchanges between individuals. This chapter elaborates on different learning styles.

It was considered vital to include learning styles in this research, as they help to explain whether or not learners learn best using digital learning materials. To these ends, the teaching process was employed as a means of analysing learners' learning styles.

Learning styles are how learners apply their knowledge based on their particular variances or inclinations (Chaw & Tang, 2023). Cakmakci, Aydeniz, Brown and Makokha (2020) defined training styles according to the three areas of learning: cognitive, emotional or affective, and physiological. These categories serve as reliable indications of how a learner sees, engages in, and reacts to their teaching-and-learning environment. Six principles were recognised by 20th century researchers who investigated ideas of interpersonal growth and development, including John Dewey, Kurt Lewin, Jean Piaget, Williams James, Carl Jung, Paulo Freire, and Carl Rogers (Udhin, 2019). They considered education as a journey rather than an end result, and notably established the notion that all training is relearning, which necessitates the resolution of contradictions amongst dialogical opposing modalities of social adaptation. They also shared the view that education can be seen as a comprehensive method of adapting to that same reality, and the result of synergistic interactions between individuals and their surroundings. Finally, they viewed education as a method of generating understanding.

Much research has been conducted to demonstrate the prevalence and importance of personal learning preferences using capacity therapy combinations. Children can be seen to have distinct learning styles – features, abilities, and inclinations in the methods they use to best absorb and integrate knowledge. Each learner's preferences determine how well they learn using different methods. This chapter concentrates on teaching patterns and training style frameworks, which assist in giving a perspective from which to evaluate education using digital learning materials. There are various forms of teaching outcomes, but for the sake of this dissertation, only well-known models have been used to highlight the topic of learning preferences. These frameworks have been chosen because they provide extensive explanations of teaching methods in contexts and coincide with a particular examination of education using digital materials in a particular context and age group.

2.5.4.1 Howard Gardner's multiple intelligences

Howard Gardner, who studied cognition, was a developer of teaching strategies, which include the following: linguistic, logico-mathematical, artistic, somatic kinaesthetic, spatial, interpersonal, and intrapersonal intelligence.

Gardner (2006) contends that the seven types of intelligences he delineated seldom operate in isolation and are commonly engaged simultaneously. These intelligences are perceived to be mutually reinforcing as individuals acquire new skills or confront challenges. Additionally, Gardner asserts that humanity possesses a distinctive amalgamation of intellects, raising the pivotal question in human capital deployment about the efficacious utilisation of the inherent diversity within human civilisation, which manifests through various forms of intelligence (Gardner, 2006). Gardner's research has had a significant influence on educational thought and practice. In 2006, Gardner posited the existence of an eighth intelligence, delineating it as naturalistic intellectual ability – an inherent faculty to discern phenomena as exemplars of a community. Gardner proposed a ninth intellect, existential intellect, in 2009, that is characterised by a capacity to conceive or tackle the greater, broader problems regarding human life. According to Gardner, the close connection between the learner's mental picture of the material world, as well as their style of expression, facilitates acquisition.

Despite the fact that Gardner's hypothesis was well received by educators, the notion of several intellects has been widely criticised. Gardner's concept of numerous intellects has been disputed by Craft, Gardner and Claxton (2007), who state that they were founded on logic and perception, rather than on empirical evidence. Another point of contention concerns how to assess cognitive preferences. According to Coffield (2013), a study on teaching strategies explains the favoured methods people use to study, but does not provide a method for appropriately quantifying different learning types. The relationship established between the intellect and learning has assisted in understanding how learners prefer to study, but due to the limitations given above, cannot be generalised to other teaching environments. The current study has attempted to address aspects of this deficit by collecting information on learners' understanding in real school settings while beginners are actively constructing ideas using electronic training tools. The conclusions reached were supported by reliable evidence and by the literature.

Another critique by Jacobson, Kapur and Reimann (2016) of the concept of several intellects is that it is not explicit as to whether the cognitive skills constitute 'capabilities', 'talents', or 'propensities'. Wu et al. (2013) considered whether an individual with bodily limitations might be viewed in a similar way as individuals with learning limitations when it came to evaluation methods.

Kang and Gyorke (2008) have argued that various cultures have distinct perspectives on thinking skills. For instance, in societies where shooting is the primary means of existence, the ability of ‘bodily kinaesthetic’ will most likely be more prized.

Gün and Atasoy (2017) have asserted that intellects are components that contribute to the creation of certain elements and that every component operates autonomously, but also collectively, depending on the demands of the situation. In summary, they argue that Gardner's multiple intelligences are perhaps composed of seven or eight interrelated components. Gardner (2006) did not, however, investigate whether the various components are used alternately or simultaneously. For example, communication might be both cognitive and social. The interaction, in this research, between learners using digitised educational materials is expected to contribute towards an understanding of this debate.

Coffield (2013) further challenged Gardner's (1983) theory of multiple intellects, arguing that the specific setting in which the learners were engaged was possibly not considered; that the situation could potentially have a significant impact on how individuals prefer to study; that the situation within which the person is studying promotes certain abilities; and that active studying is topic dependent. Coffield (2013) had not taken digital technology into account when investigating learning contexts. Coffield's study focused on the abilities that learners needed to develop, and whether the setting was favourable and sufficient for them to do so. The current study also aims to contribute to this discourse by examining how learners learn in the metamodern period, where the internet pervades children’s education, yet schools and curricula retain their conventional structure.

2.5.4.2 Kolb’s learning styles model

Kolb’s learning styles provide yet another model with which to examine learners’ learning. Kolb conducted decades of study with experts worldwide, collecting information from thousands of respondents. The Kolb model was developed as a result of these investigations. According to this model, learners are categorised into four orientations, which can be described as follows:

- The concrete-reflective learner responds well to descriptions of how the courses connect to personal hobbies, activities, and potential occupations. The teacher's function is that of a prime motivator, arousing learners' passions and allowing them to react to current encounters and future goals.

- The abstract-reflective learner reacts to knowledge structured in a rational fashion that enables individuals to think. The instructor should function as a 'specialist' in this situation.
- The abstract-active learner proactively constructs knowledge, according to well-defined objectives, using a trial-and-error method. The instructor serves simply as a trainer or mediator, guiding education via comments.
- The concrete-active learner uses knowledge to address real-world issues. The learner gains knowledge via exploration. The instructor should give opportunity for learners to understand via investigation.

Kolb and Kolb (2005) perceived learning as a dynamic process in which every experience, including the act of receiving instruction, undergoes transformation. In accordance with this perspective, if a learner reproduces information precisely as it was taught without any alteration, it is considered that learning has not taken place. According to Kolb and Kolb (2005), genuine learning necessitates a change or transformation in the learner's understanding or perspective. Kolb and Kolb emphasised that involving learners in the overall procedure improves their understanding, and stressed the importance of training as a method that includes evaluation of the efficacy of individual learning abilities. Kolb and Kolb (2005) concur with O'Toole (2008) about the importance of putting the learner at the forefront of this process – to shift the focus from pedagogical aims towards the demands of the learners. According to O'Toole (2008), learners eventually create their own understanding with such an approach.

Despite the fact that Kolb’s theories are widely accepted in the area of learning and known for their efficacy in improving productivity, the difficulty concerning these theories was that they could not take account of varied real-world conditions. Kolb's orderly learning phases might not necessarily be a mirror of people's realities. In actuality, certain phases might happen all at once, be skipped, or even be missed entirely. Likewise, Dutta et al. (2021) recognised that education does not necessarily take place in a uniform manner. Kesim and Ozarslan (2012) have proposed that education might occur concurrently with other activities. Because training is continuous, it cannot be precisely organised according to Kolb's model (1984). The current study takes cognisance of these concerns by investigating how learning occurs in a virtual classroom and also why learners learn in this manner.

These results are expected to contribute to the corpus of research about whether education is cleanly organised or imprecise while using digital training materials or AR resources.

In the past, many academics had a distinct perspective on Kolb’s learning cycle. Today they contend that the kind of learner, as well as the actions they participate in, can modify the phases of Kolb’s model in a variety of ways. Furthermore, Kolb and Kolb (2009) have emphasised the intricacy of reflective training procedures, and Wei et al. (2015) have claimed that it is extremely simplistic to describe complex reflective training procedures according to cleanly organised stages. Kyza and Georgiou (2019) assert that technologies were not available earlier to help or promote learning, and that the Kolb model may not be applicable to digital learning environments. They further assert that there is an urgent need to investigate teaching-and-learning mechanisms in an age rich with online technologies. The current study aims to comment on the applicability of Kolb’s model to teaching and learning with AR resources.

Greenaway (2007) has added to the argument by claiming that Kolb’s concept was restricted to a small number of elements that may impact training. The interpersonal, psychological, as well as other institutional aspects of education were not taken account of. Greenaway (2007) proposed that people's study skills or educational types vary over a lifetime, especially in various contexts, and these variations may need diverse perspectives for a single individual at distinct phases of their lifespan. Moreover, White et al. (2013) suggested that Kolb’s learning cycle possibly neglected to account for methods of training apart from experiential education, which may not be applicable in a variety of scenarios. Kolb and Kolb (2009) suggested that Kolb's (1984) assessment was confined to a Western culture and could not be generalised to certain other cultures. Likewise, Aura et al. (2016) noted that Kolb's (1984) study did not take account of persons from diverse origins, ethnicities, genders, ages, socioeconomic conditions, or training. The current study has attempted to take cognisance of these arguments by examining learning using computerised educational materials in an emerging multi-cultural nation, i.e., Mauritius. This contributed to influencing diverse modalities of education across various civilisations, particularly in an era where technologies have become deeply embedded in our societal fabric.

To describe the teaching processes, cognitive skills have been used and evaluated. However, significant disagreements over the notion of legitimacy continue to exist. According to many definitions of learning environments, traditional classroom approaches closely approximate to a learner’s selected learning style (Sinclaire, 2012). Many educators assume that this chosen studying method is among the aspects that lead to a learner’s educational efficiency, although this is rarely the truth. Although Gardner's (1978) model and Kolb’s learning cycle remain well known due to their accessibility, it is far more important to evaluate how well the outcomes are being applied rather than simply classifying them according to their labels. The current study attempts to gain knowledge of how learners with diverse learning styles learn with computerised learning materials such as AR.

2.6 Tensions and Contradictions in the Literature

Although many researchers highlight the potential benefits of AR to foster learners’ engagement and multimodal learning, the academic world entertains some critical tensions. Radu (2014) conducted a meta-analysis of AR in education and found overall positive effects on learning outcomes; however, he also stated that increased cognitive load and user distraction were often identified as issues. Similarly, Akçayır and Akçayır (2017) supported the motivational effect of AR while considering that, in the process, it might cause over-stimulation or fragmented attention, especially in younger learners. These conflicting findings thus pose serious questions amounting to concerns over the developmental appropriateness of AR tools in early childhood settings. Another level of contradiction comes into discussion if the level of teacher readiness is to be considered: some authors depict platforms created for AR as user-friendly and, hence, easy to be integrated into the classroom setting (Ibáñez & Delgado-Kloos, 2018), while others draw attention to teachers’ lack of confidence and training and other constraints such as resources as being the greatest impediment of successful implementation (Wu et al., 2013; Santos et al., 2014). This disparity in opportunity is even more pronounced in low- to middle-income countries where infrastructure is lacking.

In addition, while AR is praised for promoting inclusion through personalised learning, critics have argued that it may widen educational inequalities already prevailing through unequal access to digital devices and the internet (Kipper & Rampolla, 2013; Cheng & Tsai, 2013). These unresolved tensions thus merit more contextual and equity-based inquiries into installing AR in early education. By foregrounding such contradictions, this study situates itself in a critical research void that acknowledges the promise and limitations of AR, particularly with respect to under-resourced and culturally diverse primary education contexts.

2.7 Conclusion

In conclusion, this chapter has attempted to provide a comprehensive coverage of relevant literature to explain and discuss the nature of AR and its role in education, both advantages and disadvantages. The literature gap was articulated as an absence of extensive research into how children acquire knowledge using AR tools, including cognitive and affective learning. To address this gap, a review of concepts related to children's learning and development was included, namely: the impact of digital learning on identity and psycho-social development; the affordances of active learning in an ICT context; socio-cultural influences in the digital learning environment; and the development of ICT-mediated intellectual skills. The sections on learning in pre-modern, modern, late modern, and post-modern eras provided a historical backdrop against which the affordances of digital education can be properly understood, with a focus on the influence of AR resources on the learning practices of primary learners. Finally, a section on learning styles provided further insight into how and why AR resources provide the affordances they do. This section dealt with Gardner's multiple intelligences and Kolb's learning styles. Both these models are used in the data analysis and interpretation of findings in later chapters.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1 Introduction

This chapter discusses the theoretical frameworks and the various learning models used in the current study to help understand the influence of Augmented Reality (AR) resources as used in the digital classroom for a specific purpose. The aim of this research was to enable the successful implementation of AR resources in Mauritian primary schools to improve learning. It is necessary to first discuss theoretical approaches that inform the use of AR resources in primary-level learning contexts. Three theoretical frameworks are discussed in this chapter to provide a better understanding. These include Engstrom's Activity Theory, Situated Cognition Theory, and the VARK model.

One of the essential considerations of an investigation is the conceptual or theoretical underpinning, the role of which is frequently underestimated in research (Best, 2003; Smith, 2024). The theoretical underpinning serves as the blueprint for the entire investigation. It also provides a foundation for the research, as well as a framework for guiding theoretical, epistemological, pedagogical and strategic choices – the significance of theory-driven reasoning and behaviour is highlighted in this chapter. Additionally, this chapter discusses the survey questions, the contribution of literature, design strategy and analytical strategy (Osanloo & Grant, 2016).

A theoretical framework has been described as an established foundational model that directs a study by ensuring the cohesiveness of specific events and connections (Osanloo & Grant, 2016). Thus, the theoretical underpinning is made up of the chosen theory (or hypothesis) that underpins the reasoning about how the researcher understands, and intends to investigate, the issue, along with descriptions of important constructs relevant to the research. Osanloo and Grant (2016) have empirically established that the criteria for selecting theoretical frameworks to direct research should be suitability, rational comprehension, empirically supported and in alignment with the research topic. The sections that follow first discuss the learning paradigms that underpin this research. This section is followed by a discussion of the theoretical frameworks that have guided the research choices at all stages of the research process.

3.2 Learning paradigms

3.2.1 Connectivism

The debate over the development of education in the contemporary age can be summed up in two distinct ideas, which are frequently merged: connectivism and enactivism. A modern instructional paradigm known as 'connectivism' was established at the onset of the 20th century. According to Siemens (2017), constructing educational settings is related to three basic theories of learning: behavioural economics, cognitive theory and conceptualism. A disconnection still existed between the period in which such ideas were formed and 21st century educational settings, and one relevant aspect of this disconnect is that technologies had little impact on education during that time period. It has been suggested that, during that time period, content development was sluggish with an extended half-life (Siemens, 2017; Udhin, 2019). Duke et al. (2013, pp. 4–13) have claimed that “the quantity of information inside the globe has doubled over the last ten years”. The 'half-life of learning' refers to this transition in understanding.

According to Wilson (2012), the 21st century learner is therefore not exclusively limited to formal schooling. Ertmer and Newby (2013) undertook an effort to describe the relationship between the learner and institutional learning. Education can be considered a continuous activity in which technologies aided in the definition and structuring of the learners' ideas – the ‘know-how’ and ‘know-what’ having been supplemented by the ‘know-where’. Liu et al. (2007) have expressed a comparable view and regard education as a product of witnessing and engaging with the surroundings. The views of several scholars have all been linked to the employment of technologies within the 21st century to assist education and learning. Siemens (2017) elucidates this change in educational concepts in the internet age by stating that technologies and connections have been formed into academic experiences. In practice, connectivism provides educators with a mental image of educational processes that cannot be immediately witnessed or experienced. Although connectivism continues to be criticised, it has provided an essential foundation for the use of technologies in education. Several scholars have used connectivism to describe how people study in a connected digital environment (Siemens, 2017; Cabrero and Román, 2018; Johansson et al., 2018; Attar, 2018). Udhin (2019) has further stated that learners do not have complete influence over their education since the surroundings will always be changing, influenced by advancements and improvements in the broader society. A seminal exposition on connectivism is presented by Al Dahdouh, Osório and Caires (2015), offering a comprehensive elucidation of the theory within the context of knowledge acquisition.

The authors posit that viewing learning solely as an internal construction of knowledge is an inadequate perspective. Instead, they propose that what learners can access within the external network should be regarded as part of the learning process. Furthermore, the authors assert that knowledge possesses a discernible structure, challenging the perception of knowledge as an ambiguous or enigmatic entity. Despite its inherent complexity and chaos, the authors contend that knowledge exhibits an identifiable structure (Al Dahdouh et al., 2015). Siemens (2005) has articulated a perspective on the lifecycle of learning acquisition, highlighting a progression from the individual to networking and ultimately to the organisation. This trajectory underscores the significance of forming connections, as learners, through these relationships, are empowered to remain current with contemporary developments.

Web-based education provides a significant technological answer to the numerous learning environments, methodologies, and motivations. Various ideas from behavioural psychology, cognitive theory, and conceptualism have helped the development of online content. Behaviourist approaches focus on concepts, which are necessary for comprehending concepts. Constructivism has informed optimal procedural techniques. Constructivist strategies emphasise real-world application and meaning creation. Unlike behavioural psychology, cognitive theory, and conceptualism, which anticipate that learners will act in predefined ways based on training, connectivism affords insights into the cognitive abilities and activities required for learners to thrive in a virtual environment. However, Lee et al. (2019) have asked whether constructivist theory is indeed a teaching method, an educational concept, or just a pedagogical concept. Furthermore, in a connected and electronic environment, the constructivist approach might be used as both an educational guideline as well as a teaching concept to expand on earlier learning approaches, rather than simply as an individualised learning concept. This research aims to provide insight into how constructivist theory helps technology-assisted studying amongst young 21st century learners.

3.2.2 Enactivism

Enactivism is another emerging education paradigm of the internet era. During past decades, empiricism and conceptualism substantially affected the theoretical concept of how acquisition occurs. On the one extreme, objectivists felt that education should be a sociologically acknowledged fact. According to Oojorah and Udhin (2022), moral relativism has its foundations in reality and functionalism. The world, according to objectivists, is solid and organised, and its organisation can be represented to learners (Lee et al., 2017).

Objectivism held that the intellect serves a role in mirroring truth as well as its architecture. Positivism aimed to describe how learners were taught about the environment, and how they were then required to duplicate its substance and organisation in subsequent reasoning. Individuals were not considered to create their personal meaning.

Constructivism, in contrast, introduced a new perspective on learners' thinking and education. According to constructivists, a person generally develops information from previous encounters, mental architecture, and ideas about objects and occurrences. In contrast to positivism, which focussed on the content of understanding, the constructivist approach focussed on the way a person frames knowledge. Both views advocated a thorough methodology of how to evaluate knowledge and create an atmosphere conducive to study. However, both relativism and conceptualism were restricted to the way individuals 'mirror' actuality as well as their framework for formulating knowledge. Neither viewpoint gave sufficient attention to learner interaction with their surroundings through activity in an authentic setting within the classroom. To fill this need, a novel teaching paradigm known as 'enactivism' evolved in the online era.

Beyond constructivist theory, enactivism has evolved to function as a catch-all term for a broad range of approaches that place a specific focus on the relationships between learners and their surroundings. Enactivism, a theory within embodied cognition, underscores the interplay between cognition and emotion in the learning process (Varela, Thompson & Rosch, 1991; Kieren & Sookochoff, 1999). Enactivism emerged as a theoretical framework explicating cognition as a mental function originating from the dynamic interaction between the organism and its environment (Colditz, 2020). This conceptualisation posits that mental faculties are intricately embedded within neural and somatic activities, manifesting through the organism's actions (Colditz, 2020). This theoretical framework challenges conventional notions that situate self and identity as strictly individual and static phenomena (Varela et al., 1991). Enactivism acknowledges the structural coupling of teachers, learners, and the learning environment (Maturana & Varela, 1992). Within this framework, learning is conceptualised as a reciprocal activity. Enactivism, in its broad conception, contends that cognition should be conceptualised as a lifelike process, characterised by the dynamic interaction between organisms and the world, and "anchored in the living body" (Di Paolo, Bhurman & Barandiaran, 2017, p. 20).

This stands in contrast to the view of cognition as a computational process confined within the brain. In these respects, enactivism emphasises ‘experiencing’ rather than ‘understanding’, as with the constructivist approach. However, enactivism shares many similarities with radical constructivist theory, which views the particular learner as a functional object, although the radical constructivist approach does not take account of the influences of human context on education.

According to contemporary psychology studies, learning is the outcome of multisensory neural systems (Goswami & Bryant, 2007). According to these authors, concepts such as right brain/left brain or unisensory orientations are not validated by neurobiology (2007). They have contended that children learn in the same manner as adults do, with the main difference being ‘experience’. Children are also still acquiring the ability to build their individual thoughts and understanding (metacognitive awareness), allowing them to regulate their personal conduct and interpersonal connections. Children develop their personal theories to help them to understand the events they are witnessing, such as why individuals behave in certain ways. According to Goswami and Bryant (2007), children already possess a concept in their minds in their attempt to comprehend why things and occurrences follow specific patterns.

Furthermore, information formation seems to be the result of the young learner's accumulated encounters. Whenever children have various interpretations of experiences, such as motor and visual experiences, their learning, thinking, and intellectual abilities improve. Goswami and Bryant (2007) add to this relationship (between experiencing and training) by noting that varied contact contributes to varied learning opportunities. For instance, the amount of time spent studying outside of the classroom influences learners’ literary proficiency. Van Elk et al. (2010) sought to describe this disparity by portraying the linguistic knowledge as well as the perspectives of their learners. The absence of expertise was alluded to as a ‘simulation restriction'. They argued that an all-encompassing theory of intelligence could not adequately incorporate both conceptual and behavioural conceptions. The personalised framework focused on behaviours that facilitated the enhancement of the learner's cognitive functions.

Similarly, Maiese (2017) defined enactivism as the interconnectedness of cognition and action. Maiese argued that effective learning occurs when people manage and retain their own identities in terms of their bodily behaviours.

In other words, anything someone accomplishes influences the extent to which it is important to that individual alone, a process that is referred to as training. Enactivism appears to be an expansion of a metaphor provided by prior cognition scientists: 'Mind as Brain' (Holton, 2010).

3.2.3 Enactivism and connectivism

Enactivism and constructivist approaches are similar in that they both regard knowledge as being contained within an individual's mind. A significant contrast would be that constructivist theory establishes a network of engagement, whereas enactivism considers education as bodily activity within the surroundings (Maiese, 2017). Within such a place, the enactivist ideology connects with applied education and active training. This distinction creates the potential of learning and training in an educational setting that is not a regular classroom. The current research aimed to provide a new perspective on 21st century learners' embodiment of action within a computerised classroom setting.

3.3 Theoretical frameworks

This chapter discusses three important theoretical models and their accompanying constructs for purposes of accuracy and clarity. The three models that have informed this study are: Activity Theory (Engeström & Glăveanu, 2012; Hardman, 2008; Roth, 2004), Situated Cognition (Brown, Collins & Duguid, 1989; Jenlink & Austin, 2013), and the VARK model (Bilkisti & Retnaningsih, 2019; Prithishkumar & Michael, 2014). These theoretical frameworks have been integrated in order to build an improved learning model suited to this study. Because this study is centred on digital resources for learning activities, these theories are extremely valuable and can be summed up as follows. Firstly, Engeström's understanding of the Activity Model was strongly influenced by Vygotsky's earlier concept of mediation, which involves learning with people as well as via interaction with artefacts in a social context. Engeström's goal was to depict human cognitive operations, not merely on the basis of the individual, but rather on the basis of the individual's relationship within the social environment via artefacts, especially in the formative stages of an activity. Secondly, Brown, Collins and Newman developed the Cognitive Apprenticeship Model in 1989, which is rooted in Situated Cognition Theory (Woolley & Jarvis, 2007). This model is based on experiential teaching-and-learning methods, with contextual learning being critical. The key notion of Situated Cognition Theory is that intelligent behaviour develops from a continual interplay between the learner and their environment, rather than being transmitted by the teacher.

The theory recommends that contextual behaviours, rather than cognitive goals and processes, be the desired outcome of learning. Finally, teaching approaches promoted by the VARK model were developed by Fleming in 1987 (Ganesh & Ratnakar, 2014). Fleming proposed that learners can be divided into four categories in the VARK framework according to their learning styles: visual, auditory, read/write, and kinaesthetic. Individuals with one dominant learning style are known as unimodal, whereas individuals with many learning styles are known as multimodal. VARK patterns can be identified in children, and the results have been shown to be consistent. By understanding VARK, teachers can adapt teaching-and-learning methods based on their learners' preferred learning styles, while still maintaining the learning purpose.

These models are discussed below in terms of their core concepts and how they relate to the current study, as well as how they can be applied to better understand the research interest of this study, i.e., use of digitised media for learning with AR resources.

3.3.1 Activity Theory

As mentioned, Engeström's interpretation of Activity Theory (AT) is based largely on Vygotsky's previous notion of mediation, which includes studying together with knowledgeable others who can scaffold learning across the Zone of Proximal Development, as well as through contact with objects (also known as Scandinavian Activity Theory). Engeström's aim was to describe human cognition, not simply on the basis of the learner, but rather on broader considerations of the learner's interactions with the social environment via artefacts, particularly in the initial stages of learning activities.

Individuals (performers) in AT utilise exterior instruments (e.g., hammers, computers, automobiles) and interior instruments (e.g., planning, mental mapping) to attain their objectives. There are many artefacts in the social environment that are perceived, not simply as items, but as culturally embedded items, with the consequence that each item has historical and/or cultural importance.

Tools (which can limit or permit social connections) can also be used to mediate social contact, influencing both the behaviour of the individuals (those who employ the instruments) as well as the social system within which these performers reside (the environment, tools, artefacts).

The three phases of AT evolution, which are often referred to as ‘generations’, each building on the previous to address increasingly complex interactions within activity systems, are described below.

3.3.1.1 First generation: The foundations by Vygotsky

The first generation of AT stems from Lev Vygotsky's introduction of the concept of mediation. Vygotsky posited that human action is not direct but mediated through tools and signs, emphasising the individual learner’s interaction with the environment. This phase introduced the triadic relationship: subject (the individual engaging in activity), mediating tools/artefacts (instruments such as language, symbols or physical tools that shape the interaction), and object (the goal or focus of the activity). Engeström acknowledged that while this generation laid a critical foundation, it lacked an explicit framework for analysing the broader social context influencing learning and development.

3.3.1.2 Second generation: Expanding the framework

Engeström's most notable contribution begins with the second generation, where he extends Vygotsky's model into a collective activity system. He introduces additional components to account for social, cultural and historical factors, namely: rules (norms and regulations governing interactions within the activity system), community (the social group sharing the same object or goal), and division of labour (the allocation of tasks, roles and responsibilities among participants). In his description, Engeström emphasises that contradictions—inherent tensions within or between components—drive transformation and innovation in activity systems. These contradictions force participants to adapt, leading to expansive learning, where the system evolves to address new challenges or goals.

3.3.1.3 Third generation: Multivoiced Activity Systems

The third generation of AT emerged when Engeström explored interconnected activity systems. In this phase, he addresses the complexities of collaboration across different systems, each with its own object, rules, and tools. The focus shifts to how systems interact, overlap, and influence one another. For instance, a teacher’s activity system (focused on delivering education) interacts with the learners’ system (focused on acquiring knowledge), and external systems such as technology developers (focused on tool creation).

Engeström introduces the concept of boundary objects, shared artefacts or tools that mediate interactions between systems. He highlights that successful collaboration requires negotiating differences, aligning objectives, and adapting practices across systems.

3.3.1.4 Expansive learning and development

Central to Engeström's description is the concept of expansive learning, where individuals and groups collaboratively redefine the object of activity to overcome contradictions and achieve transformative outcomes. Expansive learning involves: questioning current practices, analysing systemic contradictions, modelling and testing new solutions, and implementing and refining innovations collaboratively. Engeström views learning as a dynamic, collective process embedded in real-world activities, contrasting with traditional views that isolate learning to individual cognition. Engeström elaborates on these ideas in his seminal book, *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research* (1987), where he describes the historical and practical evolution of AT. He also highlights its applications in diverse contexts, such as workplace learning, education, and technology integration, making AT a versatile framework for studying complex human behaviours.

Figure 3.1 depicts second-generation AT as it is commonly used in the literature.

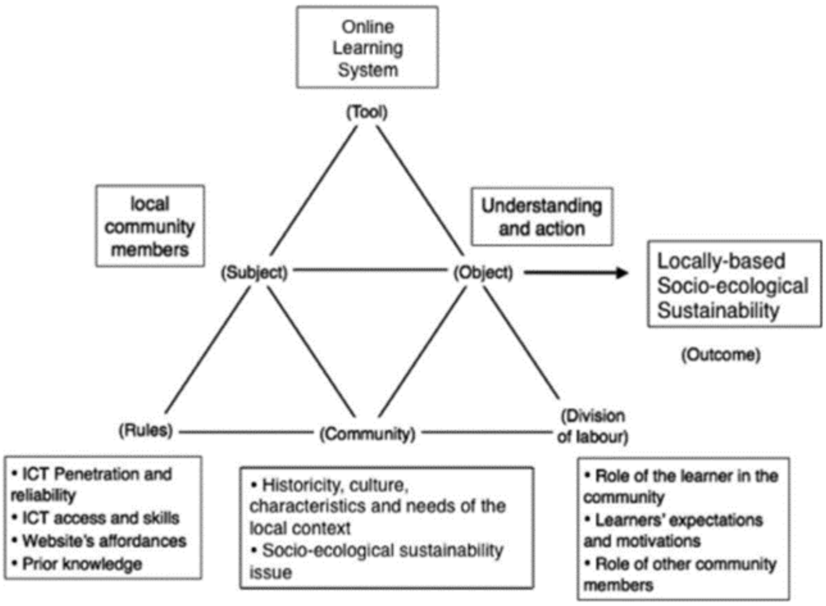

Figure 3.1: Engeström's second-generation model of an activity system

(Source: Gedera & Williams, 2015)

The AT perspective or ‘Activity Theory viewpoint’ can provide insights into how instructors' practices alter, or even how their learning is ‘restructured’ whenever a modern technological tool is introduced into their classroom teaching. AT has also been used to investigate situations where innovation is introduced into schooling, for example, when innovations are implemented and disputes arise between instructors' views and their practices; as well as for learning assessments. Engeström (2009) explored learners' academic histories as well as their experiences of using technology to better explain their opposition to new technologies in novel settings. When learners engage in new work using old routines, AT can assist in exposing issues associated with conflicting technology cultures (Blunden, 2023). Engeström (2018) used an AT framework to explore collaborative learning difficulties in digital educational contexts, as well as how software inventions help or hinder such processes. AT has also been employed to investigate the development and execution of technology-assisted education (Blunden, 2023; Yang & Kyun, 2022). As Benson et al. (2008) illustrated throughout their research on internet-based programmes, AT allowed a focus on both the standard of specific teacher practices as well as issues at the wider institutional level, i.e., uncovering e-learning interactions at the line of command (strategic plan, legislation, 'campus expansive' alternatives) and micro-organisational levels (ordinary working practice, incremental start changing, individual adjustment). Additionally, AT allows for a focus on numerous interconnected dynamic systems. When doing research on AT inclusion in education, Lim and Hang (2003) discovered that successful computer inclusion needs an emphasis on dynamic networks transcending those used by particular classes. Several scholars contended that AT provides for a focus on teachers' day-to-day instructional engagement as well as on the organisation’s departments or school-wide levels, wherein the cooperation of educators and others could culminate in behaviour change. With an AT perspective on research into the inclusion of new innovations in education, the emphasis shifts from the instruments themselves to their utility usage, or, as Wyeld (2013) describes, beyond the tools' usefulness to their social connectedness.

3.3.1.6 Activity Theory in the context of educational technology

According to Wyeld (2013), within the framework of AT, distributed cognition serves as a valuable tool for instructors, facilitating an enhanced comprehension of how learning activities unfold collaboratively. AT underscores the pivotal roles of cooperation and the division of labour among community members. Concurrently, cooperative learning emerges as a prominent instructional approach in the context of English as a Foreign Language Reading Comprehension (EFL RC).

Gillies (2003) underscores the advantageous integration of cooperative learning in reading instruction, wherein learners acquire essential skills (Bolghari, Birjandi & Maftoon, 2019) such as “conflict resolution, consideration of diverse perspectives, negotiation of task progression, and the sharing of ideas” (Gillies, 2003, p. 36).

A tool-mediated as well as goal-oriented stimulation is the basic (first-generational) unit of investigation in AT. In this case, a person or collective subject participates in an activity via a mediating artefact to achieve a purpose or 'target', yielding a consequent 'outcome'. The architectural, economic, and social characteristics of an engagement system are reflected by the 'laws', 'society', and 'partition of labour' elements of Engeström's (1987) second-generation Activity System. The third-generation engagement structure consists of two or more interconnected dynamic systems that build a chain of actions and interactions in which outcomes might subsequently constitute ‘subjects’ of successive activity networks (Engeström, 2010). The innovative aspect of this third generation is that it allows for the dynamics and complexities of human activity, which is marked by ongoing change, re-organisations, and activity growth. This understanding of individual interaction is consistent with concepts of networking and diversity in schooling.

3.3.2 Situated cognition

3.3.2.1 Situated cognition hypotheses

The fundamental concept underlying the theory of contextual cognition posits that intelligent behaviour arises through ongoing interactions between a cognisant subject and its environment, as opposed to emanating solely from the cognitive processes of an individual agent, such as thinking or control mechanisms (Smith & Collins, 1989; Strube, 2001).

It is proposed that contextual acts, rather than cognitive intentions and procedures, should be the focus of research. According to Roth and Jornet (2013), this viewpoint is diametrically opposed to the standard concept that cognition appears to be the mind's interpretation of data accessible from the surroundings and recorded similar to a monitoring system. From the standpoint of cognitivism, data does not exist before, but is generated by, and a consequence of, the organism–environment relationship (coupling). It has been posited that this perspective demands a fundamental shift in the prevailing paradigm of the behavioural sciences, akin to the transformative impact witnessed during the behavioural renaissance that led to the obsolescence of the predominant behaviourist worldview at that time.

Nevertheless, the discipline harbours diverse interpretations of 'situated cognition', marked by substantive distinctions contingent on the spatial relationship between an individual's body and its environment, within the framework of consciousness. This thesis approaches contextual perception as a scientific theory, encompassing arguments that are often interconnected yet occasionally treated as distinct entities (Clark, 1997; Clancey, 2008):

1. Cognition arises from, and is linked to, the connections that an agent's embodiment has with the physical surroundings: Cognitive is embodied and situated.
2. Cognition emerges from, and is linked to, an agent's activities with its surrounding life: Intelligence is located inside an agent's socio-cultural settings. This cognition may be instantaneous, as when normal conduct occurs in connection to other individuals, or it may be mediated, as when an attitude is influenced by the wider societal setting (communities, social networks, society).
3. Cognitive occurs as a result of, and with the goal of, activity: Intelligence is performed. Human behaviour and device usage are characterised by connections to the external environment and objectives (aspirations): 'in order to', 'what for', 'what if', and 'for the sake of' (Roth & Jornet, 2013).
4. Consciousness is spread throughout physical and interpersonal environments according to characteristics 1–3. Linguistic and material behaviours are two key categories that contain such characteristics (Roth & Jornet, 2013).
5. Many intelligent behaviours may not need apparent inner (mental) representations. What matters rather is the way the environment appears to the actor.

The contextual cognitive hypothesis profoundly questions standard concepts of borders and, by extension, the site of consciousness. Recognising the consequences of a positioned method necessitates a restructuring of our knowledge of consciousness, rather than simply adding the situated qualifier to popularly held notions of the brain and understanding.

