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University of the Witwatersrand, Johannesburg

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TEACHERS' PERCEPTIONS OF THE USE OF TECHNOLOGY IN MATHEMATICS CLASSROOMS AND HOW IT RELATES TO LEARNER MOTIVATION: AN EXPLANATORY SEQUENTIAL MIXED METHODS STUDY

A thesis submitted to the Wits School of Education,
Faculty of Humanities at the University of the Witwatersrand
in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in
Educational Information and Engineering Technology

— Siyabonga Mhlongo —

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Prof. Reuben Dlamini & Dr. Samuel Khoza

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

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ABSTRACT

The use of digital technologies has significantly influenced all areas of society, with their accelerated adoption driven by their appeal and transformative potential. In education, their integration is viewed as a potential game-changer for the future of teaching and learning, despite mixed successes in the past. A well-functioning education system is the foundation of society, as it embodies the dreams and aspirations of future generations. In South Africa, the National Development Plan (NDP) sets out ambitious educational goals, particularly for mathematics and science, that if achieved, could improve the country's socio-economic prospects. However, the current public basic education system is struggling, and achieving these goals is in doubt. To get back on track, South Africa needs a plan to rescue its education system, and the calculated and intentional use of digital technologies might just be the answer. For such a strategy to succeed, it must be underpinned by a solid understanding of how digital technologies can best support teaching and learning.

To this end, this research study aimed to explore the relationship between digital technology use and learner motivation in the specific context of teaching and learning mathematics within the public basic education system of the Gauteng province of South Africa. The study utilised social constructivist theory as a lens to interpret motivation, identifying observable interest and engagement in learners as manifestations of motivation within the classroom environment.

Situated within the Pragmatic paradigm, this study employed an explanatory sequential mixed methods design. Before the study began, permissions were obtained from institutional gatekeepers to comply with research ethics, and ethical principles were consistently upheld throughout the research process. The study began with a quantitative exploration of teachers' perceptions of the use of technology in teaching and learning mathematics, and how this use relates to the motivation of learners to learn mathematics. Following this, a qualitative phase was conducted to delve into the identified complexities and nuances.

The initial quantitative phase utilised an online survey questionnaire, designed from existing measures, and contextualised for this study. A total of 55 responses were received, of which 23 were valid for analysis. The collected data were explored and analysed using appropriate descriptive and nonparametric statistical techniques. The results indicated that teachers had a generally positive perception of the use of technology in enhancing learner motivation, alongside nuances that merited further investigation.

The qualitative phase involved six teachers who participated in semi-structured interviews. The data generated during this phase were analysed using the reflexive thematic analysis approach, revealing the multifaceted nature of motivation, and the evolving dynamics of technology use in educational settings, through teachers' experiences. The findings also demonstrated how teachers and learners navigate the use of technology in their educational journeys, and how the constantly evolving landscape of technology-enriched education is reshaping classroom dynamics and discourse.

An integrative interpretation of both the quantitative results and qualitative findings provided a more comprehensive understanding of the importance of digital technology usage by teachers and learners, not only within their specific classroom settings, but also in the wider educational landscape. This enabled significant meta-inferences and implications to be drawn. Amongst these is the nuanced understanding of the potential of technology to influence learner motivation, which is dependent on the teachers' ability and proficiency to adeptly navigate a technology-rich educational landscape. In broader terms, these insights offer pragmatic strategies for integrating digital technologies in educational settings, thereby aligning with, and potentially accelerating the achievement of the nation's broader educational goals.

DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Siyabonga Thandazani Mhlongo

13th day of September in the year 2024.

DEDICATION

I dedicate this to you, *Gogo*.

PUBLICATIONS

The following is a list of works published out of (or related to) this research:

Dlamini, R., & Mhlongo, S. (2023, November). Digital education ecosystem to achieve instructional equity and cognitive justice. In F. Maringe & O. Chiramba (Eds.), *Online teaching and learning in the COVID-19 era: Perspectives on equity and epistemic justice* (pp. 25–45). Palgrave Macmillan. https://doi.org/10.1007/978-3-031-42402-1_2

Mhlongo, S., & Dlamini, R. (2022, July). Digital inequities and societal context: Digital transformation as a conduit to achieve social and epistemic justice. In J. Abdelnour-Nocera, E. O. Makori, J. A. Robles-Flores, & C. Bitso (Eds.), *IFIP advances in information and communication technology: Vol. 645. Innovation practices for digital transformation in the Global South* (pp. 1–15). Springer International Publishing. https://doi.org/10.1007/978-3-031-12825-7_1

Mhlongo, S., Dlamini, R., & Khoza, S. (2017, December). A conceptual view of ICT in a socio-constructivist classroom. In *Proceedings annual workshop of the AIS special interest group for ICT in global development (GlobDev 2017)*. AIS Electronic Library (AISeL). https://aisel.aisnet.org/globdev2017/5

Mhlongo, S., Mbatha, K., Ramatsetse, B., & Dlamini, R. (2023). Challenges, opportunities, and prospects of adopting and using smart digital technologies in learning environments: An iterative review. *Heliyon*, *9*(6), e16348. https://doi.org/10.1016/j.heliyon.2023.e16348

Ndlovu, T. N., & Mhlongo, S. (2020, April). An investigation into the effects of gamification on students' situational interest in a learning environment. In A. Cardoso, G. R. Alves, & T. Restivo (Eds.), *2020 IEEE global engineering education conference (EDUCON)* (pp. 1187–1192). IEEE. https://doi.org/10.1109/EDUCON45650.2020.9125264

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LIST OF ACRONYMS

2D	Two-dimensional
3D	Three-dimensional
AECT	Association for Educational Communications and Technology
AES	Agentic Engagement Scale
ANA	Annual National Assessments
ANOVA	Analysis of Variance
CAPS	Curriculum and Assessment Policy Statements
CAQDAS	Computer-assisted (or aided) Qualitative Data Analysis Software
CI	Confidence Interval
CIT	Commission on Instructional Technology
COVID-19	Coronavirus Disease 2019
DBE	Department of Basic Education
FET	Further Education and Training
GDE	Gauteng Department of Education
GET	General Education and Training
HREC	Human Research Ethics Committee
ICT	Information and Communication Technology
ICTs	Information and Communication Technologies (Plural form for ICT)
IIQ	Individual Interest Questionnaire
ILSA	international large-scale assessment
IQR	Interquartile Range
ISiQ	International Situational interest Questionnaire
KR20	Kuder–Richardson Formula 20
LCD	Liquid-crystal Display

NCET	National Council of Educational Technology
NCS	National Curriculum Statement
NCTM	National Council of Teachers of Mathematics
NDP	National Development Plan
NPA	National Protocol for Assessment
NPC	National Planning Commission
NSC	National Senior Certificate
OECD	Organisation for Economic Co-operation and Development
PDF	Portable Document Format
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
SACMEQ	Southern African Consortium for the Measurement of Education Quality
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SASA	South African Schools Act
SDLR	Supplementary Digital Learning Resource
SE	Standard Error
SEACMEQ	Southern and Eastern Africa Consortium for Monitoring Educational Quality
SESQ	Student Engagement in Schools Questionnaire
SIQ	Situational Interest Questionnaire
SIS	Situational Interest Scale
SIS	Situational Interest Survey
SPSS	Statistical Package for the Social Sciences
TAM	Technology Acceptance Model
TERF-N	Teacher Engagement Report Form - New
TIMSS	Trends in International Mathematics and Science Study
TPACK	Technology, Pedagogy, and Content Knowledge
TV	Television
UK	United Kingdom
URL	Uniform Resource Locator
US	United States (of America)
UTAUT	Unified Theory of Acceptance and Use of Technology
Wits	University of the Witwatersrand
ZPD	Zone of Proximal Development

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CHAPTER 1

INTRODUCTION AND BACKGROUND

"We need to embrace technology to make learning more engaging. Because when students are engaged and they are interested, that's where learning takes place." – Anonymous

1.1 BACKGROUND AND CONTEXT

It is an indisputable fact that the field of information technology has seen remarkable growth since the mid-1990s. Whereas the initial years of the modern technology boom were focused on commercialisation, profiting, and growing market share, the major players in the field have matured and have gone on to employ humanitarian-type approaches to bring their technology closer to the people. In an effort to promote inclusive digital access, notable organisations like Microsoft have engaged in collaborations with government ministries across the African continent, specifically targeting schools and local communities (Barbir, 2016). In the same spirit, not-for-profit organisations are actively driving initiatives such as the worldwide *One Laptop per Child* initiative or the *One Child One Tablet* initiative found in countries like Ghana and South Africa. These endeavours mirror the commitment of influential for-profit organisations like Microsoft, underscoring a shared objective of fostering inclusive digital access in schools and local communities. Their collective aim is to empower underprivileged children worldwide through the transformative power of technology and education. Arguably, the underlying focus of all these and similar initiatives lies in cultivating competencies for knowledge creation within collaborative knowledge development environments, with technology serving as a crucial enabler.

In recent years, the use of technology in education has been widely recognised by researchers as a highly effective approach for increasing learner interest and engagement in the learning process. As a result, learners across various educational disciplines have demonstrated improved academic performance and achievement (Eyyam & Yaratan, 2014; Fonseca et al., 2014; Schacter, 1999; Sung et al., 2016; Wenglinsky, 1998; Yang & Wu, 2012). It is not only learners who stand to benefit from technology integration; teachers also gain significantly. While systemic challenges—such as limited access to resources, lack of training, and restrictive curricula—can hinder the effective use of technology in education (Bingimlas, 2009; Buabeng-Andoh, 2012; Fu, 2013; Hew & Brush, 2006), research shows that teachers equipped with the necessary tech-

nological tools and skills can create learning environments where learners not only engage more deeply, but also excel (Ghavifekr & Rosdy, 2015). This is particularly evident in settings where technology is used to tailor educational experiences to learner needs, thereby enhancing the overall quality of teaching and learning. For instance, Blackwell et al. (2013) reiterate that, in many cases, technology has been shown to enhance learning, particularly in early education settings. Similarly, amongst their other findings, Eyyam and Yaratan (2014) found strong correlations between the use of technological interventions in teaching mathematics to seventh-grade learners and improved academic achievement. Additional studies have supported these findings, demonstrating the effectiveness of technology as a tool for teaching specific aspects of mathematics (Bakar et al., 2010; Rajagopal et al., 2015; Verbruggen et al., 2021).

Mathematics is a "key requirement for not only entry into higher education, but also for most modern, knowledge-intensive work" (McCarthy & Oliphant, 2013, p. 3). In a developing country like South Africa, where the advancement of the economy relies heavily on this "modern" and "knowledge-intensive" work, the significance of mathematics cannot be overstated. In recognition of this crucial connection, South Africa has outlined a dedicated set of goals in its NDP[1] specifically aimed at uplifting the standards of mathematics (and science) in the country. Given this context, there is an undeniable consensus that interventions aimed at improving the standard and quality of mathematics education are not only encouraged, but also welcomed as key drivers of progress and opportunity, for both individual advancement and national growth.

One of the key indicators employed by South Africa to monitor its progress towards the attainment of these NDP objectives is its participation in international large-scale assessments (ILSAs) at both regional and global levels. The country's participation in the Trends in International Mathematics and Science Study (TIMSS), the Progress in International Reading Literacy Study (PIRLS), as well as in the Southern African Consortium for the Measurement of Education Quality (SACMEQ) is particularly noteworthy (van der Berg & Gustafsson, 2019). ILSAs play an essential role in facilitating evidence-based decision-making for educational reform, making them one of the most vital tools available to policymakers and other educational stakeholders (Rocher & Hastedt, 2020). By providing comprehensive data on student achievement and related factors on a global scale, ILSAs enable decision-makers to better understand the strengths and weaknesses of their education systems, identify areas in need of improvement, and monitor progress over time. This information can inform a range of policy interventions, including the development of responsive and robust modern curricula, the integration of technology in teaching and learning, as well as teacher training, ultimately leading to improved educational outcomes for learners.

The stark reality is that the data from these ILSAs indicate minimal progress towards attaining the NDP goals (van der Berg & Gustafsson, 2019). This implies that despite the concerted efforts of the government and other stakeholders to modernise and improve education, there is scant evidence of significant improvements in the system.

[1]The South African NDP comprises the documentation of a long-term perspective and a desired destination of the country as set out by the South African government through its National Planning Commission (NPC). It identifies the role different sectors of society need to play in working towards, and reaching the goals as set out in its document. The entirety of the South African NDP can be found online, via the following URL: https://www.gov.za/issues/national-development-plan-2030.

Nonetheless, these ILSAs have served as a critical lens through which significant deficiencies, deficits, and disparities within the South African National Curriculum Statement (NCS) Grades R–12[2] schooling system have been brought to the forefront. A striking example is the analysis of the 2011 TIMSS data, which revealed that "the average South African *Grade 9* [emphasis added] learner is 2 years' learning behind the average *Grade 8* [emphasis added] learner from 21 other middle income countries in mathematics (and 2.8 years behind in science)" (McCarthy & Oliphant, 2013, p. 7). Regrettably, subsequent TIMSS editions have shown little improvement in this regard (Reddy et al., 2016). Furthermore, an integrated analysis of data from these ILSAs illustrates a widening performance gap that emerges early in the schooling system. By the time learners reach Grade 9, the poorest 60% of these learners perform at approximately four grade levels below their wealthiest 20% peers[3] (Spaull & Kotze, 2015; van der Berg, 2015). This performance gap persists throughout the later grades, severely limiting learners' prospects for pursuing higher education and improving their and the country's economic status.