3.3.2.2 The Cognitive Apprenticeship Model and key teaching strategies

Brown, Collins and Newman developed the Cognitive Apprenticeship Model in 1989, which was strongly related to Situated Cognition Theory (Woolley & Jarvis, 2007). This model relies on experiential teaching techniques, with contextual learning being core. For example, if learners want to understand the fundamentals of design, they would not only attend academic classes on the subject, but they would also seek out real-world experiences that would enable them to become thoroughly immersed in the discipline. The Cognitive Apprenticeship Model, as the title indicates, encourages learners to develop their competencies by collaborating with, or apprenticing to, different specialists in the discipline or practice, with whom they build their cognitive and other skills. The following include some of the important educational strategies for implementing the Cognitive Apprenticeship Model, along with its potential applicability to e-learning curriculum planning:

<u>Modelling</u>

Modelling entails a specialist presenting a subject or performing an activity so that learners or trainees can obtain a comprehensive understanding. This draws on prior knowledge and helps learners to form a cognitive concept picture of the particular procedure. Tutorials may be used to create prototypes for e-learning curricula. Trainees can observe instructional videos within a week of engaging in a particular e-learning action, either in the form of videos in which a subject specialist discusses the ideas or procedures, or as screen capture demonstration with step-by-step guidelines (Jacobson et al., 2016). The former is commonly employed for online practical application training classes.

<u>Coaching</u>

Coaching happens whenever a subject-area professional permits trainees to complete a project and, thereafter, provides comments on their overall accomplishment. This allows learners to think about what they might wish to change in order to improve their performance, and how they can move to the next level in their learning pathway. Whenever people adopt e-learning, the incorporation of social networking aspects, including conversation and discussion forums, allows trainees to receive comments from both the digital presenter and from peers. The exact same is true for most concurrent e-learning delivered via digital learning events.

<u>Scaffolding</u>

Scaffolding is the practice of using strategies and procedures to improve learning programmes. This might take the form of exercises, group projects, or diversions. Throughout the exercise, the teacher monitors learners and evaluates their expertise and abilities. Any type of interpersonal engagement in e-learning, such as virtual team projects and collaborative tasks, can be viewed as a form of scaffolding, with the virtual teacher acting as a facilitator and moderator throughout the learning experience.

Another potential use of scaffolding in e-learning is gaming, in which learning goals can be achieved through play, fun, and team competition.

Articulation

When educators facilitate opportunities for learners to articulate their comprehension of e-learning materials and elucidate the problem-solving methodologies they employ, such a process is denoted as articulation. This practice commonly takes forms such as inquiry-based learning, critical reasoning, and the vocalisation of thought processes, known as 'thinking aloud'. Notably, articulation can function analogously in concurrent e-learning scenarios, as the instructor's digital presence may not necessarily impede the application of this method. Virtual facilitators can still encourage learners to share their thoughts in an attempt to address difficulties with the e-learning material. Facilitators can also give comments and prompts. Although eloquence would be challenging when applied to ‘thinking aloud’ in adaptive e-learning, the goal would be for learners to rationalise choices made during the e-learning problem-solving activities. Again, for the online facilitators, their explanations should be as valuable as the solution itself. Another teaching method for e-learning suggested by discovery learning may take the form of a deliberate application of methodologies such as inquiry-based learning, a pedagogical approach that assigns responsibilities and tasks to novices, offering them opportunities to delve into a series of challenges. The objective is to guide learners through the resolution of these challenges, fostering the development of a well-defined and specific conceptual framework for the subject under investigation. Importantly, this method is applicable to both traditional and asynchronous (delayed) e-learning environments, accommodating various modes of learning engagement.

Reflection

Reflection allows learners to evaluate their own problem-solving abilities against those of an experienced facilitator or peer. One method is to allow the teacher to assess how well a child deals with the problem, and then explain how experts address the same problem, highlighting differences and similarities. In e-learning, this could be achieved by allowing learners to revisit the activity as often as they need, in addition to assessing their final achievement against the solution advised by a subject-matter expert.

Exploration

Last, but not least, an investigation occurs whenever individuals are allowed to resolve challenges by themselves, while also being assisted with alternative approaches. This allows learners to understand challenges and then attempt to address them in authentic circumstances. In e-learning, exploration strategies function well under these conditions. Learners are challenged with difficult online activities, but with the possibility of accessing virtual assistance, such as recommendations (when needed) on how to proceed and progress. The availability of the virtual assistant will vary according to the learner's performance.

If, as researchers believe, training is indeed an assimilation activity assisted in part by social contact as well as the transmission of story, groups of professionals are especially important because social contact and discourse can only occur inside groups. The following are notable characteristics of learning within a group:

Collective problem-solving: Groups are more than a convenient forum for individuals to share their expertise. Group interactions provoke synergistic ideas and answers that would not otherwise have arisen.

Displaying multiple roles: Most group activities require members to comprehend the numerous diverse roles required for the successful intellectual performance of the group. For one individual to be competent to assume any of roles requiring engagement, as well as to constructively evaluate his or her accomplishment, is very challenging. The collective, on the other hand, allows for multiple roles to be performed and encourages thoughtful storytelling and conversations about the appropriateness of those responsibilities.

Confronting ineffective strategies and misconceptions: Researchers understand, from a large body of research, that learners have various misconceptions regarding certain science phenomena. Experienced educators are usually aware of these misconceptions and able to recognise when learners provide rote-learned responses that may be masking profound misconceptions about material phenomena or thinking processes. Groups, on the other hand, may be useful in identifying, challenging, and debating these misunderstandings and unproductive learning strategies.

Providing collaborative work skills: Learners who are educated separately rather than jointly may not acquire the necessary abilities for a collaborative effort. Understanding how and when to study and operate together is becoming critical, especially in the job market. If individuals are going to collaborate with others, they should be provided with the opportunity to learn how to do so.

Sharing information and statistics: Engaging in group study facilitates the sharing of information and knowledge, serving as an effective means to enhance learning. The collaborative environment allows each participant to articulate their individual viewpoints and perspectives on a given topic, thereby contributing to a broader and more in-depth development of knowledge. This expanded scope and depth of understanding are crucial for effective learning and the attainment of a comprehensive grasp of the subject matter. Additionally, the act of discussing or repetitively reviewing information, including statistical data, aids in retention. Group study provides learners with the opportunity to critically examine the ideas and practices of their peers, fostering a process of clarification and refinement of their own conceptual frameworks and problem-solving strategies.

3.3.3 VARK model

This study was influenced by the VARK learning model for elementary school levels and how it has been integrated with digital technology in education. VARK is an acronym for Visual, Aural, Reading, and Kinaesthetic. Fleming (2006) found that visual learners are more prone to use text and graphics in multimedia environments. Aural learners also prefer using text and graphics with audio applications, while kinaesthetic learners are more inclined to use text and graphics through assignments that require actions or hands-on work. The aforementioned study also showed how learning styles influence preferred use of senses in each mode (Wambaria, 2019; Othman & Amiruddin, 2010). Through the use of the accessible digital textbook, teachers have the capacity to create what Othman and Amiruddin (2010) refer to as learning processes that stimulate learners to engage with the subject matter. Applying the VARK model allows teachers to adjust their strategies based on a child's capabilities and learning style, but without changing the learning purpose.

Primary schools, for example, play an important role in promoting emotional maturity. Education policies should be geared towards developing the school climate as a site of intellectual and interpersonal cognitive growth.

This notion is incorporated into the Social Emotional Learning programme at various stages of schooling in several countries. Primary school learners have distinct affective traits that need particular sustained attention. They require aid or direction from both parents and instructors. Falsehood in primary school education will damage a child's emotional state and cognitive processes in adulthood. Individuals vary in terms of cognitive capacity, preparedness for education, motivational levels, and learning methods. No two people are identical. Learning strategies employed in retaining and organising information differ as well. Some children may recall the material after only one reading, while others need to read the material multiple times. Some learners can store knowledge in their minds by simply glancing at items, while others must touch, practice, and do in-depth research on a certain topic. As a result, each learner develops their own approach to handling learning resources. Heterogeneous courses are thought to be an important setting for learners with diverse learning methods.

As mentioned previously, individuals with simply one learning pattern are referred to as unimodal, whereas learners with many learning styles are referred to as multimodal. VARK study patterns may be recognised in children, and the outcomes are fairly consistent. Children in more affluent primary schools possess kinaesthetic, auditory, and reading learning modalities. Aural learners employ their audio senses to acquire and retain information through hearing, and therefore are generally articulate. ‘Read’ readers enjoy studying, and their writing is often neater; furthermore, individuals do not monopolise the chance to converse throughout the learning session. Kinaesthetic learners, on the other hand, retain knowledge in all of their bodily parts. These children are highly energetic and cannot remain passive.

Mode	Tendency in learning process
Visual	Learning by looking at pictures, graphs, videos, and graphics. Could not take complete note during presentation.
Aural	Receive learning by listening method, by speaking or from music, discussion, and explanation.
Reading	Prefer words and texts as an information obtaining method. They like presentation style, by text or writing.
Kinesthetic	More likely to experience through physical movement aspect while studying, such as, touch, feel, hold, perform and move something. They prefer hands on work, practical, project, and real experience.

Figure 3.2: The tendency in learning process based on VARK model

Source: (Othman & Amiruddin, 2010)

An individual's learning style is characterised by their favoured methods of acquiring, organising, and reflecting on knowledge. The VARK model falls under the domain of instructive preferences, according to Fleming (2001), since it interacts with perceptual modalities. As mentioned, VARK is an acronym that refers to Visual (V), Aural (A), Read/Write (R), and Kinaesthetic (K) (Gilakjani, 2012; Moayyeri, 2015; Othman & Amiruddin, 2010). Visual children prefer maps, tables, infographics, schematics, highlighters, varied colours, photographs, word representations, and various spatial layouts (Moayyeri, 2015). Aural children prefer to explain new concepts to others, discuss issues with other learners and professors, use a recording device, attend seminars, and participate in debate groups that employ humour. Read/write learners prefer lists, articles, reports, textbooks, terminologies, printed copies, texts, websites, and scribbling notes. Kinaesthetic people enjoy outdoor excursions, trial-and-error or experimental activities, experiencing phenomena to comprehend them, formulas, problem-solving, hands-on activities, using their senses, and collecting and analysing materials (Gilakjani, 2012). When using the VARK model to inform training, the following should be considered:

- The VARK method uses sensory cues, and thus the training method used has an impact on memory (Othman & Amiruddin, 2010). Memory influences an individual's emotions. The relationship between emotions and recollection has been discussed by various authors; and consequently, the effect of training methods on emotional cognition (Levine & Pizarro, 2004; Leasa, Corebima & Batlolona, 2020).

- Training patterns need to take account of the cognitive, emotional, and psychological aspects of how people engage with and react to the learning context. Whenever a learner selects a learning method, their choices indicate their particular learning style. Individuals exist who have several learning styles (Wintergerst cited in Yusoff, 2007). Fleming's VARK model was upgraded from the VAK model in 2006. This new model categorised learners into four distinct modes.

The four modes of the VARK model are elaborated below.

A. Visual

Children predisposed towards this learning style are more inclined to seek out examples and, therefore, understand better through explanation. Such learners prefer using a checklist to monitor their educational progress and to organise their thoughts. Additionally, visual learners are easily distracted by movement or activity around them, while noise normally does not affect them (Othman & Amiruddin, 2010). Furthermore, visual learners prefer to portray textual data using figures, drawings, and symbols including graphs, schematics, hierarchies, representations, and arrows. They also prefer to sketch a model or a graphic to express a concept to others. From their research, Othman and Amiruddin (2010) found that up to 29% of learners have a perceptual learning approach, which means they are skilled at employing images, optical representations, and 3D modelling. Learners with visual acumen have strong imaginations and are more likely to be innovative and insightful.

B. Aural

Auditory learners, as elucidated by Drago and Wagner (2004), acquire knowledge primarily through listening. These individuals allocate heightened attention to verbal information imparted by instructors, exhibiting a preference for auditory reception over the act of writing lecture notes. During post-lecture sessions, aural learners tend to engage in discussions with peers, leveraging collaborative discourse as a means to elucidate and consolidate their comprehension.

In alignment with their learning style, these learners participate in discussions, consult answers, or listen to recordings related to examination topics to reinforce their understanding (Murphy et al., 2004). This type of learner, according to Othman and Amiruddin (2010), might recall knowledge by loud reading or mouthing whenever they read, particularly when learning a novel skill or concept. These learners can improve their memories by listening repeatedly to audio cassette recordings, teaching others, and conversing with educators. Aural learners often read well, narrate intelligently, write stories or poems readily, acquire other languages quickly, have a large vocabulary, spell fluently, enjoy writing correspondence, and possess an excellent memory for names or information.

C. Reading

Individuals characterised by a proclivity for reading exhibit a preference for written language and textual mediums as their predominant means of acquiring information. This cohort demonstrates an inclination towards various forms of printed resources, including lists, glossaries, textbooks, lecture notes, and circulated materials. Furthermore, these learners engage in practices such as transforming lecture notes into schematic representations, paraphrasing classroom notes, and systematically approaching multiple-choice examination questions (Murphy et al., 2004). Moreover, as asserted by Drago and Wagner (2004), learners with a reading orientation tend to adopt a note-taking approach as an integral part of their study habits. They find that synthesising information through the process of note-taking, whether derived from lectures or challenging reading materials, significantly enhances their comprehension and retention abilities. According to Othman and Amiruddin (2010), these learners take notes to assist when listening to lectures or reading demanding resources.

D. Kinaesthetic

Although assessed as a different section in VARK, this learning preference is a measure of the conjunction of several sensory functions. A preference for kinaesthetic learning refers to education that is accomplished via experience and practice. In other words, kinaesthetic learners develop knowledge via experience. Othman and Amiruddin (2010) describe predisposed kinaesthetic learners as individuals who prioritise experiences to acquire knowledge and skills, enjoy activity, and prefer to employ contact, movements, and engagement with their surroundings. Such learners do not respond well to learning situations that involve only listening and visuals.

Consequently, individuals identified as kinaesthetic learners often exhibit a proclivity for physical activity, leading to potential inactivity in traditional classroom settings. According to Wambaria (2019), learners with a kinaesthetic learning style derive enjoyment from movement and action, rapidly develop physical skills, prefer thinking while engaged in physical activities, and excel in athletic pursuits. They are inclined to utilise movement patterns for recall, demonstrate enhanced coordination and tempo, and tend to find relaxation more easily. As asserted by Gilakjani (2012), incorporating physical teaching methods can significantly enhance learners' enthusiasm and motivation to learn, fostering increased engagement (Aisami, 2015). Interestingly, this physical teaching approach can yield diverse interpersonal skills or learning outcomes, even when instructional methods and materials remain comparable. Within the classroom, conceptualised as a learning community, the environment plays a crucial role in accommodating a group of learners with varied learning styles and preferences.

Several aspects impact learners' learning patterns, including physical, emotional, societal, and environmental. People with diverse learning styles need a consistent environment and atmosphere throughout the learning experience. Study skills, on the other hand, might evolve in tandem with people's maturation. VARK learning style approaches are based on sensory perceptions or basic physiological dimensions, such as allowing vision (visual), hearing (auditory), reading (visual and touch), and kinaesthetic learning (multisensory). The VARK learning style model is simple to apply to learners at various stages of schooling and likely to be durable across various scenarios (Moayyeri, 2015). Furthermore, it offers an insight into aspects of learners’ studying methods. The proportion of teaching strategies varies between educational levels. According to Leasa, Corebima and Suwono (2017), in Ambon, Indonesia, the kinaesthetic teaching style predominates over the visual, auditory, and read learning methods at a primary education level.

3.4 Conclusion

The discussion in this chapter aimed to clarify the theoretical underpinnings of this research. The theoretical models and their accompanying constructs were explained as they relate to the learning models and frameworks chosen for the study; thus, providing a fundamental understanding of the learning ideology and methodology deemed most appropriate for addressing the aim and objectives of the study. Additionally, the successful implementation of these models would be ideal in order to create effective learning settings that could be controlled digitally.

Three major theories and their corresponding models were discussed in detail in this chapter: Activity Theory, Situated Cognition, and the VARK model. These theories were deemed effective and useful for this research as they have previously been used to interrogate the use of digital resources for learning activities. The VARK model, in particular, is one of the most effective models to use for analysing learning with AR resources, since visual memory is among the most effective modes of learning. The integration of audio and visual resources is a powerful learning strategy, which is why AR resources are so effective since they use these stimuli to create real-time experiences (Mekni & Lemieux, 2014).

The next chapter presents the research design and methodology employed for this research study.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

The research design and methodology enable the choice of suitable methods and processes for the successful completion of a research study. Additionally, it helps to define core concepts used in the analysis. The main aim of this research was to investigate the influence of Augmented Reality (AR) resources at primary school level when integrated with the more familiar teaching and learning practices. This research also aimed to advise on the implementation of AR resources in Mauritian primary schools. Hence, the research adopted a social perspective on constructive community development to guide the implementation of AR resources in primary schools throughout Mauritius. This research also aims to assist in identifying constraints and challenges, as well as benefits and potential for development, of the various implementation aspects of AR resources in the country's primary schools.

The research design chapter helps to define the research approach, strategy, data collection techniques, reliability, validity, philosophy, ethical considerations, sampling methods and sample size. These are critical aspects or characteristics of any research to ensure rigour. Without maintaining an appropriate methodological strategy, the research would fail to deliver valid and reliable findings.

This chapter, therefore, provides an in-depth discussion of methodological choices made to successfully answer the research questions, to fulfil the research aims, and to support the conclusions derived. This chapter has been divided into several sections, including research design, sampling method, sample size, research approach, data collection method, and data analysis method. These sections are detailed below.

4.2 Research design

Research design describes how a research project has been organised or planned. Further detail and recommendations are provided in this chapter on how this research could be expanded. Every component of the process is discussed in the sub-sections that follow.

4.2.1 Interpretivism epistemological stance

Based on the guidance given by Collins and Stockton (2018), an investigation procedure involves three aspects: epistemological, ontological, and methodological.

The structure and extent of information and the perception of a situation are discussed under epistemology. Ontology is defined as "a representation of the ideas and connections that potentially emerge for something like an entity or a society of individuals" (Udhin, 2019, p.101), as well as the technique used in the researcher's empirical inquiry to discover what is considered to be understood. Epistemological problems address questions such as ‘How can truth be recognised?’ as well as the link between the recogniser and the recognised. Epistemology primarily explores the method and features by which information is discovered, as well as the potential of these information gathering procedures to be transmitted and replicated by other researchers. Every investigation is built on conceptual beliefs regarding what constitutes legitimate and trustworthy investigation, along with the most suitable research methodologies for the growth of information within a particular discipline. The conceptual principles and architectural tactics that drive this research project are explained throughout this section.

Typically, a person's perspective appears to have a major impact on the overall apparent comparative relevance they ascribe to various parts of actuality, most notably the ontological and epistemological components of a study. These many perspectives on the environment have a significant effect in most educational settings, although none is regarded as superior to the others. Udhin (2019) defines a study’s possible orientations as positivism, post-positivist, post-structuralist, and integrating post-modernism and post-structuralism inside a 'crucial philosophy'. The realist and cognitivist viewpoints are opposing viewpoints. The objectivist (objectivism) intellectual foundation is realism, which holds that perhaps the environment appears, and can be known, as it is; post-positivism holds that this reality is merely imprecise and based on probability. However, post-positivism is a continuation of positivism because both share an objectivist theoretical basis. A subjectivist epistemology has a stronger 'social theory' orientation wherein “the researcher as well as the examined objects are thought to be dynamically connected, with both the beliefs of the researcher… inexorably impacting the enquiry” (Guba & Lincoln, 1994, p. 110; Udhin, 2019, p. 100). Additionally, three conceptually diverse study paradigms are distinguished: positivism, interpretivism, and critical post-modernism. In a study, the choice of paradigm is very important. A paradigm can be described as “an entire system of thought” (Elmborg, 2006). For example, in the biological sciences, perspectives are typically 'hidden' inside the quantitative methods used, yet they impact how the investigation is conducted.

Any research approach incorporates the interconnected activity and thought that characterise the paradigm of the investigation. People's opinions about the world in which they exist, and desire to reside in, are reflected in their research philosophies. Following a review of available theoretical orientations, the interpretivist perspective was chosen for this investigation. According to this perspective, people contribute meaning to their social environment, and social occurrences can be comprehended through understanding the meanings and judgments that individuals impose on social events (Thanh & Thanh, 2015). The interpretivist paradigm seeks to comprehend and explain reality through the 'eyes' of its participants. Additionally, interpretive researchers believe that understanding the social environment is not attainable through a single method. Since the interpretive paradigm or approach was adopted for this investigation, the researcher addressed actuality through the learners' experiences of computerised educational materials within virtual classrooms. Because actuality is constructed through personal and interpersonal experience, data were sourced through peer–peer, learner–teacher, and learner–resource encounters. Furthermore, data were interpreted through a variety of viewpoints, providing insight into how diverse individuals make meaning of their various experiences using digitised educational materials, and also why they did so. As a result, inside this investigation, the social environment was understood according to the perspective of the participants in the investigation. Thus, interpretivism assisted the investigator in gaining new understanding about education using underlying cultural factors and institutions.

4.2.2 Ontological stance

Using a subjectivist epistemology, the investigator adopted interpretivist ontological premises pertaining to the nature of reality. Various perspectives have distinct beliefs about truth and understanding that influences the research strategy and, therefore, the investigation techniques. Ontological premises are related to questions such as 'What is there that can be known or recognised?' Throughout this research, the learners' profiles differed in terms of intellectual capabilities and settings, resulting in distinct perspectives and perceptions of reality, which necessitated the use of various interpretative design methodologies and strategies. The investigator used a semi-structured interview based on learner sketches to represent their understanding of concepts using digital learning materials. The use of an interpretative paradigm took advantage of the author's experience as a scholar, a lecturer in the discipline of pedagogy and assessment, as well as an educator. These various multi-perspective roles enabled the researcher to evaluate individuals' learning using computerised teaching materials at Grade 1 level in Mauritius primary schools from a variety of viewpoints.

According to Thanh and Thanh (2015), a basic premise of the interpretive paradigm is that truth is culturally created. Similarly, Udhin (2019) has stated that when people behave according to their native socio-cultural context, they are able to better relate to their individual acts. Throughout this investigation, the investigator watched learners in their usual school setting, despite the addition of an immersive projection. The socio-cultural context of this classroom setting provided a valuable foundation for understanding how learning unfolds with electronic tools. Insights drawn from the specific educational environment contributed to evaluating the effectiveness and realism of learning experiences supported by digital tools. The following section outlines the methods used to gather evidence of learning through digital resources, such as AR materials.

4.2.3 Research approaches

Research approaches are generally categorised into three types, i.e., qualitative, quantitative, and mixed-method research, which determine the research methodology for the data collection, interpretation, and definition of the research methods (Taherdoost, 2022). The choice of an approach assists in guiding the adoption of appropriate methodologies for the collection and analysis of data for any research thesis. For this study, a review and evaluation of the different methods is given, followed by reasons for the choices made. This process concludes with a discussion of the implementation of the research methods deemed most appropriate for the aims and objectives of the study.

4.2.3.1 Quantitative research

Quantitative analysis involves the collecting of datasets so that information may be measured and submitted to statistical techniques in an attempt to validate or refute "alternative knowledge assertions" (Kadhim & Al-Tememi, 2023, pp. 661–682). According to Creswell (2002), statistical research has its origins in the natural sciences, specifically chemistry and physics. A statistical evaluation approach employs statistical formulas. Three major themes relevant to quantitative studies include study strategy, testing and assessment methodologies, and data analysis. The quantitative approach also entails the gathering of numerical data, and the data evaluation process is often computational formalism. This quantitative approach involves collecting numerical data, with the analysis typically relying on computational methods and formal statistical techniques. Furthermore, the investigator employs inquiry techniques to determine consistency with quantitative data gathering approaches.

Quantitative research encompasses three primary types of studies: informative empirical, causal-comparative, and exploratory correlational designs. Each serves a distinct purpose within the research process. For example, exploratory studies seek to delve deeper into potential relationships or effects that are not yet fully understood. For instance, an exploratory study might assess the effects of a new therapeutic intervention on a target group, analysing outcomes such as improved physical or mental health. While exploratory studies do not confirm causation, they often lay the groundwork for subsequent experimental designs by identifying potential variables for further investigation (Polit & Beck, 2017).

Experimental techniques are classified into three forms: pre-experimental, real experimental, and then quasi-experimental. The pre-experimental phase incorporates unchanging independent variables, or even a control that has not been chosen at random. Campbell and Stanley (1963) advocated for the real experimental method, which allows greater supervision over the study and results in greater reliability. The quasi-experimental approach, in contrast, entails the non-random sampling of study subjects. As a result, supervision is restricted and meaningful experimentation is impossible. Because the variable is uncontrollable, reliability may well be compromised.

Causal-comparative research, also known as ex post facto research, investigates the potential cause-and-effect relationships between independent variables (predictors) and dependent variables (outcomes). Unlike experimental studies, causal-comparative studies do not involve manipulation of variables, but rather observation and analyses of existing differences or changes to infer relationships (Fraenkel, Wallen & Hyun, 2012). For instance, an investigator might explore how socioeconomic status (independent variable) affects academic performance (dependent variable).

In such studies, the researcher identifies whether differences in the dependent variable can be attributed to variations in the independent variable, acknowledging that causation cannot be definitively established due to potential confounding variables and the lack of random assignment (Gay, Mills & Airasian, 2011). This design is particularly useful in situations where experimental manipulation is impractical, unethical, or impossible. A multifactorial design, often used within causal-comparative research, examines the interactions between two or more independent variables and their combined effects on dependent variables.

For example, a study might investigate how teaching methods (independent variable 1) and classroom size (independent variable 2) jointly influence learner engagement (dependent variable). This approach enables researchers to explore not only individual effects, but also the interplay of variables within complex systems (Tabachnick & Fidell, 2013). Causal-comparative research offers a valuable framework for exploring relationships and generating hypotheses for future experimental validation, providing insights into natural phenomena where direct manipulation is not feasible.

4.2.3.2 Qualitative research

Qualitative studies are comprehensive approaches that include discovery. A descriptive method can be described as an unfolding model that happens in a naturalistic setting and allows the investigator to acquire a depth of knowledge from active participation in authentic events (Lim, 2024). The sociological phenomena under study was researched from the participant's perspective or opinion, which is a characteristic of descriptive studies (Vitellone, 2021). There are various study strategies that employ qualitative analysis tools to shape the methodological approach. As a consequence, the various methodologies have a significant impact on the study tactics investigated. Qualitative studies elucidate the deliberate use of obtained information for the purpose of analysis, interpretation, and understanding (Lim, 2024). According to Leedy and Ormrod (2001), qualitative approaches are less organised in their procedures as they conceptualise and establish new hypotheses. Descriptive methods provide an excellent model for implementation in a realistic context, and for allowing the investigator to generate an in-depth understanding from being immersed in the real events. A post-structuralism framework is used to perform qualitative study (Hall & Liebenberg, 2024; Hassan, 2024).

Qualitative investigation is divided into five categories: case study, ethnographic study, phenomenological study, grounded theory study, and content analysis. These five fields reflect the use of inductive and accompanying approaches (Creswell & Poth, 2018). These approaches share a common foundation in inductive reasoning, allowing researchers to explore phenomena by generating theories or insights based on observations and patterns rather than relying solely on predetermined hypotheses.

Unlike quantitative research, which is rooted in deductive reasoning and seeks to test hypotheses through numerical data, qualitative research is guided by intuition, interpretation, and contextual understanding.

Researchers aim to describe and interpret the observable characteristics of a phenomenon by asking open-ended questions and gathering rich, descriptive data (Merriam & Tisdell, 2016). For example, a phenomenological study might investigate the lived experiences of teachers during remote learning, focusing on their perceptions and emotional responses.

4.2.3.3 Mixed-methods research

Mixed-methods approaches use both statistical and descriptive study methodologies in particular combinations that have been shown to be most productive and significant (Creswell & Plano Clark, 2018; Luyt, 2012; Ponterotto & Grieger, 1999). The objective of employing mixed methods is to capitalise on the advantages of both while minimising their limitations. Additionally, the advantages and disadvantages of mixed methods depend on the context as well as the way researchers want to handle the issue under investigation. For example, if researchers wish to provide in-depth insights into a phenomenon, they may decide on a smaller but relevant sample, which is a characteristic of qualitative work. The investigator can use inferential analysis, common in statistical investigation, to measure and evaluate the findings for integration into the larger, more comprehensive research project. Researchers can now evaluate and create hypotheses by designing study projects that integrate data gathering or statistical processing techniques from numerical and interpersonal research methodologies. Within the single proposed study, researchers might use both deductive and inductive analyses. These combined methodologies allow investigators to create a more comprehensive understanding of the complex nature of phenomena from the perspective of respondents as well as from statistical results. Practitioners of the mixed approaches support the doing of ‘what works’ within the framework of investigative principles to examine, forecast, characterise, and comprehend the phenomena (Dawadi, Shrestha & Giri, 2021; Johnson & Onwuegbuzie, 2004).

In the context of the mixed-methods research strategy, practical assumptions influence decisions about what constitutes knowledge and expertise. Mixed-methods research operates on the premise that both quantitative (statistical) and qualitative (subjective) methodologies are not only distinct but also complementary. This integrative approach allows researchers to leverage the strengths of both methods to provide a more comprehensive understanding of complex phenomena (Creswell & Plano Clark, 2018). For instance, quantitative data can identify patterns and measure outcomes, while qualitative data provides deeper insight into the context and meaning behind these patterns.

The interplay between these two paradigms highlights the need for continued investment in mixed-methods research projects, as they address multifaceted questions that cannot be fully explored using a single methodological approach. This synergy contributes to a holistic view of the research problem, supporting practical applications and theoretical advancements (Bailey, Hole, Plumb & Caskey, 2022; Östlund, Kidd, Wengström & Rowa-Dewar, 2011).

4.2.4 Methodological stance

After analysing the methods available, a qualitative approach was selected as most appropriate in order that participants' perspectives could be evaluated properly. With the proper evaluation of the participant views and perspectives, the influences and impacts of teaching and learning with AR resources can best be demonstrated and core principles generated to guide practice. This will help to assist policy and implementation related to the adoption of digital resources, such as AR, at the primary school level. Qualitative methods provide descriptive data that evaluate participant experiences and views through interpersonal interactions, and the identification of fundamental issues.

The descriptive survey approach was selected for the current study's analytical viewpoint. Analysing learning through computerised educational materials using various examples enabled a comprehensive understanding of the phenomena. According to Oojorah and Udhin (2022), a case study of a unit of analysis, such as an occurrence, an organisation, or a personality, "seems to be an experimental enquiry that analyses a current phenomenon within its real-life setting utilising different kinds of data" (pp. 101–120). Case study investigation is often focused on a comprehensive examination of something, such as a person or a set of participants in order to explore a phenomenon. Thus, a case study using descriptive survey techniques was adopted to evaluate how learners were learning using electronic educational materials inside their regular learning environments, employing several methods to gather information on their performance. According to Udhin (2019), case research strategies are recommended whenever the objective of the investigation is to address 'how' and 'why' concerns, because they exclude the influence of the investigator on the respondents' actions. Yin (2009), on the other hand, argues that adopting descriptive survey techniques fails to establish distinct limits between the phenomenon and the setting. By using a case study technique, the surrounding factors could also be considered, as they are considered significant to the research analysis.

Case studies are also intended to enable knowledge to be acquired from respondents' viewpoints by using several data collection methods. Yin (2009) has classified case studies into three types: explanatory, exploratory, and descriptive.

Interpretive and descriptive analyses are used to clarify causal relationships in real-life situations (Udhin, 2019). Interpretive case studies relate to the investigation of circumstances in which actions can produce a variety of effects. According to Cronin (2014), a qualitative descriptive analysis is also employed whenever the research necessitates the characterisation of a phenomenon as well as the environment in which it occurred. He subsequently classified case investigations as solitary, comprehensive case research, and multiple-case investigations. Moreover, a solitary holistic example investigation may be used if the research's findings need to be extended from only one example. This technique is used in healthcare when only one instance is required to investigate an issue. However, complications that may occur are context-related, which is why multiple-case research is useful for solving this problem, as it enables the investigator to dive into the variations between or within cases. The primary goal of multiple-case research is to build knowledge of the phenomena by examining several instances within and across various settings. Each respondent within this survey had a distinct profile and set of features, which allowed the investigator to create deeper depictions of studying via technologies among Grade 1 learners.

The evaluation of case study results is often driven by ideas and notions (Keen & Packwood, 1995). Throughout this research, contrasts were established between instances and compared to the existing literature and conceptual foundation of the discipline. The reason for selecting a multiple-case research approach was to collect realistic experiential evidence of teaching and learning in actual classroom settings using digital learning materials, such as AR, on a tablet devise. Furthermore, while dealing with several examples, the investigator delved into a greater degree of abstraction in order to address the essential problems under examination. Originally, separate examples from three distinct schools were chosen for the research. Further details on sampling and choice of cases are provided in the succeeding sections.

4.3 Methodology

4.3.1 Gaining entry in the field

Udhin (2019) asserts that gaining entry to the field in case study research is crucial and should be handled with care. The researcher is required to manoeuvre through unfamiliar surroundings and interpersonal interactions, which can be challenging. According to Wasserman (2007), confidence and approval have to be earned in order to undertake investigations within a social setting. This may not always be a simple process, as strangers are frequently not accepted if the study involves sensitive topics that are of particular significance to the group. Gaining acceptance and trust are among the most difficult problems for researchers when collecting data. In this study, authorisation was requested from the Department of Education and Human Resource Management to acquire entry to the participating primary schools for research purposes. It took about four months to obtain consent from the Minister of State to attend the institutions. The investigator had to return to the government numerous times before being allowed admission to three institutions of varying grades, excellence, mediums, and affluence. Schools in Mauritius are classified by academic achievement. High-level schools, often referred to as 'star' institutions, are higher performing, whereas low-level schools perform at a lower academic level. Median-level or ordinary schools fall in between. The projectors within the ordinary school were broken. The investigator waited two weeks for the dynamic projectors to be fixed, but without success. Owing to time constraints, the investigator was forced to exclude the median schools from the survey.

4.3.2 Sample population

The population and sample size of any research influences the authenticity of the research, as well as the research methodology (Ahmad, Alias & Abdul Razak, 2023). This research was devoted to establishing the effectiveness of AR resources in the primary levels. Hence, it was also important to know about the influence of any technological issues in the primary educational settings. It is for this reason that this research used a number of data sources, i.e., semi-structured interviewing, art-based evidence, observation, and teachers' journals. Interviews were administered to a range of participants in order to obtain an in-depth understanding of the issues faced by both learners and teachers. Hence, the choice of the sample population was important.

The population for this research included learners who were asked questions under four categories aligned to the research questions. The four categories of questions were descriptive (what, so what, etc.), operational (how), theoretical (why), and philosophical (why). The interview questions were framed in a manner to allow for the determination of reasons, impacts, and influences of the AR resources in the digital classrooms of Mauritian primary schools. The research was carried out with 43 learners as participants to investigate the issues, significances, and challenges concerning the research topic. The 43 learners were drawn from three primary schools, i.e., School A, School B, and School C from Zone 2, which had been selected to take part in the interviews. Hence, the sample of this research was 43 Grade 1 learners from three government primary schools.

4.3.3 Sampling method

Sampling is the act of accurately selecting a subset of a community to take part in an investigation (Udhin, 2019). The sampling method chosen is known as planned selection, purposive sampling, or judgmental sampling. With this sort of selection, the investigator selects a group according to the aim of the research (Yeshaswi, 2024). The selected sample for this study included Grade 1 learners with varying cognitive skills and degrees of experience with technologies. To make their intentions more explicit, the researcher used purposive selection to select individuals for the study. Purposeful sampling, also known as judgmental sampling or non-random testing, is an intentional selection of study respondents. Purposeful sampling uses the researcher's experience and expertise when selecting respondents.