This is further emphasised by Coetzee and Mammen (2017) in their study, which examined entry-level university students enrolled in national diploma programmes in science and engineering, where mathematics is a requirement. The study found that the average score on the administered test, pitched at the Grade 8 mathematics level, was only 47.8%. These findings raise significant concerns about the preparedness of students, and the implications for their future educational and career opportunities.

These alarming data and statistics underscore the urgent need for comprehensive reforms and interventions to address the challenges faced by the South African NCS Grades R–12 schooling system. There is an urgent need to break away from dated models of schooling and start engaging modern tools and methods (including technology) to help improve the outcomes in South Africa's schooling (Dwolatzky & Harris, 2020; Jantjies, 2020; Kayembe & Nel, 2019; McCarthy & Oliphant, 2013; Stols et al., 2015). These efforts ought to focus on improving teaching methodologies, providing equitable resources and support, and implementing innovative strategies to enhance mathematics education at all levels.

The very nature of mathematics is inherently cumulative and hierarchical. This concept is adeptly explained by Pinker (1999, p. 341) in his book, *How the Mind Works*, where he emphasises that:

[2]The NCS Grades R–12 represents a policy statement for learning and teaching in South African schools and comprises: (i) the Curriculum and Assessment Policy Statements (CAPS) for each approved school subject listed in this document; (ii) the national policy pertaining to the programme and promotion requirements of the NCS Grades R–12, which describes the number of subjects to be offered by learners in each grade and the promotion requirements to be obtained; and (iii) the National Protocol for Assessment (NPA) Grades R–12. The purpose, guiding principles, and aim of the NCS are documented online at the following locations: https://www.education.gov.za/Curriculum/NationalCurriculumStatementsGradesR-12.aspx and https://www.education.gov.za/Curriculum/CurriculumAssessmentPolicyStatements(CAPS).aspx.

[3]The South African Department of Basic Education (DBE) stratifies the national public ordinary schools into five quintiles based on financial means. Each quintile represents 20% of the national public ordinary schools, with quintile one representing the poorest 20% of the schools and quintile five representing the richest 20% of the schools. Section 35(1) of the South African Schools Act (SASA), as amended, stipulates that the Minister in the DBE must determine the national quintiles for public ordinary schools on an annual basis (South African Schools Act, 1996).

> Mathematical concepts come from snapping together old concepts in a useful new arrangement. But those old concepts are assemblies of still older concepts. Each subassembly hangs together by the mental rivets called chunking and automaticity: with copious practice, concepts adhere into larger concepts, and sequences of steps are compiled into a single step.

Given this explanation, it is probable that what Spaull and Kotze (2015) and Coetzee and Mammen (2017) found in their respective works is a symptom of failure (or perhaps inability) by learners to "snap together old concepts" into new ones as they progress from grade to grade. As the gap in performance widens, with learners performing several grade levels below the expected grade-level proficiency, they enter what Lewin (2007) refers to as the "Zone of Improbable Progress" (Spaull & Kotze, 2015, p. 21). Once within this zone, learners begin to exhibit signs of despondency, disinterest, and disengagement, resulting in minimal learning despite their participation in an active learning environment. In her book chapter titled *Student Disinterest: Is It Curable?*, Dyck (2004) highlights the disheartening reality of these learners who have, in essence, "check[ed] out" of the learning process (p. 54), and who consequently exhibit a profound lack of interest and engagement. Thus, it is arguable that these behavioural traits exhibited by these learners collectively contribute to the overall poor levels of performance, both on an individual level and within the broader South African NCS Grades R–12 schooling system. In fact, numerous studies have demonstrated that motivation and interest (or the absence thereof) are significant contributing factors that can be closely linked to learners' overall underperformance in the broadest sense, and specifically in the domains of mathematics and physical science (Mabena et al., 2021; Makgato, 2007; Mji & Makgato, 2006; Tsanwani et al., 2014).

From a psychological point of view, motivation is a behavioural trait that is inferred by noting and monitoring a person's behaviour. It encompasses a range of dimensions that can vary depending on the context. In its broadest sense, it refers to the psychological process that initiates, guides, and maintains goal-oriented behaviours. It serves as a driving force that propels individuals towards specific actions or activities, and can originate from internal sources within the individual or external influences from the environment or outside sources. Moreover, motivation encompasses the specific measures undertaken by individuals to attain desired outcomes. From a theoretical perspective, motivation is underpinned by the fundamental concepts of intrinsic and extrinsic motivation (Deci & Ryan, 1985; Lepper et al., 1973; Ryan & Deci, 2000a), which serve as the foundational pillars in major theories of motivation. The central goal of education, according to Hanus and Fox (2015, p. 153), is to get "[learners] motivated to pay attention and engage with [the] material" being taught. To this fact, numerous studies have been undertaken to demonstrate how the integral aspects of intrinsic and extrinsic motivation interplay with other impacting factors in a classroom setup (Borges & de Souza Fleith, 2018; Ciampa, 2014; Cullen & Greene, 2011; Hanus & Fox, 2015; Huang et al., 2019; Xie et al., 2006).

Middleton and Spanias (1999) contend that in the domain of mathematics, unlike in other subjects, motivation, particularly intrinsic motivation, is closely related to learners' perception of their own competence. According to their argument, learners' self-perception of their mathematical abilities plays a pivotal role in their performance. When learners perceive themselves as capable and confident in mathematics, they tend to excel in the subject. Conversely, when

they perceive themselves as lacking proficiency in mathematics, their performance tends to suffer. Nevertheless, there remains a possibility, particularly from the early grades of an education system, to positively influence learners' perception of their competence, thereby triggering their inherent drive to learn mathematics. This can be achieved by implementing thoughtful instructional design and transforming classroom practices to create an environment where "the culture of the classroom can become conducive for learning and enjoying mathematics" (p. 82). Such transformations or modifications can encompass the intentional adoption or strategic implementation of technology in the classroom, as supported by numerous researchers in the field (Blackwell et al., 2013; Good & Lavigne, 2017; Kayembe & Nel, 2019; McCarthy & Oliphant, 2013; Murphy et al., 2019; Musti-Rao, 2016).

When used correctly and appropriately, technology has the power to facilitate social collaboration in ways far beyond what is possible in an ordinary classroom. Ford and Lott (2012) affirmatively state that "integrating the powerful and common tool of technology, collaboration extends beyond the four walls of a classroom to communities around the world" (para. 25). Notwithstanding, technology alone is not the solution to improving education; rather, it requires a reciprocal embrace by its users (Gaver, 1991). Several studies have highlighted the dichotomy in the results and interpretations of the use and effectiveness of technology in classrooms—notably Hu et al. (2018) and Pérez-Sanagustín et al. (2017), with other studies foregrounding some of the prominent factors associated with either the lack of adoption of technology in teaching and learning environments, or the lack of positive outcomes even within environments that have adopted technology in teaching and learning (Blackwell et al., 2013; Livingstone, 2012; Padayachee, 2017; Sherman & Howard, 2012; Stols et al., 2015). Within the South African context, McCarthy and Oliphant (2013) posed a pertinent challenge with respect to how information technology can "be adapted to help improve quality teaching and learning in South Africa's schools" (p. 13).

1.2 Problem Statement

Several iterations of the TIMSS, since it was first administered in South Africa in 1995, have highlighted the problem of poor performance faced by the NCS Grades R–12 South African schooling system, especially in the subject of mathematics (Reddy et al., 2015). South Africa has consistently been ranked at the bottom in mathematics achievement amongst participating countries worldwide (Beaton et al., 1996; Mullis et al., 2000, 2004, 2012, 2016, 2020). In the earlier administrations of the TIMSS, specifically in 1995 and 1999, South Africa participated at the Grade 8 level, consistent with international norms. However, due to the country's overall unsatisfactory performance during those years, South Africa opted to transition to participating at the Grade 9 level. This shift began with dual participation at both Grade 8 and Grade 9 levels in 2003, before eventually leading to exclusive participation at the Grade 9 level for subsequent TIMSS administrations (those of 2011, 2015, and 2019) (Reddy et al., 2015, 2016). Starting in 2015 and in 2019, South Africa also participated at the Grade 5 level, despite international norms suggesting participation at the Grade 4 level.

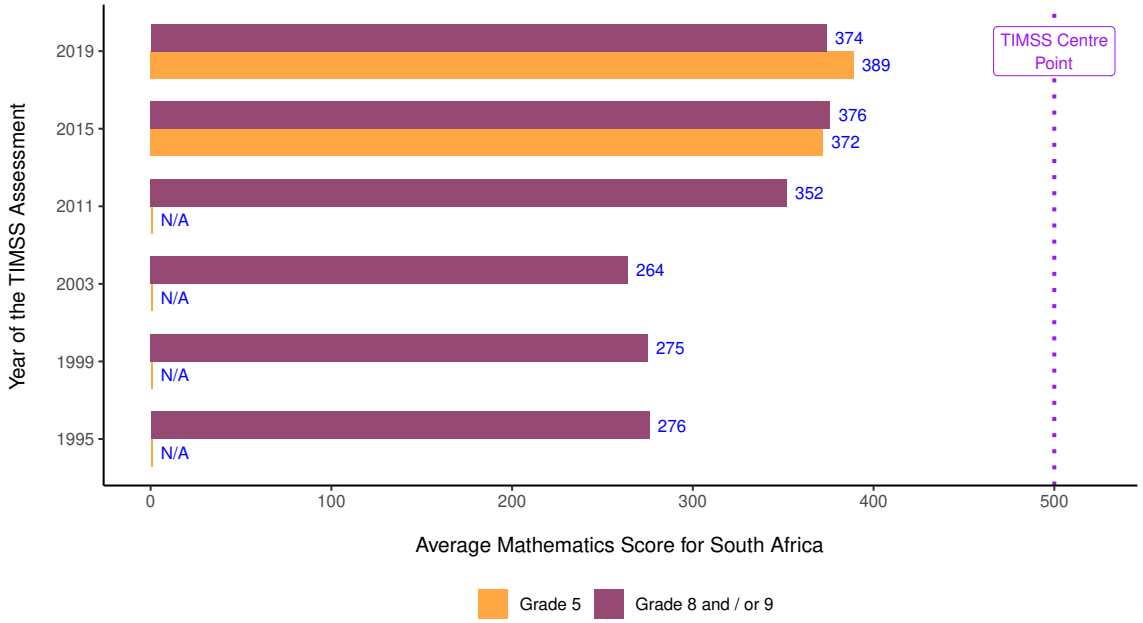
In addition to the outcomes of the TIMSS, outcomes of studies conducted by the SACMEQ[4], as well as those from national assessment programmes like the now obsolete Annual National Assessments (ANA), despite being discontinued for administrative reasons, have also brought to the fore the problem of poor performance by South African learners in mathematics (Bansilal, 2017; van der Berg, 2015; van der Berg & Gustafsson, 2019; S. Johnson, 2017, pp. 30–31). Collectively, these assessments have provided valuable insights into the state of the South African schooling system, particularly in the General Education and Training (GET) phase (Grades R–9).

The transition from the GET phase to the Further Education and Training (FET) phase in the NCS Grades R–12 South African schooling system is of great significance. At the culmination of the GET phase, learners must make subject stream choices that will not only guide them through the FET phase, but also impact their discipline and programme choices at higher education institutions, thus shaping their academic and career pathways. These subject streams are based on either mathematics or mathematical literacy. As mathematics is the foundation of most knowledge-intensive work (both current and future), particularly in fields that contribute to a country's economic development, it is crucial that learners maintain it as a subject of choice throughout their schooling, at the very least. This is especially relevant in the context of South Africa as a developing country.

South Africa's NDP has identified education, training, and innovation as key elements of the country's development, and its Chapter 9 specifically outlines ambitious goals that require collective efforts to be met by 2030. One of these goals is to improve the country's score in the TIMSS to at least 500 points, specifically for Grade 9 participation, which is the centre point of the TIMSS scale (National Planning Commission, 2012, p. 305). To put this goal into perspective, the best score that South Africa has recorded in the TIMSS assessments is 376 (in 2015) at the Grade 9 level, and 389 (in 2019) at the Grade 5 level. To compound the issue, there has been a notable stagnancy in the Grade 9 outcomes in the last three cycles of the TIMSS assessments, as demonstrated in Figure 1.1. Moreover, South Africa's participation in the TIMSS for both grades is at a grade higher than the international norms, as earlier indicated.

Another goal stipulated in Chapter 9 of South Africa's NDP is to have at least $450,000$ learners eligible to enrol for a bachelor's degree programme which has mathematics and science as prerequisites by 2030 (National Planning Commission, 2012, p. 305). To put this number into perspective, it was only in 2021 that the *overall* number of learners achieving a National Senior Certificate (NSC) pass surpassed the $450,000$ mark. In that year, a total of $537,687$ learners achieved an NSC pass, with $256,031$ achieving a bachelor-level pass (Department of Basic Education, 2022). The latest results available, those of 2022, show a slight improvement with a total of $580,555$ learners achieving an NSC pass and $278,814$ achieving a bachelor-level pass (Department of Basic Education, 2023). These and other historical figures are shown in

[4]The SACMEQ, which has evolved to become the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SEACMEQ), currently comprises 16 education ministries from Southern and Eastern Africa. It coordinates and conducts large-scale studies aimed at monitoring and evaluating the conditions of schooling, the performance levels of learners and teachers (specifically focusing on literacy, numeracy, and health at the Grade 6 level), and the quality of basic education across participating countries. Starting in 1995, there have been four completed studies or projects (SACMEQ I–IV), with the fifth (SEACMEQ V) currently in progress. Comprehensive details on these mega studies can be located via the following URL: http://www.sacmeq.org/.