The sampling area was chosen based on the institutions' geographical position. The investigator found it easy to visit the three schools from his workplace for collecting data since they were situated fairly close by. The researcher next examined the resource listing or sample selection, sample volume, and factors of significance, which are discussed further below. The sample frame for this research comprised government elementary schools of various levels located in various areas. Mauritian primary schools are categorised into four zones, named Zone 1, 2, 3, and 4. Three schools from Zone 2 were chosen for the research. The purpose of selecting three distinct schools was to obtain learners from various settings, and more specifically, varied socioeconomic circumstances, which might influence learners' access to electronic equipment at home or in their community. School A is situated in a region where households have an average socioeconomic status and the children's achievement is average. The bulk of the learners from this school stated that they lacked simple technological amenities. This served as a critical indication of the learners' experience with technology at home.

School C is located in a city. It is a 'star' school as the learners are mostly top achievers. According to a poll, School C learners were technologically knowledgeable, since they were familiar with the use of tablets, computers, and other technical gadgets. Finally, School B from Zone 2 was also chosen for research analysis. School B was an average performing school.

This performance range was deemed likely to provide the insights needed to properly understand the phenomena under investigation.

This method of sampling, i.e., purposeful sampling, is often used in descriptive studies as it serves to select ‘information-rich’ examples that can help to address the research questions (Bhardwaj, 2019; Ahmed, 2024). Purposeful sampling, as compared to probabilistic sampling, only requires comparatively small samples with the potential to provide rich data according to the aims of the investigation. With the institutions already having been chosen based on socioeconomic status and academic performance, the investigator was required to choose one Grade 1 learner from each school.

As described in the first chapter, the Sankoré initiative began in Mauritius primary schools in 2012, which is why Grade 1 learners were chosen. School A had four Grade 1 divisions and School C had three Grade 1 divisions, while School B had two similar divisions. Thus, the researcher had to rely on the headmasters of these schools to assist with the selecting process. The selection of Grade 1 classrooms (in all institutions) was based on the educators' previous experiences teaching in elementary schools, regardless of whether they had previously used an interactive screen. Furthermore, the instructors selected had at a minimum of three years of experience interacting with Grade 1–3 learners, indicating that they were familiar with the content and methodology necessary to engage with Grade 1 learners.

In terms of learners’ selection, the classroom teacher provided the assistance needed. The teachers were asked to choose the candidates, as they understood the learners in their classrooms. The researcher requested that the teacher choose learners based on their learning abilities. In this way, 43 learners were selected from the designated schools' Grade 1 classrooms.

4.3.4 Sample size

In this study, a group of Grade 1 learners from each school was chosen for interviews, followed by the selection of additional participants based on the methodological stance of the research (Veldman, Doolaard, Bosker & Snijders, 2020). A sample size must be large enough to accurately represent the phenomena of interest and adequately address the research questions. However, increasing the sample size beyond a certain point can lead to diminishing returns, as additional data may not necessarily provide more meaningful insights.

In qualitative research, the goal is often to reach saturation—the point at which adding more participants does not generate new information or perspectives (Guest, Bunce & Johnson, 2006).

Larger sample sizes may generate more data, but they do not always contribute to deeper understanding. In contrast to quantitative approaches, which aim to minimise prediction errors, qualitative research focuses on gathering rich, diverse perspectives from a smaller, more manageable sample. This allows for a deeper exploration of the research topic, without the risk of collecting redundant data. Omona (2013) emphasises that a single participant's perspective can be enough to create a meaningful code that contributes to the analytic framework. Therefore, the purpose of qualitative research is not to maximise sample size but to reach saturation.

The ideal sample size depends on various factors, including the research design, the scope of the study, and the diversity of the population. Some studies suggest that a sample size of 30 participants is appropriate for a comprehensive qualitative analysis (Fusch & Ness, 2015). However, in some cases, even smaller sample sizes of 10 participants can be highly effective, particularly when participants are carefully selected and the recruitment process is thorough. In instances where subgroups within the population are being studied, researchers may recommend a sample size of 20–30 participants for in-depth interviews (Omona, 2013).

Firstly, 23 learners from School A were chosen from the Grade 1 classes. They were asked interview questions individually, and in a group, to understand how they used AR resources for studying. Video recordings were kept of actual classes for later observation and analysis of class interactions, learning practices, as well as teachers' capabilities. Similarly, a sample was selected from the other two schools: 13 from School C and 7 from School B. Teachers from these schools also helped in the selection process and arranged for interviews and observations to be conducted without any external influence.

4.3.5 Research strategy and data collection techniques

Research strategies involve the methods or the techniques applied to collect data, and to analyse the data in order to reach the research outcomes. The strategy used for this research mainly involved qualitative methods of data collection, analysis and interpretation from the perspectives of the participants. Different qualitative methodologies are described below to provide context, and to provide a rationale for the choices made in this study.

There are various approaches to performing descriptive studies. Most researchers agree on the following five categories: case studies, grounded theory, ethnography, content analysis, and phenomenology. Udhin (2019) discusses how these strategies are best suited to various research demands. Case studies and grounded theory research, for example, investigate procedures, actions and occurrences, whereas ethnographic studies investigate shared culture-based behaviours of people or organisations. People can be studied using case reports and phenomenology.

4.3.5.1 Case Study

Cronin (2014, pp. 19–27) describes case studies as follows: "[when a] researcher analyses in detail a programme, an occurrence, an action, a procedure, and one or maybe more persons". According to Udhin (2019), case study research must also contain a time period. The real-world example might be a solitary instance or an example with temporal and locational constraints. Yin (2009) gives examples from various fields, such as clinical studies of rare diseases (incident) or political science studies on presidential contests (activity). Case studies seek to understand more about a poorly recognised or understood scenario (Cronin, 2014). According to Yin (2009), the framework of a case study should include the topic, background, difficulties, and lessons learned. Additionally, a case study requires substantial data gathering from a variety of resources, including direct or indirect observations, interviews, documentary analysis or papers, physical objects, and multimedia resources (Cronin, 2014). The investigator is also required to spend time interacting with the participants. The presentation of case study research includes experiences gained or trends discovered that are related to theories.

4.3.5.2 Ethnography Study

A case study differs from an ethnographic study. Case study research investigates a specific individual, programme, or occurrence, whereas ethnography investigates an entire population that embraces a shared culture (Creswell, 2017). Creswell (2009, p14) describes ethnographies as: "…where the researcher observes an entire cultural group in some kind of a naturalistic setting across an extended length of time by gathering, largely, observable data". The emphasis is on daily activities in order to uncover norms, attitudes, social hierarchies, and other elements. Ethnographic investigations often attempt to comprehend the collective variations in a group's culture through time. As a consequence, generalisation should be made with caution. The ethnography approach requires the investigator to submerge him- or herself in the group's regular routines in an attempt to monitor their behaviour and, later, analyse the cultural or sociological grouping and institutions. Obtaining entry to a location is the very first step in ethnography study. Secondly, the investigator must obtain the support, and gain the confidence, of the individuals in the group. Finally, the analyst employs a 'big-net strategy', interacting with everyone to find significant sources or 'key informants' within the group. The information is obtained through observations of, and interviews with, numerous informants. If the interviews are extensive, the investigator will have to record this data on audio or video. Ethnographic findings should highlight key aspects of the study, including the purpose behind the investigation, a detailed description of the population, and the methods used for analysis. The findings should also provide evidence to support the researcher's observations and conclusions, clearly connecting them to the research topic. Importantly, the findings must illustrate how the group's shared culture has developed and evolved over time.

4.3.5.3 Grounded theory research

Creswell (Creswell, 2009, p.4) describes grounded theory investigation as when the "investigator seeks to construct a broad, abstraction concept of a system, activity, or encounter founded inside the opinions of respondents" within a research study. According to Ivankova and Creswell (2009), a deductive research investigation begins with evidence that is gradually developed into a conceptual framework. The term 'grounded' reflects the method's foundation—that the theory emerges from data collected in real-world contexts rather than being derived solely from pre-existing literature. Grounded theory is widely applied in sociology, as it focuses on analysing human activities and social interactions within their natural environments.

Grounded theory practice gathers data, interprets the data, and builds constructs using a constant comparison technique (Kolb, 2012). Information can be gathered from a variety of sources, including interviews with respondents or witnesses, analysis of previous video recordings or documents, and on-site investigations (Creswell, 2009). The usual approach to data analysis in grounded theory research comprises open coding, axial coding, selective coding, and theory building (Ivankova & Creswell, 2009). Lastly, the final report includes six components: a description of the study issue; a study of the research literature; a description of the technique; data evaluation; an explanation of the concepts and constructs; and a discussion of the consequences (Younas, Durante & Fàbregues, 2024).

4.3.5.4 Phenomenological Study

The goal of phenomenological research is "to comprehend an event from the participants' perspectives" (Hassan, 2024; McLeod, 2024). The research attempts to address concerns about the event by focusing upon respondents' views of the incident or scenario. According to Creswell (2009, pp. 3–20), the core of this type of research seems to be the quest for "the fundamental underpinning significance of the experience and [it] stress[es] intentionally of awareness where encounters involve both the external appearance and internal cognition founded on memory, picture, and interpretation" (Ishtiaq, 2019). The investigator typically has some relationship, expertise, or involvement in the study topic; thus, framing (mitigating prejudgments) is essential.

Whenever interviews are done, the approach used in an experiential investigation is comparable to that used in grounded theory. Long (1–2 hour) conversations are used to gather information in an attempt to comprehend and analyse an individual's assessment of the significance of an event. According to Ivankova and Creswell (2009), the prescriptive format consists of publishing research queries that discover the significance of the expertise, undertaking discussions, analysing information to identify groupings of definitions, and concluding with such a study that reinforces the reader's comprehension of the crucial framework of the expertise (Heigham & Croker, 2009). The research gathers data in order to find similar trends in a person's assessments or meaning-making of their own experiences.

4.3.5.5 Content analysis

This approach is defined as "a comprehensive and methodical investigation of the substance of such a given body of information with the objective of discovering trends, topics, or prejudices" (Seale & Silverman, 1997, pp. 379–380). Content analysis can be used to study many types of human interactions, such as literature, journals, and movies, among others, to detect trends, motifs, or agendas (Gheyle & Jacobs, 2017).

The approach is intended to extract certain features from people's interactive material. The investigator looks for trends, patterns, or prejudices in linguistic, sensory, or behavioural data. Content analysis aims to accomplish the most objective assessment conceivable, in that it analyses a collection of data to determine the features or attributes to be studied (Nicmanis, 2024). Data analysis is a two-step procedure. After data collection, the data are recorded in a frequency distribution table for each trait or quality indicated. Secondly, the investigator undertakes a statistical study to ensure that the findings can be stated quantitatively. The systematic review is split into five segments: a summary of the components researched, an overview of the features and attributes researched, a summary of the research methods, a statistical analysis displaying the frequencies, and conclusions (Phillips & Barker, 2021).

4.4 Qualitative data

This portion of the methodology chapter discusses the different methods of data collection and analysis used in this study to achieve the research objectives and inform the research questions. Four methods were used to gain an in-depth understanding of those aspects of teaching and learning using AR resources: interviewing, observation, art-based analysis, and teachers' journals.

Interviewing is considered one of the most effective methods for collecting qualitative data in educational research, as it allows researchers to directly interact with participants and gather their perspectives and experiences (Wu et al., 2013). Interviewing also helps to understand the ground-level problems that participants face in actuality (Benlahcene & Ramdani, 2021). Observation is another important method for collecting data in educational research, as it allows researchers to directly observe and, in this case, document the use of AR technology in the classroom. Another recommended method for young learners is art-based research (Barton, 2015). Art-based approaches are a more innovative method for collecting data in educational research, and involve using creative and expressive methods such as drawing, painting, or photography to capture learners' experiences and perspectives (Levitt et al., 2018). This method can be particularly useful for engaging learners who may not be comfortable with traditional interview or observation methods. Finally, teachers' journals can provide a valuable source of data, as teachers can reflect on their experiences and document the challenges and successes they encounter. However, as discussed earlier, there are also potential drawbacks to using teachers' journals, such as bias and incomplete data.

In this study, the Grade 1 learners were provided with tablets or iPads which were already in use in the schools, and thus familiar to the learners. The third data collection method used was observation, using both an observation schedule and video recordings.

The final method used was teachers' journals or reflections on the utilisation, significance, and employment of the AR resources in the digital classroom. The sub-sections that follow provide further detail.

4.4.1 Interviews

According to Cohen, Manion and Morrison (2007, pp. 180–207), interviewing is a versatile data collecting method that allows "an exchange of perspectives between two or more persons". He advises that the discussion should centre on the study goals and focus on a topic of common interest to all participants. According to Cohen et al. (2007), an 'interview' cannot be either subjective or objective, but should be considered as intersubjective. The interview provides an opportunity for participants to expressing their views and debate their personal perspectives with the aim of reaching intersubjective consensus (Cohen et al., 2007).

Using the interview approach for data gathering entails presenting oral and verbal stimuli. An interview, according to Udhin (2019), comprises a set of questions asked by the investigator in order to gain clarification regarding a phenomenon. Interviewing is an effective method because it allows respondents to express their views, ideas, and attitudes under their own circumstances. Furthermore, throughout a conversation, the interviewer enjoys discretion over the order of the queries, allowing for both flexibility and control. However, although the interview can be a strong tool, Cohen et al. (2007) warn that the investigator must be mindful that it is time demanding and susceptible to interviewer bias (University of Florida, 2018).

The researcher can choose to use one or more of the three most common interview techniques: unstructured, structured, and semi-structured. An unstructured interview is most versatile with few, if any, planned questions, but rather a general direction (research interests), allowing the interviewer to explore issues as they emerge (Given, 2008; Department of Psychology EDI Committee, McGill University, 2021). This approach allows the interviewer to delve into topics as they naturally arise during the conversation. However, a significant limitation of this method is the difficulty in making direct comparisons between responses from different interviews, as the questions and topics explored may vary widely across participants.

The biggest challenge with this style of questioning is that ready comparisons between the responses obtained from different interviews cannot be made. A structured interview, on the other hand, adheres to a pre-determined set of questions (Cohen et al., 2007).

The structured interview approach has the disadvantage of not permitting interviewers to explore emerging issues or probe for additional details. Semi-structured interviews fall somewhere in between and have the advantages of a structured question schedule and the flexibility to probe and explore. Sub-questions are often added as prompts for both interviewer and interviewee (Ruslin, Mashuri, Rasak, Alhabsyi & Syam, 2022).

In this study, the researcher employed semi-structured interviews, providing participants with the opportunity to openly share their perspectives and experiences with AR-mediated lessons. This approach facilitated the collection of in-depth and meaningful data relevant to the research questions. While the structured questions provided a solid framework for the interviews, they also allowed for flexibility, enabling the researcher to probe further and explore emerging themes during the discussions. All the interview questions were carefully crafted to align with and address the overarching research questions. A key focus of the interviews was to explore the learners' artwork, as their illustrations served as tangible evidence of their understanding and knowledge acquisition. Artwork, as a visual representation, can provide valuable insights into learners' cognitive and creative processes, offering a unique perspective on their learning experiences (Barone & Eisner, 2012). This approach highlights the role of art-based methods in educational research, where visual data can enrich traditional narrative findings by uncovering nuanced aspects of learners' understanding. The investigator had to engage a few individuals in Kreol Morisien (KM), and their native language, to establish connection with them.

After completing the semi-structured interviews, all participants were brought together for a group interview session. The primary objective of conducting the group interview after the individual sessions was to encourage peer interaction and engagement. As noted by Cohen et al. (2007), group interviews can be less intimidating for participants, fostering a more relaxed and open exchange of ideas. Udhin (2019) emphasises the influence of authority and positional dynamics in questioning children, underscoring the importance of creating a supportive environment. To ensure inclusivity, the researcher made certain that every child had an opportunity to speak and that the interview was conducted in a comfortable and conducive setting. Clear guidelines were established prior to the discussion to promote smooth facilitation, ensuring that all participants could contribute while preventing any one individual from dominating the conversation.

The group interview followed the same introductory statements and question structure as the individual sessions, with added flexibility to allow for richer discussions and the enhanced energy generated by group dynamics. Details of how the interview schedule was designed, tested, and refined for accuracy are provided in Appendix A1.

The respondents were asked questions that had been phrased to address the research questions. The questions fell into three categories: firstly, descriptive; secondly, operational; and lastly, theoretical or philosophical. Descriptive questions were associated with what learners learn with the use of AR resources. Operational questions related to the method or how they learn. Theoretical concepts explored the reason behind the use or the impacts of the technology. Interviewing questions were organised to ensure a fair coverage of the three categories.

4.4.2 Art-based research

According to McNiff (2008), art-based research is characterised by the deliberate application of the creative process – the real creation of artistic representations through various kinds of art – as a key approach of comprehending and assessing the experiences of both investigators as well as the individuals they study. These studies are distinct from study activities in which the arts might perform a key part, but are predominantly utilised as information for investigations conducted inside academic fields that use conventional scientific and mathematical explanations and interpretations of phenomena (McNiff, 2008).

Art-based research is a qualitative method for data collection, analysis, interpretation, and representation that is used in a number of research paradigms (Leavy, 2020). Risking expression, invention, and cooperation in the face of possible discomfort associated with ambiguity is critical for the art-based investigator (Prior, 2019). Therefore, art-based research was chosen to assist in defining the issues related to the utilisation of the AR resources at the primary level. Investigators can gain unique insight using this method; hence, its suitability to qualitative and interpretive case studies. In this case, learners' learning capacities as well as teachers' effectiveness with AR resources were evaluated through the use of art-based research. Art-based investigation, which is a focussed implementation of a broader epistemological approach of creative knowledge investigation, has experienced a major rise in higher schooling and corporate practice (Huet & Kapitan, 2021).

The potential for interdisciplinary collaboration is also an advantage of art-based research, which has the potential to bring together researchers from different disciplines, as well as artists and other creative professionals, to work on a common research question or topic. This interdisciplinary collaboration can lead to new insights and perspectives that may not have been possible with traditional research methods alone.

The above notwithstanding, researchers are sometimes apprehensive when deciding whether or not to undertake art-based investigations, even within organisations that recognise their importance, as researchers often feel compelled to conform to more traditional corporate and societal norms (Montuori & Donnelly, 2013). In this research, the researcher used art-based research in order to determine what learners actually learn through the implementation of AR resources. Art-based research is an effective way to understand the challenges and opportunities at grassroot level, as it can be interpreted according to the actualities of the settings (Barone & Eisner, 2011).

4.4.3 Observation

Observation is among the most commonly used research methods (Udhin, 2019). When using observation as a data gathering method, perception is organised and documented according to an observation schedule designed to gather information to address a particular research aim or research question. Additionally, Udhin (2019) notes that observation is a basic and extremely significant tool in qualitative research. According to Cohen et al. (2007), observation is a research technique that allows the researcher to collect 'live' information from authentic social settings (Cohen et al., 2007).

For example, observation produces data through the investigator's first-hand inspection of individuals in their actual situations. When using observation as an information gathering technique, the setting should be organised so as to allow the investigator to observe carefully, hear accurately, and record or document correctly. Udhin (2019) adds that observation is a form of surveillance comprising careful note-taking and capturing of occurrences, actions, and phenomena within the social environment selected for research.

Observation as a data collection strategy offers several advantages. Firstly, when done correctly, it assists in mitigating personal biases. Secondly, it captures 'live occurrences' – what is really occurring today and not what occurred before or will occur in future.

Finally, the observational approach does not rely on participants' willingness to answer or participation (Cohen et al., 2007). These authors add that observation is a very useful tool when participants are not entirely capable of providing verbal descriptions of their activities, emotions, or views.

Consequently, this research used observation as a method to gather information on the learning practices of primary learners, as it helped to gain an insight into learners’ thoughts, sentiments, and perspectives as they interacted with the computerised educational resources. Another rationale for using this method was that Grade 1 learners may not be mature enough to express their thoughts or sensations while studying. Consequently, seeing 'live occurrences' supplied the investigator with valuable data about learner learning in their familiar classroom environment. Participant and non-participant observation are the two basic forms of this method. Participant observation occurs when the observer is a member of the group being observed (Hurst, 2023).

The participant-observer incorporates their observations and experiences as part of the data, which helps to develop a deeper understanding of the research question. With a non-participant analysis, the observer is removed from the research situation. The non-participant observer or outsider does not interfere and observes from a naturalistic stance without involvement in the research situation. The primary benefit of non-participant observation is that the data obtained is less influenced by researcher bias (Given, 2008). In the current study, the researcher adopted the position of a non-participant observer who did not participate in activities, but gathered observational data from the learners in their normal classroom context. The researcher enlisted the assistance of two experts to record the subjects' conversations (as inconspicuously as possible). Two fake cameras were set up in the classroom two weeks before the data collecting process began in order that the learners could become accustomed to their presence. After the two-week period, learners had stopped paying attention to the surveillance cameras in the classroom, which enhanced the data's validity.

The decision to record the observations was made to ensure that no evidence was lost during data collection. Additionally, the videos could be examined numerous times by the researcher. The videos provided rich information that enabled an in-depth investigation of the phenomena through the learners' activities and exchanges inside the digitised classroom.

Together with the recordings, the researcher made observations during specified observational periods. The observational schedules are provided in Appendix B.

A classroom set-up and routine were established before starting the research. Figure 4.1, for example, depicts the classroom layout used for the study. This classroom layout enabled the researcher to plan the positioning of the learner being monitored as well as the position of the video. One 360-degree camera was used. The camera focused on the learners and the entire classroom, capturing all of the learners' activities inside the classroom environment. By placing the camera in the centre of the class, the investigator was able to gather comprehensive information on the learner's performance in their familiar classroom situation.

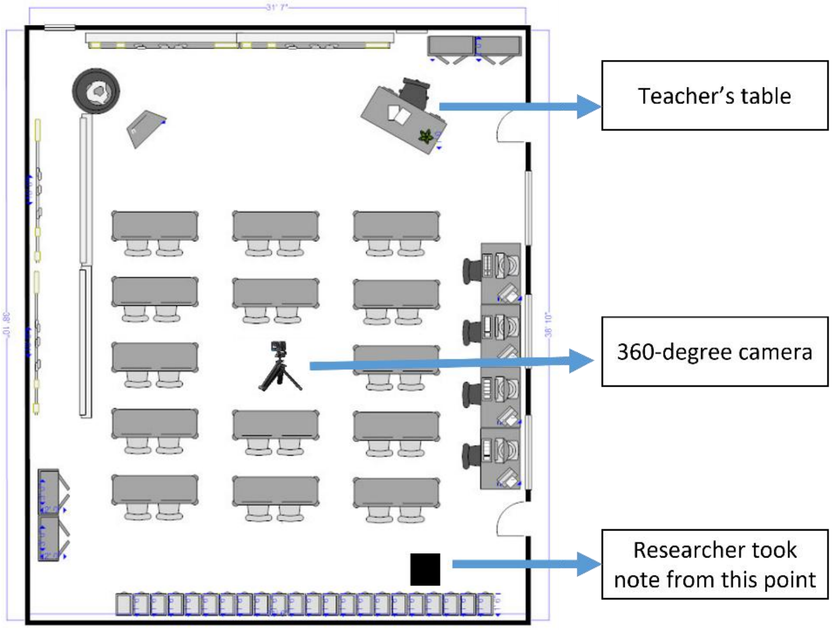

Figure 4.1: Camera settings in the classroom

4.4.4 Teachers' journals

Teachers' journals provided a means of collecting data from the educators involved directly in the digitised settings (Pang, 2020). These educators are in the best position to be critical of the digitised teaching-and-learning experiences. They are, for example, already familiar with the learners, their learning styles, behaviour and past academic performances, i.e., they have a baseline. The teachers were interviewed as well as engaged in *ad hoc* discussions. The input from these teachers assisted significantly in collecting and interpreting data about the impacts of AR resources on teaching and learning. This data collecting methods proved to be an effective way of identifying problems in the system and how to address these.

Reflection can bring new insights into comprehending an experience, clarifying concepts and attitudes, and exposing researcher bias. The teacher journals also provided information that helped to guide the research process and broaden interpretations. Data from the teacher journals were also analysed to address the research questions.

In accordance with a symbolic interface viewpoint, teachers behave in social contexts according to their attitudes about the circumstances, as well as their interpretations of events (Eriksson, Björklund Boistrup & Thornberg, 2018). People behave in, and according to, an environment that they create, and even if there is an ultimate truth, their creation is far more significant and impactful on their choices. Consequently, it is critical for the researcher to understand the teachers' evaluations. The way teachers characterise the circumstances of the environment, and explain what is required, determines how they provide feedback. Thus, it is necessary to explore this in an attempt to better understand daily teacher assessment in the classrooms. Their feedback can be viewed as a significant aspect of formative evaluation when it is part of the instructors' dialectical capacity and daily classroom evaluation. As a result, depending on the extent of constructive activity, feedback can contribute to efficiency (Morris, Perry & Wardle, 2021).

Regardless of how educators conduct classroom evaluation, it is obvious that they will have an impact on learners' academic achievement and sense of self-worth. According to Eriksson et al. (2018), instructors view feedback to be most successful when there is a confident teacher–learner connection, which is more likely to contribute to improved academic achievement. Classroom observations allow for in-depth examination of many facets of instructor feedback (Mammadov & Schroeder, 2023). Researchers have defined and discussed many types of autonomy-promoting comments from instructors, emphasising how instructor evaluation might possibly help children's growth as autonomous learners (Eriksson et al., 2020).

Eriksson et al. (2018) have identified a number of feedback types, including: 'do it quickly and do it correctly', which focusses on correct responses to a variety of assignments quickly completed; as opposed to 'reasoning takes a lot of time', which advocates a comfortable pace, allowing attention to be given to substance and procedure.

This author also notes that much feedback or evaluation documented in the research is either informal, implicit, or frequently wordless, as is the evaluation often provided in conversations between teacher and learner.

4.5 Research philosophy

The philosophy adopted for a study signifies a researcher's understanding of truth and reality, including beliefs about how learning takes place. It defines the views and ideas that govern the planning of a scientific research project, as well as the collection and analysis of data, and the interpretation of results (Carter & Illing, 2018).

Ontology refers to a researcher's beliefs about what can be recognised as real as opposed to what others consider to be true (Alharahsheh & Pius, 2019). An ontological stance may favour realism, historical realism, or relativism, among other classifications (Stutchbury, 2021). Realists consider reality to exist independent of the researcher's influence, and that it is explorable (Alharahsheh & Pius, 2019). In contrast, relativists contend that reality relies on the way a person perceives and encounters it (i.e., the world is different to different people).

Interpretive paradigms arose in response to critical positions on positivism. Interpretivism is focused on in-depth and situational understanding, and posits that social phenomena cannot be investigated using similar methods to those used to interrogate biophysical phenomena (Pervin & Mokhtar, 2022). Consequently, the study of ideas, attitudes, cognition, etc., necessitates the use of methodologies distinct from those used in the natural sciences. According to Ryan (2018), interpretivism considers variables such as ethnicities, conditions, and periods in order to build diverse social truths. Interpretivism differs from positivism because it seeks to explore the wealth of views and experiences of people rather than establish clear and uniform principles to be standardised and generalised (Alharahsheh & Pius, 2019).

The interpretative paradigm, as described above, allows researchers to evaluate changes in participants' descriptions of reality depending on their individual experiences (Pervin & Mokhtar, 2022). Additionally, the interpretive approach allows investigators to approach the research context as distinct from the particular conditions and people involved. This perspective also encourages the study to remain focussed on contextual issues, as opposed to a positivist approach which strives for generalisation. Using the interpretivism paradigm, this study achieved the following:

- Rather than focus on specific aspects of an event, the study was able to investigate the entire encounter (Ryan, 2018).
- The research interests, engagement, and dedication influenced the discovery and growth of investigation topics and challenges.
- The researcher was able to delve into personal experiences via formal conversations and interviewing.
- In-depth investigation of subjective conditions was achieved through the use of qualitative methods and approaches.
- The use of knowledge as a critical input into the study was facilitated.
- It allowed for a deeper dive into personal experiences instead of relying on generic measures or predictions, as provided by positivism (Thanh & Thanh, 2015).
- Since knowledge is deeply embedded in individuals and things, it yielded useful insights and results.

In summary, the interpretive paradigm enabled the use of qualitative approaches that are best suited for exploring and exposing important contextual insights. In contrast, the positivist approach would not have produced the same in-depth insights (Ryan, 2018), as quantitative approaches allow greater generalisability rather than detailed situation-specific understanding (Thanh & Thanh, 2015). Consequently, the subject matter of the study and its setting impact the choice of the best-suited paradigm.

4.6 Reliability and validity of the research

Udhin (2019) has proposed a number of criteria to use to assure trustworthiness in qualitative studies. These are referred to as the credibility, dependability, and transferability of a study. Credibility refers to the inner consistency or validity of a study, dependability to reliability, and transferability to generalisability or outward validity. Oojorah and Udhin (2022) acknowledged that the interpretive approach accepts prejudice and subjectiveness in data collecting and operates within a jointly accepted ethical system. Thus, Udhin (2019) uses legitimacy to describe the level of coherence between the respondents' realities and the accuracy with which the investigator perceives and presents them. These authors also argue for the use of the construct confirmability, as synonymous with impartiality. Together, dependability and confirmability ensure reliability, since different truths occur in a study rooted in an interpretivism philosophy.

Dependability refers to how the consistency of the information can be identified or monitored (Udhin, 2019). Udhin went on to say that confirmability is the degree to which perceptions are established in real circumstances and individuals rather than being fake.

Because this research represents a qualitative case study, the dimensions of dependability were verified by gathering evidence from numerous sources. Information through one resource would be used to interpret other sources of information. For example, learners were prompted to sketch their knowledge of ideas, after which they were questioned about their drawings. Moreover, observation was employed to record the learners' interactions while using the digitised materials. All of these different databases contributed to the research's credibility.

Another significant methodological difficulty that researchers encounter in descriptive study is the sample's dependability and faithful representation of the larger population or unit under investigation (Wagner, Glaser & Strauss, 1968). In qualitative studies, the concept of originality is employed rather than dependability. Authenticity is achieved when facts concerning personal views are 'genuine', and open-ended inquiries are typically employed (Miorandi, Sicari, De Pellegrini & Chlamtac, 2022). When qualitative studies have a smaller number of participants, the rapport between the investigator and the participants might be enhanced to assure the information's validity (Subedi, 2021). The next section discusses the ethical considerations that were taken into account for this research.

4.7 Ethical consideration

Interviewers carry a large responsibility to act ethically, as they wield significant influence and control over the interview process and the interviewees. Irrespective of the organisation served, interviewers are influenced by their socio-cultural and political contexts. Every interview should therefore be undertaken with the purpose of gathering information without negatively impacting the interviewee. It is thus vital that interviewers prepare well so that they are acquainted with both the subject as well as the case under investigation. All researchers, particularly interviewers, must determine the moral aims of the interview. These objectives must be balanced against the fulfilment of their duties. The participants should have faith in the honesty and ethical norms of the research. In the case of this study, teachers from different schools have depended on, and trusted, the researcher to collect data ethically and accurately. Authenticity, validity, reliability, and conformity of the analysis have to be maintained and no data tampered with or distorted (Wagemaker, 2020). As discussed, the current study adhered to stringent measures to ensure research rigour.

4.8 Conclusion

This chapter discussed the research design and methodology used in this study. The discussion included support for the use of interpretivism and qualitative methods of data collection and analysis. The study's ontological and epistemological viewpoints were also explained. A descriptive survey technique was used for the investigation, and the respondents were Grade 1 learners. This chapter additionally dealt with the steps followed to obtain access to the classroom and to engage with elementary school learners. The rational for the sampling methods used was also given. Methods of data generation were explained, including a definition and explanation of the study methodologies and equipment. Several methodologies and instruments were used to improve the validity and credibility of the findings. As a result, the researcher was able to investigate teaching and learning using digital educational materials in an authentic classroom environment, as well as using a variety of approaches. Also presented in this chapter were the techniques used for the presentation of the findings, as well as the development of narratives from the information recorded and the evaluation of such narratives to achieve a higher degree of abstraction. Additionally, the chapter provided a thorough explanation about how ethical problems were evaluated and resolved. Finally, the chapter discussed reliability and authenticity. The next chapter deals with the results and discussion of the data analyses.

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Introduction

Chapter 5 presents and discusses the results of the data analyses from the various data sources. Graphs, charts, and other visual aids are used to illustrate the results and any significant trends or patterns observed. Examples of how learners engaged with the AR resources and their responses are also provided to support inferences and conclusions (Sandelowski & Leeman, 2012). Additionally, this chapter provides an analysis of the intervention in terms of the elements of a second-generation activity network. Chapter 6 that follows will address the research questions based on the triangulation of the results from the analysis of these four different data sources, and will discuss implications of the research and how it contributes to our understanding of learners' engagement with AR resources. This includes recommendations for educators and future directions for research in this area.

5.2 Data analysis and discussion

There are several steps to the presentation of research findings. These include the collection of data, which in this study involved the use of interviews, observation, art-based artefacts and teacher journals. The use of multiple methods for data collection was intended to make the research comprehensive and provide a rich understanding of the issues and challenges related to the use of AR technology in the classroom (De Jonckheere & Vaughn, 2019). Additionally, using multiple methods allows the data to be triangulated, strengthening the validity of the findings (Hastings, 2010). Furthermore, for research on AR resource use in education, it is crucial to look at the ITC gadgets that are being used in the field of study, as the architecture of AR systems is complex and involves a combination of hardware and software components working together seamlessly to create an immersive AR experience (Timulak, 2009). Figure 5.1 summarises the AR architecture used in this study.

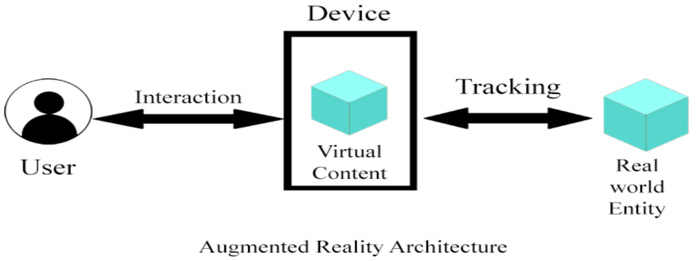

Figure 5.1: Architecture of Augmented Reality

(Source: https://www.geeksforgeeks.org/)

5.2.1 Interview data

In this study, interviewing was employed as one of the methods of data collection to obtain insights into the learning outcomes, learning processes, and learning motivations associated with the use of AR resources by learners. According to the learners' feedback, the incorporation of AR resources in the learning process resulted in increased engagement and enjoyment, leading to a subsequent enhancement in their motivation and enthusiasm towards learning. The results of the questionnaire (Appendix A1 and A2 and Table 5.1) indicated that the utilisation of AR resources positively impacted the learning process of learners. Specifically, the interactive nature of AR resources was found to enhance information retention and provide a more personalised and interactive learning experience. The study participants expressed their satisfaction with the experiential and participatory nature of AR materials, which contributed to their sustained attention and involvement throughout the educational experience.

The interview schedule containing learner responses is given in Appendix A1. The responses were first organised into categories, which were in turn clustered to form themes based on shared meanings (Alordiah & Ossai, 2023). Four themes were identified, each of which 'speaks' to one of the research questions; and were used in conjunction with the results of the analyses of other data sources (triangulation) to answer the research questions (see Chapter 6). The identified themes with all contributing categories and learner responses are given in Appendix A2. The identified categories and themes are summarised in Table 5.1, each with exemplar learner responses. Table 5.1 is followed by a discussion on the themes.

Table 5.1: Thematic analysis of learner responses to interview questions

Theme 1: Learners engage in various subjects and activities using AR, which enrich their learning experiences in unique ways. (Speaks to RQ1: What do learners learn with Augmented Reality resources?) **Math and shapes:** Students used AR apps to learn shapes and numbers, enhancing their understanding through interactive 3D models. Learner 4: "The AR app made the letters and numbers come alive. I could see the shapes pop out of the screen, and it was like magic." Learner 5: "I saw the animals and shapes move on the tablet. It made learning more fun than just looking at the book."