Source: Author.

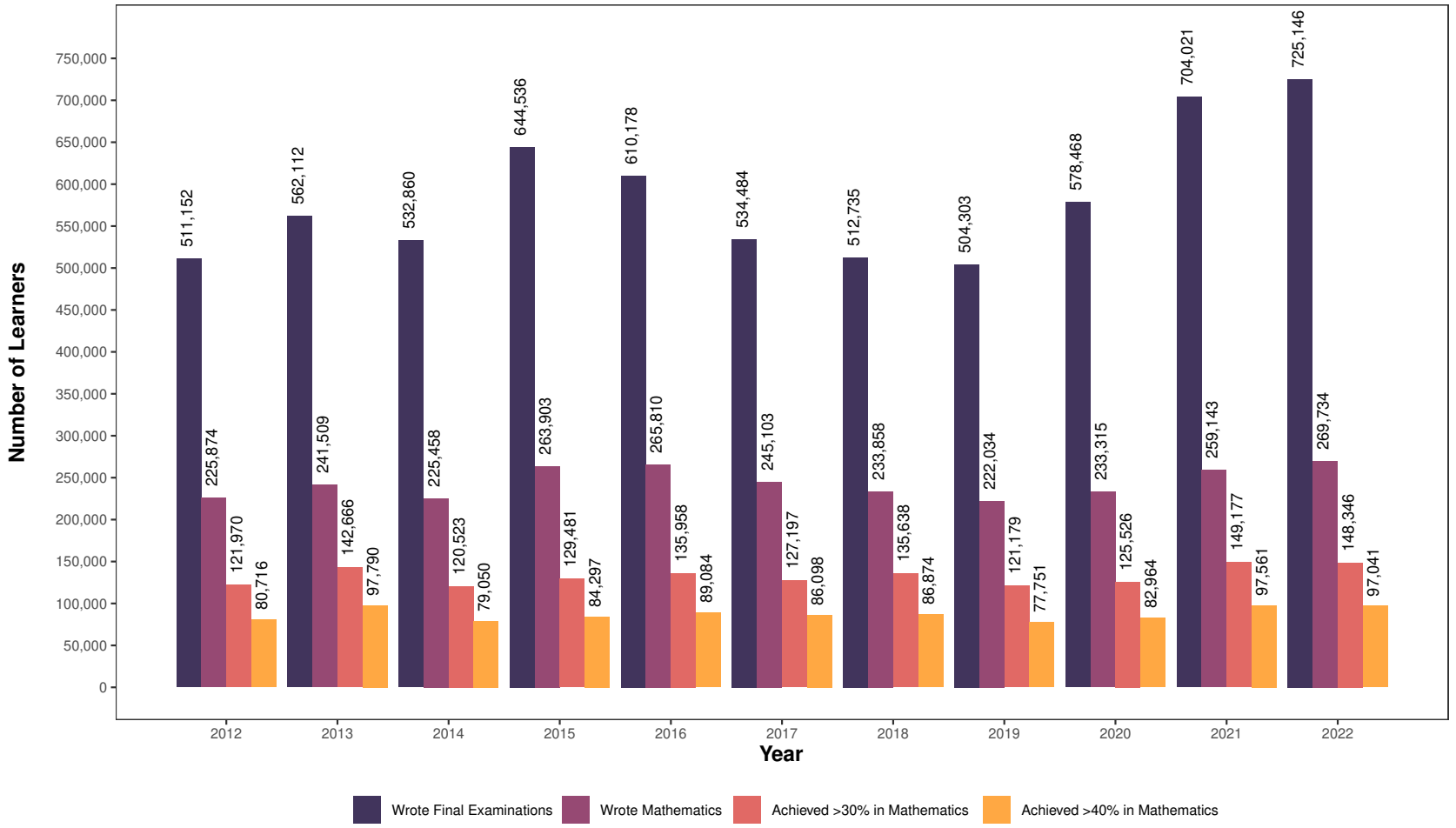
Figure 1.1: South Africa's mathematics performance in all the TIMSS assessments from 1995 to 2019 for participation at both Grade 5 and Grade 8 or 9 levels.

Table 1.1. Focusing exclusively on mathematics performance, the 2022 results further reveal that of the 269, 734 learners who wrote the final mathematics examination (which is the highest

Table 1.1: Performance in the NSC final examinations for the period 2012 to 2022: Total number of learners who wrote the finals, number and percentage of learners who achieved an NSC pass, and number and percentage of learners who achieved a bachelor-level pass.

Year	Wrote	Achieved an NSC Pass		Achieved a Bachelor-level Pass	
		n	%	*n*	%
2012	511, 152	377, 829	73.92	136, 047	26.62
2013	562, 112	439, 779	78.24	171, 755	30.56
2014	532, 860	403, 874	75.79	150, 752	28.29
2015	644, 536	455, 825	70.72	166, 263	25.80
2016	610, 178	442, 672	72.55	162, 374	26.61
2017	534, 484	401, 435	75.11	153, 610	28.74
2018	512, 735	400, 761	78.16	172, 043	33.55
2019	504, 303	409, 906	81.28	186, 058	36.89
2020	578, 468	440, 702	76.18	210, 820	36.44
2021	704, 021	537, 687	76.37	256, 031	36.37
2022	725, 146	580, 555	80.06	278, 814	38.45

Source: Author.



Source: Author.

Figure 1.2: Mathematics performance in the NSC final examinations for the period 2012 to 2022: Total number of learners who wrote the finals, number of learners who wrote mathematics, number of learners who achieved at least 30% in mathematics, and number of learners who achieved at least 40% in mathematics.

number of learners to have written the final mathematics examination since 2012), only $148,346$ and $97,041$ learners achieved a pass mark above 30% and 40% respectively. Figure 1.2 provides a more elaborate illustration of mathematics performance in the NSC final examinations for the period 2012 to 2022. Indeed, it is evident that the current numbers fall short of the targeted $450,000$ learners by a considerable margin, further demonstrating the mathematics performance challenges in the FET phase. Additionally, the relatively small number of learners writing the NSC final mathematics examination could be a consequence of learners having dropped mathematics as they transitioned from the GET phase to the FET phase of the NCS Grades R–12 South African schooling system.

If the poor performance of learners in mathematics persists, and the schooling system fails to encourage learners to continue with mathematics into the FET phase of the schooling system—thereby giving them a real chance at the aforementioned bachelor's degree programme eligibility, South Africa faces the real possibility of never being able to accomplish its 2030 goals. This further implies that its overall aim of the NDP, which is to "eliminate poverty and reduce inequality by 2030" (National Planning Commission, 2012, p. 24), will not be fulfilled.

Despite the significant performance challenges highlighted above, South Africa has made concerted efforts to support the delivery of goals ascribed in the NDP. In 2014, the South African government launched the Operation Phakisa Presidential Programme, based on a successful implementation model from Malaysia, aimed at addressing these goals (RSA Department of Planning, Monitoring and Evaluation, 2014). Subsequently, in 2015, a sub-programme called Operation Phakisa: ICT in Education was unveiled, with the aim of achieving education-specific goals of the NDP. This sub-programme is predominantly based on, and pre-dated by, a 2004 White Paper on e-Education[5]. By its own admission at the launch of this sub-programme, the government (through the President's launch remarks) alluded to the fact that it had "...not taken full advantage and exploited the potential that ICTs can bring in assisting [it] to attain educational outcomes in this country" (The Presidency, 2015, para. 19). By launching this sub-programme, or "national ICT implementation plan" as the Government advocates it to be (The Presidency, 2015, para. 41), and amidst the performance challenges plaguing the Grades R–12 South African schooling system, it is arguable that the Government bets on this implementation plan being the silver bullet for decisively tackling the non-performance problem, while accelerating delivery towards the NDP goals.

Globally, many other countries[6], in much the same way as South Africa has, have proceeded to incorporate ICT in education into their school and curricular policy frameworks, developmen-

[5]In 2004, the South African government issued a landmark legislative document known as the "White Paper on e-Education", which focused on the use of Information and Communication Technologies (ICTs) in the country's education system. This document is the only one of its kind and outlines the government's response to the changing educational landscape that is increasingly reliant on ICTs. The paper is readily accessible online via the following URL: https://www.education.gov.za/Portals/0/Documents/Legislation/White paper/DoE White Paper 7.pdf

[6]The World Bank maintains a working document that serves as a master list of policy documents related to Information and Communication Technology (ICT) / education, as part of its efforts to track the prevalence and evolution of national educational technology policies around the world (Trucano, 2016). This comprehensive list covers all educational levels, with Kuwait's *Kuwait Educational Technology* policy document from 1983 serving as the earliest dated entry.

tal plans, as well as other similar legislative documents, on the premise that the marrying of ICTs and education fosters much-needed improvement and growth in their respective education systems. While the stance taken by these countries as a collective cements the co-existence of ICTs and education in the future, the impact of ICT interventions in education are not yet fully comprehensible (Fernández-Gutiérrez et al., 2020; Mlambo et al., 2020; Timotheou et al., 2022; Tyagi et al., 2020). Indeed, there are pockets of evidence across isolated studies which suggest that within specific boundaries and contexts, ICTs have been found to be impactful (Heflin et al., 2017; Hu et al., 2018; Pérez-Sanagustín et al., 2017; Sung et al., 2016).

In light of the foregoing, the next section outlines the overall purpose of this research study and how this purpose ties back to the problem as outlined in this current section.

1.3 Purpose Statement

The purpose of this sequential mixed methods study was twofold:

- Its primary intent was to adopt a quantitative approach, through the lens of Sivan's (1986) conceptualisation of motivation in a social constructivist setting, to explore teachers' perceptions of learner motivation as it relates to the use of ICTs to teach and learn mathematics. This exploration was conducted through an online survey questionnaire administered to a sample of teachers across all school districts and educational phases of the Gauteng province of South Africa.

- The study's secondary intent was to adopt a qualitative approach to further explore the nuances of learner motivation and the different discourse practices in the use of ICTs in teaching and learning mathematics. This was conducted so as to explain and explicate the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics as uncovered in the quantitative strand of this research study. This qualitative approach adopted semi-structured interviews as a method of inquiry with teachers who volunteered to participate in both the quantitative and qualitative strands of this research study.

Sivan (1986) suggests that in a classroom learning environment, motivation is a socially negotiated process, where all members of the classroom interact during classroom discourse. This process of motivation culminates in observable manifestations of interest, cognitive engagement, and affective engagement in learners, ultimately leading to improved performance in classroom tasks. These manifestations can be observed by all members of the classroom environment, teachers and learners included. However, teachers have the unique advantage of being able to view the entire class dynamically and holistically, drawing on their professional expertise. Their perspectives are crucial as they can identify subtle cues and patterns across different learners that may not be immediately apparent to the learners themselves.

While learners' self-reports of motivation can provide valuable insights into their personal experiences regarding their interests and levels of engagement, teachers' perceptions offer a unique vantage point that encompasses the entire classroom. Teachers are positioned to observe a broad range of behaviours and interactions, allowing them to identify patterns and gauge overall motivation across different contexts. Furthermore, as highlighted by Hardré et al. (2008), instru-

ments assessing teachers' perceptions of learner motivation not only capture observable learner behaviours, but also serve as critical tools for teachers' self-reflection and self-regulation. Understanding these perceptions is crucial because they directly influence the strategies teachers adopt and their efforts to enhance motivation, ultimately affecting learning outcomes (Bernaus & Gardner, 2008; Hardré et al., 2006; Ratminingsih et al., 2018). Thus, this study focused on teachers' perceptions to leverage their comprehensive understanding of classroom dynamics, providing a broader and potentially more actionable perspective on learner motivation that can inform effective educational practices.

The problem statement highlights that learner performance in mathematics is currently a challenge faced by the South African schooling system, which puts the goals of the NDP at risk. Taking a multifaceted approach that considers various factors, such as the use of ICTs in the classroom learning environment and the subsequent influence of this usage on learner motivation, can contribute to a deeper understanding of the problem and inform effective strategies for addressing it. Motivation is hypothesised to be a crucial factor in this context because, as numerous studies have shown, the presence or absence of motivation significantly influences learner performance, particularly in mathematics and physical science. By enhancing motivation through targeted interventions, such as the effective incorporation of ICTs, it may be possible to improve interest, engagement, and, consequently, achievement in these subjects, thereby aligning with the NDP's educational objectives.

1.4 Research Questions

Research questions serve to narrow the purpose statement into more focused questions to be answered in a research study (Creswell, 2014; Creswell & Plano Clark, 2017). In formulating research questions for a sequential mixed methods study, Creswell (2014) and Creswell and Plano Clark (2017) advise that it is necessary to explicitly include quantitative, qualitative, and mixed methods questions in the process.

Pursuant to the purpose of this research study as expressed in the preceding section, and in line with the above approach for presenting research questions for a mixed methods study, the following subsections expound the research questions that guided this research study.

1.4.1 Quantitative Research Questions

The quantitative phase of this research study comprised the following three main research questions:

RQ_{1a} – What is the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics, as observed by teachers in their classrooms?

RQ_{1b} – Are there any differences in the way in which teachers from different school districts observe motivation traits in their classrooms when ICTs are used in teaching and learning mathematics?

RQ_{1c} – Are there any differences in the way in which teachers from different educational phases observe motivation traits in their classrooms when ICTs are used in teaching and learning mathematics?

1.4.2 Qualitative Research Questions

The qualitative phase of this research study comprised the following main research question:

RQ_{2a} – What might explain the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics, as observed by teachers in their classrooms?

In addition to the main qualitative research question, the following qualitative research questions formed part of the qualitative phase of this research study:

RQ_{2b} – How do teachers describe a motivated learner?

RQ_{2c} – What is the perceived use of ICTs in teaching mathematics in the classroom?

RQ_{2d} – What is the perceived use of ICTs in learning mathematics in the classroom?

The purpose of these additional research questions was to solicit the teachers' contextual explanation and understanding of the terms "use of ICTs" and "motivation". Collectively, this was to establish the extent to which these terms were perceived to mean the same thing to the participants of both the quantitative phase and the qualitative phase of this research study.

1.4.3 Mixed Methods Research Questions

In the context of conducting mixed methods research, Creswell (2014) and Creswell and Plano Clark (2017) emphasise the importance of incorporating mixed methods research questions. These research questions serve as a distinct type of question that not only highlights and specifies the integration of quantitative and qualitative phases in the study, but also act as a hallmark or signature of the mixed methods approach. In this research study, three mixed methods research questions guided the mixing or connecting of the quantitative and qualitative phases. These research questions were:

RQ_{3a} – To what extent and in what ways do the findings of the qualitative phase of this research study assist with explaining and understanding the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics, as observed by teachers in their classrooms?

RQ_{3b} – What insights can be drawn from the relationship between the use of ICTs in teaching mathematics and the motivation of learners to learn mathematics, as observed by teachers in their classrooms?

RQ_{3c} – What insights can be drawn from the relationship between the use of ICTs in learning mathematics and the motivation of learners to learn mathematics, as observed by teachers in their classrooms?

1.5 RESEARCH SIGNIFICANCE

This research study makes a significant contribution to the literature in terms of its methodological rigour, practical applicability, and scholarly relevance. The following subsections provide detailed elaboration on these significant contributions.

1.5.1 Methodological Significance

This research study advances the use and applicability of mixed methods approaches, both in a general context and specifically in the use of ICTs in classroom environments, within the unique cultural and developmental context of South Africa as a developing country. Adopting an explanatory design enabled an in-depth investigation aimed at better understanding the interplay and relationships amongst various variables associated with the use of ICTs in classroom environments and the motivation of learners to learn, and allows for the adoption and integration of diverse methods to effectively support the generated insights. Restricting the research approach to either quantitative or qualitative would yield partial insights, insufficient to comprehensively investigate the problem presented in this research study.

A key aspect of employing a mixed methods approach is the cohesive connection and integration of quantitative and qualitative strands within the chosen research design. As noted by Hands (2022), the literature has documented the scarcity of integration examples in mixed methods research, emphasising the need for research studies considering the use of mixed methods to explicitly include integration approaches in order to make meaningful contributions to the methodological canon. The integrated analysis presented in Chapter 7 serves as a direct response to this call for action.

1.5.2 Practical Significance

From a practical perspective, this research study provides a candid account of the various practices employed in utilising ICT as a teaching and learning tool in mathematics classrooms under investigation, according to the data obtained from the participants. Furthermore, it provides insights into the relationship between the use of ICTs and the motivation of the learners to learn mathematics. These findings have implications for how ICTs can facilitate learner interest and engagement in mathematics throughout their foundational education, promote interactivity amongst learners, content, and teachers, and foster desired behavioural traits in the classroom setting.

Moreover, in line with the problem statement elucidated in Section 1.2, this research study adds a significant dimension to the understanding of the practicality of South Africa's government's aspirations for its "national ICT implementation plan" to contribute towards its 2030 NDP goals.

1.5.3 Scholarly Significance

The debate surrounding the utility of ICTs in the classroom has been a prominent topic of discussion over the past few decades. As ICTs have advanced and become more prevalent in educational settings, the debate has evolved from a simple question of whether or not to adopt ICTs in pedagogical practices, to a focus on theory-driven efforts aimed at understanding how to effectively integrate and model these technologies as classroom norms, and the true value they bring to teaching and learning. In line with this, the present research study employs a socio-constructivist lens to comprehensively explore and analyse the use of ICTs in a classroom setup. The choice of this theoretical perspective was influenced by arguments put forth by researchers that an effective way to integrate and model technology in the teaching and learning process is through a constructivist approach (Dede, 1995; Doolittle & Hicks, 2003; Feyzi Behnagh & Yasrebi, 2020; Ford & Lott, 2012; Papert, 1993; Reid-Martinez & Grooms, 2021; Rieber, 1996). Moreover, the study operationalises the conceptualisation of motivation within the framework of social constructivist theory (Sivan, 1986), and extends it to incorporate additional elements that reflect disciplinary advancements, thereby enhancing the applicability of this conceptualisation. The study also provides in-depth insights into the socio-psychological and practical uses of ICTs in classroom discourse.

In sum, this research study contributes to the ongoing global dialogue around the usefulness, or lack thereof, of ICTs in the classroom, particularly from the perspective of a developing country. Its purpose was driven by the need to further explore how technology interplays with education, shedding light on both its beneficial aspects and its potential drawbacks. By doing so, this study provides valuable insights into how the positive aspects of technology can be leveraged, and how any potential challenges might be addressed and mitigated.

1.6 Research Delimitations, Limitations, and Assumptions

In order to provide a more focused and comprehensive understanding of the research study, it is essential to define its delimitations, acknowledge its limitations, and highlight the assumptions that shaped the research process and its outcomes (Creswell, 2014; Creswell & Plano Clark, 2017; Leedy & Ormrod, 2020; Simon & Goes, 2017). These aspects help define the boundaries and scope of the study, providing a clearer understanding of its context and potential implications, thereby augmenting the research purpose and research questions already defined. The following subsections delve into these elements.

1.6.1 Delimitations

Delimitations serve the purpose of defining and narrowing the scope of a research study, outlining its boundaries and specifying the aspects within the researcher's control (Creswell, 2014). In this particular research study, two key delimitations were identified.

The first delimitation involved confining the research to the Gauteng province of South Africa, with a specific focus on the jurisdiction of the Gauteng Department of Education (GDE), the provincial government body responsible for public primary and secondary education in Gauteng. Consequently, this research inquiry did not encompass private or independent primary and secondary education institutions, nor did it extend to public schools outside the province.

This geographic delimitation restricted the sample's range and affected the generalisability of the quantitative results as well as the transferability of the qualitative findings. Expanding the research to include other provinces in South Africa would enhance the overall applicability of the results. Additionally, by solely focusing on the public primary and secondary schooling system, the findings may not be readily generalisable or transferable to the context of private or independent schools.

The second delimitation of this study is centred around a specific population: teachers within the provincial schooling system who actively incorporate technology in their mathematics classrooms. This delimitation is grounded in the recognition of the essential role that the integration of technology in the South African schooling system can play, and the critical emphasis on mathematics education as a basis for achieving national developmental goals, as discussed in earlier sections of this chapter. By narrowing the focus to teachers who utilise technology in mathematics instruction, the study aims to delve deeper into their experiences, practices, and the influence of technology on teaching and learning.

It is important to clarify that this research study primarily focused on the relationship between the use of ICTs, as perceived by the sample of teachers, and learner motivation in the context of learning mathematics. The study did not delve into the intricate details of mathematics learning or the specific integration of ICTs into classroom pedagogy.

1.6.2 **Limitations**

The limitations of a research study highlight potential weaknesses arising from theoretical, methodological, or practical constraints encountered during the research process (Simon & Goes, 2017). While delimitations define the boundaries set by the researcher, limitations often lie outside the researcher's control. In the case of this research study, several limitations were identified, some of which arose from the chosen core mixed methods research design, namely the explanatory sequential mixed methods design (Creswell, 2014; Creswell & Plano Clark, 2017).

Firstly, the sequential nature of mixed methods studies often leads to longer durations compared to monomethod approaches. In this research study, the two distinct sequential data collection stages, one during the quantitative phase and another during the qualitative phase, required additional time, as the second stage relied on the outcomes of the first. This sequential process necessitated the identification of separate samples for each data collection stage, potentially introducing challenges in sample selection and management.

Secondly, the geographic delimitation of the study to the Gauteng province of South Africa and the jurisdiction of the GDE influenced on both the sampling strategies and sample sizes of the two phases of this research study, making it susceptible to potential judgement errors and selection bias (Mertens, 2023; Palinkas et al., 2013; Teddlie & Yu, 2007). This has further implications for the generalisability of the results and the transferability of the findings.

Additionally, the analysis methods chosen for this study, which inherently have scientific limitations, had to be carefully considered in relation to the research purpose, research questions, and sample sizes. It is important to note that the reliance on self-reported experiences of the

participating sample for certain statistical measures had the potential to introduce subjectivity and recall bias.

Lastly, an overarching limitation encountered during the study was the impact of the coronavirus disease 2019 (COVID-19) pandemic. The pandemic had adverse effects on the data collection and generation stages from both the researcher and participant perspectives. This unforeseen circumstance introduced limitations in terms of access, availability, and the ability to gather data in the desired manner. Despite adapting research procedures to accommodate remote data collection and virtual interactions, the limitations imposed by the pandemic may have influenced the study's outcomes and should be taken into consideration when interpreting the outcomes.

1.6.3 **Assumptions**

In a research study, assumptions play a vital role as they represent unverifiable facts that the researcher considers to be true. These assumptions are taken for granted and establish the foundational conditions necessary for the research study to retain its purpose (Leedy & Ormrod, 2020; Simon & Goes, 2017). In this particular research study, various types of assumptions were recognised, including those related to theoretical underpinnings, philosophical orientation, and the research methods employed.

Theoretical assumptions in this study were grounded in the conceptualisation of motivation in a socio-constructivist context, as stated by Sivan (1986) and discussed in detail in the first part of the third chapter of this thesis.

Furthermore, this research study aligned with the philosophical assumptions of the Pragmatism paradigm, encompassing epistemological assumptions about the nature of knowledge, ontological assumptions about the nature of reality, axiological assumptions about ethical behaviour, values, attitudes, and biases, and methodological assumptions about the most effective approaches for inquiry. These philosophical assumptions are elaborated upon in the second part of the third chapter of this thesis.

One significant assumption, concerning the methodological approach, pertained to the data collection and generation methods. It was assumed that the participants would respond with accuracy, honesty, truthfulness, and a thorough understanding of the survey questionnaire and interview questions. Additionally, it was assumed that the researcher approached the study with academic rigour, maintaining objectivity and subjectivity in the quantitative and qualitative aspects, respectively, especially in relation to the chosen analysis methods.

1.7 **Structure of the Thesis**

This thesis document consists of eight chapters and an appendix, structured in accordance with the guidelines set forth by Creswell and Plano Clark (2017) for presenting a mixed methods study effectively, and tailored to fit the adopted research design. The following subsections provide a concise summary and overview of the contents of each chapter.

1.7.1 Chapter One: Introduction and Background

The first chapter of this thesis establishes the background and context for this research study. On the one hand, it highlights the emergence of and opportunities arising from the use of ICTs in classroom settings, while on the other hand, it sheds light on the challenges faced by the South African schooling system. This sets the stage for presenting the research problem, research purpose, and research questions that guided this research study. Additionally, the chapter emphasises the significant contributions of this research study in terms of methodological rigour, practical applicability, and scholarly relevance. Furthermore, it outlines the delimitations, limitations encountered, and underlying assumptions that shaped this research study. Lastly, it presents a structural overview of the thesis.

1.7.2 Chapter Two: Literature Review

The second chapter of this thesis presents a comprehensive literature review, aiming to strengthen the rationale of this research study by examining prior research relevant to the subject matter. This chapter serves two main purposes: firstly, to bring attention to key issues and concepts related to this research study, and secondly, to establish meaningful connections amongst these concepts in alignment with the problem statement, purpose statement, and research questions introduced earlier. The chapter begins by providing a broad overview of technology in educational settings, both globally and within the local context. It then narrows its focus to the use of technology specifically for teaching and learning mathematics. By the end of the chapter, key insights from the reviewed literature are synthesised, setting the stage for the subsequent exploration of how these insights intersect with the concept of motivation, which is further examined in the third chapter of this thesis.

1.7.3 Chapter Three: Theoretical and Philosophical Underpinnings

The third chapter of this thesis provides an in-depth exploration of the theoretical and philosophical foundations that formed the foundation of this research study. The chapter begins by providing an overview of constructivism theory and argues for the relevance of social constructivism as the theoretical lens that guided this research. It further explores motivation theories and their applicability in the context of technology and education, and specifically draws focus on how motivation was framed and measured within this research study. Shifting to philosophical underpinnings, the chapter explores the concept of a paradigm and its fundamental beliefs, followed by an examination of dominant research paradigms in education. The chosen paradigm and philosophical assumptions are then justified in light of the problem statement, purpose statement, and research questions. Finally, the chapter concludes with a concise summary of its key points.