National symbols and flags:
Learners explored national symbols, such as the Mauritian flag, using AR to view detailed and interactive representations, which made the learning experience more immersive and visually appealing.

> Learner 2: "We used the tablet to colour the flag, and it was different from just using a book."
> Learner 4: "When the flag appeared on the tablet, I felt like I was holding the real flag."

Alphabet and letters:
AR made letters pop out of books, making learning to read more engaging and interactive for learners.

> Learner 3: "We matched letters with pictures on the screen, and it was fun to see them connect."
> Learner 5: "The letters were moving and making sounds. It was so cool to learn that way."

Animals and sounds:
AR resources introduced animals in a dynamic and interactive way, allowing learners to connect sounds and movements with their learning.

> Learner 1: "When the lion roared on the tablet, I felt like it was in the room with me."
> Learner 4: "The animals moved, and I could see them come alive on the tablet. It was fun to watch."

Comparative experience with books:
The differences between traditional learning methods (e.g., books) and AR resources stood out to learners, who noted how the interactive and vibrant features of AR enriched their learning.

> Learner 1: "The AR app shows shapes and numbers in 3D, which is different from the book. The book has pictures, but the app makes them move."
> Learner 2: "The AR app is more fun because I can play with it. The book is okay, but it doesn't do anything."

Learner enjoyment and motivation:
The excitement and novelty of AR significantly motivated learners, making them more eager to participate in class activities.

> Learner 1: "Today, we learned about shapes and numbers using a cool AR app. It was really fun!"
> Learner 3: "The class was easy. I liked the AR app because it made the colours look really bright."

Theme 2: The operational use of AR in the classroom was facilitated by teachers, but learners often explored the resources independently after initial guidance. (Speaks to RQ2: How do learners learn with Augmented Reality resources?)

Self-directed learning:
High-performing learners demonstrated confidence in using AR tools independently after minimal instruction. These learners were able to engage with AR resources on their own, reflecting their adaptability and curiosity.

> Learner 4: "Once I learned how to use it, I didn't need help anymore. I could explore everything on my own."
> Learner 5: "I liked figuring things out by myself. It made me feel smart when I got it right."

Teacher assistance:
Lower-performing learners required additional support and guidance from teachers, highlighting the varied learning needs in the classroom. These learners relied on the teacher's presence to help them navigate the technology and resources.

> Learner 2: "The teacher helped me a bit ... waited because I didn't know what to do at first."
> Learner 3: "I felt scared to press the wrong button. The teacher stayed with me and showed me what to do."

Independent exploration:
After initial guidance, most learners enjoyed the freedom to explore AR resources independently. This hands-on approach fostered curiosity and creativity among learners.

> Learner 2: "At first, I needed help, but then I tried by myself and it worked. It was fun to discover things."
> Learner 5: "Exploring on my own was the best part. I could do it my way."

Varied learning paces:
The use of AR revealed differences in learners' pacing and adaptability to new tools. While some quickly adapted to AR, others required more time and reassurance to build confidence.

> Learner 1: "Some of my friends finished quickly, but I needed to check with the teacher before moving on."
> Learner 4: "We all learned at different speeds, but the teacher made sure everyone understood before starting."

Theme 3: Learners' engagement with AR was influenced by its interactive and immersive nature, which made learning more appealing and effective. (Speaks to RQ3: Why do learners learn the way they do with Augmented Reality resources?)

Enhanced engagement:
AR resources captivated learners with their interactive and dynamic features, making the learning process enjoyable and improving information retention.

> Learner 4: "I understood better when I could see and touch things on the tablet. It was more interesting than reading."
> Learner 5: "Learning with AR feels like playing a game. I remember more because it's fun."

Challenges with technology:
Although AR had clear benefits, some learners faced initial challenges with the technology but eventually adapted and appreciated its value.

> Learner 2: "The tablet was confusing at the beginning, but the teacher showed me, and it became fun."
> Learner 3: "At first, I pressed the wrong buttons, but then I got used to it. It's easy now."

Immersive experience:
The immersive quality of AR created a sense of wonder and excitement, motivating learners to engage more deeply with the content.

> Learner 2: "I loved how the letters and shapes came alive. It made me want to learn more."
> Learner 4: "The AR app made me feel like I was inside the story. It was so cool!"

Improved understanding:
The interactive and visual aspects of AR helped learners grasp complex concepts more easily, bridging gaps in traditional teaching methods.

Learner 2: "It was easier to learn with AR because I could see and hear everything."
Learner 5: "Seeing the shapes in 3D helped me understand better than the book."

Theme 4: The immersive experience of AR significantly impacted learners' understanding and retention of information. (Speaks to RQ4: Why do Augmented Reality resources influence (enhance or undermine) learning?)

Visual and interactive learning: AR's visual appeal and interactivity helped learners grasp complex concepts and maintain interest in subjects.

> Learner 1: "I loved using the AR app because it made learning fun. The 3D shapes and numbers were so cool!"
> Learner 4: "The letters came alive on the screen. It was like magic, and I could really see them better."

Positive learning environment: AR resources created a positive and stimulating learning environment, encouraging learners to participate and explore.

Learner 1: "I feel more confident learning with AR. It's fun and helps me understand better."
Learner 5: "I liked how the animals moved and made sounds. It made the lesson more exciting."

The results obtained from the interviews provided insight into the factors that influence the learning preferences of individuals when using AR resources. According to the learners' responses, the use of AR resources facilitated a more profound and enduring connection with the subject matter, thereby augmenting their overall educational encounter.

The interview analysis indicated that the influence of AR resources on learning outcomes could be attributed to their interactive and immersive nature. Specifically, learners were able to better comprehend and visualise abstract concepts, leading to improved learning outcomes. In general, the results of the interview yielded significant insights regarding the content, methodology, and impact of AR resources on learners' acquisition of knowledge. The results indicated that the use of AR resources has the potential to augment the educational experience of first grade learners in classrooms. This was achieved by creating a more captivating and participatory learning milieu that was able to nurture inventiveness, critical thinking, and information retention. The themes are further discussed in Chapter 6 where they are interpreted according to the theoretical frameworks of the study and used in conjunction with the results of the analysis of the other data sources to answer the research questions.

5.2.2 Art-based data

Art-based research is a type of research that involves the use of creative and artistic methods to explore a particular research question or topic. This type of research can involve a wide range of artistic practices, such as painting, drawing, sculpture, performance art, and more (Dunleavy et al., 2009). Art-based research can generate visual and sensory data that can be used to complement or supplement traditional research methods, providing a more holistic understanding of a particular topic or issue (Dunleavy et al., 2009).

According to Tsai, Lin, Hong & Tai (2018), the use of AR resources in art-based research is crucial, particularly in the context of art and culture. Some of the potential findings of art-based research could include offering new and unique perspectives on a particular topic or issue. Additionally, emotional and affective responses can be collected, as art has the power to evoke strong emotional and affective responses (Dunleavy et al., 2009).

The potential findings of art-based research will depend on the specific research question or topic being explored, as well as the artistic methods used to conduct the research (Priestley, 2021). The three activities that were used for data collection are described below, including observational data. Samples of artwork discussed are provided in Appendices D, E and F. The results are interpreted in Chapter 6 to answer the research questions.

5.2.2.1 Activity 1: Colouring Activities

The Colouring Activity was specifically designed to engage young learners, aged between five and six years old, with replicating drawings of birds as seen through AR tablets. This activity was conducted among 45 participants from three selected primary schools in Mauritius, with the goal of integrating AR technology into early childhood education to enhance both cognitive and motor development. Using AR, children interacted with animated or 3D models of birds displayed on tablets, gaining detailed visual insights into the birds' colours, shapes, and features. They were then tasked with recreating these visual representations on paper, using traditional materials such as crayons and colouring pencils.

The activity was aimed at developing fine motor skills by encouraging precise hand movements and attention to detail. As the young learners carefully matched the colours and shapes of the birds they observed on their AR tablets, they demonstrated improved hand–eye coordination and dexterity. This was evident in the observational data collected from the classrooms, where approximately 32 out of 45 children showed enhanced motor control when using crayons, as compared with their performance in previous activities that did not incorporate AR technology. The visual engagement provided by the AR models enabled the children to concentrate on details such as feather textures and beak shapes, which translated into more accurate representations on paper.

Moreover, the activity provided a multisensory learning experience by bridging digital visuals with hands-on artistic expression. AR allowed children to rotate, zoom, and explore the 3D models of the birds, offering them an interactive and immersive experience that is typically not achievable through traditional means. This multisensory approach facilitated deeper cognitive engagement, as children were able to observe the birds from multiple perspectives before committing their interpretations to paper. According to Anderson (2017), "AR's immersive nature can significantly improve information retention and cognitive skills by providing memorable, interactive learning experiences" (p. 76). In this case, AR technology helped the learners to not only observe the models closely, but also to translate these observations into tangible artwork, thereby enhancing their creative and cognitive abilities.

Out of the 45 participants, 28 children replicated the bird models with a high degree of accuracy in terms of shape and colour. However, nine learners struggled with colour matching and applied colours not present on the AR models, such as using purple or orange instead of the natural bird hues.

This suggests that, while AR enhances engagement, individual differences in colour recognition and visual memory can affect outcomes, as noted by Kimura (2012), who stated that engaging with colourful materials can “improve memory retention, but external factors such as prior knowledge and developmental stage can impact performance” (p. 244).

In addition to fine motor skill development, the Colouring Activity fostered creativity and visual-spatial reasoning. The AR models served as a scaffold for the children's creativity, allowing them to choose how closely they wished to replicate the birds or add their own artistic touches. For instance, five children chose to add unique features such as additional feathers or altered wing shapes, reflecting a higher level of creative thinking and imagination. Runco (2014) explains that "children who engage in creative activities develop better problem-solving skills and cognitive flexibility" (p. 102). The ability to experiment with colours and shapes, within the structure provided by the AR models, further promoted the learners' creative freedom and critical thinking.

Furthermore, the cognitive development of the learners was significantly enhanced through the use of AR in this activity. By observing 3D bird models and replicating them in a 2D format on paper, children practiced translating visual information from one medium to another, which strengthened their visual-spatial reasoning abilities. The immersive aspect of AR helped to hold their attention and allowed for a more engaging learning environment, as approximately 85% of the learners remained focused on the task throughout the 50-minute activity. According to Smith (2020), "AR creates an engaging environment that helps young learners stay focused and improves their attention span" (p. 34), an observation that aligns with the findings from this activity.

As mentioned, engagement and retention were positively affected. The use of AR significantly impacted the children’s overall engagement levels. According to Carvalho, Bidarra and Russo (2020), AR technologies have been shown to captivate learners' attention, increasing their motivation to participate in educational tasks. In this activity, the children exhibited heightened enthusiasm, particularly in the initial stages when they interacted with the AR birds (see Appendix E).

In conclusion, the Colouring Activity successfully combined AR technology with traditional artistic expression, resulting in a rich, multisensory learning experience. It not only fostered fine motor skills and attention to detail, but also promoted cognitive engagement, creativity, and visual-spatial reasoning. The integration of AR proved to be a valuable tool in enhancing young learners' ability to observe, interpret, and replicate visual information, making it a promising approach for future educational practices.

5.2.2.2 Activity 2: AR Flashcard Activity

The AR Flashcard Activity was designed to foster creativity and reinforce alphabet recognition skills among the young learners. The activity incorporated AR-enabled flashcards that displayed interactive and visually engaging alphabet letters, which participants could explore using AR tablets. By interacting with these flashcards, the children were exposed to vibrant, animated versions of each letter, giving them a multisensory experience. This activity not only aimed to enhance their letter recognition, but also encouraged the development of fine motor and handwriting skills, as the children were challenged to reproduce the letters creatively on A4 sheets.

In this activity, the learners were tasked with interpreting the animated AR letters and reproducing them using their own artistic expression. The AR flashcards allowed the children to observe each letter in 3D, which they could rotate and manipulate to understand its shape better. As noted by Anderson (2017), this interactivity made the learning of alphabet letters more engaging and effective for the children.

The AR Flashcard Activity had a significant impact on the children's handwriting and fine motor skills. Approximately 38 out of 45 participants demonstrated improved handwriting precision when attempting to replicate the letters they observed on the flashcards. The task of drawing letters required controlled hand movements and attention to detail, both of which are key components of early childhood fine motor development. The multisensory nature of the activity—combining the digital AR visuals with physical drawing—helped to reinforce the children's hand–eye coordination and fine motor skills, as also supported by Ziviani and Watson-Will (1998), who stated that "structured, creative activities significantly contribute to the development of fine motor control, which is essential for later academic tasks such as writing" (p. 25).

Moreover, the alphabet recognition aspect of the activity was strengthened through AR's dynamic interaction. Children could see letters animate into different forms or be accompanied by visual cues (e.g., an 'A' turning into an apple), which made the alphabet more memorable and connected to real-world objects.

According to Smith (2020), "AR enhances memory retention by transforming abstract symbols into more meaningful and interactive representations, making it easier for children to recall and learn" (p. 34). This was evident, as 30 out of 45 learners were able to correctly identify and replicate the letters after the AR interaction, compared to previous classroom exercises where fewer than half of the learners demonstrated strong letter recognition.

The creative dimension of the AR Flashcard Activity allowed learners to go beyond simple replication of letters. By encouraging the children to creatively interpret the letters they saw, the activity stimulated their imagination and artistic expression. For instance, five learners chose to embellish the letters with additional drawings, such as adding flowers to the letter ‘A’ or turning the letter ‘S’ into a snake. Runco (2014) emphasises that "encouraging creativity in educational settings helps children develop cognitive flexibility and problem-solving skills" (p. 89). This creative freedom, combined with the structure of the task, helped to nurture the learners’ ability to think divergently and express themselves artistically.

In addition to fostering individual creativity, the AR Flashcard Activity encouraged collaboration among the participants. As the children worked in pairs or small groups to explore the AR flashcards, they often discussed how best to draw or decorate the letters, sharing colouring materials and ideas. This collaborative aspect was observed to be highly beneficial in promoting social skills such as cooperation, communication, and sharing. As Vygotsky (1978) highlights, "social interaction plays a fundamental role in the development of cognition, especially in the early years, as children learn from both peers and educators" (p. 86).

The effectiveness of AR in engaging learners was also evident during the activity. The immersive nature of AR, combined with the fun of creatively drawing letters, held the children’s attention for extended periods. Forty-two out of 45 children remained fully engaged throughout the 50-minute session, which indicates a higher level of focus compared to traditional letter-writing exercises. Smith (2020) posits that "AR not only improves learning outcomes but also helps maintain a child's attention span, making educational activities more interactive and enjoyable" (p. 37). This increased engagement likely contributed to the observed improvement in the children’s letter recognition and handwriting skills.

In conclusion, the AR Flashcard Activity successfully combined AR technology with traditional handwriting practice to create a multisensory learning environment that was both engaging and educational.

It effectively enhanced alphabet recognition, fostered creativity, and promoted fine motor skill development. By making learning interactive, immersive, and fun, AR proved to be an excellent tool for early childhood education, helping young learners connect with abstract concepts, such as letters, in more meaningful ways.

5.2.2.3 Activity 3: Create Your Own Flag Activity

Devised for approximately 50 minutes in the three schools, the Create Your Own Flag activity was designed to introduce young learners to Mauritian Independence through a practical and engaging colouring exercise. Out of 45 participants, 19 were given outlines of the Mauritian flag and instructed on the symbolic meanings of its colours in relation to national identity and independence. Using various colouring materials – crayons and colouring pencils – the children carefully filled in the flag's colours according to the provided model. The children were observed while they worked with the AR tools and interacted with peers.

Research has shown that children who engage in creative activities develop better problem-solving skills and a higher level of cognitive flexibility (Runco, 2014). The use of AR in educational settings can further stimulate children's creativity by offering dynamic and interactive content that inspires imagination and innovation. In this case, the AR application transformed a simple flag colouring activity into a 3D animated scene, allowing children to see their artwork come to life and encouraging them to experiment with different colours and designs.

Out of the 19 children, 10 learners openly demonstrated their ability to recognise the four primary colours – red, blue, yellow and green; while two children included orange and purple, which do not appear on the Mauritian flag. The researcher's observation identified the learners' dexterity and ability to master the colouring process through their choice of colours. It is interesting to note that, despite the majority of the children having paid attention to the flag's colours, one child was unable to identify and remember the colours correctly; this learner demonstrated a potential difficulty in cognitive and retention skills as the child used only red and green as the two colours for the flag. Additionally, the child was unable to draw straight lines to differentiate between the colours as the other nine participants had done.

The researcher also noticed that two young learners had added the colour orange and one added purple, respectively, in their colouring process; another used shades of green and one used only red and green – highlighted these learners' inability to recognise and retain the colours. This may indicate that the children were not fully developed in their cognitive motor skills and retention abilities. Colour retention is a fundamental cognitive skill that aids in memory and learning, and children in the five-to-six age group are generally particularly adept at recognising and remembering colours, which is an essential aspect of their visual development.

It was also noticed that among those 10 children who correctly identified the flag's colours and coloured the flag on the colouring sheets provided, nine were unable to use the ruler and pencil to draw the four rectangles, whereby their colouring was 'messy' with white spaces; one child attempted to draw the rectangles, but was unable to draw straight lines. This can be aligned to the critique that the novelty effect of AR may diminish over time, potentially reducing its long-term effectiveness in maintaining high retention levels (Johnson, 2019).

The learner who added the colour 'orange' to their flag has demonstrated the skill and ability to use the ruler properly in ensuring that the rectangles were of the same size; however, they added a fifth rectangle to fit in the non-existent colour orange. The learner who included the purple colour also attempted to use the ruler, yet demonstrated the same line drawing skills as the first child. Finally, the other child who included orange in their flag also managed to use a ruler to create five rectangles. Two of the children demonstrated their inability to use rulers and hand-drew the lines. Both flags contain nine rectangles each with repeated colour patterns: red, blue, yellow and green (twice) to end with blue. Ten out of the 19 children were not able to use a ruler to draw their colouring rectangles, while five demonstrated the aptitude to use a ruler to draw the rectangular boxes as a replica of what they have memorised and understood from the visuals.

The study also noted that one child, despite having recognised the colours correctly, drew the pattern incorrectly without using a ruler, but clearly demarcated the colour sections. This learner coloured the flag horizontally, which does not represent the Mauritian flag. This scenario offers a valuable insight into the cognitive, creative, and motor skills of the learner. The child's ability to recognise and correctly use colours demonstrates strong colour retention and visual memory skills. The clear demarcation of the colour sections indicates a developed sense of organisation and attention to detail, both of which are essential cognitive skills. From a creative perspective, the child's horizontal colouring of the flag, although incorrect, reflects a willingness to experiment and think outside traditional representations. This creative deviation is indicative of a flexible and imaginative mindset, which is crucial for problem-solving and innovative thinking. It shows that the child is not merely copying what they see, but is interpreting and representing the information in their unique way.

Uneven shapes and lines may indicate underdeveloped fine motor skills. According to Luria (1973), fine motor skills are crucial for tasks that require precision, such as writing and drawing. Children who struggle with these tasks may have difficulty with hand–eye coordination and controlling small muscle movements. These challenges can manifest as irregular shapes or lines in drawings, as seen in this child's attempt. Encouraging activities that enhance fine motor control, such as playing with building blocks or engaging in arts and crafts, could help improve these skills (Ziviani & Watson-Will, 1998).

Additionally, a child's approach to the task might reveal specific behavioural attitudes. For instance, if the child shows frustration or a hurried approach, it could suggest a lack of patience or difficulty in managing frustration, both of which can impact task performance (Barkley, 1997). Conversely, if the child remains calm and indifferent to the unevenness, it might indicate a more relaxed attitude towards the task, possibly reflecting low self-monitoring or a lack of concern for precision (Schunk & Zimmerman, 2011). Behavioural observations during the task could provide deeper insights into these attitudes.

The motor skills of the child are also noteworthy. Although the pattern was drawn without a ruler, the demarcation of the colour sections implies fine motor control and hand–eye coordination. These motor skills are essential for various activities and tasks, including academic and daily living. However, this case also highlights areas for development. The incorrect patterning suggests that while the child can remember and apply colours, they may need more support in understanding and replicating specific patterns and structures. This could be addressed through targeted activities that combine creativity with more structured tasks, helping to bridge the gap between free-form creativity and accurate representation.

Cognitively, drawing the Mauritian flag requires visual-spatial reasoning and symbolic recognition. Piaget's theory of cognitive development suggests that children in the preoperational stage (typically aged two to seven) may struggle with tasks requiring the accurate replication of shapes and patterns due to still-developing spatial awareness (Piaget, 1952). The inaccuracies in a child's drawing could reflect these developmental stages, where the understanding of geometric concepts and proportionality is still emerging (see Appendix E). Moreover, the children's attempt to replicate the flag, despite inaccuracies, demonstrates an awareness of the symbol's basic structure, indicating the presence of foundational cognitive skills (Goswami, 2008).

A child's drawing reflects developmental progress across motor, cognitive, and behavioural domains. However, the unevenness in the drawing highlights areas where additional support may be beneficial, particularly in fine motor skill development and visual-spatial reasoning. Understanding these developmental stages is crucial for providing appropriate interventions and fostering further growth. In this case, it is essential to use AR in moderation and in conjunction with traditional learning methods to ensure the overall well-being and development of young children. The case study further illustrates how individual differences in these skills can be nurtured and developed through appropriate educational approaches.

Through this activity, various indicators of success can be observed, particularly in terms of behavioural observations, fine motor skills, attention span, and overall enthusiasm for learning. Additionally, the collaborative spirit, willingness to help, and the sharing of materials among the children further underscored the effectiveness of the activity in fostering positive social and developmental outcomes. The activity has clearly fostered a strong sense of collaboration among the children. When children work together on a creative project such as flag-making, they naturally engage in teamwork, which is critical for their social development. This positive collaborative spirit is evident when children assist each other with tasks, such as helping to draw straight lines by holding the ruler. This not only shows their ability to work together, but also reflects their understanding of mutual support and shared responsibility. Collaborative activities such as this help children develop essential social skills, including communication, empathy, and cooperation (Vygotsky, 1978).

The observed behaviour of children sharing colouring materials and assisting one another highlights their emerging prosocial behaviour. Sharing is a significant milestone in social development and reflects the child's ability to consider the needs of others. Helping behaviour, such as holding the ruler for a peer, demonstrates a sense of empathy and an understanding of cooperation (Eisenberg & Mussen, 1989). These actions are indicative of a supportive learning environment where children feel secure enough to offer and receive help.

Such behaviours are crucial for building a classroom culture where collective success is valued over individual achievement (see Appendix G).

The research study also observed that the act of drawing, particularly when it involves precision tasks such as outlining and colouring within specific shapes, is an excellent exercise for enhancing fine motor skills. Throughout the flag-making activity, the children's ability to manipulate tools such as pencils, rulers, and crayons was put to the test. Fine motor skills are critical for many academic tasks, including writing, and their improvement can be a direct result of engaging in structured, creative activities such as this. Children who previously struggled with tasks requiring fine motor precision can exhibit marked improvements, such as better control over their hand movements, more accurate use of colouring tools, and the ability to draw straighter lines. These skills are foundational for academic success, as they directly impact the child's ability to engage in more complex tasks such as writing and detailed artwork (Ziviani & Watson-Will, 1998).

The extended engagement observed during the flag-making activity also points to an increase in the children's attention span. Sustained attention is a critical cognitive skill that allows children to focus on tasks for longer periods, leading to better learning outcomes (Posner & Rothbart, 2007). The ability of the children to concentrate on the details of their flags, from drawing shapes to colouring them meticulously, suggests that the activity effectively captured their interest and attention. An increased attention span is not only beneficial for completing tasks more efficiently, but also for enabling children to engage deeply with the material, fostering a deeper understanding of the concepts being taught. This cognitive engagement is crucial for academic success, as it helps children retain information and apply it in different contexts.

The enthusiasm displayed by the children during the activity was a strong indicator of the activity's success. When children are excited about learning, they are more likely to participate actively and take pride in their work. This enthusiasm can be seen in their eagerness to complete the task, their willingness to collaborate, and their joy in the creative process. Such positive emotions towards learning are vital, as they foster a lifelong love for education and a willingness to engage with new challenges (Fredrickson, 2001). In this case, the children's enthusiasm for creating their own flags not only makes the activity enjoyable but also enhances their learning experience.

When children are engaged and motivated, they are more likely to retain what they have learned and apply it in future tasks. The study also demonstrated that incorporating AR into the Create Your Own Flag activity enhanced its effectiveness as a tool for observing and fostering key developmental skills among children.

5.2.2.4 Activity 4: Numbering Sequence Activity

The Numbering Sequence Activity was designed to reinforce basic numerical skills among young learners. In this activity, learners were tasked with writing numbers from 1 to 10 as numerals and words, such as writing ‘1’ alongside ‘one’, ‘2’ alongside ‘two’, and so on. The primary goal of the activity was to strengthen the learners' numerical literacy by building a foundational understanding of number sequences, while also integrating basic literacy skills. Through hands-on practice and guided instruction, this activity aimed to enhance the children's numerical fluency, confidence, and ability to connect numerical symbols with their corresponding verbal representations.

The AR technology used in this activity played a key role in making the process more engaging and interactive. Children interacted with AR-enabled number cards, which displayed 3D models of the numbers 1 to 10 together with corresponding visual cues, such as one apple for ‘1’ and two oranges for ‘2’. This immersive experience allowed learners to not only see the numbers, but also to understand their real-world associations. According to Anderson (2017), "AR enhances the learning experience by providing a multisensory approach that helps young learners connect abstract concepts to tangible, real-world representations" (p. 78). In this case, AR technology enabled children to visualise numbers in a more dynamic way, improving their understanding of numerical order and quantities.

Out of the 45 participants, it was observed that 35 children successfully wrote both the numerical and word representations of numbers 1 to 10 with a high level of accuracy. However, 10 learners struggled with writing the number words correctly, such as spelling errors in ‘three’ and ‘eight’. This highlights the developmental differences in literacy skills among the participants, particularly with longer and more complex number words. Nonetheless, the visual and auditory reinforcement provided by AR helped most learners in recalling the correct sequence of numbers. Smith (2020) explains that "AR aids memory retention by making learning experiences more interactive and memorable, particularly in young learners who benefit from multisensory input" (p. 36). In this context, the AR cards helped children retain both the numerical symbols and their corresponding words.

The integration of literacy and numerical learning in this activity was key to developing a more holistic understanding of numbers. As the children wrote both the symbols and words for each number, they practiced letter formation, spelling, and numerical recognition simultaneously. Approximately 30 participants demonstrated strong letter formation when writing the number words, indicating that the activity supported fine motor skills development in addition to reinforcing numerical skills. Ziviani and Watson-Will (1998) note that "structured writing activities that involve both numbers and words are essential in developing fine motor precision and handwriting skills in early learners" (p. 26).

In terms of numerical fluency, the activity significantly improved the children's ability to sequence numbers correctly and understand their corresponding quantities. By interacting with the AR numbers, children could visualise the relationship between each number and the objects they represented. For instance, 40 out of 45 learners were able to correctly associate the number ‘5’ with five objects displayed in the AR environment, showcasing an improved understanding of numerical value. This aligns with findings from Kimura (2012), who stated that "visual representations of numbers, when combined with tactile learning activities, enhance children's understanding of quantities and sequencing" (p. 248).

The confidence of the learners in their numerical abilities also increased throughout the session. The AR-enabled feedback provided real-time guidance, such as correcting errors or reinforcing correct answers, which boosted the learners' motivation and confidence in completing the task. This instant feedback loop, which is a key feature of AR, allowed learners to self-correct and develop a stronger sense of mastery over number sequences. Anderson (2017) highlights that "AR's ability to provide immediate visual and auditory feedback can be instrumental in increasing learners' confidence and reducing the fear of making mistakes" (p. 79).

Moreover, the collaborative nature of the activity helped foster social skills among the learners. Many children worked together, sharing ideas and helping each other with the spelling of number words or checking the correct number sequence. Vygotsky (1978) emphasises that "peer collaboration is crucial for cognitive development, as learners build knowledge through shared social interactions" (p. 85). This collaborative spirit was evident, as children shared their AR tablets and helped one another in completing the activity.

In conclusion, the Numbering Sequence Activity successfully integrated AR technology to create a highly engaging and educational experience for young learners. It not only reinforced basic numerical skills, but also supported the development of literacy, fine motor skills, and numerical fluency. The use of AR enhanced the learners' ability to understand number sequences in both symbolic and verbal forms, while also fostering greater confidence and collaboration among the participants. This activity demonstrated the potential of AR to enrich early childhood education by making learning more interactive and enjoyable.

5.2.2.5 Discussion

According to the analysis of the art-based research, learners were receptive to the use of AR tools in the classroom. Learners' use of vibrant colours and creative patterns in their AR-inspired artwork reflected their engagement with, and enjoyment of, these tools. Learners' ability to use the knowledge they gained from using AR tools to enhance their classroom experience was reflected in the quality of their final projects. Some learners, for instance, illustrated flora and fauna using digital superimpositions, showcasing how AR elements assisted their understanding of animals in a more engaging and dynamic fashion. Learners were also provided with an original and creative outlet through which to share their experiences using AR tools through the art-based research techniques. The learners' artwork allowed for a deeper understanding of their experiences and provided a visual representation of their mental and emotional states. The artwork aided the learners in seeing commonalities in their experiences using AR tools.

It was discovered that the results from the art-based research approach complemented those from other data sources, such as the interview and observational study. Learners' experiences with AR materials were better understood through the results from the art-based research, which also helped to validate results from other data analyses. Results revealed important information on first graders' use of AR tools in the classroom. Learners' levels of creativity and self-expression were boosted by this approach, and they were better able to use visuals to share their stories. Because results were used to augment other data collection strategies, a more well-rounded understanding of learners' interactions with AR tools emerged.

5.2.3 Observational data

Observational research is a method of collecting information in which participants' behaviours, interactions, and academic outcomes are observed and recorded (Allan, 2009).

To better understand how learners in first grade benefit from AR tools, careful observation was one of the data collecting techniques used. Additionally, the researcher took an active role in monitoring how learners used AR tools in the classroom as part of this observational study approach. The learners' actions, relationships, and academic progress were all recorded by the researcher. The teacher's facilitation of the learning process and their use of AR tools were also observed and recorded.

The observation schedule is provided in Appendix B. Analysis of observations are given in Table 5.2.

Table 5.2: Analysis of observations

Observation schedule **Observing learners using Augmented Reality resources** **Researcher/Observed by:** Shoueib Bunnoo **Date of Observation: 15 March 2023** **Activity Observed:** Use of AR resources in learning **Location:** Classroom (3 Schools) [3 observations combined?] **Handling of tablets** ***Observations*** **Description:** Learners demonstrated the ability to handle and manipulate tablets with both hands, utilising touch gestures such as swiping, pinching, and tapping to interact with AR content. **Remarks:** Most learners could independently launch and navigate the AR application, though a few required initial assistance. ***Analysis*** **VARK Model:** The use of tablets and touch gestures caters primarily to kinaesthetic learners who benefit from hands-on interaction. The tactile engagement allows these learners to explore and learn through direct manipulation of the AR content (Fleming & Mills, 1992). **Situated-Cognition Model:** Handling tablets situates learners in a technology-enhanced learning environment, allowing them to develop digital literacy skills within a meaningful

context. This real-world application of skills reinforces learning through practice in a relevant setting (Brown, Collins & Duguid, 1989).

Activity Theory: The tablet serves as a mediating artefact in the activity system, facilitating the interaction between learners and the AR content. The teacher's role as a guide helps learners overcome initial challenges, integrating technical skills into their learning activities (Engeström, 1987).

Seating posture and movement

Observation

Description: Learners were seated at individual desks, often leaning forward to engage closely with the AR content. They moved around the classroom to collaborate with peers and teachers.

Remarks: Engagement levels were high, with minimal distractions observed, though prolonged use could cause discomfort.

Analysis

VARK Model: Visual learners benefit from the AR content, which provides rich visual stimuli. The seating posture indicates high engagement, as learners physically position themselves to better view and interact with the content (Fleming & Mills, 1992).

Situated-Cognition Model: The physical movement and seating arrangements reflect the situational dynamics of the classroom. Learners' engagement and physical responses to the AR content highlight the embodied nature of situated learning (Wilson, 2002).

Activity Theory: The classroom setup, including seating and movement, constitutes the physical environment in the activity system. This environment supports interaction among learners, tools (AR resources), and the learning objectives, enhancing collaborative and individual learning experiences (Engeström, 1987).

Interaction with AR resources

Observation

Description: The use of AR involved physical books and markers to trigger digital content, allowing learners to explore 3D models, animations, and interactive games.

Remarks: Learners displayed excitement and motivation, evident through their enthusiastic reactions.

Analysis

VARK Model: AR integrates multiple learning styles by combining visual (digital models), auditory (associated sounds), read/write (text overlays), and kinaesthetic (interactive gestures) tools, providing a multimodal learning experience (Fleming & Mills, 1992).

Situated-Cognition Model: The interaction with physical books and AR content situates learning in a context that blends traditional and digital mediums. This approach helps learners make connections between physical objects and digital information, grounding abstract concepts in tangible experiences (Brown, Collins & Duguid, 1989).

Activity Theory: The interaction with AR resources is mediated by physical markers and digital devices, forming a complex activity system. The AR technology acts as a bridge between the physical and digital worlds, enhancing the learning process through multimodal engagement (Engeström, 1987).

Application of learned concepts

Observation

Description: AR facilitated learning in counting, pronunciation, reading, and writing by overlaying digital content onto physical materials.

Remarks: Learners showed improved engagement and comprehension, with AR making abstract concepts more accessible and enjoyable.

Analysis

VARK Model: AR supports various learning preferences: visual (digital overlays), auditory (pronunciation guides), read/write (text displays), and kinaesthetic (interactive tasks). This multimodal approach helps cater to diverse learner needs (Fleming & Mills, 1992).

Situated-Cognition Model: Learning is situated within meaningful contexts, such as using AR for counting with digital objects or reading with text overlays. This situational approach enhances relevance and retention by connecting new knowledge to familiar activities (Brown, Collins & Duguid, 1989).

Activity Theory: The application of learned concepts through AR integrates tools (tablets, AR applications) and objectives (counting, reading) within the activity system. The dynamic interaction among these elements supports a comprehensive learning experience (Engeström, 1987).

Emotional and social engagement

Observation

Description: Learners expressed positive emotions such as happiness and eagerness, and engaged in collaborative activities with peers, providing and receiving assistance.

Remarks: The social interaction facilitated by AR activities contributed to a supportive and dynamic learning environment.

Analysis

VARK Model: The engaging and interactive nature of AR caters to various learning preferences, fostering positive emotional responses and social interaction. Visual and kinaesthetic elements, in particular, enhance enjoyment and engagement (Fleming & Mills, 1992).

Situated-Cognition Model: Emotional and social engagement is enhanced by situating learning within interactive and collaborative contexts. AR activities create opportunities for learners to share experiences and learn from each other in a meaningful setting (Lave & Wenger, 1991).

Activity Theory: Emotional and social dynamics are integral to the activity system, where collaboration and peer support play key roles. The AR environment encourages social interaction, promoting a sense of community and shared learning (Engeström, 1987).

Communication and collaboration

Observation

Description: AR activities encouraged peer feedback, discussion, and collective problem-solving, with learners actively helping and learning from each other.

Remarks: There was noticeable synergy among learners, enhancing both individual and group learning experiences.

Analysis

VARK Model: Collaborative AR activities appeal to auditory learners through discussion, read/write learners through feedback, and kinaesthetic learners through shared manipulation of AR content. This diverse engagement fosters deeper learning (Fleming & Mills, 1992).

Situated-Cognition Model: Communication and collaboration are situated within the AR-enhanced learning context, where learners engage in meaningful interactions. These social processes support the co-construction of knowledge (Lave & Wenger, 1991).