1.7.4 Chapter Four: Research Methodology and Design

Chapter four of this thesis delves into the methodological and design considerations that guided this research study. It begins by highlighting the significance of methodology within the chosen research paradigm and its role in providing a systematic framework to address the research questions effectively. The chapter explores different methodological approaches documented in literature and argues for the appropriateness of the mixed methods approach in this particular

research study. It then introduces the principal designs within the mixed methods research approach, and subsequently justifies the chosen design—the explanatory sequential mixed methods research design. Specific to this design, the chapter further outlines the design procedures, the integration of data sets, the rationale behind its adoption, the priority of the research methods, its strengths, and its challenges. The core of this chapter is in its in-depth argument on the research methods that this study employed, encompassing sampling strategies, data collection methods, and data analysis and interpretation techniques. These methods are contextualised within the problem statement, purpose statement, and research questions to establish their alignment with the overall research objectives. Finally, the chapter concludes with a concise summary of its key points.

1.7.5 **Chapter Five: Quantitative Results**

Chapter five of this thesis presents the results derived from the quantitative phase of the research study, which aimed to examine the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics. The chapter starts off by providing an overview of the participants who were involved in this phase, offering insights into their characteristics and representation. Subsequently, it presents comprehensive results obtained from the administration of the six subscales measuring various dimensions of motivation. The presentation begins with a focus on the interest dimensions of motivation, followed by a shift in focus towards the engagement dimensions of motivation. Furthermore, the chapter includes an integrated analysis of the entire set of results, identifying specific findings that warranted further exploration in the qualitative phase of the study. These findings hold significance in understanding and explaining the relationship between ICT use in mathematics education and learners' motivation. Finally, the chapter concludes with a succinct summary, summarising the key outcomes of the quantitative phase.

1.7.6 **Chapter Six: Qualitative Findings**

The sixth chapter of this thesis shifts to the findings from the qualitative phase, which aimed to explore learner motivation nuances and discourse practices surrounding the use of ICTs in the context of mathematics education. This chapter takes its cue from the quantitative phase results, probing deeper into how the use of ICTs in teaching and learning mathematics influences learners' motivation to learn mathematics. It begins with an overview of the participants involved in this phase, outlines the conventions and nomenclature used for presenting the findings, and provides a structural overview of the chapter. The core of the chapter is dedicated to presenting thematic findings derived from the reflexive thematic analysis method, which are systematically organised into five distinct sections. The penultimate section offers a preliminary contextualisation of these findings, specifically focusing on their relation to the guiding research questions of this phase. This section, along with the chapter's final section—which summarises the key findings of the qualitative phase—establishes a foundation for the comprehensive discussion and interpretation of both the quantitative results and qualitative findings in the subsequent chapter.

1.7.7 **Chapter Seven: Discussion and Interpretation**

In the seventh chapter of this thesis, an integrative discussion and interpretation of the quantitative results and qualitative findings from the previous two chapters are presented. The primary

objective of this chapter is to establish meaningful connections between the research outcomes, the problem statement, purpose statement, and research questions, while also drawing connections to the existing relevant literature. By synthesising the quantitative and qualitative data, this chapter offers a cohesive analysis that provides a deeper understanding of the research outcomes. The discussion and interpretation presented in this chapter consolidate the implications of the study's outcomes, shedding light on their significance within the broader research context. Furthermore, a concise summary of the key insights derived from the analysis is provided, paving the way for the final chapter of this thesis.

1.7.8 **Chapter Eight: Conclusion**

The final chapter of this thesis draws upon the integrated interpretation of the quantitative results and qualitative findings to present conclusive statements, all in the context of addressing the research questions. In addition to the conclusions, this chapter provides important recommendations that can guide governmental and non-governmental agencies, policymakers, and other key stakeholders in harnessing the potential of ICTs in educational settings, highlighting the potential benefits and opportunities they offer. Moreover, the chapter reflects on the strengths and limitations of this research study, while identifying potential avenues for future inquiry and exploration. By summarising the key findings, implications, and potential areas of further investigation, this chapter serves as a holistic conclusion to this research study.

1.7.9 **Appendix**

The appendix chapter of this thesis serves as a comprehensive documentation and explanatory section, providing essential supplementary materials to enhance the content presented in the main body of the thesis. It is organised into five distinct sections, each serving a specific purpose. The first three sections focus on the ethical considerations that were integral to the research study. The first section includes institutional approvals and certificates obtained to ensure adherence to ethical guidelines. The second section consists of research permission letters and relevant forms that were necessary to seek permissions from institutional gatekeepers. The third section comprises information sheets and consent forms that were used to inform participants and obtain their consent to participate in the study. Moving forward, the fourth section of the appendix chapter contains the research instruments employed in both the qualitative and quantitative phases of the research study. Lastly, the fifth section of the appendix chapter presents extended details and statistical tables that supplement and augment the results presented in Chapter 5 of this thesis. These additional materials offer comprehensive information and statistical analysis, providing further insights to support the results and findings discussed in the main body of this thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

2.1.1 Chapter Purpose

The preceding chapter introduced the research study, providing background and foundational context for the problem under investigation. This introduction led to the articulation of both the problem statement and the purpose statement, as well as the derivation of research questions from these foundational statements, which guided this inquiry. The purpose of this chapter is to examine the key concepts identified in the foundational statements by dividing them into distinct areas of focus, and exploring pertinent literature for each. This exploration adheres to the guidelines set forth by Cooper (2017), as detailed in the subsequent subsection.

2.1.2 Approach to the Review of Literature

According to Cooper (2017), a literature review serves multiple purposes, including: (i) the integration of existing research through comparison and contrast; (ii) the critique of previous scholarly works; (iii) the establishment of connections between related topic areas; and (iv) the identification of central issues within a field. Creswell (2014) supports this perspective, emphasising that the literature review in a mixed methods study should be conducted in a manner that aligns with the research design, in the process illuminating key concepts relevant to the research. He further notes the challenges posed by a sequential design, such as potential alignment issues between quantitative and qualitative phases, and highlights the importance of a pragmatic and reflexive approach throughout the research process. This process, characterised by continuous reflection and adaptation, evolves alongside the research, aiming to achieve a comprehensive understanding of the literature in relation to the research purpose and questions, as underscored by Teddlie and Yu (2007).

In the context of this research study, the literature review primarily aims to achieve the third goal outlined by Cooper (2017)—building bridges between related topic areas. This endeavour focuses on four central concepts: (i) the generic use of technology in learning environments; (ii) its specific use in teaching and learning mathematics; (iii) the theoretical underpinnings of teaching and learning with technology; and (iv) the motivational dynamics that influence

learning in technology-enhanced environments. This chapter addresses the first three concepts. Discussions related to learner motivation in technological settings are reserved for exploration within the context of the study's theoretical and philosophical underpinnings in the subsequent chapter.

2.1.3 Chapter Outline and Organisation

The remainder of this chapter, beginning with Section 2.2, addresses the prevalence of technology in learning environments. It defines educational technology and discusses how it is reportedly used to facilitate learning. Section 2.3 then focuses specifically on the role of technology in the teaching and learning of mathematics. Following this, Section 2.4 examines the theoretical aspects of using technology in educational contexts, thereby setting the stage for a detailed discussion on the theoretical and philosophical underpinnings of this study in the subsequent chapter. The chapter concludes with Section 2.5, providing a summary that encapsulates the key insights from the literature review, and their relevance to the study's foundational statements.

2.2 Technology in Learning Environments

2.2.1 Defining Educational Technology

Technology in learning environments (or educational ICT, or ICTs in the classroom, or just simply, educational technology) goes by several labels that mean different things within different schools of thought. In a book chapter aptly entitled *What Field Did You Say You Were In?*, Resier (2017) tracks the definition of educational technology from its apparent roots in the early 1900s with the advent of educational film. What followed thereafter was a series of definitions, predominantly by the Association for Educational Communications and Technology (AECT) and the Commission on Instructional Technology (CIT), both from the US, that likened educational technology to a process, with one such definition defining it as a "complex, *integrated process* [emphasis added] involving people, procedures, ideas, devices, and organization, for analysing problems and devising, implementing, evaluating, and managing solutions to those problems, involved in all aspects of human learning" (AECT Task Force on Definition and Terminology, 1977, as cited in Resier, 2017, p. 3).

Over the years, other researchers and organisations have also contributed to the definition soup of what educational technology is. The then National Council of Educational Technology (NCET) in the UK defined it as "the development, application and evaluation of systems, techniques and aids to improve the process of human learning" (as cited in Wilkes, 1978, p. 79); while Unwin (1969) asserted that it "is concerned with the application of modern skills and techniques to requirements of education and training" and further elaborated that "this includes the facilitation of learning by manipulation of media and methods, and the control of environment insofar as this reflects on learning" (as cited in Aggarwal, 2014, p. 5). All these (and other) definitions of educational technology are powerful and intricate in their own right, but there is a strand of similarity in them. They all emphasise the primary purpose of incorporating technology in educational environments, which is to facilitate the learning process. This emphasis is the primary strand of this research study. Further exploring the specific characteristics of technology that enable it to facilitate the learning process, the next subsection provides a

detailed examination of these aspects.

2.2.2 Using Technology to Facilitate Learning

The unprecedented growth and innovation concerning the development of ICTs for various applications across numerous disciplines has provided a range of possibilities that can be explored as a result of incorporating ICTs in the learning (and teaching) process (Wilson & Boldeman, 2012). Not only have ICTs become more affordable to deploy in classrooms, they have also become more intuitive to use in progressive ways (Hu et al., 2018). This has opened doors for researchers to explore the usefulness—or otherwise—of their existence in learning environments, and over time, researchers have conceptualised frameworks that assist in facilitating and understanding the mutual relationship between ICT and its uses. For instance, Conole and Dyke (2004a) conceptualised a generic taxonomy of ICT affordances comprising ten[1] key aspects or characteristics to consider with the use of ICTs. They clarified that by affordance they meant the relationship between the infrastructure of ICT and the people's use of this infrastructure, specifically: "what uses ICT invites and facilitates, what it lends itself to and what it can do well" (Conole & Dyke, 2004a; Conole & Dyke, 2004b, p. 301). The prevalence and application of frameworks such as the technology acceptance model (TAM) (Davis, 1989; Davis et al., 1989), the unified theory of acceptance and use of technology (UTAUT) and its successor UTAUT2 (Venkatesh et al., 2003, 2012), and the technology, pedagogy, and content knowledge (TPACK) framework (Koehler & Mishra, 2009; Mishra & Koehler, 2007) closely align with the concept of technology affordances. TAM emphasises how the affordances of ICT—specifically its perceived usefulness and ease of use—shape user acceptance and adoption. UTAUT (and UTAUT2) build on this by considering broader factors such as social influence and facilitating conditions, which are influenced by the affordances perceived by users in specific contexts. Meanwhile, TPACK highlights how teachers can harness the affordances of technology to effectively integrate it with pedagogy and content, tailoring educational experiences to learner needs.

Other research efforts have explored the notion of ICT affordances from another angle, opting to look instead at the possibilities of the use of ICTs as perceived by individuals (Haines, 2017; Lloyd, 2018). In this instance, Haines (2017) explored the idea of ICT affordances for teaching and learning in a classroom environment from the point of view of both the learner and the teacher. From a similar point of view, Lloyd (2018) asserted firmly that "affordances are not static or fixed within a technology but are rather how an individual imagines a technology's use and how this is enacted in differing settings" (p. 37). She qualified this view by further stating that "[t]here is an idiosyncracy to the identification and use of the affordances of a technology particularly in educational settings" (p. 37).

From a historical perspective, the different approaches to viewing ICT affordances stem from the works of James Jerome Gibson (whose works advocate for *actual* properties of an artefact that suggest its uses) and Donald Arthur Norman (whose works advocate for *perceived*

[1]The ten aspects of the taxonomy of ICT affordances as conceptualised by Conole and Dyke (2004a, pp. 116–120) are: (i) "accessibility"; (ii) "speed of change"; (iii) "diversity"; (iv) "communication and collaboration"; (v) "reflection"; (vi) "multimodal and non-linear"; (vii) "risk, fragility and uncertainty"; (viii) "immediacy"; (ix) "monopolization"; and (x) "surveillance".

properties of an artefact that suggest its uses) on the notion of affordance, which in themselves reflect different ontological assumptions (Gibson, 1979; K. S. Jones, 2003; Norman, 1988, 1999, 2013). In the context of this research study, both the actual and perceived uses of ICTs in the teaching and learning processes in mathematics classrooms were of fundamental interest in pursuit of the study's foundational statements and research questions.

Mao (2014) qualifies that technology affordances can also be "economic, social, cognitive, or affective" (p. 214). This sets up a platform of inquiry to explore how the use of ICTs, through its actual or perceived affordances, relates to the socio-psychological and behavioural traits (grouped under the umbrella of motivation) in a socio-cultural setting of a classroom. This social setting, together with the culture, experience, as well as intentions of the teachers and learners, become some of the determining factors in the realisation of these technology affordances (Gaver, 1991). Collectively, this interplay again aligns with the foundational statements and research questions of this research study. Sections 3.2.3 and 3.2.4 delve into the properties of motivation that were of interest in this research study, while the next subsection draws focus to the existence of ICTs in classrooms from a global point of view.

2.2.3 A Global Snapshot of ICTs in the Classroom

Several studies emerging from the educational technology research community have been instrumental in highlighting the advances in the diffusion of ICTs into classrooms worldwide, while also painting a vivid picture of the benefits, challenges, and other general implications that surface as more classrooms globally become technology-enabled (Fu, 2013; Hu et al., 2018; Livingstone, 2012; Pérez-Sanagustín et al., 2017; Somekh, 2008). Notably, Pérez-Sanagustín et al. (2017) conducted a review of experimental and survey-based studies spanning a four-year period between 2011 and 2015, while Hu et al. (2018) advanced a multilevel analysis of the relationship between ICT and literacy in mathematics (and other subjects) across 44 countries drawn from their participation in the Programme for International Student Assessment (PISA) administered by the Organisation for Economic Co-operation and Development (OECD).