Activity Theory: The collaborative nature of AR activities integrates social interaction into the activity system. Learners act as co-participants, mediating each other's learning through shared tasks and feedback, enhancing the collective learning experience (Engeström, 1987).

5.2.3.1 Learner engagement levels

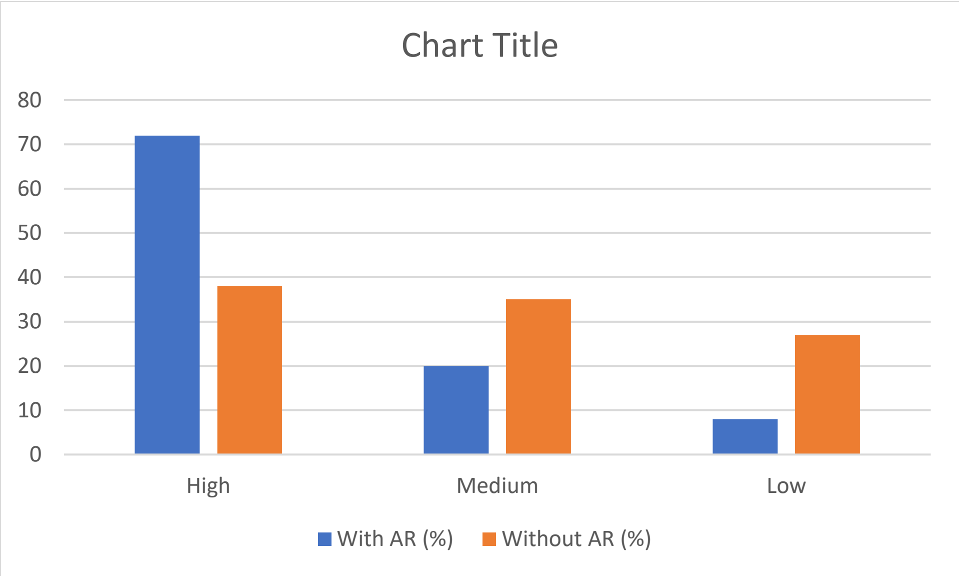

Figure 5.2: Learner engagement levels

Data table for Figure 5.2

Engagement Level	**With AR (%)**	**Without AR (%)**
High	72	38
Medium	20	35
Low	8	27

Interpretation:

High Engagement: 72% of learners showed high engagement when using AR resources, compared to only 38% without AR. This indicates that AR significantly increases learner engagement.

Medium Engagement: There is a slight drop in medium engagement with AR (20%) compared to without AR (35%). This suggests that AR may either elevate learners to a high engagement level or leave some less engaged.

Low Engagement: Only 8% of learners exhibited low engagement with AR, while 27% exhibited low engagement without AR. This demonstrates AR's potential to reduce disengagement.

5.2.3.2 Learner interaction with AR resources

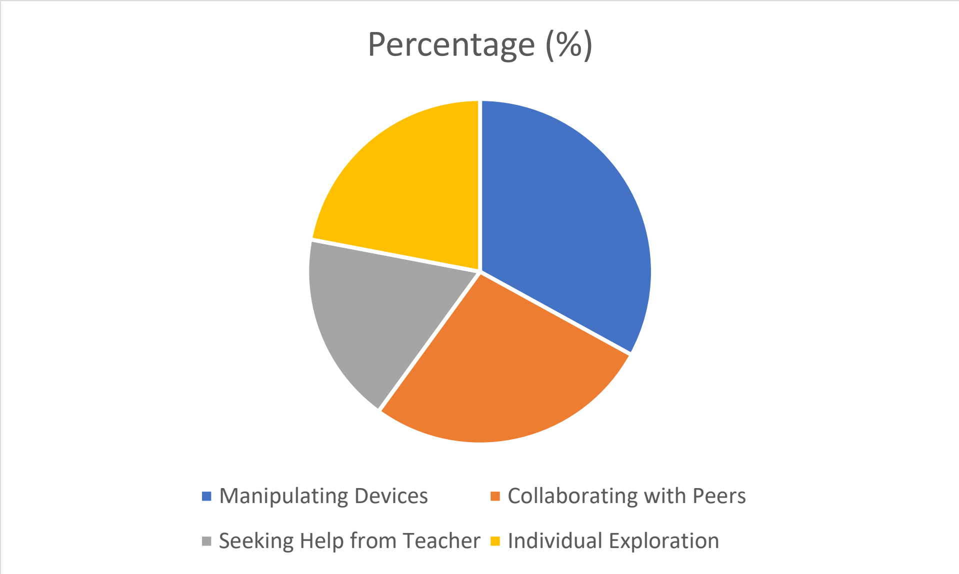

Figure 5.3: Learner interaction with AR resources

Data table for Figure 5.3

Interaction type	**Percentage (%)**
Manipulating devices	33
Collaborating with peers	27
Seeking help from teacher	18
Individual exploration	22

Interpretation

Manipulating devices: A significant portion (33%) of interactions involved learners directly manipulating AR devices, indicating hands-on engagement.

Collaborating with peers: 27% of interactions were collaborative, highlighting AR's role in fostering teamwork and social learning.

Seeking help from teacher: 18% of interactions involved teacher assistance, suggesting some reliance on guidance.

Individual exploration: 22% engaged in individual exploration, showing that AR encourages independent learning.

5.2.3.3 Frequency of behaviours observed

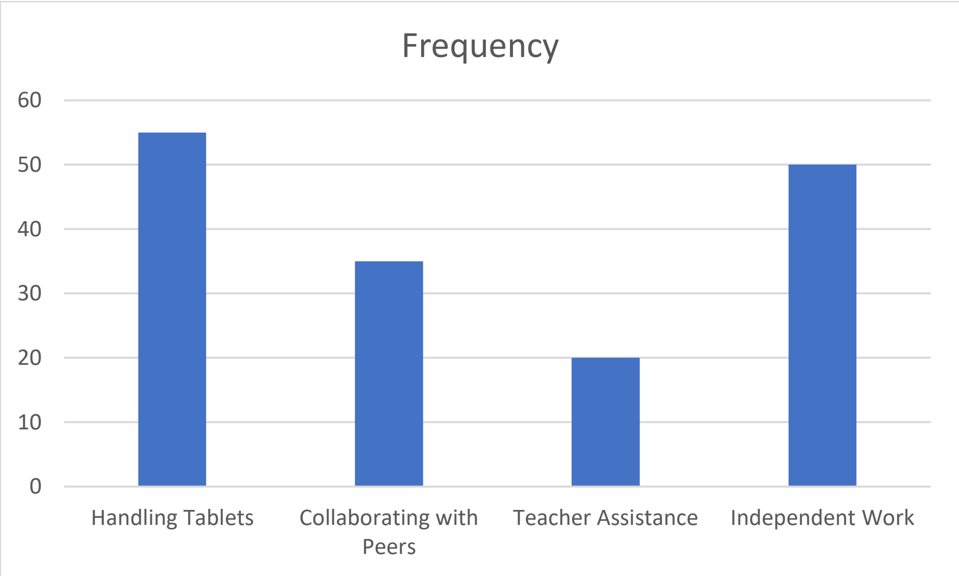

Figure 5.4: Frequency of behaviours observed

Data table for Figure 5.4

Behaviour	**Frequency**
Handling tablets	55
Collaborating with peers	35
Teacher assistance	20
Independent work	50

Interpretation

Handling tablets: The handling of tablets was the most frequent behaviour observed (55 instances), emphasising the importance of device interaction in AR learning.

Collaborating with peers: Peer collaboration was observed 35 times, indicating a strong social component.

Teacher assistance: Teacher assistance was less frequent (20 instances), suggesting learners often worked independently or with peers.

Independent work: Independent work was also common (50 instances), reinforcing AR's role in promoting self-directed learning.

5.2.3.4 Learner posture and movement

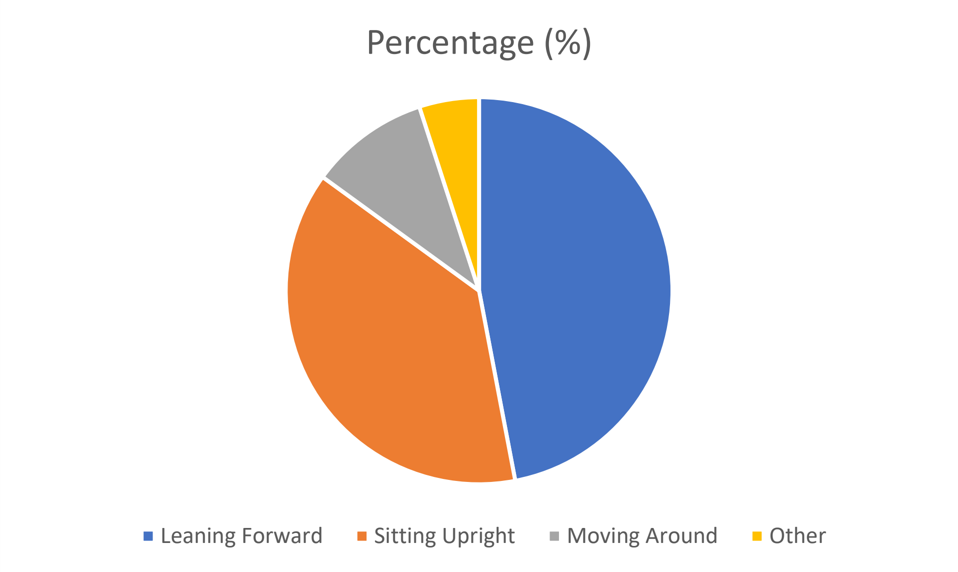

Figure 3.5: Learner posture and movement

Data table for Figure 3.5

Posture	**Percentage (%)**
Leaning forward	47
Sitting upright	38
Moving around	10
Other	5

Interpretation

Leaning forward: 47% of learners leaned forward, indicating high engagement and focus.

Sitting upright: 38% maintained an upright posture, showing attentiveness.

Moving around: 10% moved around, possibly reflecting kinaesthetic learning styles or restlessness.

Other: 5% exhibited other postures, suggesting a variety of engagement levels and learning styles.

5.2.3.5 Learner feedback on AR experience

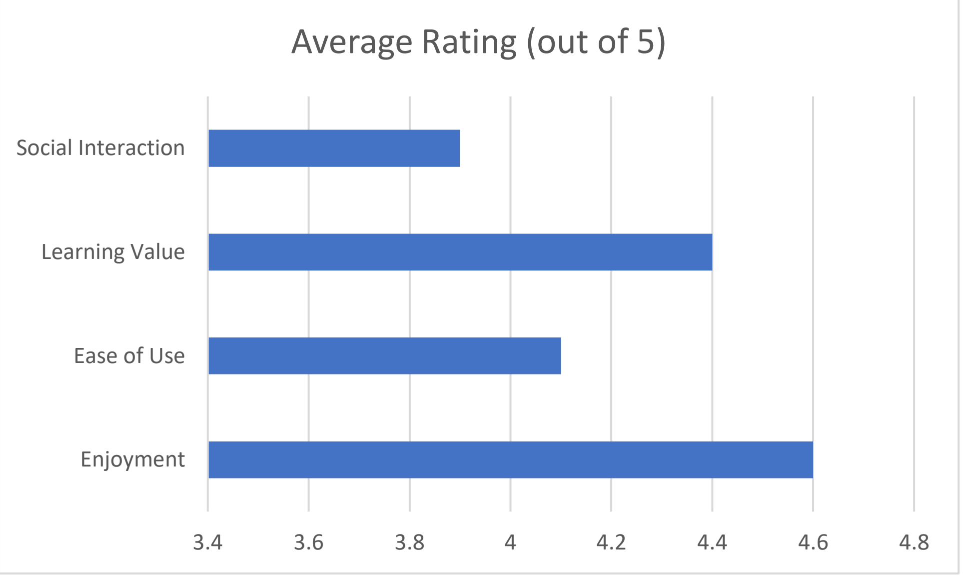

Figure 5.6: Learner feedback on AR experiences

Data table for Figure 5.6

Feedback category	**Average rating (out of 5)**
Enjoyment	4.6
Ease of use	4.1
Learning value	4.4
Social interaction	3.9

Interpretation

Enjoyment: High enjoyment (4.6) suggests AR is fun and engaging for learners.

Ease of use: A rating of 4.1 indicates that, while generally user-friendly, some learners may have faced usability challenges.

Learning value: A high rating (4.4) demonstrates that learners perceive significant educational benefits from AR.

Social interaction: A lower rating (3.9) suggests AR resources are less focused on social aspects but still reasonably effective in facilitating interaction.

5.2.3.6 Discussion

The results of the observational study showed that learners were highly engaged and motivated while making use of AR tools in the classroom. Learners showed impressive levels of involvement in the learning process when they were given the opportunity to use these tools. Additionally, learners' ability to understand and remember what they learned was significantly improved. The learners also commented on how well the instructor had facilitated the learning process. The teacher encouraged learner participation and collaboration by providing clear directions and advice on the use of AR materials. The teacher incorporated AR tools into their teaching in a way that complemented the established curriculum and learning goals.

The observations also exposed certain limitations on how AR can be used in the classroom. Some learners had trouble accessing the AR materials, which negatively impacted their learning experience. Thus, teachers may encounter problems if they do not have the time or money to devote to the additional planning and preparation that using AR resources requires. The observations revealed important insights into how learners in Grade 1 use and learn with AR tools in the classroom. Learners' motivation and engagement, as well as the instructor's ability to guide the learning experience effectively, could be measured due to this observational approach.

Learners were seen utilising tablets with remarkable ease, navigating AR information and interacting with digital objects by means of touch movements including swiping, pinching, and touching. The fact that most learners could open and close the AR app without assistance demonstrates that they are comfortable with the most fundamental aspects of tablet use. Some learners had difficulty understanding the touch motions or meeting the technological requirements of the AR programme, but these issues were resolved via modelling and practise.

When it came to where and how learners sat during class, the vast majority used seats or desks, while some learners even stood up to use the tablets. Learners looked engaged in the AR activities; several leaned forward or stooped over tablets to get a better look at the information. Despite this, the majority of learners appeared to be paying close attention throughout class. However, learners may have experienced discomfort from having to sit or lean forward for extended periods of time during lengthier lectures.

Several benefits were seen when combining AR with a traditional book and marker. Because these were tools that learners were already acquainted with, their use helped to ground abstract digital material. Secondly, these tools allowed for reading and language development to be specifically linked to the AR experience. As digital information can be modified and updated to suit the requirements of individual learners and classroom settings, it made for a more dynamic and interesting educational experience.

Digital animal models that could be controlled using touch movements, AR animations such as butterflies, birds and rainbows, as well as interactive learning games and digital overlays of text and pictures, were among the virtual artefacts that appeared on the screen during the usage of AR technology. The learners were prompted to engage with the AR resources, and the 'wow' expressions on their faces suggested enthusiasm and engagement, as noted by other authors (e.g., Ramdani et al., 2020).

The last activity involved the actual use of AR tools for counting, pronunciation, reading, and writing while this content was being taught. By using these virtual artefacts in a predetermined sequence, learners were, for instance, assisted in acquiring and practising their counting skills. Displaying virtual artefacts such as letters, words, or phonetic sounds on the screen assisted with pronunciation. The ability of AR to show virtual overlays of text and graphics on the actual book assists in improving reading comprehension. Learners could also use a stylus or digital pen on a tablet or mobile device with virtual overlays of letters or words shown on the screen to practise their handwriting. Most learners found AR technology very engaging and interactive, noting that it provided them with an enjoyable and innovative learning experience that helped them stay focused on the work at hand.

The results gained from the different methods of data collection used in this research were supplemented by the results produced from the observational inquiry, which provided a more thorough and complex understanding of learners' development employing AR resources. This triangulation is used in Chapter 6 to address the research questions.

5.2.4 Teachers' journal data analysis

This study looked at how teachers in the first grade utilise AR tools to help learners learn. One of the data sources used included and analysed data from teachers' journals to explore how they used AR in the classroom and how they monitored their learners' progress.

The instructor’s educational strategy was to have teachers keep a diary in which they recorded their thoughts, feelings, and experiences with AR tools in the classroom, detailing how AR tools affected their teaching methods, how their learners responded to AR materials, and what difficulties the teachers had when incorporating AR into the classroom. These journal entries are provided in Appendix C. Summaries of teacher journal entries are given in Table 5.3 below. The journal entry themes are given in Table 5.4 with supporting quotes. The results or overall implications of the analysis are discussed in the final section.

Table 5.3: Researcher’s summaries of teacher journal entries

Teacher 1
• Utilised AR to teach about volcanoes, enhancing learners' understanding through 3D visualisations. • Identified strengths and weaknesses of AR, including its effectiveness in diversifying teaching methods, but also the need for investment in digital gadgets, and technical issues. • Observed positive impacts on learners' educational experience, such as increased curiosity and faster learning. • Plans to continue exploring AR integration into lessons.
Teacher 2
• Impressed by the level of enthusiasm and engagement among learners when using AR. • Recognised AR as a tool for addressing diverse learning needs and providing interactive learning experiences. • Expresses eagerness to explore more opportunities for integrating AR into teaching practice.
Teacher 3
• Introduced Quiver as a tool for bringing colouring sheets to life, identifying strengths and weaknesses through SWOT analysis. • Highlighted the application's positive impact on learner education, particularly in fostering creativity and understanding. • Recognised the challenges of integrating technology, but emphasised the potential of Quiver to revolutionise teaching and learning.
Teacher 4
• Incorporated AR flashcards into a lesson on fruits, resulting in increased engagement and interaction among learners.

- Noted the strengths of AR in creating involvement and facilitating observation of learners' development.
- Plans to explore further integration of AR tools into future lessons.

Teacher 5

- Utilised Quiver 3D colouring application to teach about aquatic animals, emphasising its effectiveness in enhancing fine motor skills and creativity.
- Acknowledged challenges faced by some learners in understanding the application, but ultimately found it to be an effective teaching tool.
- Intends to use the application again in future lessons and explore additional ways to incorporate technology.

Table 5.4: Themes and supporting quotes from teacher journal entries

Theme 1: Enhanced Learner Engagement

Category: Motivation and sustained attention

- **Unit of Meaning:** Teachers frequently noted increased enthusiasm and focus among learners when using AR tools.
- **Supporting Quotes:**
    - *"Learners were so excited during the AR lessons that they couldn't stop talking about the activities even after class." **(TJ1)***
    - *"Even learners who usually appeared disinterested were fully attentive when the AR components were introduced." **(TJ2)***
    - *"The interactive nature of AR kept learners engaged for longer periods, which is something I rarely observe during traditional lessons." **(TJ2)***
    - "*Learners actively participated in lessons and appeared more focused, especially those who previously struggled with engagement in traditional settings." **(TJ4)***

Theme 2: Facilitating Interactive Learning

Category: Multisensory and hands-on experiences

- **Unit of Meaning:** AR encouraged learners to engage with content actively, promoting deeper comprehension through interaction.
- **Supporting Quotes:**
    - *"The combination of visuals, sound, and touch created an immersive experience that helped learners grasp challenging topics." **(TJ1)***

- *"The AR flashcards turned something as simple as learning letters into an adventure, where learners could manipulate objects and connect them to real-world meanings."* ***(TJ4)***
- *"Learners felt like they were part of the lesson, not just observing it, which made a significant difference in their understanding."* ***(TJ4)***
- "*The ability to visualise 3D models and interact with virtual environments helped my learners understand complex ideas in ways I could not achieve through standard teaching methods."* ***(TJ1)***
- *"Quiver's interactive colouring activities brought lessons to life, making learning a more hands-on and enjoyable experience for the entire class."* ***(TJ5)***

Theme 3: Improved Conceptual Understanding

Category: Grasping abstract and complex topics

- **Unit of Meaning:** AR made abstract concepts tangible, leading to better retention and application of knowledge.
- **Supporting Quotes:**
  - *"I used AR to explain the alphabets, and the learners could see animals appearing—it made the concept much more real for them."* ***(TJ1)***
  - *"The animations transformed my lessons, making an abstract idea something they could visualise and remember."* ***(TJ3)***
  - *"Learners who struggled with geometric concepts showed clear improvement after manipulating AR models that demonstrated real-world applications of shapes."* ***(TJ5)***

Theme 4: Addressing Diverse Learning Needs

Category: Inclusivity and accessibility

- **Unit of Meaning:** AR supported differentiated learning by accommodating various learning styles and needs.
- **Supporting Quotes:**
  - *"AR gave struggling readers a way to connect text to images, helping them build confidence and comprehension."* ***(TJ2)***
  - *"Learners with ADHD would focus better during AR activities, possibly because of the engaging and structured nature of the tasks."* ***(TJ5)***
  - *"I saw quieter learners take the lead during group AR activities, showcasing talents that often go unnoticed in traditional setups."* ***(TJ4)***

- *"Learners with visual or kinaesthetic learning preferences thrived with AR tools, as they could see and manipulate the content at their own pace." **(TJ2)***
- *"Struggling learners gained confidence, as AR allowed them to explore and repeat concepts without pressure, bridging gaps in their understanding." **(TJ4)***

Theme 5: Challenges in AR Integration

Category: Technical, logistical, and time-related constraints

- **Unit of Meaning:** Teachers encountered practical challenges that sometimes hindered the seamless use of AR tools.
- **Supporting Quotes:**
  - *"The app froze a few times during the lesson, which interrupted the flow and frustrated the learners." **(TJ1)***
  - *"It took me almost 10 – 15 minutes to set up the AR materials, leaving me with less time for other important activities." **(TJ2)***
  - *"Not all devices were charged or updated, which meant some learners had to share, reducing their individual engagement." **(TJ4)***
  - *"Setting up AR activities took time, leaving less room for other parts of the curriculum." **(TJ3)***

Theme 6: Positive Impact on Pedagogical Practices

Category: Innovation and professional growth

- **Unit of Meaning:** Teachers reflected on how AR tools reshaped their teaching methods and inspired innovation.
- **Supporting Quotes:**
  - *"Using AR made me rethink how I teach and inspired me to try more learner-centred approaches." **(TJ2)***
  - *"I learned to integrate technology into my lessons more effectively, and it's something I plan to do regularly." **(TJ5)***
  - *"Reflecting on these lessons through my journal helped me identify what worked and what didn't, making me a better educator." **(TJ3)***

Theme 7: Social and Emotional Impact on Learners

Category: Collaboration, empathy, and emotional engagement

- **Unit of Meaning:** AR activities encouraged peer collaboration and fostered emotional connections to learning.
- **Supporting Quotes:**
  - *"I saw learners helping one another navigate the AR app, which created a sense of teamwork and camaraderie (friendship)."* ***(TJ4)***
  - *"The AR storytelling activity led to discussions about empathy, as learners analysed characters' emotions and actions."* ***(TJ3)***
  - *"Some learners expressed joy and pride after completing AR tasks, boosting their confidence and emotional well-being."* ***(TJ5)***

Theme 8: Creativity and Innovation in Learners

Category: Encouraging imagination and problem-solving

- **Unit of Meaning:** AR tools promoted creative thinking and innovative solutions among learners.
- **Supporting Quotes:**
  - *"When given AR tools, learners started coming up with their own ideas for animations and models, showing real creativity."* ***(TJ2)***
  - *"One group designed a virtual diorama for a history project, combining what they learned with their artistic skills."* ***(TJ5)***
  - *"The open-ended nature of AR tasks allowed learners to explore their imaginations and present unique perspectives."* ***(TJ4)***

Theme 9: Building Technological Fluency

Category: Developing digital literacy and confidence

- **Unit of Meaning**: AR activities helped learners and teachers become more comfortable with technology.
- **Supporting Quotes**:
  - *"Learners who were initially hesitant to use tablets gained confidence as they explored AR features independently."* ***(TJ1)***
  - *"I saw significant improvement in how learners handled devices, from launching apps to navigating complex menus."* ***(TJ5)***
  - *"Teaching with AR has also boosted my confidence in integrating technology into my lessons effectively."* ***(TJ2)***
  - *"We don't need to teach these kids how to use tablets, smartphones and technology!"* ***(TJ5)***

The teachers' journals collectively demonstrate the potential of AR as an effective tool for enhancing learner engagement, understanding, and creativity in the classroom. Despite challenges such as technical issues posing a learning curve for some learners, the overall sentiment is positive, with a desire to further explore and integrate these technologies into teaching practice. This suggests a growing recognition among the teachers of the benefits of incorporating AR and interactive applications into the learning environment, paving the way for more innovative and engaging educational experiences.

The teachers' positive attitudes towards incorporating AR tools into their classrooms were shown in the analysis of the data recorded in their reflective journals. Teachers stated that using AR materials increased learner interest and motivation, and were useful for both teaching and reviewing previously learned material. Teachers reported increased understanding of their learners' needs and a more engaging, individualised instructional approach after incorporating AR materials. Some of the challenges that teachers faced while trying to use AR tools in the classroom were also identified through an examination of their reflective writings. Some teachers complained that they were unable to teach effectively due to technical difficulties with the AR materials. In addition, some teachers noted that using AR materials required much time to set up, which distracted them from their normal teaching methods.

The journal analysis allowed teachers' experiences with AR tools to be examined in depth and from a personal perspective. This included the benefits and challenges of using AR materials in their educational settings. Significant insights into the use of AR tools in the classroom and their effect on learner learning were uncovered through a review of teacher journals. The selected methodology enabled a subjective and introspective perspective on the use of AR materials in first grade classes, which corroborated the results of the analysis of data from observations and questionnaires. The journal themes were triangulated with the other results in Chapter 6 to answer the research questions.

5.3 Outcomes of the Activity System analysis

Activity Theory was used to interrogate the pedagogical approach at Lanalhue Lake Primary School. Specifically, the Education for Sustainability (EfS) web page was viewed as a tool to facilitate the achievement of the programme's intended EfS objectives.

The anticipated outcome of the Lanalhue Lake interactive learning network, as shown in Figure 5.4, was to encourage awareness of, and engagement with, current sustainability challenges. Individuals (the subjects) participate in an educational opportunity (the object) via their contact with the EfS webpage (the instrument or mediating artefact), which is reliant on, and impacted by, the specifics of the regional environment and an analysis of the school's philosophical underpinnings; as well as comprehending its use by local society members.

In the current study, the activity network is represented in Figure 5.4. In practice, this meant that the data collection tools and the intervention were designed to accommodate each of the elements of a second-generation activity network. The various key Activity Theory concepts that directed the observations and explanations included: item orientedness; idealisation procedures; hierarchical framework and continued advancement of activity structures; multi-voicedness; advancement; expanding conversion; frictions, confusion, and contestations; surroundings of the activity diagram; motivating factors; interplay and sophistication of real-world situations; and infrastructures of interdependence.

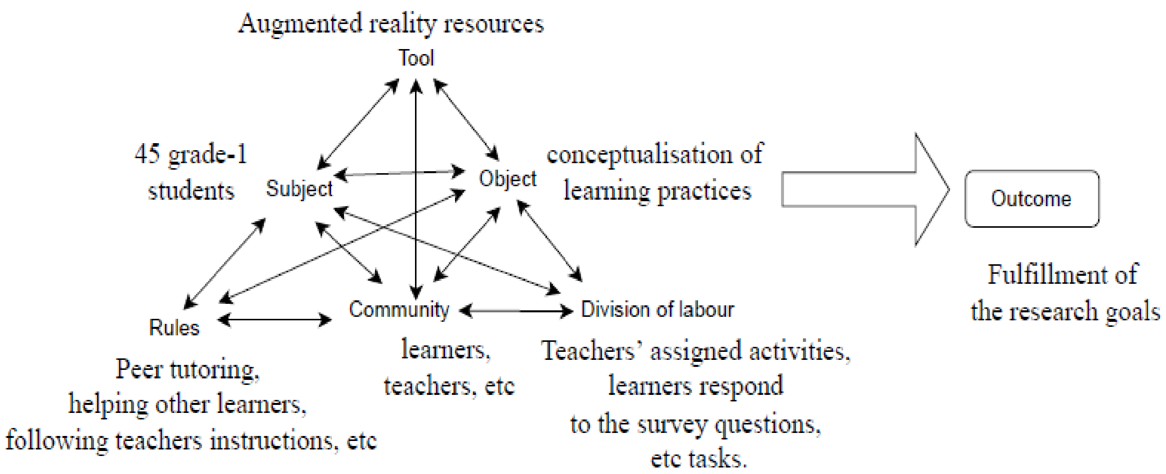

Figure 5.4: Activity Theory for the current research study

(Source: Self-created)

In this research analysis, the tool represented the AR resources; the subject was the participants (45 Grade 1 learners); the object was associated with the conceptualisation of learning practices using AR resources in Mauritian primary schools; the outcome was the fulfilment of the research goals; rules were concerned with peer tutoring, helping other learners, following teachers' instructions and abiding by classroom rules; the community was associated with the learners, MIE, teachers, etc.; and finally, the division of labour was related to teachers' assigned activities, learners responding to the survey questions, tasks, etc.

Data interpretations using this activity network are discussed in Chapter 6 to demonstrate the outcomes of the learning activities using Activity Theory in practice. This section of the analysis helps to describe how well this theory can be applied to the research purpose, and for the development of the conclusion. Additionally, the conclusion can demonstrate how well the theory satisfies the research results concerning the development of AR resources in the primary-level schools in Mauritius.

5.4 Conclusion

To conclude, Chapter 5 provided the presentation and results of the analysis of data from the four data sources used to inform this research, as well as the outcomes of the activity system analysis. In summary, the results suggest that Grade 1 classrooms where AR materials are used lead to improvements in learner performance and teacher pedagogical strategies. However, several difficulties were also acknowledged, including technological difficulties and constraints on planning time. The results discussed in this chapter are triangulated in Chapter 6 to provide the findings of the study as a whole, and these findings are used to address the research questions. Limitations and implications of the research are discussed in Chapter 7, as well as their potential to direct the future implementation and improvement of AR resources in educational settings, leading to improved learner outcomes.

CHAPTER 6: CONCLUDING DISCUSSIONS

6.1 Introduction

Augmented Reality (AR) is revolutionising how learners engage with content, facilitating immersive, multimodal, and interactive experiences that transcend traditional classroom boundaries. AR's capacity to layer digital information over real-world environments offers new opportunities for contextual learning and multimodal engagement. This study explored the ways in which AR enhances learning experiences by investigating its impact through three core theoretical frameworks: Activity Theory, Situated Cognition and the VARK model. These frameworks allowed for an in-depth understanding of how AR mediates learning, fosters contextual relevance, and caters to diverse learning styles.

Grounded in an interpretivist research paradigm, this study employed qualitative methods—focus group interviews, art-based research, observation, and reflective journaling—to generate rich, contextualised data. The focus was on understanding how learners make meaning of their AR-enhanced experiences and how these experiences impact their learning processes.

This chapter presents a critical reflection on the findings, discussing the contributions of AR to learners' engagement**,** knowledge construction**,** and social interaction within a learning environment, alongside the ethical and accessibility considerations that accompany AR integration in education.

6.2 Research question 1: What do learners learn with Augmented Reality resources?

The first research question clearly necessitates a descriptive presentation of findings after analysing the qualitative data obtained from interviews, observations, art-based analysis, and analysis of teachers' reflective journals. These findings focus on the learners' learning ability, as well as the effectiveness of the teachers in maintaining the class curriculum, with the use of the technological gadgets that enable AR technology. Grade 1 learners were assessed to identify the research outcomes that would measure the efficiency of learning whenever the traditional method of learning was replaced with AR resources. Their learning ability was shown to improve with the use of AR gadgets and the applications downloaded via their tablets. Cognition is an important indicator of expertise, and was measured during discussions and problem-solving. Grade 1 learners who participated showed that their cognition improved with the use of AR.

The use of AR technology has the potential to radically alter the ways in which learners engage with course material and interact with the world around them. The use of AR resources in an educational setting can create an environment that is more engaging and exciting, which in turn can increase learner participation, persistence, and comprehension. The following sections discuss cognitive outcomes of the use of AR technologies and resources.

6.2.1 Spatial awareness and visualisation

The use of AR tools has greatly assisted learners to improve their ability to understand space and visualise ideas. Interviews showed that learners gained a better grasp of 3D concepts when they interacted with AR resources such as virtual models of animals, shapes, and flags. When learners tilted and rotated their tablets to view these AR models, they physically engaged with the content, which helped them understand how different objects relate to each other. Additionally, art-based research revealed that learners turned their digital experiences into creative works, showing a clearer understanding of space in their art. Teachers also noted in their journal that learners who had trouble with abstract concepts made significant progress when using AR tools that made complex ideas easier to explore. By mixing digital experiences with hands-on methods, learners enjoyed a richer learning experience that allowed them to visualise and manipulate objects in a 3D world.

The infancy stage of a child's ability to grasp and sense spatial connections as well as mentally modifying objects or pictures in their thoughts is referred to as the child's perception of space and visualisation abilities, respectively (Alkouri, 2022). Children start to become curious about their surroundings and attempt to understand them throughout this initial phase of development. It is essential to promote development and keep developing skills throughout infancy. In this section, we will examine how AR may help the development of spatial awareness as well as visualisation knowledge. This can occur in the following ways:

● The ability to manipulate 3D Objects: Using AR, learners are able to engage using 3D models in virtual reality while in real-world situations. They have the opportunity to scale, spin, and shift things, allowing them to be seen from a variety of angles and viewpoints. Learners benefit from such hands-on training, as it helps them build a better knowledge of spatial connections and the manipulation of objects in space.

● Creating a simulation of real-world environments: AR is capable of superimposing virtual aspects upon real-world settings, thereby producing an AR experience. These augmented worlds can be explored and navigated by learners, allowing them to develop their perception of size, distance, and dimensions. Learners can acquire a spatial awareness by understanding how items fit into a specific area by digitally putting objects or buildings in their immediate surroundings and seeing how they appear in that context.

- Virtual diagrams and guidance: AR-based guidance systems offer real-time direction by superimposing technological data over the actual world. Learners can improve their sense of place and directional abilities by using AR diagrams to obtain a better understanding of instructions, lengths, and objects.

- Visualisation: An excellent method for a youngster to learn to visualise information is via AR. Learners are able to form mental images of the places they may encounter in the actual world. The notion of moonlight may serve as an illustration of this. By basing an illustration on the learner's recollections from infancy, a teacher may quickly and simply represent moonlight, providing learners with a better understanding.

- Digital modelling and designing: AR technology allows learners to develop digital models and designs, as well as visualise them. They are able to construct and control virtual objects or surroundings, evaluating their viability in terms of space, as well as their appearance and practicality. The iterative method improves creativity in design that helps develop abilities in geographical visualisation.

The use of AR technology helps learners improve their spatial awareness, increases their visualisation skills, and allows them to better comprehend and manage the actual and virtual surroundings. This can be accomplished by involving learners in events that are fun and realistic.

6.2.2 Complex concepts and processes

The integration of AR resources has proven effective in helping learners understand complex concepts and intricate processes by transforming abstract ideas into interactive visual experiences. AR applications allowed learners to explore detailed simulations, such as observing the photosynthesis components by virtually dissecting a plant’s internal structure. These dynamic representations offer a hands-on learning approach that would be difficult to achieve through traditional teaching methods alone. Art-based activities further enhanced this experience by enabling learners to animate their drawings, such as sketching a bird and using AR tools to bring it to life on their screens. This interactivity fostered a deeper emotional connection to the material, making learning both memorable and engaging.

Observations and teacher reflections highlighted how such immersive experiences not only clarified challenging concepts, but also motivated learners to actively participate and sustain their interest throughout the lessons. These findings suggest that AR has significant potential to enhance learners' comprehension and engagement when dealing with abstract and complex educational content.

AR resources can improve education by helping learners better understand abstract concepts and labour-intensive processes through the use of interactive visuals. Learners may benefit from using AR materials because it allows them to simulate complex processes more accurately and to effectively visualise concepts that are intangible. For example, learners used AR to examine the inner workings of a plant to discover more about the processes behind photosynthesis. Additionally, they were able to sketch on their computers and tablets with the help of apps that enabled them to make their artwork interactive. After a learner sketched an image of a bird, they were able to use gadgets to make it fly across the screen, for example, which helped them become much more invested and engaged in the lessons being taught. As a result, it is reasonable to conclude that AR technology can aid in enhancing learners' levels of participation.