Although the scope of their research was limited to only relevant articles published in the *Computers & Education* journal, Pérez-Sanagustín et al. (2017) reported on the dichotomy of findings pertaining to the use of ICTs in schools. On the one hand, and drawing from previous works by Fu (2013) and Condie and Munro (2007), they reported on there being a level of consensus amongst educational technology researchers that successful integration of ICTs into the teaching and learning processes requires a collaborative effort from a number of stakeholders including learners, teachers and school leadership. Furthermore, they stated that ICTs have the greatest impact on learner performance only when they are included as a regular part of classroom discourse. Collectively, this leads to improved learning and fosters the development of basic skills and competencies (Pérez-Sanagustín et al., 2017). On the other hand, they reported that there is still scepticism and uncertainty with regard to the real transformative potential of ICTs across all the phases of education as advanced by the OECD and Luckin et al. (2012). They substantiated this position by pointing to evidence derived from the OECD which states that the use of computers in the classrooms is still very low and that this use "does not lead to appreciable improvements" in a number of skills sought by learners, including mathematics and science (Pérez-Sanagustín et al., 2017, A1–A2). Two of the key findings by this review are that:

(i) more research is necessary, which will illuminate how ICTs are integrated into the teaching and learning processes, especially in the area of mathematics; and (ii) only those studies that embrace what teachers do (that is, how they go about embedding ICTs in practice) will be of value to the educational technology research community.

In their multilevel analysis, Hu et al. (2018) conceptualised and tested a framework of the potential influence of various ICT factors at play across national, school, and learner levels on learner literacy in the mathematics, reading, and science subjects. Their rationale was that a multitude of studies have focused predominantly on school-level and learner-level factors of ICT integration and how these relate to learner performance, with very little research aimed at understanding the national climate on ICT and education integration. From a dataset of a little over $305,000$ learners from 44 countries, their key findings indicated that: (i) at national level—and with relation to ICT skills, use, and access—learners living in countries with more advanced ICT skills tended to perform better than the rest across all subjects, whereas there was no statistical significance between learner performance and either of national ICT use or access; (ii) at school level, there was no statistical significance between either the "ratio of computers to school size" or the "proportion of computers connected to the internet" (p. 7) and learner performance across all subjects; and (iii) at learner level, the influence of various ICT factors on learner performance showed a complex pattern, for instance: (a) ICT availability at school did not affect learner performance, whereas at-home availability correlated negatively with learner performance; (b) ICT usage at school had a negative correlation with learner performance, yet outside-school usage (whether for academic or leisure purposes) showed mixed effects, with positive or negative correlations varying by subject; and (c) learner attitudes towards ICT were significantly associated with learner performance, but much like ICT usage, these were either negatively or positively correlated with learner performance depending on the subject and whether the learners used the ICT at school or at home, and for what purpose. Hu et al. (2018) concluded by stating that the mixed nature of their findings "indicate that ICT was not used in a satisfactory approach to enhance student learning" (p. 9) and that the limited ways in which teachers use ICT for pedagogical purposes further diminishes the value of ICTs in educational settings, no matter how frequent their use.

A notable limitation with these global studies is the under-representation of developing countries, which brings to question the applicability of their findings in the contexts of such developing countries in general, and African countries in particular. Only two published works from Africa fell within the scope of the study by Pérez-Sanagustín et al. (2017), while out of the 44 countries analysed in the study by Hu et al. (2018), Africa had no representation. The next subsection addresses this limitation by taking a closer look at the current state of affairs pertaining to the integration and use of ICTs in South African schools.

2.2.4 The South African Context

Padayachee (2017) explored the integration of ICTs in South African schools, looking specifically at a particular district of the Gauteng province through an exploratory research design, employing both qualitative and quantitative methods of inquiry. She found that while ICTs are being deployed to schools by the relevant government bodies, there remains a gap in their uptake as classroom norms, mainly due to a lack of training programmes to upskill teachers

towards integrating ICTs in pedagogy (Padayachee, 2017). This finding was contemplated a decade earlier by Somekh (2008), who, from a synthesis of other research studies, reported a lack of pedagogical affordances in ICTs as one of the factors inhibiting the uptake of ICTs in classrooms. This is also consistent with the conclusion by Hu et al. (2018) as earlier stated, which points to the restricted ways in which teachers integrate ICTs with their pedagogical undertakings. Another key finding that Padayachee (2017) cited was that of access; this is related to both the equal opportunity that ought to be afforded to learners to access and use the deployed ICTs, as well as the necessary access to the complete infrastructure underlying the deployed ICTs, for instance, access to the internet.

Exploring teachers' attitudes towards educational technology, also within the Gauteng province and from a conveniently selected sample of 117 teachers, S. A. Hart and Laher (2015) adopted a quantitative approach specifically focusing on access to ICTs, together with its perceived usefulness, its cultural relevance, as well as their perceived competence in using ICTs. They reported that the teachers' attitudes towards the integration of ICTs into the teaching and learning processes were generally positive, with perceived usefulness of the technology and perceived cultural relevance emerging as key predictors of the teachers' attitudes (S. A. Hart & Laher, 2015). Access to technology was not a fundamental issue, as their findings reported teachers to have had high access to ICTs both at school and at home, however access was reported to be significantly less in the classroom itself.

Access is one of the constituents of the taxonomy of ICT affordances proposed by Conole and Dyke (2004a), and from the studies conducted by Padayachee (2017) and S. A. Hart and Laher (2015), as limited in scope as they may be, access to ICTs in classrooms by both teachers and learners becomes a prominent affordance in the integration of ICTs in teaching and learning. Another aspect of access, as advanced by Howie et al. (2005), is a historical and socio-political one, which stems from the apartheid legacy of South Africa. They remarked that "patterns of school ICT access in South Africa are markedly skewed as a consequence of apartheid discrimination and on account of the capability of advantaged communities to sustain their advantage in the post-[apartheid] period" (Howie et al., 2005, p. xiii). In line with this monolithic legacy dynamic, Sherman and Howard (2012), through a qualitative study conducted in the Western Cape province, further outlined impacting barriers faced by teachers when it comes to ICT integration into the teaching and learning processes, citing access (to the technology at a classroom level, to technical training, as well as to technical support) as one of the major impediments.

2.3 Technology in Teaching and Learning Mathematics

The teaching and learning of mathematics inherits all the pros and cons of teaching and learning in ICT-enhanced environments, as discussed in Section 2.2. The position advanced by the National Council of Teachers of Mathematics (NCTM)[2] on the use of technology in the processes of teaching and learning mathematics is that the strategic and thoughtful integration of ICTs in these processes strengthens and supports how both teachers and learners experience, communicate, learn, and do mathematics (National Council of Teachers of Mathematics, 2015).

[2]The US-based NCTM is the world's largest mathematics education organisation, which advocates for high-quality mathematics teaching and learning for each and every mathematics learner. Additional details about this organisation can be accessed via the following URL: https://www.nctm.org/.

Some of the recent studies investigating the use of ICTs in teaching and learning mathematics have demonstrated: (i) how technology can support various mathematics teaching and learning practices, while at the same time offering new ways of thinking about mathematical learning (Radović et al., 2019); (ii) how certain mathematical software programs facilitate and improve the learning and understanding of key mathematical concepts (Bakar et al., 2010; Ningsih & Paradesa, 2018); (iii) how the use of mobile devices and associated software contributes to the processes of teaching and learning mathematics (Sincuba & John, 2017; Sung et al., 2016); (iv) some of the environmental factors to consider—for instance, the school grade in which technology is used, the duration or frequency of the use of technology, as well as the instructional role of technology—when incorporating technology in a mathematics classroom (Young et al., 2018); and (v) how the use of technology in teaching and learning mathematics relates to the learners' psychological predictors, such as attitude, to learn and achieve in mathematics (Eyyam & Yaratan, 2014; Rajagopal et al., 2015; Sincuba & John, 2017). These studies emphasise "how" ICTs are or could be used in order to add value in the classroom environment and maintain the focus of instruction on mathematics rather than on the technology (National Council of Teachers of Mathematics, 2015, 2023), re-iterating the view that technology alone is not a panacea for improving the teaching and learning environment (Gaver, 1991).

Within the South African context, Bowie (2017) explored the use of technology in supporting mathematics learning for learners in Grades 7 through 9 in an after-school environment, focusing on a specific location in the Gauteng province. She reported that "no technology is a magic wand – it is a tool that, in the hands of a good teacher who thinks carefully about what learning aims it can fulfil, can be an effective aid for teaching" (p. 20). As reported in previous sections, teachers often struggle to think carefully about what learning aims technology can fulfil due to their limited training on the capabilities of technology and its integration into classroom pedagogy. In exploring the perceptions and needs of South African mathematics teachers through a pilot mixed methods study comprising 22 mathematics teachers, Stols et al. (2015) cited the teachers' negative perceptions about their own technical skills and knowledge, leading to the study's conclusion that further training for these mathematics teachers was needed. Similar perceptual views were reported by Waller and Maxwell (2017) from a study of mathematics teachers' perceptions of resources in South Africa's post-apartheid schooling environment, conducted at specific schools in the Gauteng province. They found that the negative perceptions of teachers on classroom technology integration had a cascading effect on the learners they taught, in that the teachers themselves were "discouraged to serve as advocates for technological learning in their own classrooms", which ultimately results in the learners suffering "the lack of exposure" to using ICTs as part of their learning experience (Waller & Maxwell, 2017, p. 753). This situation is compounded by the findings of George and Adu (2018), which reveal a lack of teacher-driven motivation in mathematics, ultimately detracting from learner attitudes towards the subject. Additionally, prior research has highlighted motivation and interest as contributory factors influencing secondary school learners' poor performance in mathematics and science (Makgato, 2007; Mji & Makgato, 2006). Therefore, incorporating technology into mathematics teaching and learning, grounded on solid and relevant theoretical foundations, offers a promising avenue to explore its potential in enhancing learner motivation.

The following section further expands upon this discussion by presenting key theoretical approaches related to learning, and briefly evaluating their suitability and applicability in the con-

text of teaching and learning with technology.

2.4 Theoretical Aspects of Teaching and Learning with Technology

The interplay between learning theories and technological advancements in educational settings is pivotal for harnessing the full potential of technology in learning environments. This relationship, however, is marked by an inherent asymmetry, as theories traditionally lead the way for technology's integration into educational practices. Lowyck (2013) identifies this asymmetry as a significant challenge, underscoring the importance of aligning educational psychology with technological innovations to overcome the complexities this imbalance presents.

Historically, the evolution of learning theories from behaviourism, through cognitivism, to constructivism charts a trajectory commonly used to understand how technological tools, and their subsequent use, can enhance learning. This linear perspective, foundational as it may be, often falls short of capturing the multifaceted and dynamic nature of digital technologies. C. Jones (2015) critiques this linear progression for its oversimplification. Separately, Crook and Sutherland (2017) deepen this critique by pointing out that digital technologies not only support learning, but also transform the very essence of how learning is conceived and enacted.

In response to these limitations, alternative perspectives such as associationist, cognitive, and situative views have emerged, challenging the traditional tripartite model (C. Jones, 2015). These perspectives offer fresh insights into how digital learning environments can accommodate diverse learning theories, including those previously marginalised. However, the rapid pace of technological change calls for theories that not only adapt to this flux, but are also rooted in solid philosophical foundations.

Siemens (2005) introduces connectivism as a learning theory for the digital age, positing it as an evolution from constructivism, and presenting distinct epistemological and ontological perspectives on learning and knowledge creation. Central to connectivism is the idea that learning occurs through the navigation and creation of social networks, via technology, where these networks facilitate the emergence of new forms of knowledge. Despite its innovative approach, connectivism has faced criticism for several reasons, including: (i) its claim as a new theory; (ii) its foundational basis as a learning theory; (iii) its perceived de-emphasis on learner autonomy in favour of networked learning; and (iv) the lack of empirical testing to support its assertions (Goldie, 2016; Hazeldine, 2020). These criticisms, particularly within the context of this research study, emphasise the drawbacks of connectivism in situations where the infrastructure required for establishing and maintaining such networks is limited, or in contexts that are significantly different from higher education settings, where connectivism has predominantly been employed, such as primary education environments (Hazeldine, 2020).

This critique underscores the enduring relevance of constructivism, which, with its emphasis on learning as a social process, and the active role of learners in constructing knowledge, remains particularly suited for navigating the complexities, challenges, and opportunities of technology-integrated learning across diverse environments, as observed over the past three decades (Dede, 1995; Doolittle & Hicks, 2003; Feyzi Behnagh & Yasrebi, 2020; Ford & Lott, 2012; Papert,

1993; Reid-Martinez & Grooms, 2021; Rieber, 1996). In the context of this research study, the emphasis constructivism places on active, contextual learning through social interactions, combined with its ability to adapt to technological advancements, establishes it as an especially pertinent theoretical perspective. By focusing on how individuals construct knowledge through their interactions within the environment, including with technology, constructivism offers a compelling lens through which to explore technology-enhanced learning, offering a robust theoretical foundation for this research study, that is both grounded and forward-looking.

The subsequent chapter delves into the core aspects of constructivism, emphasising the role of learners as active participants in their own learning process. This discussion will illustrate how constructivism naturally aligns with the affordances of technology, providing a solid foundation for exploring the potential of ICT use to markedly enhance learners' educational experiences.