6.2.3 Language learning

AR resources have emerged as innovative tools for enhancing language learning by offering immersive, interactive environments that promote vocabulary acquisition, pronunciation practice, and reading comprehension. Learners interacted with AR-enabled flashcards and storybooks where virtual characters and animated text helped illustrate word meanings and sentence structures. This multisensory approach allowed learners to associate words with vivid images and sounds, improving recall and engagement. Teachers observed that learners, particularly those who were hesitant with traditional reading methods, showed increased enthusiasm and confidence when using AR applications. Additionally, AR activities supported language development by encouraging collaborative learning, as learners often discussed and shared their AR experiences with peers. The ability to visually and audibly engage with language concepts contributed to a richer learning experience, making abstract linguistic elements more accessible and fostering improved communication skills.

Thus, AR technology has the potential to improve the acquisition of languages by offering learners an environment that is both engaging and immersive in which they may practise and improve their language abilities. Here are some ways AR can support language learning in this context:

- The use of vocabulary and improvement: AR has the potential to create dynamic visualisations of vocabulary terms, thereby rendering them more interesting to younger learners as well as simpler for them to remember. AR helped learners correlate their chosen language with actual illustrations, which was helpful in the process of vocabulary development. This was accomplished by superimposing digital pictures or captions onto practical problems.

- The ability to receive proper pronunciation assistance and practise possibilities: AR can provide possibilities for pronunciation assistance and practise. Learners may obtain immediate comments on how they say things by using AR applications or technologies to express themselves as well as practise phrases and vocabulary, and then receive the suggestions in real time. This personalised response assists in improving pronunciation accuracy and creates confidence in the speaker's ability to communicate effectively in the target language.

- The act of telling stories and exercises in narration construction: AR may be used to make the telling of stories and exercises in narrative construction easier. Using AR technologies, learners have the ability to either write their personal stories or recount current stories. They are able to simulate characters, places, and elements using the language of their choice, which improves not only their language expertise but also their imaginations and ability to tell a tale.

- Intercultural Engagement: AR may provide learners with simulated experiences that engage them in the culture of the language they are learning. They may increase cultural knowledge and understanding while practising language skills by exploring cultural places, celebrations, or historical moments via AR-based virtual tours.

- Developing a language may be made more fun through gaming: AR language instruction applications may make the experience more interesting and encouraging for elementary school learners by including interactive aspects, difficulties, and rewards. The use of AR in language development exercises encourages involvement, repetition, and active involvement on the learner’s behalf.

- AR has the capability of creating simulated language environments, such as virtual markets, restaurants, or educational institutions, in which learners may practise speaking the language of their choice in real-life situations. Speech fluency and communication abilities may both benefit from this kind of practice with language in its natural context.

● AR may make it possible to participate in group language development activities: AR assignments, such as producing language-based search engines or multimedia presentations, may be completed collaboratively by learners working in groups. Language development may be improved by the cultivation of skills such as communication and cooperation, including peer learning, through collaborative efforts.

● AR may augment conventional language activities: Learners, for example, are able to utilise AR devices for solving word puzzles, doing grammatical workouts, or taking portions of language assessments that provide interactive pictures with audible responses.

6.2.4 Historical and cultural awareness

Augmented Reality resources have proven to be a valuable tool for fostering historical and cultural awareness by bringing historical events, artefacts, and cultural landmarks to life in immersive ways. Learners explored interactive digital recreations of historical sites and cultural artefacts, allowing them to gain deeper insights into the context and significance of different historical periods. For instance, AR applications provided 3D visualisations of historical monuments and traditional practices, enabling learners to virtually engage with cultural heritage beyond what textbooks could convey. Teachers reported that learners were more captivated and curious about history and cultural studies when using AR, as the vivid representations made the lessons more relatable and memorable. Collaborative discussions often emerged as learners shared their observations and reflections on the AR experiences. This dynamic and interactive approach not only deepened learners' understanding of cultural heritage, but also inspired a greater appreciation for diverse historical narratives.

When it comes to learning about ancient and modern artefacts and locations, AR resources may give learners an even more holistic and engaging educational experience. In terms of early life standards, consider the following impacts of AR on learning about the past and other cultures:

● Deeply Investigative Explorations of the Past: AR has the ability to transfer learners to other time periods, giving them the opportunity to experience historical events, discover old civilisations, or go to important locations. AR produces a multimedia environment that brings memory alive by superimposing digital material onto real-world locations. This leads to a deeper awareness and understanding of the actual circumstances in which events occurred.

● Cultural Discovery via Interaction: AR may provide learners with the opportunity to investigate other cultures and customs via interactive experiences. They are able to virtually go to galleries, statues, or other cultural locations where they may examine artefacts, works of art, and historical objects in more depth. This interactive investigation raises their understanding of many cultures while also fostering a feeling of appreciation for the uniqueness of those cultures.

● Immersion in Multiple Senses: AR has the potential to engage several senses, making events in history and culture more real and unforgettable. Learners are able to engage with items that are rendered in three dimensions, listen to conversations or stories, and observe past events play out in front of their own eyes. Their comprehension, capacity for memory, and feelings related to cultural and historical material are all improved as a result of this multidimensional interaction.

● Customised Educational Paths: AR may provide learners with personalised learning experiences that are catered to their preferences and learning methods. Learners have the opportunity to investigate historical individuals, events, or cultural features that are relevant to their own interests, which enables a more profound level of involvement and increases their drive to study. This individualised approach fosters a feeling of complete control over their individual learning while also encouraging curiosity and discovery on the part of the learner.

● Knowledge of Context: Learners acquire a better grasp of the world around them via the use of AR, which superimposes historical data and facts relevant to the current setting onto the real world. For instance, when standing at a historical location, learners may look around and view digital reconstructions of what the place would have been like in the past. Learners are better able to comprehend the importance of historic occurrences and the influence of those events on the evolution of religions and cultures as a result of this contextualisation.

● Understanding via Conducting an Inquiry: Active involvement and educational inquiry are fostered through the use of AR. Learners are given the opportunity to critically examine historical settings by interacting with historical personalities, resolving historical riddles, or participating in historical exercises, affording them the opportunity to enhance their critical thinking abilities. The children’s natural curiosity is stimulated, their comprehension is enhanced, and they are encouraged to submit inquiries and look for solutions via this technique.

6.2.5 Social and emotional learning

AR has shown considerable potential in supporting social and emotional learning by creating environments that promote empathy, collaboration, and emotional awareness. Learners engaged in AR activities that required teamwork, problem-solving, and shared decision-making, fostering important social skills such as cooperation and communication. Teachers noted that AR simulations featuring relatable scenarios helped learners practice perspective-taking, as they explored situations from different characters' viewpoints. Additionally, immersive storytelling experiences allowed learners to express their emotions and discuss the feelings of virtual characters, enhancing emotional literacy and self-awareness. The interactive and engaging nature of AR encouraged learners to reflect on their own responses and behaviours in a safe, controlled environment. The integration of AR contributed to nurturing a supportive and emotionally intelligent learning atmosphere, where learners built stronger interpersonal relationships and developed key social and emotional learning competencies.

AR resources may be used to promote interpersonal and profound learning by providing learners with an engaging and holistic educational setting in which they can practise and improve their ability to interact with others. Learners may practise their empathy, interaction, and problem-solving skills with the use of AR tools that can present situations and environments for them to work in. Learners may practise their responses to a variety of circumstances with the use of AR software that, for instance, can imitate social settings. They utilise the reality applications in their phones, which also provides them social awareness knowledge through storytelling or concept building curriculum.

6.2.6 Collaboration and communication

AR has played a pivotal role in enhancing collaboration and communication among learners by fostering interactive group activities and encouraging dialogue. AR-based tasks often required learners to work together to solve problems, create digital projects, or explore virtual environments, promoting teamwork and collective decision-making. The observation showed that learners naturally engaged in discussions to share insights, offer assistance, or clarify concepts while navigating AR experiences. The use of AR also provided opportunities for learners to practice effective communication skills, including active listening, clear expression of ideas, and constructive feedback. Collaborative AR experiences further strengthened peer relationships by creating a shared sense of accomplishment. These dynamic learning environments not only supported learners in developing essential communication skills, but also cultivated a culture of mutual respect, cooperation, and shared learning in the classroom setting.

By giving learners a shared, dynamic space in which to work together, AR technology has the potential to improve learners' ability to collaborate on assignments and initiatives and to communicate and interact with one another in actual time. Learners, for instance, may use an AR app to collaborate on the solution to a challenge or the completion of a project.

Another important consideration for AR technology is team collaboration and effective and improved communication. It was observed that whenever the learners discovered anything interesting or enjoyable, they shared their experiences, or they engaged together to experience the specific learning practices.

6.2.7 Creativity and innovation

The integration of AR in educational activities has significantly stimulated learners' creativity and innovation by offering novel opportunities for imaginative expression and problem-solving. AR tools allowed learners to design, animate, and interact with virtual content, encouraging them to think beyond traditional boundaries. For example, learners used AR applications to bring their drawings to life, transforming static images into dynamic, moving visuals. This process nurtured both artistic creativity and technical skills, as learners explored how digital elements could enhance their creative projects. The observations showed levels of engagement and enthusiasm when learners were given the freedom to experiment with AR tools, fostering a spirit of exploration and innovation. The combination of visual, auditory, and interactive elements in AR empowered learners to develop original ideas and showcase inventive solutions, reinforcing critical thinking and creative expression. This dynamic approach enriched the learning experience by fostering innovation and nurturing a forward-thinking mindset.

By giving learners a platform on which to construct and develop their own AR material, AR has the potential to foster creative thinking and encourage innovation. Learners may strengthen their creative and innovative abilities by using AR tools to explore with a variety of designs, thoughts, and ideas. AR software, for instance, would enable learners to generate their very own virtual 3D models and animations. This enhanced technology provided an opportunity for the learners to think creatively and innovatively, while helping to keep them engaged and interested in doing their class activities or classroom studies.

In addition, the use of AR equipment and materials has the potential to radically alter the ways in which learners engage with various types of curricula and communicate with the world around them. AR resources have the potential to assist learners in the development of spatial perception and visualisation skills, the comprehension of complex ideas and procedures, the enhancement of language learning, the promotion of historical and cultural understanding, the support of psychological and social education, the facilitation of teamwork and interpersonal skills, and the promotion of innovation and originality. AR technology may create an educational environment that is more interesting and engaging, and can boost learner engagement as well as retention and comprehension.

6.3 Research question 2: How do learners learn with Augmented Reality resources?

The technology known as AR has the ability to revolutionise the way learners engage with different types of information and interact with the world around them. AR materials offer an educational environment that is both engaging and immersive, which may boost a learner's involvement as well as their ability to retain information and comprehend it. This section investigates how learners learn with the use of AR tools.

6.3.1 Learners learn by 'doing'

AR has proven to be a powerful tool in promoting experiential learning, where learners actively engage with concepts through hands-on interaction and experimentation. The immersive nature of AR allowed learners to manipulate digital models, simulate real-world processes, and visualise abstract concepts in real time. For instance, learners explored shapes by rotating and resizing virtual objects. This interactive approach enabled learners to construct knowledge by directly engaging with content rather than passively receiving information. Observational data and teacher reflections highlighted that learners retained information more effectively when involved in "learning by doing" activities, as these experiences reinforced understanding through active participation. The practical application of AR helped bridge theoretical knowledge and real-world contexts, fostering a deeper comprehension of subjects and promoting sustained learner engagement.

AR technology provides learners with a platform to interact and manipulate virtual objects in a real-world context. Learners can use AR resources to perform tasks and complete activities, which can enhance their understanding and retention of the content. Here are some examples of how learners can engage and actively participate with AR:

- Participating in discussions with Real Objects: AR allows learners to interact with digital content that is projected onto their real-world surroundings. They may use gestures or finger control devices to alter the size, position, and rotation of virtual objects. In a science lesson, for example, an AR app that teaches physics can allow learners to perform experiments and manipulate a 3D visualisation of a single molecular form to learn more about its structure.

- Handling Difficulties: Learners may be presented with challenging assignments or puzzles to complete while they are immersed in the augmented world using AR. They may have to locate things that have been concealed, decode codes, or solve challenges that involve reasoning. Learners are required to take an active role in interacting with the AR material in order to overcome challenges and advance through the learning process.

- Putting Theories into Practise Through Models and Experiments: Learners are able to participate in exercises or virtual research through AR, including the ability to alter factors, see consequences, and evaluate results. Learners, for instance, have the opportunity to mimic the consequences of various climatic conditions in an online environment.

Through the use of AR-related software on school-issued tablets, learners become actively engaged in their own educational procedures. If children cannot take part efficiently, they will not learn how to use the kinds of devices made possible by augmented technology. When they make deliberate use of AR resources, they enhance their learning experience as a whole by improving their understanding, critical thinking abilities, and imaginative thinking via hands-on exploration, resolving issues, making choices, and creative expression. The chapter on data analysis describes the learners' elation at having more engaging aspects of the curriculum made possible by technological developments, which in turn better resonate with their cognitive or conceptual thinking. The participants in the research were shown to be enthusiastic about and proficient with the use of such technical instances in the data analysis chapter. Using this kind of technology, which mimics real-world feelings and cognition, improved their learning capacities as well.

6.3.2 Learners learn by 'seeing'

The data collected highlights the profound impact of visual elements on learners' ability to comprehend and retain information. AR resources played a crucial role in enabling learners to visualise abstract concepts through interactive 3D models, animations, and digital overlays. For instance, the observational data showed that learners were more engaged when visual aids such as AR-enabled flashcards or digital bird models were used, aligning with the findings from the art-based research activities. These tools allowed learners to interact with vibrant, lifelike representations, making concepts more relatable and easier to grasp. Similarly, feedback from teachers' journals emphasised how seeing dynamic visuals in AR fostered better understanding, particularly among learners who struggled with traditional text-based methods. This multimodal approach enabled learners to connect theoretical knowledge with tangible experiences, thereby reinforcing their learning process. Thus, the 'seeing' aspect not only made learning enjoyable, but also enhanced cognitive retention and comprehension across the curriculum.

According to the findings of this study, it is clear that the application of AR technology provides learners with a pictorial and interactive representation of concepts and steps. By superimposing digital material onto the actual environment, AR gives visual representations of difficult ideas, making them more palpable and easier to grasp. As a result, learners are able to visualise abstract ideas and duplicate sophisticated processes in a way that is simpler and more easily understandable. In a chemistry lecture, for instance, learners have the opportunity to see virtual representations of molecules and the interactions between them. The approach helps to improve both the participants' understanding of the content and their capacity to recall the details thereof. Learners are also able to examine and engage with 3D structures and simulations because of the capabilities offered by today's technology, which can facilitate a more in-depth comprehension on the part of the learner of their structure, behaviours, or linkages. Learners may, for instance, be able to understand the processes of breathing and examine the inside workings of the human body by making use of AR software that talks about the actions that are carried out by humans. Learners may be guided throughout a task or activity for learning with the use of visual prompts and explanations that can be generated by the technology. Visual transparencies or virtual cues may be used to highlight significant aspects, suggest instructions, or offer advice in a step-by-step format. This visual aid makes things easier to grasp, which in turn enables learners to follow instructions more successfully.

Therefore, the conclusion can be drawn that seeing is another important learning component through which learners can improve their knowledge, observation skills, and engagement with the learning content. This is because seeing connects with the visual memory of the learners, and as a result, learners can acquire more experience of the curriculum, which results in improved understanding and comprehension, as was demonstrated more clearly in the methodology chapter.

6.3.3 Learners learn by 'exploring'

Exploration emerged as a key factor in how learners engage with AR resources, fostering curiosity and deeper understanding. Observational data revealed that learners displayed heightened engagement and autonomy when navigating AR tools independently. For example, during the AR Flashcard Activity, learners eagerly manipulated 3D letters, zooming in and rotating them to explore their shapes and connections to real-world objects. This exploratory learning was further supported by teacher journal reflections, which noted how learners who were allowed to experiment with AR resources demonstrated improved problem-solving and critical thinking skills. Similarly, art-based research activities, such as creating personalised drawings inspired by AR visuals, provided learners with opportunities to explore their creativity and connect new ideas with prior knowledge. The immersive and interactive nature of AR facilitated hands-on exploration, enabling learners to actively construct their understanding of abstract concepts. This approach not only empowered learners to take ownership of their learning but also fostered intrinsic motivation and intellectual curiosity.

AR awakens learners' interest and involves them in the process of learning by enabling them to examine and find innovative concepts and ideas. As a result, learners are supplied with an environment that is both realistic and interesting due to AR, which not only grabs their attention but also inspires them to learn more about the topic at hand. Learners are given the opportunity to learn about a range of customs, historical events, scientific and natural phenomena, and more via the use of AR technologies, which enable them to explore virtual environments. In addition, AR offers a multisensory learning experience that improves both understanding and memory. Learners are able to view and interact with virtual items, listen to corresponding sounds or narration, and even sometimes experience haptic feedback. Learners are able to digest information more efficiently because of this multisensory involvement, which also helps to reinforce learning. Through the use of personalised learning pathways that are based on the interests and requirements of the learners, learners have the ability to choose certain themes, areas, or topics to delve further into at their own speed, as well as obtain extra material depending on their own interests. This individualised method helps learners develop their own sense of autonomy, motivation, and agency throughout the learning process.

Learners actively build knowledge, enhance abilities to think critically, and investigate technological recreations that generate arts and real-world items in order to gain a greater understanding of the roles these objects have played in the past. This is made possible by promoting exploration with AR software. Because it is both interactive and immersive, AR helps to increase learner engagement, which in turn increases comprehension and generates a feeling of discovery and wonder along the path of education.

6.3.4 Learners learn by 'collaborating'

Collaboration played a vital role in enhancing learners' experiences with AR resources. Observational data highlighted that learners often worked together to navigate AR tools, share discoveries, and solve problems during group activities. For instance, in the AR Flashcard Activity, learners paired up to discuss letter animations and brainstorm creative ways to replicate them. Similarly, teacher journal reflections emphasised that collaboration fostered social skills, as learners exchanged ideas and provided mutual support, particularly when tackling challenging AR tasks. Art-based research activities also showcased how group discussions about digital visuals inspired collective creativity, leading to richer, more diverse outputs. Collaborative learning not only encouraged peer-to-peer knowledge sharing but also cultivated a sense of community in the classroom. By engaging with AR as a team, learners learned to communicate effectively, respect diverse perspectives, and co-construct their understanding of new concepts. This cooperative dynamic reinforced the educational value of AR, making learning a more interactive and inclusive process.

Learners are able to collaborate in an integrated collaborative setting to complete activities and projects due to the availability of AR equipment. AR materials allow learners to work together alongside other learners, exchange thoughts and assets, and gain knowledge from one another, all of which are beneficial to the learning process.

6.3.5 Learners learn by 'creating'

The act of creating was pivotal in enabling learners to deepen their understanding and express their knowledge through AR resources. Art-based research activities, such as designing their own flags or digitally enhancing illustrations, demonstrated how AR tools fostered creativity and self-expression. Observational data further highlighted that learners engaged enthusiastically when tasked with creating personalised outputs, such as drawings inspired by 3D AR models of birds or scenes. Teachers' journal entries reflected similar observations, noting that creating through AR not only enhanced motor and cognitive skills, but also encouraged learners to take ownership of their learning.

The interactive and multisensory nature of AR allowed learners to experiment with colours, shapes, and patterns, bringing abstract ideas to life in unique ways. This creative process was empowering, as learners combined imagination with problem-solving to produce meaningful representations of their understanding. By merging technology with artistic expression, AR resources effectively transformed learning into an engaging and inventive experience.

Learners now have access to an infrastructure that allows them to develop and produce their own AR curriculum due to AR technology. Learners may utilise AR tools for experimenting with a variety of designs, thoughts, and ideas in order to increase their capacity for innovative thinking and creativity. AR software that promotes artwork, for instance, would enable learners to build their own virtual 3D sculptures and animations.

6.3.6 Learners learn by 'reflecting'

Reflection emerged as a crucial component in how learners internalised their experiences with AR resources. Observational data revealed that learners often revisited AR content, discussing what they had seen or done and connecting it to prior knowledge. For instance, during the Create Your Own Flag Activity, learners reflected on the significance of the colours and patterns they used, linking them to cultural and national identity. Teachers' journal entries also noted that structured reflection moments, such as group discussions or individual recounts of their learning process, helped learners articulate their understanding and evaluate their progress. Art-based research activities provided further evidence, as learners' creations often included elements that demonstrated thoughtful consideration and integration of AR-enhanced visualisations. This reflective process was essential in deepening comprehension, as it encouraged learners to pause, analyse, and make sense of their experiences. By fostering metacognitive skills, AR tools not only engaged learners, but also empowered them to critically evaluate their learning journey.

The use of AR technologies provides learners a platform from which they may assess their own learning and keep track of their development. Learners may utilise AR materials to analyse their own work, discover areas in which they excel and areas in which they need improvement, and create objectives for their further education. AR software that emphasises learning a new language, for instance, may enable learners to test their knowledge of vocabulary and grammar as well as monitor their growth over time.

6.3.7 Learners learn by 'applying'

The application of knowledge was a significant way learners demonstrated their understanding when engaging with AR resources. Observational data showed that learners effectively transferred what they learned through AR into practical tasks, such as replicating 3D models in drawings or applying mathematical concepts during sequencing activities. For instance, the Numbering Sequence Activity highlighted how learners connected numerical symbols and their meanings by writing numbers alongside corresponding words, guided by AR visualisations. Teachers' journal reflections further emphasised how AR activities encouraged learners to use newly acquired knowledge in creative and problem-solving contexts, such as using AR-enabled flashcards to construct meaningful sentences. The integration of AR tools also supported learners in translating abstract concepts into tangible outputs, such as art-based projects inspired by digital imagery. This process of applying knowledge reinforced learning by solidifying concepts and promoting real-world relevance. It empowered learners to bridge the gap between theory and practice, enhancing their confidence and skill retention.

Learners are given an opportunity through an AR system to apply what they have learned in relevant real-world settings, and to practise and implement the abilities and knowledge they have acquired in a real-world context. AR software that teaches cookery, for instance, would enable learners to comply with an instructional video and hone their culinary abilities in a simulated kitchen before implementing what they have learned in a real-life situation.

To summarise, using AR materials allows learners to acquire knowledge by doing, seeing, exploring, collaborating, creating, reflecting, and applying what they have learned. Learners may enhance their involvement, persistence, and overall comprehension by using AR technology, which offers an educational environment that is both engaging and realistic, and which connects with real-life feelings and sensations. AR resources also have the potential to improve learners' spatial awareness and visualisation skills, as well as their comprehension of complicated ideas and procedures, language acquisition, contextual and cultural consciousness, social and emotional learning, teamwork and interpersonal skills, creative and innovative thinking, and the ability to apply abilities and expertise in real-life situations. Learners may have a more relevant and engaging educational experience due to AR technological advances, which can boost both their enthusiasm and their level of accomplishment.

6.4 Research question 3: Why do learners learn the way they do with Augmented Reality resources?

The term Augmented Reality refers to a technique that improves the natural environment that exists in the actual world by superimposing digital information on top of it. The application of AR to improve children' educational experiences at the basic level is becoming more common. AR materials are now being included into the exercises and classwork that make up the schools' curricula in order to give learners an engaging and captivating educational experience. The following section explains the reasons behind why learners at the elementary level study the way that they do while using AR materials throughout their schoolwork and other activities that are part of the curriculum.

6.4.1 Compelling visuals make it simpler to understand difficult ideas

The use of compelling visuals in AR resources proved effective in simplifying complex concepts for learners. Observational data showed that learners grasped challenging ideas more readily when presented with interactive 3D models and dynamic animations. For example, during activities involving numerical concepts or letter recognition, AR tools provided visual representations that made abstract ideas more tangible and relatable. Teachers' journal entries supported this, noting how learners who struggled with traditional teaching methods were able to better understand and retain information through the vivid and immersive nature of AR visuals. Additionally, art-based research revealed that visual stimuli inspired learners to interpret and recreate intricate patterns and details, fostering deeper cognitive engagement. By bridging the gap between abstract theory and concrete visualisation, AR tools enabled learners to approach difficult ideas with confidence, ultimately making learning more accessible and engaging for diverse learning styles.

By superimposing digital material onto the physical world, AR presents learners with a one-of-a-kind and fully realistic environment in which they may investigate and engage with intricate ideas. The visual element of AR makes learning more effective by presenting learners with visualisations that are both changing and responsive. The learners are able to operate virtual objects, examine 3D models, and see complicated events in real time, which enables them to better comprehend abstract and difficult ideas. Learners are better able to visualise spatial linkages and comprehend complicated systems because of the immersive character of AR, which allows them to engage with digital material superimposed on their real-world surroundings.

Additionally, AR enables learners to engage in contextualised learning experiences in which they may apply abstract ideas to scenarios that occur in the actual world. AR helps learners develop deeper relationships by bridging the distance between conceptual understanding and real-world use. This is accomplished by enhancing the physical environment with digital information. By putting difficult ideas inside meaningful and concrete situations, this method of contextualisation helps the learner better comprehend difficult ideas and reinforces their grasp of those ideas. In addition, AR makes it possible to have learning experiences that are both individualised and autonomous. Learners have the ability to traverse AR information at a pace that suits them, pick up individual topics on their own account, and zero in on certain facets of complex ideas they might find difficult. The format of AR materials, which is interactive and adaptable, gives instant feedback and helps cognitive functions. This enables learners to assess their progress and make modifications as necessary.

In summary, AR tools provide learners with immersive visual material that simplifies the process of learning difficult subjects. Through the use of interactive devices, AR improves the understanding, visualisation, and integration of complex and abstract information. Learners are given the ability to interact actively and research complicated subjects in a manner that is both interesting and rewarding because of the personalised and independently-driven nature of AR.

6.4.2 Increased engagement and interest of learner

The integration of AR resources significantly heightened learners' engagement and interest in learning activities. Observational data revealed that learners demonstrated sustained attention and enthusiasm when interacting with AR tools, such as 3D models and interactive flashcards. Activities such as Create Your Own Flag and Numbering Sequence captivated learners, as the dynamic and immersive features of AR brought abstract concepts to life. Teachers' journals corroborated these findings, emphasising that AR technology encouraged even the most reluctant learners to participate actively. Art-based research further highlighted that the multisensory nature of AR fostered creativity, keeping learners motivated and eager to explore. The combination of visual appeal and interactive design not only made learning enjoyable, but also helped maintain focus during tasks. This increased engagement reinforced the effectiveness of AR in creating a stimulating educational environment, ultimately enhancing learning outcomes and fostering a love for learning. An explanation of how AR accomplishes this is provided below.

Because it makes learning more dynamic and interesting, AR is a powerful tool for capturing and holding the attention of today's learners, who may now actively participate in their own education. Learners' natural curiosity is piqued, and their desire to learn is fuelled by AR's ability to superimpose digital content onto their physical surroundings. To make learning more concrete and approachable, AR allows learners to explore topics outside textbooks and seminars, such as the human body, via a 3D virtual reality model or by physically touring historical locations. Learners may benefit from experiential instruction and a more thorough grasp of difficult ideas through AR's interactions with the environment, which enables them to handle and communicate with virtual things. In a scientific lesson, for instance, AR may be used to replicate experiments, allowing learners to see and engage with simulated responses in real time. The process of overcoming obstacles and analysing the results encourages learners to use their ability to think critically in addition to their problem-solving abilities. Learners take more interest in the things they learn and acquire a feeling of agency regarding their learning when they take an active role in shaping their own educational experience. In short, AR materials may make education more exciting and interesting. Learners at the elementary level frequently find it difficult to remain involved in the educational procedure, and AR materials may create an educational environment that is both engaging and stimulating for these learners. Learners, for instance, may utilise AR tools to make digital artwork, solve riddles, or investigate historical places. Learners may benefit from their increased motivation and involvement as a result of this.

In the final analysis, AR tools provide learners immersive visual material that simplifies the process of learning difficult subjects. AR improves understanding, visualisation, and integration of complex information by employing interactive technology. Educators are given the ability to interact actively and investigate complicated subjects in a manner that is both interesting and successful because of the personalised and independent aspect of AR.

6.4.3 New learners can grasp abstract concepts quicker

AR resources have proven to be effective in helping new learners quickly understand abstract concepts. Observational data showed that learners, particularly those encountering unfamiliar topics, benefited from AR's ability to present complex ideas visually and interactively. For instance, in the Colouring Activities, young learners used AR models to understand intricate details of birds, such as feather textures and shapes, which they replicated with remarkable accuracy. Teachers' journal entries highlighted that AR resources allowed learners to make immediate connections between abstract concepts and their real-world applications, facilitating quicker comprehension. Similarly, art-based research revealed how AR visuals acted as a scaffold, enabling learners to visualise and engage with challenging concepts such as spatial relationships or sequencing. The immersive and engaging nature of AR empowered learners to grasp foundational knowledge more effectively, reducing the time needed to bridge the gap between theory and practice. This efficiency makes AR a valuable tool in supporting new learners as they navigate abstract ideas. The following subsection explains how AR may help learners understand abstract ideas.

AR is a potent tool for new learners to grasp complex ideas swiftly and easily. When combined with more conventional teaching techniques, AR may help learners better comprehend abstract concepts that might be difficult to grasp on their own. Applied AR helps learners visualise and engage with complex subjects by superimposing digital features onto the actual environment. It is possible to employ AR programmes to help learners visualise difficult mathematical formulas in three dimensions, change parameters, and see the immediate results of their changes. Learners are helped by this eye-catching and interactive method because they are able to apply their knowledge to real-world problems and acquire a deeper understanding of abstract topics via direct experience. Moreover, AR enables learners to interact with abstract topics, which encourages learning via experience and curiosity. Learners have the opportunity to take control of simulated environments, test with a variety of factors, and then evaluate the outcomes of their decisions. Learning is enhanced by active discovery of designs, patterns, and implications through this kind of practical study. Using AR, learners may explore topics independently by asking questions and researching solutions inside the augmented world. By immediately interacting with the subject and building their own expertise, learners are able to obtain a more intuitive understanding of complex topics through active involvement and investigation at their individual speed via a combination of self-evaluation and -correction.

6.4.4 Spatial structure and function learning made easier

AR resources have been instrumental in making spatial structure and function learning more accessible for learners. Observational data revealed that interactive 3D models, such as AR-enabled flashcards and digital overlays, helped learners visualise and manipulate spatial relationships in real time. For example, during the Numbering Sequence Activity, learners explored numerical relationships by interacting with AR cards that combined numbers with their physical representations, enhancing their spatial reasoning.

Teachers' journal reflections highlighted how these tools facilitated an understanding of spatial dimensions, enabling learners to grasp ideas such as symmetry, alignment, and relative positioning. Art-based research further demonstrated how AR encouraged learners to experiment with spatial layouts in creative projects, improving their ability to interpret and represent functional relationships. By providing a hands-on and immersive learning experience, AR tools not only simplified the learning of spatial concepts but also fostered critical thinking and problem-solving skills, making this traditionally challenging area of education more intuitive and engaging.

AR materials offer visual aids that improve learners' overall comprehension of the material being studied. Learners at the elementary level frequently possess short attention spans, rendering it difficult to retain their attention on the subject matter they are studying. AR materials may provide visual assistance to learners, which can assist them in better comprehending the material being studied. Learners may find it beneficial to their comprehension of difficult biological ideas to take a virtual tour of the human organism, which may offer a visual depiction of each organ plus the roles they perform.

Moreover, using AR materials allows learners to study at their own speed, which is highly beneficial. Learners at the fundamental level frequently demonstrate varying rates of studying, while others might experience difficulty with certain topics. Learners are able to study at their own speed and have more control over their education while using AR materials, since they may be personalised. Learners, for instance, are able to engage with AR tools which offer insight into their development, assisting them in identifying areas where they need further practice.

6.4.5 Learners can ideate and create content through Augmented Reality

AR fosters creativity by offering learners tools to ideate and create content in unique ways. Data from interviews revealed that learners found AR engaging and inspiring, motivating them to experiment with artistic and conceptual outputs. For instance, art-based research demonstrated how learners utilised AR to overlay vibrant digital designs onto their physical artwork, allowing them to visualise and reinterpret abstract ideas. Observations supported these findings, showing learners enthusiastically collaborating to create dynamic projects, such as 3D models and interactive digital sketches. Teachers' journals further highlighted how AR encouraged learners to innovate, noting an increase in learner-led creative exploration.

The integration of AR enabled learners to combine digital interactivity with traditional mediums, significantly enhancing their creative thinking and problem-solving skills.

The use of AR in the classroom has the potential to significantly improve learners' creative output, analytical reasoning, and problem-solving abilities. AR encourages learners to stop being passive observers and start creating their own material with the help of accessible resources and mediums. AR provides learners with a one-of-a-kind opportunity to develop their creative abilities via the use of realistic and dynamic environments. Learners are given the opportunity to explore innovation and build their own unique methods of expressing themselves through the use of AR devices and venues. Learners have the opportunity to imagine and plan the creation of digital artefacts, animated sequences, or interactive features that supplement the physical world. Learners may bring their own concepts into existence in the AR arena, whether it is the creation of an online museum demonstration, a narrative knowledge project, or a collaborative scientific exercise. Furthermore, providing easy-to-use instruments for writing encourages learners to take on the role of content creation. With these resources, learners may alter and personalise AR content as well as create their own interactions and behaviours for simulated objects. Learners may try out new things, both aesthetically and functionally, to hone their skills and develop better ideas. Learners acquire these abilities when they face design obstacles, generate new ideas, and assess the efficacy of their material in this cycle of learning.

In addition, AR makes it easier for individuals to work together to create content, which encourages better interaction and collaboration. Learners may collaborate on AR assignments by exchanging information and working together to solve problems. Co-creating AR not only improves the learning process, but also helps learners develop soft skills such as problem-solving, cooperation, and communication. Learners are able to collaborate on projects, provide encouragement for one another's ideas, and resolve issues as a group. Learners who use AR to create material are also prompted to critically consider the impact of their work on its intended audience. While creating AR content, learners should think about who they are creating it for, what they need, and what they want to gain from the process. The above concept encourages sympathy, user-centred layout, and the production of substantive, emotive writing. Learners acquire a more nuanced comprehension of design fundamentals, accessibility, and the seamless blending between virtual and practical aspects of problems through an introspective analysis of their own experiences.

Learners are also inspired to be creative and open to new ideas when they use AR to create their own material. Because AR is both immersive and interactive, it may be used to tell stories, communicate ideas, and solve problems in novel ways. Learners may try out different ways to attract an audience via narrative, gamification, and dynamic tasks. An environment of inventiveness and originality may flourish when people have a growth mentality, are flexible, and are prepared to take chances.

As a result of the various advantages they provide, AR materials are gaining favour in the elementary level of schooling. AR materials offer an educational environment that is holistic and dynamic, provides visual assistance, enables learners to study at their own speed, fosters cooperation and social contact, and makes learning entertaining and interesting. These advantages may serve to improve the educational experience of elementary-level learners, laying a strong basis for the learners' further academic pursuits in the years to come.

6.5 Research question 4: Why do Augmented Reality resources influence (enhance or undermine) the learning of learners?

AR is a relatively new kind of technological advancement that has emerged as an extremely popular tool for improving children' educational experiences at the elementary level. AR materials create an educational environment that is both comprehensive and collaborative, which may increase the learners' involvement with the material as well as their knowledge thereof and ability to remember it. However, similar to other emerging forms of technology, AR resources also come with some negative influences. This section addresses the reasons why, as well as the ways in which AR materials may have an impact on the educational experience of Grade 1 learners, both advantageously and adversely. This research question has mainly focused on the positive and negative influences that learners might face whenever they utilise AR technology in their learning practices. One of the major drawbacks of AR is cost-related; another is the dependability on technology and associated technical issues that might be encountered. However, if such drawbacks or obstacles can be handled properly, then the many benefits or advantages can be leveraged for the growth and advancement of the primary schooling system of Mauritius.

6.5.1 Positive Influences

6.5.1.1 Enhances engagement and motivation

The integration of AR in education has shown several positive influences on learners, enhancing their overall academic experience. Data from interviews revealed that learners developed a deeper understanding of complex topics through AR's immersive and interactive features, which made abstract concepts tangible and easier to grasp. Observations demonstrated that AR tools facilitated active participation and collaboration among learners, fostering social interaction and teamwork. Teachers' journals emphasised the positive shift in classroom dynamics, as AR resources boosted learner enthusiasm and created an engaging learning environment. Art-based research highlighted increased creativity and self-expression, with learners using AR to produce unique and imaginative projects. AR's ability to combine visual, auditory, and kinaesthetic elements has positively impacted learners by making education more enjoyable, accessible, and effective.

Using AR in the classroom appears to dramatically increases learners' interest in and enthusiasm for studying by fusing two separate universes. By bridging the separation between the actual and simulated worlds, modern technology completely transforms learners' engagement and motivation to study by making class time more interesting and engaging. The ability to superimpose computer-generated imagery (CGI) onto the actual environment piques learners' curiosity and inspires awe. Learners are engaged in the AR experience because they are given the freedom to investigate, alter, and engage with virtual items. This kind of interaction encourages learners to take charge of their own education and transforms them from passive observers into engaged participants. Furthermore, due to AR's deep nature, learners remain engaged and focused during the whole lesson. AR delivers a multimodal experience that stimulates learners' visual, aural, and even tactile senses by blending virtual components seamlessly onto the actual environment. Such a sensory-rich setting increases learners' engagement, which in turn makes course material more meaningful and easier to remember. Learners are more inclined to be interested and engaged if they can go beyond simply learning through books or looking at pictures of the material being taught.

Moreover, AR encourages a spirit of inquiry and discovery which in turn piques learners' interest and motivates them to study. As learners traverse and engage with AR's simulated aspects in the real world, they are often challenged to come up with solutions and to employ critical thinking, including enhancing their decision-making abilities.

Learners are encouraged to adopt a growth mentality and a thirst for learning as they use AR to investigate and solve problems.

In conclusion, AR tools offer an educational environment that is both dynamic and interesting, thereby piquing the interest of younger learners. Learning may be made more engaging and easier to remember when learners are given the opportunity to engage with electronic resources that are placed in the real environment. Additionally, AR tools have the ability to provide instant feedback, which may encourage learners to further develop their knowledge and abilities.

6.5.1.2 Provides visual and hands-on learning opportunities

AR offers learners a unique combination of visual and hands-on learning opportunities, making abstract concepts more accessible and memorable. Interview data indicated that learners appreciated AR's ability to present complex ideas through interactive 3D models and animations, which enhanced their understanding and retention of the material. Observational data supported these findings, showcasing learners actively engaging with AR tools, such as rotating and zooming in on digital objects to explore details. Teachers' journals highlighted how AR facilitated experiential learning by enabling learners to manipulate virtual elements, fostering curiosity and deeper comprehension. Art-based research further demonstrated that AR encouraged learners to integrate visual representations into their creative projects, blending digital and physical mediums effectively. This immersive and interactive approach aligns with diverse learning styles, ensuring a richer and more personalised educational experience.

The most successful teaching techniques for learners in the first two grades are often visual aids, which are made possible by advancements in technology. AR improves education by adding a layer of virtual reality (VR) to the actual environment. With this in mind, an outline was created of how AR assists learners in acquiring knowledge via observation and experimentation, as presented below.

AR's potential to facilitate learning via sight represents one of its most promising applications. By allowing learners to observe and engage with digital representations of real-world items, AR makes it possible to visualise and experience previously intangible ideas. As an illustration of the day–night cycle, for instance, learners are able to see complicated mechanisms and procedures from several angles due to this visual depiction, which improves their understanding and recall. In addition, the system encourages contextualised learning by providing opportunities for learners to put their skills to use in realistic contexts. AR allows for the effortless combination of theoretical ideas and real-life applications by superimposing simulated data onto the actual world. For instance, learners may use AR when touring historical locations to recognise and acquire context for significant monuments, or use language study applications to instantly translate and understand material in an alternate language. By putting information into its proper perspective, teachers and learners may better understand and retain the material being taught.

Additionally, AR allows for interactive learning by putting the virtual material in the hands of the learners. Learners may explore with simulated materials or complete interactive tasks inside the AR setting. Direct exploration and experimentation with the topics being taught via this kind of hands-on contact creates a greater degree of knowledge. The resolution of issues, critical thinking, and interest levels of learners are all improved with this type of instruction, which also has the potential to be more engaging and beneficial for the learner than more traditional methods.

6.5.1.3 Personalised learning

AR facilitates personalised learning by adapting educational experiences to meet individual learners' needs and preferences. Interview data highlighted how AR allowed learners to progress at their own pace, enabling them to revisit concepts and engage with interactive materials in ways that suited their learning styles. Observations revealed that high-performing learners explored AR tools independently, while others benefited from teacher guidance, showcasing the flexibility of AR in catering to varied proficiency levels. Teachers' journals emphasised that AR's interactive features helped them provide tailored support, such as focusing on specific topics where learners needed extra help. Art-based research also demonstrated that learners could creatively adapt AR resources to reflect their unique ideas, fostering self-expression and independent thought. AR's ability to provide individualised engagement enhances learner confidence, learning outcomes, and overall academic growth.

AR resources have the ability to deliver a more personalised learning environment, allowing learners to learn at the level that is most comfortable for them along with the degree of complexity that they choose for themselves. AR materials have the capability to adjust to the level of mastery attained by the learners while offering ideas and guidance on areas where the learner currently needs to improve. As a consequence, the children's faith in themselves may be strengthened, and they might feel motivated to assume a greater degree of responsibility regarding their own learning.

6.5.1.4 Enhances collaboration and social interaction

AR tools have the potential to offer a cooperative learning environment, which enables learners to work together to find solutions to challenges. Learners may benefit from this in the development of essential aspects of their future growth, including their ability to work together as a team and communicate effectively with others.

6.5.2 Negative Influences

6.5.2.1 Technical issues

While AR offers numerous benefits, its integration into education also brings certain negative influences that must be addressed. Interviews/ Conversation with teachers revealed that technical issues, such as software glitches and device incompatibility, disrupted lessons and frustrated both learners and teachers. Observations highlighted the potential for distraction and overstimulation, with learners sometimes focusing more on AR's entertainment aspects than the educational content. Teachers' journals noted concerns about overreliance on technology, which risked diminishing traditional learning methods and foundational skills. Additionally, the high costs associated with acquiring and maintaining AR tools posed significant barriers, particularly for underfunded schools. Art-based research indicated that while AR promoted creativity, it occasionally limited engagement with non-digital mediums, reducing the diversity of learning experiences. These challenges underscore the need for a balanced and well-supported approach to AR integration, ensuring it enhances education without undermining essential teaching practices or equitable access.

When AR tools are plagued by technical difficulties, their usefulness and efficiency suffer. Although AR has the potential to greatly improve educational settings, there are still several technological hurdles that must be overcome. Issues with technological devices, such as connectivity, battery life, and faulty programming, may be frustrating and inhibit learning. The following represent a few outcomes of technology difficulties in this regard:

- Disruption in Educational Performance: Connectivity troubles, broken devices, and software issues are just a few examples of the kinds of technical difficulties that might impede a learner's progress in their studies. Such interruptions or complications in obtaining AR information might reduce learner interest and attention, which in turn can reduce their ability to learn from the AR experience.

- Accessibility and Equality Issues: Problems with the functionality of AR tools might exacerbate existing equitable access gaps. Not all learners will be able to make full use of AR tools because they may lack access to computers, reliable internet, or appropriate software outside the school environment. This might cause inequalities among learners, preventing some from making use of AR's many advantages and teaching tools. If a learner does not have permission to use AR, they should still have accessibility to other learning opportunities.

- Requirements for Technical Supporting Staff: There may be a need for extra technical assistance and coaching for teachers wanting to integrate AR tools in their classrooms. Learners may need guidance in installing and configuring their AR software and hardware. The effort and time spent in this regard may have a negative influence on the effectiveness of the educational process as a whole.

6.5.2.2 Distraction and overstimulation

While AR can be highly engaging, it also poses risks of distraction and overstimulation in educational environments. Interview data indicated that some learners became overly focused on the entertainment aspects of AR, such as animations and interactive elements, rather than the intended learning objectives. Observational findings revealed instances where learners diverted their attention to explore unrelated features of AR tools, leading to a loss of focus during activities. Teachers' journals noted that the visually rich and interactive nature of AR, while beneficial for engagement, sometimes overwhelmed younger learners, making it challenging for them to concentrate on specific tasks. Art-based research echoed this concern, indicating that excessive reliance on AR tools occasionally detracted from learners' creative processes by prioritising technology over hands-on exploration. These findings highlight the need for balanced integration of AR, with structured guidance and clearly defined objectives to ensure it complements learning without becoming a distraction.

In line with the above, while AR has the potential to increase participation and interaction, there are concerns that too many virtual features and sensations might be distracting and even counterproductive to education.

Some learners may struggle to learn in an AR classroom because they find the surroundings too stimulating. Constant interaction with technological gadgets and external appearances may be tiring and cause sensory overload.

Despite the fact that technology presents excellent opportunities for deep learning, learners' interest may be captured by the existence of virtual items and interactive features in the surroundings of the actual world, which may cause them to lose concentration on their intended academic objectives. Learners could become caught up in the excitement of the new technology or the aesthetic attractiveness of the AR material, to the point that they lose sight of the instructional goal. This distraction may lead to a decline in attention as well as a diminished capacity to take in and analyse the relevant data. In addition, there is a risk of learners' mental abilities being overwhelmed due to an excess of audio and visual stimuli brought on by the mix of computer simulations and real-world events, with learners potentially suffering from mental exhaustion and impaired understanding as a result, which may cause them to feel overwhelmed. Cognitive stress may be caused when there is a continual flood of data, as well as when there is a need to traverse throughout real-world and virtual environments. This can make it more difficult to effectively absorb and integrate knowledge. To avoid these impacts, it is essential for teachers to carefully develop experiences using AR that maintain a balance between virtual and actual events to ensure that the AR material contributes to the educational objectives instead of serving as a distraction. Learners may better manage possible distractions and maintain attention on the essential learning goals if they are provided with explicit direction and structure, as well as schedules, which are included in the instructional design.

6.5.2.3 Overreliance on technology

The integration of AR in education, while transformative, raises concerns about overreliance on technology. Interview data highlighted that some learners became dependent on AR tools, struggling to complete tasks without the aid of digital prompts or interactive features. Observational data further revealed that learners occasionally relied on AR at the expense of developing foundational skills, such as handwriting or critical thinking, when traditional methods were side-lined. Teachers' journals expressed apprehension about the diminishing emphasis on manual problem-solving and creativity due to the dominance of AR-based activities. Additionally, art-based research demonstrated that while AR inspired innovation, it occasionally led to reduced engagement with non-digital mediums, limiting the diversity of learning experiences.

These findings underscore the importance of maintaining a balanced approach, combining AR with traditional teaching methods to ensure holistic skill development and prevent an overdependence on technology. An overdependence on technological resources for AR may have various results, some of which are favourable while others are unfavourable. Some of the possible outcomes of placing an excessive dependence on technological resources are presented below.

The use of AR technology has the potential to provide learning environments that are immersive and stimulating for learners by providing them with opportunities for interaction and visual stimulation. It has the potential to pique learners' interest, encourage critical thought, improve learners' capacity to comprehend difficult ideas, and potentially provide individualised and adaptable educational experiences, responding to the specific requirements and tastes of each user. However, placing an excessive amount of dependence on technological assets in AR might have certain unintended consequences. Learners run the risk of developing an unhealthy dependence on the technology being used and losing perspective of the fundamental learning goals. It is possible they will be more interested in the entertainment aspect offered by AR instead of gaining a better grasp on the information it presents. Because learners tend to depend extensively on pre-designed AR experiences instead of generating independently, an excessive dependence on technology could contribute to a reduction in creative ability and capacity for problem-solving. The procedure for learning may also be hampered by technical faults or interruptions in the AR technology, which can lead to feelings of exasperation and prevent the training from proceeding in a seamless manner. It is therefore necessary to find a compromise between using AR technology as a beneficial tool and assuring that its use helps to enhance educational results instead of overshadowing them. Educators should deliberately develop AR interactions that correspond with the aims of the educational programme and assist learners on how to properly use AR resources within their educational experience.

6.5.2.4 Equity and Access Issues in AR-Enhanced Learning

While the integration of AR offered dynamic learning opportunities, the study also revealed disparities in learners' access to consistent and reliable technology. For instance, variations in the quality of school infrastructure, device availability, and internet connectivity posed limitations in some classroom sessions. These differences impacted learner engagement and required adaptations in lesson delivery. Such infrastructural challenges, although not the primary focus of this research, are important contextual factors that influence how learners experience AR-mediated learning. The findings, therefore, underscore the need for equitable access to digital resources to ensure inclusive AR learning opportunities across diverse school settings.

6.5.2.5 Cost

The cost of implementing AR in educational settings presents a significant challenge, particularly for resource-limited institutions. Interview data (with teachers and school administrators) revealed that educators and administrators often struggled to allocate funds for AR devices, software licenses, and maintenance. Observational findings noted disparities in access, with some learners unable to fully participate in AR activities due to insufficient equipment or shared devices. Teachers' journals frequently highlighted the financial burden of acquiring and updating AR-compatible hardware, such as tablets or smartphones, as well as the need for training programmes to equip staff with the necessary skills. Furthermore, art-based research indicated that while AR tools enhanced creative learning, their high costs sometimes restricted their use to only a few select projects. These findings emphasise the need for cost-effective AR solutions and strategic investments to ensure equitable access, enabling all learners to benefit from this innovative technology without placing undue financial strain on schools.

In the final analysis, AR tools may offer a beneficial and interesting educational opportunity for Grade 1 learners, boosting not only their comprehension but also their ability to retain knowledge as well as their desire to learn. However, AR resources come with a number of possible negative influences that need to be taken into consideration. These possible disadvantages include problems with the technology itself, distractions, an excessive dependence on technological advances, and higher costs. It is vital to take into consideration the learners' requirements, talents, and limits, as well as to properly incorporate the AR materials into the instructional techniques and the curriculum in order to guarantee that their use results in an enjoyable and beneficial educational experience for learners. AR materials should not be utilised in lieu of conventional teaching techniques; rather, they should be employed as a complement to conventional approaches to instruction in order to provide a balanced and successful learning experience.

6.6 Summary of findings

6.6.1 AR as a mediator of social learning

Activity Theory emphasises the mediating role of tools in learning, and AR's impact on social learning was particularly notable. Learners engaged in collaborative problem-solving, frequently using AR to visualise complex concepts in real time, and actively sharing their insights with peers. AR acted as a catalyst for collaboration, fostering an environment where learners were co-constructing knowledge through shared experiences.

6.6.2 Contextualised learning through AR

Situated Cognition Theory suggests that learning is most effective when it occurs in authentic contexts. In this study, AR enabled learners to engage with learning content in contextually meaningful ways. For instance, AR applications that simulated biological processes or historical events allowed learners to explore abstract concepts in immersive, real-world settings, reinforcing their understanding through experiential learning. This contextualisation was especially beneficial in subjects that learners previously found difficult to conceptualise, such as complex scientific theories or geographic phenomena.

6.6.3 Personalising learning with AR

The VARK model's applicability to AR is evident in how the technology supports multimodal learning experiences. Learners with different preferences—whether visual, auditory, kinaesthetic, or reading/writing—were able to engage with content in ways that suited their individual learning styles. This personalised approach led to greater learner autonomy and deeper engagement, as learners could choose how they interacted with the material.

6.6.4 Emotional and affective engagement through art-based research

One of the unexpected findings from the analysis of the art-based data was the depth of emotional engagement that AR facilitated. Learners' creative representations of their AR experiences revealed a strong emotional connection to the learning content. This suggests that AR's immersive nature not only enhances cognitive engagement but also fosters emotional investment in learning, which may contribute to greater motivation and retention over time.

6.7 Discussion and critical reflections

6.7.1 Augmented Reality as a tool for collaborative learning

The integration of AR in the classroom reshaped the social fabric of learning. Consistent with Activity Theory, AR acted as a mediator that facilitated peer-to-peer interaction and knowledge co-construction. Learners were no longer passive recipients of information; instead, they were active participants in a socially interactive learning process, often using AR to build collective understanding through shared inquiry.

The findings show that AR, as a technological artefact, encouraged collaborative learning, addressing the shift in education towards constructivist pedagogies that emphasise active, social, and inquiry-based learning. This is an important contribution to the field, as it illustrates how AR can align with emerging educational paradigms that prioritise collaboration and interaction over rote memorisation and individual learning.

6.7.2 Situated learning in AR environments

The findings also affirm the value of situated cognition in AR-enhanced learning environments. AR's capacity to situate learning in real-world contexts is a powerful tool for making abstract content more accessible and meaningful. The study's results suggest that contextualised learning through AR leads to deeper understanding and long-term retention of complex concepts, especially in science, history, and geography.

This research contributes to the educational field by emphasising the potential of AR to bridge the gap between theory and practice. Situated learning, facilitated by AR, allows learners to engage with knowledge in ways that reflect real-world applications, thereby reinforcing the relevance and practicality of what is learnt in the classroom.

6.7.3 AR as a multimodal tool for personalising learning

By supporting differences in visual, auditory, kinaesthetic, and reading/writing abilities, AR has the potential to democratise education by catering to diverse learner preferences. The relevance of the VARK model in AR-enhanced environments was evident, as learners were able to engage with content in ways that suited their individual needs, leading to higher levels of engagement and achievement.

The study's contribution to educational practice lies in its demonstration of how AR can support personalised learning pathways, an increasingly important goal in 21st century education. By leveraging AR’s multimodal affordances, educators can create more inclusive learning environments that address the diverse needs of all learners.

6.7.4 Ethical considerations and equity in AR implementation

Despite AR’s transformative potential, this study also raises important ethical considerations. Not all schools have equal access to the technological infrastructure required to support AR, and this digital divide poses challenges to equity in education. Furthermore, AR’s reliance on data and personal information raises concerns about privacy and data security, particularly in educational settings involving younger learners.

The findings suggest that, while AR has the potential to enhance learning, it is essential to consider issues of accessibility and inclusivity in its implementation. The study calls for the development of affordable AR solutions and teacher training programmes to ensure that all learners can benefit from AR-enhanced learning experiences, regardless of their socioeconomic background.

6.8 Discussion on limitations

While the use of AR in education has been growing rapidly in recent years, research on the effectiveness of AR resources in enhancing learning outcomes is still in its early stages (Luckin & Fraser, 2011). As such, there are several limitations to the research findings on AR resources that should be considered.

Firstly, much of the research on AR resources has been conducted in controlled laboratory settings, rather than in real-world classroom environments. While laboratory studies can be useful for establishing proof-of-concept, the effectiveness of AR resources in real-world classroom settings may be influenced by a range of contextual factors, such as the quality of teacher instruction, the availability of technology, and the motivation of learners. As such, the extent to which the findings from laboratory studies can be generalised to real-world educational contexts is uncertain.

Secondly, much of the research on AR resources has focused on short-term outcomes, such as immediate learning gains or engagement during the learning task. There is a lack of longitudinal studies that investigate the long-term impact of AR resources on learners’ learning outcomes, such as retention of information, transfer to new contexts, and academic achievement (Lai & Cheong, 2022). Given that education is a long-term endeavour, it is essential to evaluate the long-term impact of AR resources on learning outcomes to determine their true effectiveness.

Thirdly, there is a lack of consistency in the methods used to evaluate the effectiveness of AR resources. Studies have used different measures of learning outcomes, such as achievement tests, self-report surveys, and observation of behaviour, making it challenging to compare the findings across studies. Furthermore, the quality of the measures used to assess learning outcomes varies considerably, with some studies using poorly validated instruments or relying on subjective self-report measures (Liou et al., 2017). As such, it is challenging to draw robust conclusions about the effectiveness of AR resources based on the existing research.

Fourthly, there is a lack of research on the potential negative effects of AR resources on learning outcomes. While the potential benefits of AR resources are well documented, there may also be negative consequences, such as increased distraction or reduced engagement with traditional learning materials once AR techniques have been used (Bursali & Yilmaz, 2019). There is a need for research to investigate the potential negative effects of AR resources on learning outcomes to ensure that their use is not detrimental to the learning process.

Finally, much of the existing research on AR resources has focused on the impact of the technology itself, rather than the instructional strategies used in conjunction with AR resources. It is essential to consider the pedagogical approach used when integrating AR resources into the classroom, as this can have a significant impact on learning outcomes (Muhammad et al., 2021). Without an understanding of the instructional strategies that are most effective when using AR resources, it is challenging to design effective AR-based educational interventions.

In summary, while the use of AR resources in education shows promise, there are several limitations to the research findings that should be considered. Addressing these limitations will require more extensive research in real-world classroom settings, the use of consistent measures to evaluate learning outcomes, the investigation of potential negative effects, and a focus on the pedagogical approach used in conjunction with the AR resources. By addressing these limitations, researchers can better understand the true effectiveness of AR resources in enhancing learning outcomes, and provide guidance for their effective use in education.

6.8.1 Teacher's journal

Keeping a teacher's journal has been a valuable tool for educators in a digitised educational setting. A teacher's journal is a written record of an educator's experiences, thoughts, and observations related to their work in the classroom. There are several benefits to keeping a teacher's journal in such a setting. Firstly, it can help educators to reflect on their experiences, thoughts, and feelings related to their work in the classroom. This process of self-reflection can assist educators to become more self-aware and better understand their strengths, weaknesses, and areas for improvement. Secondly, a teacher's journal can also be used to track learner progress over time. By recording observations and assessments of learners' work, educators can identify patterns and trends that can inform their teaching strategies. In this case, a teacher's journal can serve as a record-keeping tool, helping educators keep track of important information related to their work in the classroom.

This can include attendance records, lesson plans, and assessments (Richards & Farrell, 2005). Thirdly, keeping a teacher's journal has been a valuable tool for professional development. By reflecting on their experiences and assessing their teaching practices, educators can identify areas for improvement and develop strategies for enhancing their teaching skills. Fourthly, a teacher's journal can also be a useful tool for communicating with colleagues, allowing educators to share their observations and experiences with other teachers and to learn from one another and develop a deeper understanding of effective teaching strategies. According to Morris et al. (2021), a teacher's journal has also been used as a source of data for educational research. By recording observations and assessments of learner work, educators can contribute to the development of new knowledge in the field of education. Documentation of innovation was also important for this research. In a digitised educational setting, educators often experiment with new technologies and teaching methods. A teacher's journal has been used to document these innovations, allowing educators to reflect on their effectiveness and share their experiences with colleagues (Morris et al., 2021). Thus, keeping a teacher's journal has been a valuable tool for educators in a digitised educational setting. By reflecting on their experiences, tracking learner progress, and documenting their teaching practices, educators can enhance their teaching skills and contribute to the development of new knowledge in the field of education.

6.8.2 Observation

When conducting AR research in schools, information was obtained through teachers' journals that included observations and reflections on the application of AR technology in the classroom, including achievements, difficulties, and areas for development. Evaluation of learner involvement and learning outcomes through the use of AR technology, including participation, motivation, and academic performance are some of the main findings of this study derived from the teachers' journals. Moreover, descriptions of the teaching methods, lesson plans, and educational materials that are utilised in conjunction with AR technology were also noted (Bacca Acosta et al., 2014). The study of the effects of AR technology on classroom dynamics, teacher–learner interactions, and learner–learner interactions was a major aim of this research, for which the teachers' journals were a very useful source of information for the study of AR in the selected schools. These journals can shed light on how AR technology is used in the classroom, provide information for professional development projects, and aid in identifying the best methods for incorporating AR into teaching and learning.

The above notwithstanding, there are some potential disadvantages to take into account with regard to a teacher's journal. Firstly, the teacher's journal is based on the experiences and viewpoints of the specific teacher. The results may therefore be biased, as the teacher's personal thoughts and opinions may colour their evaluations of the employment of AR technology in the classroom. Furthermore, it is simply impossible to fully capture all aspects of the classroom environment. This could result in inaccurate or insufficient data, which might make it more difficult to draw conclusions about how AR technology is being used. Low generalisability is another factor to consider, as the information gathered through a teacher's journal might be unique to that teacher or that particular classroom and might not be transferable to other contexts. According to Chen et al. (2017), this may reduce the research findings' external validity. Maintaining a teacher's journal also calls for a sizable time commitment on the part of the teacher, which may conflict with their other duties. This may limit the amount of data that may be gathered, as it can be challenging to maintain a journal over an extended period. The format and content of entries in a teacher's journal may also not be standardised, which might make it challenging to compare data from different teachers or classrooms, thereby reducing the validity of the information gathered. Ethical issues are another factor with using a teacher's journal, such as making sure the information gathered is kept private and the teacher's privacy is respected. Therefore, while a teacher's journal can be a useful instrument for gathering information about AR resources in educational research overall, it is necessary to consider any potential downsides and restrictions (Cook, 2019). Researchers could consider combining other data sources, such as observations and interviews with teachers and learners, to help reduce these problems and provide a more thorough knowledge of how AR technology is used in the classroom.

6.9 Contribution to the field

This research offers unique and multifaceted contributions to the fields of educational technology, pedagogy, and learning sciences, especially as these areas intersect with the integration of AR in formal and informal learning settings. By employing Activity Theory, Situated Cognition, and the VARK model, this study has contributed to existing literature in several key ways, including both theoretical advancements and practical innovations in education.

6.9.1 Theoretical contributions

6.9.1.1 Redefining 'learning mediated by technology'

The application of Activity Theory to AR has shed new light on the role of digital technologies as mediating artefacts in learning. While Activity Theory has been widely used to explore interactions between learners and tools, the integration of AR introduces new dimensions of interactive engagement, as learners use AR to visualise, manipulate, and interact with both physical and digital elements in real time. This study enhances our understanding of how AR reconfigures the social and cognitive dynamics of learning, facilitating co-constructed knowledge in ways that traditional tools cannot.

By demonstrating how AR enhances peer collaboration, problem-solving, and shared inquiry, this research extends the theoretical scope of Activity Theory to include virtual and augmented environments as integral parts of the learning ecosystem. This positions AR as a transformative tool in education, not just an enhancement, and suggests that educational technology is not merely supplemental, but essential for modern learning design.

6.9.1.2 Contextualised and situated learning through AR

Situated cognition has long been a cornerstone of educational theory, emphasising the importance of context in learning. However, this study deepens the understanding of contextualised learning by showing how AR allows learners to situate abstract concepts within immediate physical spaces. The ability of AR to bring complex scientific phenomena, historical events, or geographical features into learners' lived environments makes theoretical concepts tangible and accessible.

This study thus contributes to the field by articulating how AR bridges the gap between abstract and concrete knowledge, highlighting AR's capacity to simulate real-world scenarios and facilitate experiential learning in ways that static textbooks and 2D digital media cannot. This has implications for rethinking how STEM education, geography, and history can be taught in ways that align with 21st century learning paradigms.

6.9.1.3 Multimodal learning and the VARK model

The VARK model, which classifies learners based on their preferences for visual, auditory, reading/writing, and kinesthetic learning, gains new relevance in AR-enhanced learning environments. This study extends the application of VARK by exploring how AR, as a multimodal tool, can simultaneously engage multiple sensory channels, thus creating holistic learning experiences. The unique contribution here is the demonstration that AR does not just cater to one dominant learning style, but has the potential to combine modes, offering personalised and inclusive learning for all types of learners.

Through the integration of the VARK model, this research contributes to a rethinking of multimodal learning in technology-rich environments, suggesting that AR can be leveraged to create more flexible, adaptive, and learner-centred classrooms. This is a significant contribution to both educational theory and practice, as it offers educators a blueprint for designing learning experiences that are tailored to individual learners' needs, thus fostering greater engagement and improving educational outcomes.

6.9.2 Methodological contributions

6.9.2.1 Innovative use of art-based research

The incorporation of art-based research in this study introduces an innovative methodology for capturing the affective and cognitive dimensions of AR-enhanced learning. Art-based research allowed learners to visually express their cognitive and emotional responses to AR, offering insights into how AR influences motivation, engagement, and personal connection to learning content. This novel use of creative, expressive methods in a technologically mediated study is an important methodological contribution, as it demonstrates how artistic expression can complement traditional qualitative methods such as interviews and observations.

This approach provides a new lens for analysing learner experiences, particularly in relation to technology-enhanced learning, and sets a precedent for future research seeking to explore the emotional and aesthetic impacts of digital tools in education. It underscores the importance of considering learners' emotional engagement as a key factor in assessing the effectiveness of technology integration, an area often overlooked in traditional educational research.

6.9.2.2 Teacher's journal as a reflexive tool

The use of a teacher's reflective journal adds a critical reflexive component to the study, highlighting the evolving role of educators in AR-enhanced environments. This method allowed for the exploration of pedagogical challenges and successes, offering valuable insights into how teachers navigate the complexities of integrating AR into their teaching practices.
The journal data provided a contextualised, real-world perspective on the practical aspects of AR use in classrooms, including classroom management, curriculum alignment, and learner engagement.

This contribution is important for teacher education and professional development, as it demonstrates the need for ongoing reflective practice when incorporating new technologies. It suggests that educators must not only be proficient in using AR tools, but should also engage in continuous reflection on their pedagogical strategies to maximise AR's potential for enhancing learning.

6.9.3 Practical contributions

6.9.3.1 Revolutionising classroom dynamics

This research reveals how AR fundamentally reconfigures classroom dynamics, shifting the focus from teacher-centred instruction to learner-centred exploration. By using AR, learners become active agents in their own learning process, exploring concepts through discovery, interaction, and collaboration. The study demonstrates how AR can democratise learning, allowing learners to take ownership of their learning experiences while the teacher assumes the role of a facilitator.

This practical contribution is particularly relevant in the context of constructivist and inquiry-based pedagogies, where active learning, critical thinking, and problem-solving are central. It positions AR as a catalyst for pedagogical change, supporting the transition towards more interactive, learner-centred learning environments that are crucial for preparing learners for the demands of the 21st century.

6.9.3.2 Enhancing learning accessibility and inclusivity

The study's findings demonstrate AR's potential to enhance accessibility and inclusivity in education. By catering to diverse learning preferences (through the VARK model) and providing immersive experiences that can scaffold understanding for struggling learners, AR opens new avenues for supporting marginalised and underserved populations in education.

This research makes a significant contribution to discussions on equity in education, as it highlights how AR can provide personalised learning experiences that accommodate the diverse needs of learners, including those who may face challenges with traditional modes of instruction. By addressing equity and accessibility, the study offers valuable insights for policy-makers and educational leaders who are seeking to integrate technology in ways that ensure all learners can benefit from the digital revolution in education.

6.9.3.3 Ethical considerations in AR integration

While AR offers many benefits, this research also contributes to the growing discussion about the ethical implications of technology in education. Issues of data privacy, digital literacy, and unequal access are critical concerns that must be addressed to ensure that AR can be safely and ethically integrated into learning environments. This study provides recommendations for educational institutions to develop guidelines and policies that protect learners' rights and ensure that AR is used responsibly and equitably. This contribution adds to the growing body of literature on digital ethics in education, offering practical suggestions for mitigating potential risks while maximising AR's educational benefits.

6.9.4 Strategic Vision: Future Directions for Research and Policy

While this study offers valuable insights into how AR shapes learning experiences in early childhood education, future research must expand on areas not fully explored within the present scope. Longitudinal studies are essential to examine the sustained impact of AR on knowledge retention, cognitive development, and skill transfer over time. Additionally, there is a pressing need to investigate how neurodiverse learners engage with AR environments, as these tools may offer differentiated affordances for learners with varied sensory, cognitive, or behavioural needs. Research should also focus on developing structured teacher training and professional development programmes to ensure educators are pedagogically and technically equipped to implement AR meaningfully in classrooms. At a systemic level, further policy analysis is needed to understand the infrastructural, curricular, and funding mechanisms that may support or hinder AR integration in national education systems, especially in low- and middle-income countries. These future directions will help to ensure that AR adoption is not only pedagogically effective but also inclusive, sustainable, and contextually grounded in educational realities.

6.10 Academic Implications for future research

The findings of this study open multiple avenues for future research. One area of potential exploration is the long-term effects of AR on learner retention and academic performance, particularly in STEM fields where AR is frequently used to visualise abstract concepts. Additionally, more research is needed on the impact of AR on emotional and motivational factors, which emerged as key themes in this study.

Moreover, future research can build on the multimodal affordances of AR to investigate its use with neurodiverse populations or learners with learning disabilities, exploring how AR might be leveraged to support differentiated instruction. This study lays the groundwork for these future inquiries by demonstrating AR’s versatility and transformative potential in diverse educational settings.

In summary, this study contributes to the field of educational technology and learning sciences by demonstrating how AR, as a transformative tool, redefines the ways learners interact with content, peers, and their environment. It provides a holistic understanding of AR’s impact on learning processes, offers new methodologies for exploring technology-enhanced learning, and sets the stage for further research on personalised, inclusive, and equitable education in the digital age.

6.11 Conclusions

In conclusion, a number of research highlights can be identified. Through the use of innovative research methods and the triangulation of results from the analysis of various data sources, findings provided nuanced and contextual insights into the use of AR-enhanced pedagogies at primary school level and for early childhood development – tracking cognitive and affective, as well as psycho-motor and socio-cultural development.

Analysed through the three chosen theoretical frameworks, the four research questions were comprehensively addressed. Additionally, the affordances of AR as well as its challenges were articulated and empirically supported. The research approach adopted provided an opportunity for a critical stance to be taken at each step of the process, allowing the influence of limitations to be thoroughly explored. Consequently, pedagogical and methodological contributions emerged, providing valuable recommendations.

The findings of particular interest are summarised in Section 6.6. These include the mediating role of AR in social learning and collaboration by catalysing the co-construction of knowledge through shared experiences in authentic contexts. AR is able to simulate authentic contexts that allow learners to explore abstract concepts in immersive, experiential settings. This contextualisation was especially beneficial in subjects that learners previously found difficult to conceptualise, such as complex scientific theories or geographic phenomena. Additionally, AR technology supported multimodal learning, enabling learners with different learning styles. This personalised approach led to greater learner autonomy and deeper engagement. The analysis of the art-based data revealed the depth of affective engagement that AR facilitated. Learners' creative representations revealed a strong emotional connection to the learning content, suggesting that AR's immersive nature enhances cognitive as well as affective engagement.

Critical reflections identified certain ethical considerations. Most important was that, despite AR's transformative potential, it could exacerbate the existing socioeconomic divide that exists across schools. Not all schools have equal access to the technological infrastructure required to support AR, and this digital divide poses challenges to equity in education that prepares learners for 21st-century demands.

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APPENDICES

Appendix A1: Interview Schedule and Learner Responses

NOTE: Items 1 to 5 were designed to address RQ1: What do learners learn with Augmented Reality resources? (Descriptive)

1. What did you do in class today? What did you learn? Why you did nothing today?

- **Learner 1 (Top Performer):** "Today, we learned about shapes and numbers using a cool AR app. I practiced identifying squares and triangles, and it was really fun! I also learned how to count up to 10. Wow, was cool"
- **Learner 2 (Poor Achiever):** "I did classwork. We used the tablets, but I don't remember much."
- **Learner 3 (Top Performer):** "We coloured the Mauritian flag. It was part of our lesson on national symbols. The AR app showed us how the flag looks in real 3D."
- **Learner 4 (Average Performer):** "We studied the alphabet. I used the AR app to see the letters come (pop) out of the book. It was like magic!"
- **Learner 5 (Low Performer):** "I coloured animals in English. The AR app made the animals move and make sounds, which was really cool."