2.5 SUMMARY

This chapter sought to connect and interrelate the core concepts arising from the foundational statements of this study through a detailed examination of relevant literature. This examination centred on three of the four identified central concepts, providing insights into the role and influence of technology in educational settings.

The initial sections of this chapter explored the generic use of technology in learning environments, starting with clarifying what is encompassed by 'educational technology', and how it serves to enhance learning. Special attention was given to the concept of technology affordances, defined within this study as both the actual and perceived properties of ICTs that facilitate their use in teaching and learning. This discussion revealed varied global perspectives on the use, effectiveness, and efficacy of ICTs in education, highlighting the urgent need for adaptive research approaches that can effectively embed ICTs into specific disciplines, such as mathematics, with a pointed consideration for environments confronted with accessibility hurdles, exemplified by the South African educational landscape.

Following the broader examination of technology in education, the chapter narrowed its focus to the specific implications of technology in the mathematics teaching and learning context. It emphasised technology's capacity to foster innovative learning methodologies, while concurrently recognising the challenges teachers face in integrating technology into their instructional practices. This part of the discussion underscored the essentiality of thoughtful integration of technology, debunking the notion of it as a universal solution for educational challenges.

The chapter further delved into the theoretical underpinnings that scaffold teaching and learning processes with technology, offering an overview of classic (behaviourism, cognitivism, constructivism) and emerging (connectivism) learning theories, and their relevance in today's modern, technology-rich learning environments. Additionally, it presented alternative theoretical perspectives that intersect with digital technology use. This discussion laid the groundwork for an in-depth exploration of the motivational dynamics involved in technology-facilitated learning—the fourth central concept—to be detailed in the subsequent chapter.

CHAPTER 3

THEORETICAL AND PHILOSOPHICAL UNDERPINNINGS

3.1 INTRODUCTION

3.1.1 Chapter Purpose

Building upon the review of literature presented in the preceding chapter, which focused on the prevalence and use of technology within educational settings, this chapter extends the discussion to the theoretical and philosophical foundations of this research. Its primary objective is to articulate and justify the theoretical and philosophical choices that were made to appropriately situate this study within its academic context. This objective is accomplished in the following manner: First, the chapter explores constructivism as the overarching theoretical perspective that guided the inquiry. Second, it ventures into various theories of motivation, elucidating their significance and application in the context of ICT usage in education, and how some of the key concepts from these theories were integrated into this study. Finally, the chapter expounds on the philosophical stances that framed the research.

3.1.2 Chapter Outline and Organisation

This chapter is organised into two main sections. The first, Section 3.2, focuses on the theoretical underpinnings of the study. It commences with an exploration of different facets of constructivist theory, with a special emphasis on social constructivism as the primary theoretical lens adopted for exploring the dynamics between ICTs use in teaching and learning mathematics and learner motivation. The section further progresses into an in-depth discussion on the various conceptualisations and theories of motivation, as identified in the literature. This discussion paves the way for a context-specific exploration of how motivation is conceptualised and framed within this study. Additionally, it delves into the manifestation of motivation in educational settings, and concludes with a detailed exposition of the measures used to assess motivation attributes, thereby defining the analytical parameters of the study.

The second, Section 3.3, addresses the philosophical aspects of the research. It starts by delineating the concept of a research paradigm, outlining its foundational beliefs, principles, and significance in conducting research. The section then examines the four predominant paradigms

in educational research, leading to a detailed justification for the chosen paradigm for this study.

Finally, Section 3.4 succinctly summarises the chapter, weaving together the theoretical and philosophical strands that constitute the core of the chapter.

3.2 THEORETICAL UNDERPINNINGS

3.2.1 An Overview of Constructivism Theory

Section 2.4 has underlined the foregrounding of the adoption of a constructivist theory approach when integrating technology in classroom pedagogy. The basis of any constructivist theory is that those who are defined as learners actively, continually, and adaptively construct their own understanding, meaning and knowledge based on their lived experiences rather than acquiring understanding, meaning, and knowledge from sources external to self (Cobb, 1994; Duffy & Jonassen, 1992).

From a philosophical perspective, constructivism is a view which "holds that any so-called reality is, in the most immediate and concrete sense, the mental construction of those who believe they have discovered and investigated it" (Saunders, 1992, p. 136). For many scholars, constructivism has its roots in the works of Jean Piaget (a Swiss clinical psychologist, 1896–1980), Lev Vygotsky (a Soviet psychologist, 1896–1934) and Ernst von Glasersfeld (a German philosopher, 1917–2010). Their works marked a departure from traditional Western philosophy and theories of knowledge, and have led to the three most familiar categories of constructivism: (i) cognitive constructivism (the Piagetian approach); (ii) social constructivism (the Vygotskian approach); and (iii) radical constructivism (the von Glasersfeld approach) (Blake & Pope, 2008; Pass, 2007; Powell & Kalina, 2009).

While these three approaches share a common general epistemological stance, or *postepistemological* stance (as von Glasersfeld (1995) more accurately advocated), they each differ in their theoretical perspectives and applicability, with the Piagetian and Vygotskian approaches strongly favoured by many researchers as the most applicable theories of learning in the classroom (Blake & Pope, 2008; Palincsar, 1998; Powell & Kalina, 2009).

Social and cognitive constructivism both emphasise the learner as the centre of the learning process. Whereas the latter advocates for individual learning (that is, a learner learning in their own space), the former emphasises collaboration and social interaction as cornerstone to the learning process (that is, a learner learning within a group setup, as one instance) (Powell & Kalina, 2009, pp. 242–247). While radical constructivism may too emphasise the learner as the centre of the learning process, it differs from the other two categories in that its foundation is in the learner cognising and internalising external reality, thus forming internal knowledge (Doolittle & Hicks, 2003).

This research study adopted the Vygotskian principles of constructivism as illuminated through social constructivism because of their applicability in a classroom setting and their socio-collaborative appeal. The following subsection further articulates the characteristics of this category of constructivism.

Characteristics of Social Constructivism

In a broad sense, McMahon (1997) articulates that learning in a socio-constructivist environment is facilitated through a collaborative effort within an educational group consisting of teachers, parents, and peer learners, amongst many other members of a community, with a strong emphasis on culture and context. Sivan (1986) identifies three fundamental elements that underpin social constructivism, and which are key in the learning process. These elements are: (i) cognitive activity; (ii) cultural knowledge, tools and signs; and (iii) assisted learning.

This research study subscribed to the definition of social constructivism as so far defined (albeit piecewise), and adopted these three fundamental elements, as fleshed out over the next subsections, as part of the social constructivism definition.

Cognitive Activity

Cognitive activity refers to the mental processes and activities that are involved in acquiring, processing, and using information. It is a developmental process of meaning-making (Sivan, 1986). This process is "shaped through association with adults" (p. 212) and, according to Cole and Scribner (1974), "shapes and regulates behaviour by mediating context and behaviour" (as cited in Sivan, 1986, p. 212). It includes a range of mental processes such as perception, attention, memory, language, problem-solving, reasoning, and decision-making (Anderson, 2020; Malim, 1994). These processes play a fundamental role in many aspects of human functioning, especially in how individuals perceive and interact with the world around them.

Cultural Knowledge, Tools and Signs

There is no universal definition of what culture is (Hofstede, 2003; Pillai & Chaudhary, 2009; Sivan, 1986; Valsiner, 2007). For instance, in illustrating this from an anthropology point of view, White (1959, p. 227) writes:

> To some, culture is learned behavior. To others, it is not behavior at all, but an abstraction from behavior—whatever that is. ... Culture exists only in the mind, according to some; it consists of observable things and events in the external world to others. Some [scholars] think of culture as consisting of ideas, but they are divided upon the question of their locus: some say they are in the minds of the peoples studied, others hold that they are in the minds of ethnologists.

Distilling this polychotomous view of culture and without being too simplistic, it is evident that at its core and at the very least, culture is built upon behavioural, cognitive, and ideational aspects contextualised within a people.

In the context of social constructivism, Sivan (1986) defines culture as "the features in a group of people, such as beliefs, social forms, knowledge, and the means of transmitting knowledge, that distinguish those people from another group" (p. 213). Through a culture, one then manifests extensions such as tools (such as technology) and signs (such as language and numbers) as well as knowledge (a definitive body of effective and cognitive information), however in most cases, these are said to be unique only to a particular culture (Sivan, 1986). Noteworthy in social constructivist theory, language is an important tool of thought and cognitive activity.

Together with knowledge, language is a culturally fashioned activity and a means by which an individual's psychological functioning develops (Sivan, 1986).

Assisted Learning

Assisted learning is a process whereby cultural elements are transferred from one member of society to another through structured sets of information with an aim of developing independent functioning. Sivan (1986) asserts that there are four distinguishing characteristics of assisted learning which collaboratively facilitate the process of assisted learning, and sets it apart from other forms of socialisation.

The first one is that assisted learning requires a committed involvement by both the learner and a more knowledgeable member of the culture. The second distinguishing characteristic is the zone of proximal development (ZPD); Vygotsky (1978) describes the ZPD as the difference between the learner's "actual development level as determined by independent problem solving" and the "level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (as cited in Sivan, 1986, p. 215). The third distinguishing characteristic of assisted learning is to view the process as a means of internalisation. This means that cultural knowledge is transferred to an individual such that there is no need to further rely on external interventions for that same piece of cultural knowledge. The ultimate defining feature of assisted learning is the aim of achieving independent functioning, which is gradually developed through the other three distinguishing characteristics. Collectively, these characteristics of assisted learning serve to differentiate it from other forms of socialisation where behaviour may be viewed as the outcome of observational learning (that is, learning that occurs as a result of observing and imitating the actions and behaviours of others), or as cue-produced responses.

These characteristics of assisted learning articulated by Sivan (1986) are consistent with the *scaffolding* instructional technique as introduced by Wood et al. (1976). Several scholars have in the recent past demonstrated how this technique can be operationalised in various contexts. For instance, Chi and her colleagues (Chi et al., 2008, 2001) demonstrate various configurations and tactics of human tutoring as a means to assist tutees in the learning process. They show that the effective approaches are those in which there is a collaborative effort between the tutors and the tutees. In another instance, M. C. Kim and Hannafin (2011) and Sharma and Hannafin (2007) illustrate empirically the utility of the scaffolding technique in technology-supported learning environments, and provide techno-pedagogic frameworks and best practices for operationalising this technique in classroom settings. The scaffolding technique thus assists learners traverse the ZPD in a systematic way (Khaliliaqdam, 2014; van Merriënboer & de Bruin, 2014).

3.2.2 Theories of Motivation

In broad terms, motivation refers to the psychological process that initiates, guides, and maintains goal-oriented behaviours. It is a driving force that encourages an individual to engage in certain actions or activities, and it can be both internal (arising from within the individual) or external (arising from the environment or outside sources). It can also refer to the specific actions that an individual can take in order to reach the desired outcome. Thus, motivation is a multifaceted construct that can take on various forms depending on the situation at hand.

The concept of motivation has been studied for many decades, and there is a large body of literature on the topic. This has resulted in a variety of theories of motivation that have been proposed, tested, applied, and have become widely accepted. One of the most widely accepted and well-established motivation theories is the self-determination theory (Deci & Ryan, 2008, 2012a, 2012b; Ryan & Deci, 2000b). The self-determination theory is the culmination of decades of work centred on the concepts of intrinsic and extrinsic motivation (Deci & Ryan, 1985; Lepper et al., 1973; Ryan & Deci, 2000a), which are fundamental theoretical concepts in the discourse of motivation. Other key theories of or related to motivation, especially as it relates to educational settings, are the expectancy-value theory (Wigfield & Cambria, 2010; Wigfield & Eccles, 2000; Wigfield et al., 2016), the self-worth theory (Covington, 1984, 2009; Covington & Beery, 1976), and the self-efficacy theory (Bandura, 1977). The following subsections further unpack these concepts and theories in chronological order.

Expectancy-value Theory

In its most elementary form, the expectancy-value theory purports that an individual's motivation to engage in a particular behaviour is influenced by both their expectancy of success and the value they place on the outcome. Graham and Weiner (2012) categorise the expectancy-value theory as one of the grand theories of motivation, and attribute its development to the early works of Kurt Lewin (a German-American psychologist, 1890–1947) on the dynamic theory of personality, Julian B. Rotter (an American Psychologist, 1916–2014) on the social learning theory, and John William Atkinson (an American psychologist, 1923–2003), whose pioneering works, which include the theory of achievement motivation, established motivation as a distinct field of study. Other proponents of expectancy-value theory include Fishbein and Ajzen (1975), whose works during the 1970s extended the theory to include beliefs, attitudes, and intentions about the behaviour itself, developing the theory of reasoned action. This extension added a social component to the theory, taking into account the influence of social norms and the attitudes of others on an individual's motivation.

These historical manifestations of the expectancy-value theory brought about a new wave of contemporary constructs and models of the expectancy-value theory that are specific to educational settings and characterise the expectancy-value theory as it is known today (Wigfield & Cambria, 2010; Wigfield & Eccles, 2000; Wigfield et al., 2016). In this conceptualisation, the theory emphasises the role of learners' expectancies and subjective task values in predicting their engagement and achievement both in school and in associated classroom activities. Furthermore, it suggests that if learners believe they can succeed in a particular task (high expectancy) and perceive the task as important or interesting (high value), they will be more motivated to engage in the task and achieve better academic outcomes.