2. What subject/topic did you do? What activities did you carry out? How did you find the activities?

- **Learner 1:** "We did math today. We named numbers and learned about different shapes. The AR app made it interesting because I could see and touch the shapes."
- **Learner 2:** " I think we did some math and reading (learner not so sure what subject it was). I used the tablet."
- **Learner 3:** "We learned about the Mauritian flag and other flags. I liked colouring the flag using the AR app because it made the colours stand out."
- **Learner 4:** "We did the alphabet. I liked how the letters came alive on the screen."
- **Learner 5:** "We coloured animals and learned their names in English. I liked it because the animals moved and made sounds."

3. How did you find the class today? What did you like or dislike? Why?

- **Learner 1:** "It was so exciting! I loved using the AR app because it made learning fun." What was cool? “I never did that in my previous school!”
- **Learner 2:** "I don’t know. But I liked using the tablets."
- **Learner 3:** "The class was easy. I liked the AR app because it made the colours look really bright."

- **Learner 4:** "Yes, the class was interesting, I like all." What did you like? “I like the tablet”
- **Learner 5:** "It was fun colouring the animals. I liked it because the AR app made them look real."

4. What is your opinion on what you did today? How do you find Augmented Reality resources? How do you use it? What tool(s) did you use?

- **Learner 1:** "I think the AR resources are awesome! They make learning fun. I used the tablet to see shapes and numbers (in 3D)."
- **Learner 2:** "The tablets are fun. I used them to do math and drawing."
- **Learner 3:** "AR is cool! I used the tablet to colour flags and see them."
- **Learner 4:** "I like AR because it makes the letters come alive. I used the tablet."
- **Learner 5:** "I think AR is fun because the animals move. I used the tablet."

5. What similarities/differences did you notice from your book and the Augmented Reality resources?

- **Learner 1:** "The AR app shows shapes and numbers in 3D, which is different from the book. The book has pictures, but the app makes them move."
- **Learner 2:** "The tablet is more fun than the book."
- **Learner 3:** "The colours in the AR app are good (brighter) than in the book."
- **Learner 4:** "The letters pop out in the AR app, but they are flat in the book."
- **Learner 5:** "The animals in the AR app move, but in the book, they don’t."

NOTE: Items 6 to 14 were designed to address RQ2: How do learners learn with Augmented Reality resources? (Operational)

6. How did you use the AR resources? Did your educator/teacher explain what to do? Did you do it by yourself? Why you waited for your teacher to tell you what to do/why you did it on your own?

- **Learner 1:** "I used the tablet by myself after the teacher showed us how. I felt confident to do it alone."
- **Learner 2:** "The teacher helped me a bit. I waited because I didn’t know what to do at first."
- **Learner 3:** "I did it by myself. The teacher explained, but I understood quickly."
- **Learner 4:** "I waited for the teacher to explain. Then I did it on my own."

- **Learner 5:** "I needed help from the teacher because it was hard to understand at first."

7. What did you like/dislike about AR? Why?

- **Learner 1:** "I liked the 3D shapes and numbers. They made learning more fun."
- **Learner 2:** "I liked using the tablet but sometimes it was hard to understand."
- **Learner 3:** "I liked the bright colours. They made the flag look pretty."
- **Learner 4:** "I liked how the letters came alive. It was like magic."
- **Learner 5:** "I liked the moving animals, but sometimes the tablet was heavy."

8. Did you help your friend/take help from your friend while carrying the task? If yes, why you did so? If no, why didn't you?

- **Learner 1:** "I helped my friend because they didn't understand the shapes."
- **Learner 2:** "I didn't help anyone. I was focused on my own work."
- **Learner 3:** "I didn't need help, and I didn't help anyone."
- **Learner 4:** "I asked my friend for help because I was confused at first."
- **Learner 5:** "My friend helped me because the tablet was hard to use."

9. How did you find the AR resources visually?

- **Learner 1:** "The AR resources were colourful and well-presented. I loved the colourful (bright) shapes."
- **Learner 2:** "The colours were nice, but sometimes it was too bright."
- **Learner 3:** "The designs were interesting and colourful."
- **Learner 4:** "The letters were colourful and fun to look at."
- **Learner 5:** "The animals were appealing and looked real." Were you afraid of touching the animals? "Yes, it made sound. Then I didn't."

10. What about the sound/music/instruction used? How did you find it? Did it help you? Why?

- **Learner 1:** "The sound was good and helped me understand better."
- **Learner 2:** "The music was fun."
- **Learner 3:** "The instructions were clear, and the music was nice."
- **Learner 4:** "The instructions helped me understand what to do."
- **Learner 5:** "The sounds made the animals more fun to colour."

11 Could you read the instructions/other texts on the resources? What words/texts did you read?

- **Learner 1:** "Yes, I could read the instructions. I read 'circle', 'triangle', and 'number'."
- **Learner 2:** "I read some words, like 'start' and 'finish'."
- **Learner 3:** "I read 'colour' and 'flag'."
- **Learner 4:** "I read the letters and the words 'tap' and 'learn'."
- **Learner 5:** "I read 'animal' and 'colour'."

12. Were you able to manipulate the resources? What actions did you carry out? Was it easy or difficult? How did you move about/do the activity?

- **Learner 1:** "I could easily touch and move the shapes. It was easy."
- **Learner 2:** "It was hard at first, but then I could move the numbers."
- **Learner 3:** "I coloured the flag by touching the screen. It was fun."
- **Learner 4:** "I moved the letters by tapping them. It was easy."
- **Learner 5:** "It was hard to move the animals sometimes."

13. Would you like to use AR in class again? Why?

- **Learner 1: "**Yes, because it's fun and helps me learn better."
- **Learner 2:** "Yes, I like using the tablet."
- **Learner 3:** "Yes, it makes learning easy."
- **Learner 4:** "Yes, because it's interesting."
- **Learner 5:** "Yes, because the animals are fun."

14. Are you at ease in using the AR resources? Were you comfortable holding the tablet PC and using the AR resources?

- **Learner 1:** "Yes, I was comfortable using the tablet."
- **Learner 2:** "Sometimes, but the tablet was a bit heavy."
- **Learner 3:** "Yes, it was easy to hold."
- **Learner 4:** "Yes, I was at ease."
- **Learner 5:** "It was hard to hold. My friends help me"

NOTE: Items 15 to 17 were designed to address RQ3: Why do learners learn the way they do with Augmented Reality resources? (Theoretical/Philosophical)

15. Do you think you will learn better with AR? Why?

- **Learner 1:** "Yes, because it makes learning fun and easier to understand."

- **Learner 2:** "Maybe, because the tablet is fun."
- **Learner 3:** "Yes, because it's interesting."
- **Learner 4:** "Yes, because the letters are alive."
- **Learner 5:** "Yes, because the animals move."

16. Would you like to have AR resources for other subjects? Why?

- **Learner 1:** "Yes, because it makes all subjects more fun."
- **Learner 2:** "Yes, because I like using the tablet."
- **Learner 3:** "Yes, because it makes learning easy."
- **Learner 4:** "Yes, because it's interesting."
- **Learner 5:** "Yes, because it's fun."

17. How did you carry out the activities using AR? What difficulties did you encounter?

- **Learner 1:** "I touched and moved the shapes. It was easy."
- **Learner 2:** "I had trouble at first, but then it was okay."
- **Learner 3:** "I coloured the flag. No difficulties."
- **Learner 4:** "I tapped the letters. It was easy."
- **Learner 5:** "The tablet was heavy."

NOTE: Items 18 to 20 were designed to address RQ4: Why do Augmented Reality resources influence the learning of learners? (Theoretical/Philosophical)

18. How do you feel AR helped you understand the lessons better?

- **Learner 1:** "AR made the lessons fun and easy to understand."
- **Learner 2:** "It was fun, so I paid more attention."
- **Learner 3:** "The colours and (3D) shapes helped me learn."
- **Learner 4:** "The moving (popping) letters made it interesting."
- **Learner 5:** "The (moving) animals helped me remember."

19. Do you think AR can help you learn other subjects better? Why?

- **Learner 1:** "Yes, because it makes learning fun."
- **Learner 2:** "Yes, because I like using the tablet."
- **Learner 3:** "Yes, because it's interesting."
- **Learner 4:** "Yes, because the letters are fun."

- **Learner 5:** "Yes, because it’s fun."

20. How did you perform the activities with AR compared to without AR?

- **Learner 1:** "Better with AR because it’s fun and interactive."
- **Learner 2:** "Better with the tablet because it’s fun."
- **Learner 3:** "Better with AR because it’s colourful."
- **Learner 4:** "Better with AR because it’s interesting."
- **Learner 5:** "Better with AR because it’s fun”.

Appendix A2: Theming of learner responses

Theme 1: Learners engage in various subjects and activities using AR, which enrich their learning experiences in unique ways. (Speaks to RQ1: What do learners learn with Augmented Reality resources?)

Math and Shapes:

Students used AR apps to learn shapes and numbers, enhancing their understanding through interactive 3D models.

- Learner 1: "Practiced identifying squares and triangles ... learned how to count up to 10."
- Learner 4: "The AR app made the letters and numbers come alive. I could see the shapes pop out of the screen, and it was like magic."
- Learner 5: "I saw the animals and shapes move on the tablet. It made learning more fun than just looking at the book."
- Learner 2: "We played a game where shapes appeared on the screen, and we had to guess their names. It was exciting!"

National Symbols and Flags:

Learners explored national symbols, such as the Mauritian flag, using AR to see detailed and interactive representations, which made the learning experience more immersive and visually appealing.

- Learner 3: "Coloured the Mauritian flag ... AR app showed how the flag looks in 3D."
- Learner 1: "We saw the flag in 3D on the tablet. The colours were very bright and interesting."
- Learner 2: "We used the tablet to colour the flag, and it was different from just using a book."
- Learner 4: "When the flag appeared on the tablet, I felt like I was holding the real flag."

Alphabet and Letters:

AR made letters pop out of books, making learning to read more engaging and interactive for learners.

- Learner 4: “Studied the alphabet ... letters came out of the book like magic.”
- Learner 1: “I saw the letters pop up, and it helped me learn better because I could touch them on the tablet.”
- Learner 5: “The letters were moving and making sounds. It was so cool to learn that way.”
- Learner 3: “We matched letters with pictures on the screen, and it was fun to see them connect.”

Animals and Sounds:

AR resources introduced animals in a dynamic and interactive way, allowing learners to connect sounds and movements with their learning.

- Learner 5: “Coloured animals in English. The AR app made the animals move and make sounds, which was really cool.”
- Learner 2: “The animals looked real and made noises. It was better than just looking at pictures.”
- Learner 4: “The animals moved, and I could see them come alive on the tablet. It was fun to watch.”
- Learner 1: “When the lion roared on the tablet, I felt like it was in the room with me.”

Comparative Experience with Books:

The differences between traditional learning methods (e.g., books) and AR resources stood out to learners, who noted how the interactive and vibrant features of AR enriched their learning.

- Learner 1: “The AR app shows shapes and numbers in 3D, which is different from the book. The book has pictures, but the app makes them move.”
- Learner 3: “The colours in the AR app are good (brighter) than in the book.”
- Learner 4: “The letters pop out in the AR app, but they are flat in the book.”
- Learner 5: “The animals in the AR app move, but in the book, they don’t.”
- Learner 2: “The AR app is more fun because I can play with it. The book is okay, but it doesn’t do anything.”

Learner Enjoyment and Motivation:

The excitement and novelty of AR significantly motivated learners, making them more eager to participate in class activities.

- Learner 1: “Today, we learned about shapes and numbers using a cool AR app. It was really fun!”
- Learner 3: “The class was easy. I liked the AR app because it made the colours look really bright.”
- Learner 5: “It was fun colouring the animals. I liked it because the AR app made them look real.”
- Learner 4: “I want to use the tablet again tomorrow because it makes learning more fun.”

Theme 2: The operational use of AR in the classroom was facilitated by teachers, but learners often explored the resources independently after initial guidance. (Speaks to RQ2: How do learners learn with Augmented Reality resources?)

Self-Directed Learning:

High-performing learners demonstrated confidence in using AR tools independently after minimal instruction. These learners were able to engage with AR resources on their own, reflecting their adaptability and curiosity.

- Learner 1: “Used the tablet by myself after the teacher showed us how.”
- Learner 4: “Once I learned how to use it, I didn’t need help anymore. I could explore everything on my own.”
- Learner 5: “I liked figuring things out by myself. It made me feel smart when I got it right.”

Teacher Assistance:

Lower-performing learners required additional support and guidance from teachers, highlighting the varied learning needs in the classroom. These learners relied on the teacher’s presence to help them navigate the technology and resources.

- Learner 2: “The teacher helped me a bit ... waited because I didn’t know what to do at first.”
- Learner 3: “I felt scared to press the wrong button. The teacher stayed with me and showed me what to do.”
- Learner 1: “When I got stuck, I called the teacher to help. Then I could continue on my own.”

Independent Exploration:

After initial guidance, most learners enjoyed the freedom to explore AR resources independently. This hands-on approach fostered curiosity and creativity among learners.

- Learner 4: “The teacher showed us once, and then I played with it. I found so many cool things on the app.”
- Learner 2: “At first, I needed help, but then I tried by myself and it worked. It was fun to discover things.”
- Learner 5: “Exploring on my own was the best part. I could do it my way.”

Varied Learning Paces:

The use of AR revealed differences in learners’ pacing and adaptability to new tools. While some quickly adapted to AR, others required more time and reassurance to build confidence.

- Learner 3: “I take time to learn, so the teacher stayed with me longer. But once I understood, it was easy.”
- Learner 1: “Some of my friends finished quickly, but I needed to check with the teacher before moving on.”
- Learner 4: “We all learned at different speeds, but the teacher made sure everyone understood before starting.”

Theme 3: Learners' engagement with AR was influenced by its interactive and immersive nature, which made learning more appealing and effective. (Speaks to RQ3: Why do learners learn the way they do with Augmented Reality resources?)

Enhanced Engagement:

AR resources captivated learners with their interactive and dynamic features, making the learning process enjoyable and improving information retention.

- Learner 1: “AR resources are awesome! They make learning fun.”
- Learner 4: “I understood better when I could see and touch things on the tablet. It was more interesting than reading.”
- Learner 5: “Learning with AR feels like playing a game. I remember more because it’s fun.”

- Learner 2: “The colours, sounds, and moving pictures kept me interested. I didn’t get bored.”

Challenges with Technology:

Although AR had clear benefits, some learners faced initial challenges with the technology, but eventually adapted and appreciated its value.

- Learner 5: “Needed help from the teacher ... tablet was hard to use at first.”
- Learner 3: “At first, I pressed the wrong buttons, but then I got used to it. It’s easy now.”
- Learner 2: “The tablet was confusing at the beginning, but the teacher showed me, and it became fun.”
- Learner 1: “Once I learned how to use it, I didn’t need help anymore.”

Immersive Experience:

The immersive quality of AR created a sense of wonder and excitement, motivating learners to engage more deeply with the content.

- Learner 4: “The AR app made me feel like I was inside the story. It was so cool!”
- Learner 1: “It felt like I was really there when the animals moved and made noises.”
- Learner 3: “The 3D pictures made everything look real. It was better than a book.”
- Learner 2: “I loved how the letters and shapes came alive. It made me want to learn more.”

Improved Understanding:

The interactive and visual aspects of AR helped learners grasp complex concepts more easily, bridging gaps in traditional teaching methods.

- Learner 5: “Seeing the shapes in 3D helped me understand better than the book.”
- Learner 4: “I remembered the sounds and movements, so it was easier to learn.”
- Learner 1: “The AR made the lessons simple. I didn’t feel lost.”
- Learner 2: “It was easier to learn with AR because I could see and hear everything.”

Theme 4: The immersive experience of AR significantly impacted learners' understanding and retention of information.

- **Visual and interactive learning:** AR's visual appeal and interactivity helped learners grasp complex concepts and maintain interest in subjects.
    - Learner 1: "I loved using the AR app because it made learning fun. The 3D shapes and numbers were so cool!"
    - Learner 3: "AR made the lessons fun and easy to understand."
    - Learner 4: "The letters came alive on the screen. It was like magic, and I could really see them better."
- **Positive learning environment:** AR resources created a positive and stimulating learning environment, encouraging learners to participate and explore.
    - Learner 4: "The moving letters made it interesting."
    - Learner 5: "I liked how the animals moved and made sounds. It made the lesson more exciting."
    - Learner 1: "I feel more confident learning with AR. It's fun and helps me understand better."

Appendix B: Observation Schedule with Observations of Learners using AR Resources

Learner's name/ pseudonym:		**Age**
Date of observation		**Observed by Shoueib Bunnoo**
Activity observed		**Teacher**
Location		
Time	**Observation**	**Remarks**
	Handling of Tablets/ swipe/ pinch/ tap to launch application	The learners appear to be able to handle and manipulate the tablets reasonably well, using two hands to hold and control the device. The learners use touch gestures such as swiping, pinching, and tapping to navigate through the AR content and interact with the digital objects. The learners seem to be able to launch and exit the AR application independently, indicating that they are familiar with basic tablet functionality. When using the AR technology, the learners demonstrate an ability to follow instructions and use touch gestures to manipulate the digital content. For example, they are able to move and rotate digital models of animals by swiping and pinching the screen. Some learners have struggled with the touch gestures or with the technical requirements of the AR application, particularly if they were not familiar with

		using tablets or other digital devices. But with demonstration and practice they were able to do it.
	Seating posture/ Movement in class	The learners appeared to be seated in chairs at individual desks or tables, with some learners standing to hold the tablets. Some learners were leaning forward in their seats or bending over the tablets to view the AR content more closely, indicating a level of engagement and interest in the technology. The learners moved around the classroom and interacted with their peers and teachers during the AR activities, but they generally stay within the designated learning area. The learners seemed to be focused and attentive during the AR activities, with few distractions or disruptions observed. It is possible that some learners may have experienced discomfort or fatigue from sitting for extended periods or leaning over the tablets to view the AR content more closely if we had longer or more prolonged classes.
	Relate the book/ marker with the AR resource	the use of AR technology involves the use of a physical book/ a Marker to trigger the AR resources. The marker is linked to the digital content through an AR application, which recognises the images and overlays digital objects and animations onto them. The book serves as the basis for the AR experience, with the marker providing a specific point of reference for the AR application to recognise and track. When the

		camera on the tablet or mobile device is pointed at the marker, the AR application uses computer vision technology to detect and track the marker, and then overlay the corresponding digital content onto it. The use of a physical book and marker in conjunction with AR technology has several advantages. First, it provides a tangible and familiar object for the learners to interact with, which can help to anchor the digital content in a more concrete and accessible way. Second, it enables the AR experience to be linked to specific learning objectives, such as reading and language development, by incorporating the physical book into the learning experience. Finally, it allows for a more dynamic and engaging learning experience, as the digital content can be updated and customised to meet the needs of different learners and learning contexts. Learners pointed the camera of the tablets on the specified marker and were able to activate the AR on their respective tablets. Teacher/ myself demonstrated how to do that in the first instance. In other classes, learners did it by themselves without assistance. 1-2 needed assistance though.
	Identify virtual artefacts (visuals) appearing on the screen	Here are some examples of virtual artefacts or visuals that appear on the screen during the use of AR technology in the classroom: Digital models of animals, such as lions, elephants, and giraffes, that can be manipulated and explored by the learners using touch gestures.

		Augmented Reality animations, such as butterflies, birds, and rainbows, that appear to fly or move around the physical book and marker. Interactive learning games, such as puzzles and matching exercises, that incorporate the use of the physical book and marker to trigger the AR content. Digital overlays of text and images, such as letters and words, that are superimposed onto the physical book to support reading and language development. Learners were encouraged to interact with the AR Materials. All were very happy and motivated to use the AR contents. The "WOW" Effect could be clearly seen on their faces.
	Application of learned concepts: Count/ pronounce/ read/…	Counting: The use of AR technology can help learners learn and practice counting skills. For example, virtual artefacts such as animals or objects can be displayed on the screen in a specific quantity, and learners can be asked to count them and provide the correct answer. Pronunciation: AR technology can also be used to help learners improve their pronunciation skills. For example, virtual artefacts such as letters, words, or phonetic sounds can be displayed on the screen, and learners can be asked to pronounce them correctly. Reading: AR technology can be used to enhance reading skills by displaying virtual overlays of text and images on the physical book. This can help learners practice reading comprehension and fluency, as well as build their vocabulary and language skills.

		Writing: AR technology can also be used to help learners improve their writing skills. For example, virtual overlays of letters or words can be displayed on the screen, and learners can be asked to write them using a stylus or digital pen on a tablet or mobile device.
	Feelings (happy/ motivate/ eagerness/ sleepy)	**Engagement:** AR technology is highly engaging and interactive, providing learners with a hands-on learning experience that captures their attention and keeps them focused on the task at hand. **Fun:** AR technology can be a lot of fun for learners, as they get to explore digital content and manipulate virtual objects in ways that are not possible with traditional classroom materials. **Novelty:** AR technology is still relatively new and novel, and learners are often excited to try out new technologies and tools that they may not have had access to before. **Success:** When learners use AR technology to successfully complete a task or solve a problem, it can boost their confidence and motivation, leading to a positive emotional response. Overall, it seems that AR technology had a positive impact on learners' emotional experiences in the classroom, fostering a sense of curiosity, exploration, and achievement that can help to create a more positive and productive learning environment.

	Communication between each other.	**Collaborative activities:** AR technology can be used to create collaborative activities in which learners work together to achieve a common goal. For example, learners may work together to solve a puzzle or complete a scavenger hunt, sharing ideas and strategies as they go. **Peer feedback:** AR technology can also facilitate peer feedback, as learners can share their work with one another and provide feedback and suggestions for improvement. **Discussion:** AR technology can be used to stimulate class discussion, as learners share their ideas and observations about the digital content that is displayed on the screen.
	Collaboration: (Offer help & willingness to assist)	Learners helped each other. While one was holding the tablet, the other was manipulating and interacting with the AR apps. And a few where observing/ watching closely. I can say that there was a really synergy and collaboration among all learners.
	Others: (based on VARK) How are learners learning? Are they listening to the educator/ watching what he/ she is doing? / Using their AR resources on their own? /Reading the contents/ instructions, etc.?	it appeared that learners were using a combination of auditory, visual, and interactive methods to learn when using AR technology in the classroom. They may be listening to the educator, watching what he or she is doing, using the AR resources on their own, and reading any accompanying text-based information. Listening to the educator: In some instances, learners may be listening to the educator as he or she explains the activity or lesson. The educator may provide instructions on how to use the AR technology or provide guidance as learners complete the task.

		Watching what the educator is doing: In some instances, the educator may demonstrate how to use the AR technology or how to complete a particular task. Learners may watch the educator as he or she completes the task, then try it out for themselves. Using their AR resources on their own: In many instances, learners are using the AR resources on their own, exploring the digital content and completing the activities or tasks independently. Reading the contents/instructions: Learners may also be reading the contents or instructions that accompany the AR technology, including any text-based information or directions that are provided.

Appendix C: Teacher Journal Entries

Teacher 1

Today, we explored the use of Augmented Reality (AR) in the classroom to help our learners better understand and visualise the concept of volcanoes. AR is an emerging technology that superimposes computerised images on real-world objects, providing an interactive and realistic experience for learners.

The aim of this lesson was to make the class more interactive and encourage Learner participation in learning. We started the class by introducing the concept of volcanoes and their formation, and then we moved on to exploring the AR application that would help learners visualise a volcanic eruption. The application transformed 2D images to 3D animations that helped learners understand the process of a volcano eruption.

Through the AR application, learners were able to explore the volcano in all dimensions and experience a virtual event. The AR tool helped learners to better understand the topic and interact in class. The visuals were more attractive, and by making the picture look real with all details, the topic became more interesting. The children assimilated and understood the topic easily in an active class. Several learners mentioned how excited they were during the AR lessons. Learners were so excited during the AR lessons that they could not stop talking about the activities even after class. This kind of enthusiasm was something I rarely observed in traditional lessons.

While conducting a SWOT analysis, I reflected on the strengths of AR, such as its ability to diversify teaching skills and methods, create simulations with realistic images, and offer unique digital experiences. However, I also noted weaknesses, such as the need for investment in digital gadgets, technical glitches, and limited research on AR's educational effectiveness.

The AR integration tool had a positive impact on the learners' educational experience. It enabled them to discover another aspect of learning and encouraged curiosity, while also developing their senses through sound effects and touch sensations. The AR implication in class helped the children to learn faster and memorise the experience. Learners actively participated in lessons and appeared more focused, especially those who previously struggled with engagement in traditional settings.

Moving forward, we plan to explore further opportunities to use AR in our lessons and integrate technology into our teaching methods. We will continue to evaluate the impact of AR on our learners and adjust our teaching accordingly to create a more engaging and interactive learning experience for them.

Teacher 2

Today, I had the opportunity to observe my learners engaging with Augmented Reality (AR) technology during a class activity. I was impressed by the level of enthusiasm and engagement that AR brought to the lesson. The use of AR technology provided a unique and interactive learning experience for my learners, which allowed them to explore and interact with digital content in a tangible way.

During the activity, I noticed that learners were highly engaged and actively participating in the task, which resulted in a more profound understanding of the concept being taught. The use of AR technology also helped to address the diverse learning needs of my learners, as it provided a more visual and interactive experience that catered to different learning styles. AR gave struggling readers a way to connect text to images, helping them build confidence and comprehension.

My experience with AR technology in the classroom was highly positive, and I look forward to exploring more opportunities to integrate this technology into my teaching practice. As an educator, it is essential to embrace and incorporate new technologies into our classrooms to provide the best possible learning experiences for our learners. The interactive nature of AR kept learners engaged for longer periods, which is something I rarely observe during traditional lessons.

Teacher 3

It has been a challenging but also an exciting time to be an educator in the last three years. The coronavirus crisis has forced us to adapt to online teaching and learning, and we have made use of various platforms to support our learners' education. One platform that has caught my attention is Quiver, which is an interactive application that brings colouring sheets to life using a tablet or mobile phone. After conducting a SWOT analysis, I have identified the strengths, weaknesses, opportunities, and threats of this application.

The strengths of Quiver include its interactive nature, which allows children to see the forms properly, and its ability to improve their understanding of the topic being worked on. This application caters to all types of learners and matches the lifestyle of our learners, which is necessary for the new generation. The AR flashcards turned something as simple as learning letters into an adventure, where learners could manipulate objects and connect them to real-world meanings. The app’s immersive experience made the learning process much more engaging for the children. Additionally, it can be used educationally and entertainingly, and each child's colouring is unique.

On the other hand, some weaknesses of Quiver include its high cost, the need for monitoring by parents when scanning papers, and the inability to make use of other papers. However, there are opportunities for this application, such as its effectiveness in this century, the opportunity for children to be creative with colouring their drawings, and the ability to be used for education and entertainment.

There are also potential threats to Quiver, such as insufficient funding for the purchase of digital devices and the potential harm to health when using digital devices for a long time, which could lead to posture and eyestrain issues.

Despite these challenges, I have noticed that the application of Quiver has had a positive impact on the education of young learners. It has changed the way children acquire knowledge in a creative way and allowed educators to show the real side of a topic. This application is personal, displaying the talents and creativity of our learners and identifying the skills it develops in the child. It is also free and can be accessed by anyone, making it a better way to present a topic to children.

In conclusion, technology has changed the educational system, and the coronavirus crisis has encouraged online teaching and learning. As educators, we must use technology with moderation and be open-minded about its use in education. While Quiver has some limitations, its strengths outweigh its weaknesses, and it has the potential to revolutionise the way we teach and learn.

Teacher 4

Today's lesson was on fruits, and I decided to teach the children a popular nursery rhyme, "Apples and Bananas." I wanted to incorporate the use of Augmented Reality (AR) flashcards to make the lesson more engaging and interactive for the children.

As the children arrived, I arranged the classroom and placed the mat in the centre for them to gather around. Once all the children were seated, I introduced the lesson by showing them the banana and apple flashcards on paper. They were curious and wanted to touch and examine the cards. Then, I turned on the camera on my mobile phone and placed it in front of the flashcards to activate the AR effect.

I could see the excitement and amazement on their faces as they saw the 3D fruit models on the screen. I allowed them to explore the AR tool, ask questions and experiment with it for a few minutes. After that, we began singing the "Apples and Bananas" song.

Initially, I recited the song as a poem, and then I made the children repeat each word after me. I slowly introduced the tune and sang the song phrase by phrase. I could see the children trying their best to remember the lyrics and the tune. We sang the song several times, and towards the end of the lesson, I let the children sing the song by themselves.

The use of AR flashcards was a great success. It made the lesson more exciting, and the children were able to make a stronger connection between the actual and virtual worlds. I also noticed that the children were more engaged in the lesson and communicated more effectively.

One of the strengths of using the AR flashcards was the level of involvement that it created. It allowed us teachers to observe and take notes on how the children were developing their senses. The children were also able to enjoy the singing lesson, as they were fascinated by the AR tool.

In conclusion, I feel that this lesson plan was a success, and I would love to explore more ways of incorporating AR technology into future lessons. The use of AR tools in the classroom is an excellent way to make learning more fun, interactive and engaging for the children.

Teacher 5:

Today's lesson was focused on utilising the Quiver 3D colouring application to teach children about aquatic animals. The main objective of this activity was to help the children understand how to use the application, to use fine motor skills for colouring and to identify different aquatic animals. The activity was designed to engage children in a fun and interactive way, using technology to enhance their learning experience.

Before the lesson began, I printed out the pictures of the aquatic animals from the Quiver app and provided the children with coloured pencils. I then instructed them to colour the pictures while I explained how the application worked. After they had completed colouring their pictures, I showed them how to use the application and brought their pictures to life on the tablet screen.

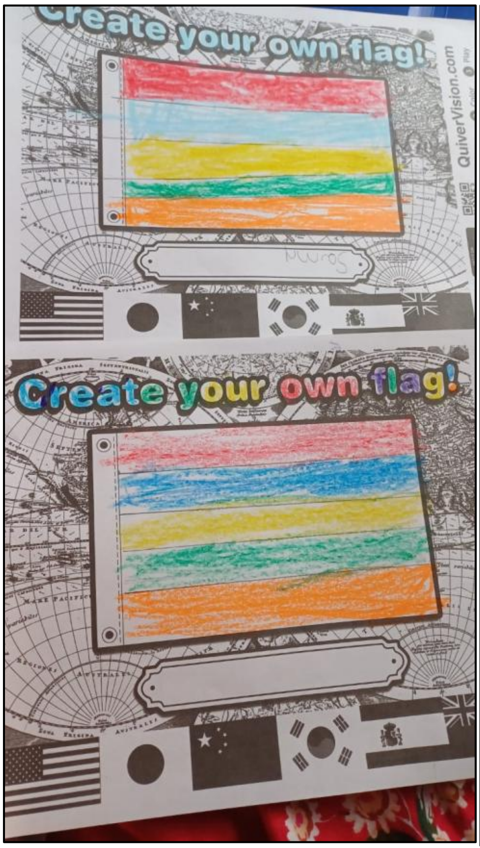
The children were excited and engaged throughout the activity, and they were able to identify the different animals they had coloured. They also used descriptive language to talk about the animals and their behaviour on the screen. The open-ended nature of AR tasks allowed learners to explore their imaginations and present unique perspectives. I was impressed with their creativity and imagination, as they used different colours to make their animals look livelier.

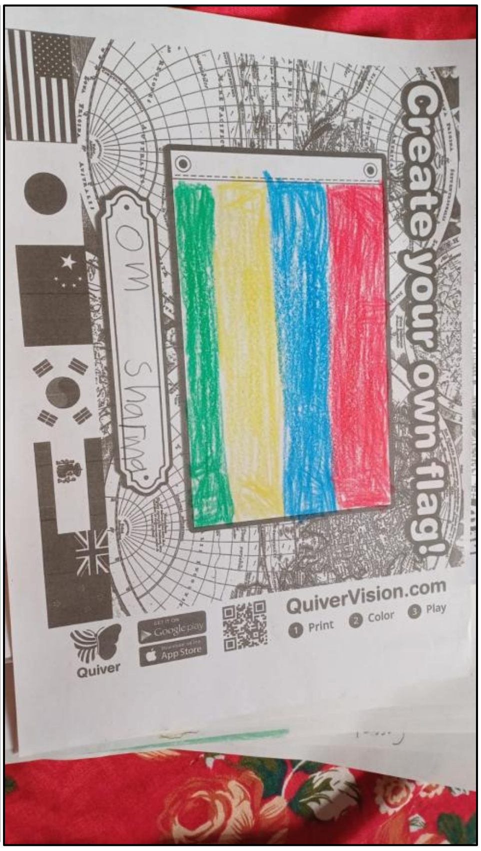
As I observed the children using the application, I noticed that some of them had difficulty understanding how to use it. I gave them extra time and assistance, and they eventually grasped the concept. One learner was scared when they saw the animal, they coloured moving on the tablet screen, but I was able to calm them down and reassure them that it was just an illusion.

In conclusion, the Quiver 3D colouring application proved to be an effective teaching tool that helped to enhance the children's learning experience. It helped to develop their fine motor skills, creativity, and communication skills. The children enjoyed the activity and were motivated to learn more about aquatic animals. I will definitely use this application again in the future and explore other ways to incorporate technology into my lessons.

Appendix D: Colouring Activity

Appendix E: Create Your Own Flag Activity





Appendix F: Examples of Collaboration



Appendix G: Ethical Clearance – Approval Notification

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

19 March 2020

Mr Shoueib Ibne Amine Bunnoo (218081673)
School Of Education
Pietermaritzburg Campus

Dear Mr Bunnoo,

Protocol reference number: HSSREC/00000288/2019
Project title: Learners learning with Augmented Reality (AR) resources.
Degree: PhD

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 16 August 2019 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 19 March 2021.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Urmilla Bob
University Dean of Research

/dd

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

Appendix H: Ethical Clearance – Access in Government Schools in Zone 2

MINISTRY OF EDUCATION AND HUMAN RESOURCES, TERTIARY EDUCATION AND SCIENTIFIC RESEARCH – ZONE 2

Our Ref: Z2/2/123/2016-2019
Your Ref:

Date: 11.07.2019

From: Director, Ministry of Education and Human Resources, Tertiary Education and Scientific Research, Zone 2

To: Bunnoo Mr. Shoueib Ibne Amine, Railway Square, Gopal Street, Riviere des Anguilles.

SUBJECT: REQUEST FOR ACCESS IN PRIMARY GOVERNMENT SCHOOLS IN ZONE 2

Dear Sir,

Further to your letter dated 30 May 2019, approval is herewith conveyed to you to access [redacted] GS, [redacted] GS and [redacted] GS as study sites for your PhD research supervised by the UKZN/MIE.

It is understood that all considerations pertaining to Ethics requirements as per the UKZN Ethics Committee will be observed.

Accordingly, you will have to issue to all participants in the research study, consent forms outlining the research focus and the necessary clauses that address their constitutional rights to privacy and most particularly about video recording of class intervention and observation sessions.

You are kindly advised to meet the Head Masters to discuss about the time line and all other aspects about the research study.

[redacted]
for Director

Copy to: Head Masters

1. [redacted] GS
2. [redacted] GS
3. [redacted] GS

MINISTRY OF EDUCATION & H.R., T.E. & S.R.
PRIMARY INSPECTORATE
* ZONE 2 *

Appendix I: Turnitin Report

Turnitin Originality Report

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LEARNERS' LEARNING WITH AUGMENTED REALITY RESOURCES By Shoueib Ibne Amine Bunnoo 218081673 Supervisor: Prof. D.W. Govender A thesis submitted in fulfilment of the academic requirements for the Degree of Doctor of Philosophy in Computer Science Education, School of Education, College of Humanities University of KwaZulu-Natal, Edgewood campus Durban, South Africa (15November, 2024) i DECLARATION I, Shoueib Ibne Amine BUNNOO, declare that the thesis LEARNERS' LEARNING WITH AUGMENTED REALITY RESOURCES submitted to the University of KwaZulu-Natal, South Africa, for the degree of Doctor of Philosophy in Computer Science Education has not been previously submitted