From this viewpoint, there have been several studies exploring interventions aimed at increasing learners' expectancy and value beliefs, with a focus on technology-based interventions. Some studies have examined the role of teachers and their use or intended use of technology when teaching (Ranellucci et al., 2020; Safitry et al., 2015), while others have focused on learners or both learners and teachers (Ball et al., 2016; J. A. Chen et al., 2013; Jackson et al., 2019), and some have even incorporated parental elements (Bradley, 2020). These are evidence that there is steady interest in developing technology-based interventions in educational and extracurricular

settings aimed at increasing learners' expectancy and task value beliefs. Furthermore, these interventions could be particularly relevant in the context of online and hybrid learning, where technology plays an increasingly prominent role in education.

Notwithstanding, the discourse surrounding the expectancy-value theory continues to expand as theorists deepen their understanding of its relevance across various disciplines, particularly in educational contexts. Recent research has revealed that the inclusion of an additional construct, that of cost, is necessary to fully capture the impact on academic performance within the expectancy-value model. As such, scholars are gaining valuable insights into the intricacies of how learners' expectations and values, as well as perceived costs, influence their academic achievement (Rosenzweig et al., 2019).

Self-worth Theory

The self-worth theory is a contemporary motivational theory that places an individual's "sense of self at the center of human existence" (Covington, 2009, p. 142). It emphasises the importance of maintaining a positive sense of self-worth in driving human behaviour (Covington, 2009). Furthermore, the theory suggests that individuals are motivated to protect their self-worth or self-value or sense of worth, and that their behaviour is influenced by the need to avoid situations that threaten their sense of self-worth (Covington, 1984, 2009). The grounding of the self-worth theory, like the expectancy-value theory, traces its origins to John William Atkinson's work on achievement motivation, which suggests that the need for achievement arises from an interplay between two opposing tendencies: the desire to succeed and the fear of failure (Covington, 1984).

In classroom settings, the self-worth theory can be observed in the behaviour of learners who avoid seemingly difficult tasks or activities. This behaviour is driven by the need to preserve their own and others' perception of their competence, even by learners who have the potential to excel academically (Covington, 1984; Eccles & Wigfield, 2002). Other manifestations of the self-worth theory in classroom settings include learners attributing reasons for failure to external factors through deliberately setting unrealistic goals, adopting self-handicapping techniques, or making excuses, strategies which Covington (1984) calls "failure–avoiding tactics" (p. 12).

Theoretical perspectives rooted in the self-worth theory have been utilised in various studies predominantly to understand motivational elements in teaching and learning environments (Castella et al., 2013; Leis et al., 2022; Thompson et al., 1995). However, there is an apparent scarcity of studies whose objective is to investigate how certain interventions, such as the use of technology in teaching and learning, can be employed to enhance motivation to learn from the self-worth theoretical viewpoint (Heafner, 2004). This may be due to the theory's complex dynamics, which render it less suitable as a theoretical framework for studies investigating how technology can enhance motivation to learn. In addition, Eccles and Wigfield (2002) have raised concerns about the self-worth theory's assertion that "academic competence beliefs are the strongest determinant of self-worth" (p. 123). They argue that instead, individuals manipulate the value they place on the area of competence to maintain their sense of self-worth.

Intrinsic and Extrinsic Motivation

Although intrinsic and extrinsic motivation may not be classified as standalone theories, they are fundamental concepts that play a significant role in many established theories of motivation. These concepts, while not mutually exclusive, outline the most basic distinction of motivation (Ryan & Deci, 2000a), and they have been founded on the works of pioneer John William Atkinson, as well as those of Lepper et al. (1973), and Deci and Ryan (1985).

Intrinsic motivation is characterised by engaging in activities that are inherently satisfying or enjoyable, and not driven by external factors such as rewards or punishments. This type of motivation is noninstrumental, meaning that the behaviour itself is its own reward, and not contingent on any separate outcome (Legault, 2020; Ryan & Deci, 2000a). Essentially, the means and ends of intrinsically motivated actions are inseparable (Legault, 2020). Central in the concept of intrinsic motivation is the balance between autonomy and control. As argued by Ryan and Deci (2000a), environments that support autonomy enhance not only intrinsic motivation, but also foster curiosity, and a natural inclination for challenge, while environments that are excessively controlling can severely undermine intrinsic motivation. This is embodied in their cognitive evaluation theory (Deci & Ryan, 1985)—a subtheory of the self-determination theory, whose goal was to identify the elements within social environments that create diversity in intrinsic motivation.

In contrast to intrinsic motivation, extrinsic motivation is characterised by engaging in behaviours that are dependent on achieving specific outcomes that are separate from the behaviours themselves. This type of motivation is instrumental, meaning that the behaviour is performed in order to gain a reward, avoid a punishment, or achieve some other external goal (Legault, 2020; Ryan & Deci, 2000a). In essence, extrinsic motivation is driven by external factors rather than an inherent enjoyment of the behaviour itself. Fundamental in the concept of extrinsic motivation are the notions of "internalization and integration of values and behavioural regulations" (Ryan & Deci, 2000a, p. 60). In this instance, internalisation refers to the process by which individuals take in and adopt external values, beliefs, or behaviours as their own, while integration refers to the process of integrating extrinsic values and regulations into one's self-concept and personal belief system, so that they become more congruent with one's own goals and values (Ryan & Deci, 2000a). Similar to how intrinsic motivation and the cognitive evaluation theory relate, Deci and Ryan (1985) articulate these notions within the framework of the organismic integration theory, which is another subtheory of the self-determination theory that provides insight into the various types of extrinsic motivation stratified on an internalisation continuum and the extent to which they are autonomous (Legault, 2020; Ryan & Deci, 2000a).

Numerous studies have investigated the role of technology in mediating intrinsic motivation (Ciampa, 2014; Hanus & Fox, 2015; Huang et al., 2019; Xie et al., 2006), as well as fostering extrinsic motivation (Borges & de Souza Fleith, 2018; Cullen & Greene, 2011), within classroom settings. These studies have looked at the pedagogic integration of technology from both the learner and teacher perspectives, either as individual conceptual constructs or as part of broader theoretical frameworks. While these efforts have broadened the understanding of the mediating power of technology in educational contexts, some researchers contend that the dualistic nature of intrinsic and extrinsic motivation is inconsistent with scientific concepts such

as "construct validity, measurement reliability, and experimental control" (Reiss, 2012, p. 152), implying that studies on motivation should instead employ more comprehensive and multi-faceted theories.

Self-efficacy Theory

The self-efficacy theory is another contemporary theory of motivation that focuses on the beliefs that individuals hold about their ability to successfully perform a specific task or achieve a particular goal (Eccles & Wigfield, 2002; Graham & Weiner, 2012). This is premised on the proposition that "people process, weigh, and integrate diverse sources of information concerning their capability, and they regulate their choice behavior and effort expenditure accordingly" (Bandura, 1977, p. 212). The self-efficacy theory is the central tenet of Bandura's social learning theory, which he later relabelled as the social cognitive theory (Bandura, 1986, 2012; Schunk, 2012), and which "stresses the idea of human *agency*, or the belief that one can exert a large measure of control over the important events in one's life" (Schunk & DiBenedetto, 2016, p. 34). Bandura believed that self-efficacy was an important factor in determining an individual's level of motivation and performance. When an individual believes they have the skills and abilities necessary to successfully complete a task, they are more likely to be motivated to engage in the task and to perform at a higher level. Conversely, when an individual lacks confidence in their ability to complete a task, they may be less motivated to engage in the task and may perform at a lower level. These beliefs, or "expectations of personal efficacy" (p. 191), about their ability to complete a task are a derivative of: (i) performance accomplishments—comprising previous successes or failures in similar tasks; (ii) vicarious experience—entailing observing others who are similar to oneself successfully complete a task; (iii) verbal persuasion—encompassing encouragement, feedback, or similar social persuasion from others; and (iv) physiological states—pertaining emotional or affective arousal (Bandura, 1977).

In educational contexts, researchers have focused on identifying and verifying several types of self-efficacy applicable to learners and teachers, including self-efficacy related to performance, learning, self-regulated learning, collective self-efficacy (for learner groups), teacher (instructional) self-efficacy, and collective teacher (instructional) self-efficacy (Schunk & DiBenedetto, 2016). In the context of technology integration in teaching and learning, self-efficacy theory-based theoretical perspectives have largely concentrated on exploring teachers' beliefs about incorporating technology in their teaching pursuits (Albion, 1999; Bull et al., 2016; Gcabashe & Ndlovu, 2022; Hartell, 2017; Mannila et al., 2018), with limited focus on the learners, especially at primary and secondary education levels (Hatlevik et al., 2018; Joo et al., 2000).

In a general sense, the application of self-efficacy theoretical perspectives to various contexts has underlined self-efficacy as one of the integral contributors to individuals' motivational behaviours. Notwithstanding, some researchers have argued "that the power of self-efficacy as an independent predictor of behavior has been overstated" (Graham & Weiner, 2012, p. 375), especially when considering the utility of value-based theories such as expectancy-value theory. Thus, it remains a research inquiry imperative to continue efforts to operationalise and explore the effectiveness of self-efficacy principles and methods in different settings, and how these interplay with other theories of motivation (Schunk & DiBenedetto, 2016, 2021).

Self-determination Theory

The self-determination theory traces its origins to the study of how extrinsic rewards impact intrinsic motivation during the early- to mid-1970s (Deci & Ryan, 2012a). Over the years, this theory has evolved and expanded, drawing on numerous empirical studies to support its framework. The founders of the self-determination theory, Deci and Ryan, have dedicated decades to refining its concepts and exploring its applicability to various contexts. To this end, the theory currently comprises five interrelated subtheories that together explain its posited three fundamental psychological needs that are necessary for optimal development and functioning. These three fundamental psychological needs of competence, autonomy, and relatedness form its core, and the theory suggests that these needs must be fulfilled in a balanced manner for individuals to engage in activities for intrinsic or autonomous reasons with a sense of meaning. This highlights the idea that individuals are more likely to experience a sense of fulfilment and satisfaction when they are able to act on their personal values and interests, as opposed to solely responding to external pressures.

The self-determination theory incorporates both intrinsic and extrinsic motivation, which collaboratively shed light on the "effects of social–contextual factors on human motivation, behavior, and personality" (Deci & Ryan, 2012a, p. 432), particularly within pro-autonomy environments. Within this framing, extrinsic motivation is expressed as a continuum of four subtypes: (i) external regulation; (ii) introjected regulation; (iii) identified regulation; and (iv) integrated regulation (Deci & Ryan, 2008; Ryan & Deci, 2000a, 2000b). External regulation, which is the least self-determined form of motivation (that is, the least autonomous state of motivation), is situated closest to amotivation. In contrast, integrated regulation, the most self-determined form, approaches intrinsic motivation, since individual behaviours reflect personally endorsed goals (Deci & Ryan, 2012a; Graham & Weiner, 2012; Ryan & Deci, 2000b; Vallerand et al., 2008).

Research efforts in the field of digital education have utilised self-determination theory as a theoretical framework to investigate the integration of technology into classroom settings. Specifically, studies have, amongst many other disciplinary areas of focus, examined: the pedagogical integration of technology in classroom environments from a teacher perspective (Chiu, 2022; Sørebø et al., 2009); the development of digital-based curricula (Chiu & Chai, 2020); as well as the affordances of digital technologies that support and facilitate competence, autonomy, and relatedness in learning environments (Chiu, 2021; Oga-Baldwin, 2015; Salikhova et al., 2020).

Pro-autonomy environments are characterised by their active support of individuals in developing and maintaining their ability to take initiative and act independently, thereby fostering a sense of agency. In line with this, Vallerand et al. (2008) commend the heuristic power and versatility of self-determination theory, and especially emphasise that pro-autonomy environments "lead to qualitatively superior forms of motivation characterised by high levels of self-determination" (p. 257). Thus, together with the individual's sense of agency, these environments are conducive to more adaptive behavioural, affective, and cognitive outcomes. These constructs were positioned as indicators of engaged behaviour within the context of this research study, and are expanded upon in the next section.

3.2.3 Framing Motivation in the Context of this Study

In the context of social constructivist theory, Sivan (1986, p. 226) presented a reconceptualised definition of motivation which is directly linked with the three fundamental elements of social constructivism—(i) cognitive activity, (ii) cultural knowledge, tools and signs, and (iii) assisted learning—earlier presented in Section 3.2.1. This reconceptualisation consists of four elements characteristic of its very nature:

> (a) Motivation becomes inextricably linked to the learning process of the [learner], enabling us to say that there exists a conjunctive process of cognitive-motivational development occurring in the classroom. (b) It can be thought of as developmental in nature. It changes as the cognitive and emotional states of the [learner] develop with the help of the teacher or more experienced peer. A nonstatic conceptualization of motivation means greater opportunities for the development of interest and cognitive and affective engagement. (c) Motivation is not only the result of individual differences, but of the social conditions at the time of learning. It is constrained by social context, the goals, wishes, and desires of both [learner] and teacher that are not obvious in surface interactions yet give impetus to action, the setting, the time, and interpersonal relations. (d) Motivation is a means to competent classroom functioning. As a cultural norm, it is used in the classroom to define what is appropriate and what is desirable. Understanding this norm helps the [learner] behave in appropriate motivated behaviours and thus achieve competent membership and social acceptance by either or both the teacher and peers.

The first element implies that the process of learning that a learner undergoes in the classrooms is symbiotically bound to the learner's motivation. This in turn promotes the cognitive development of the learner through assisted learning, which is observable through manifestations of interest and engagement demonstrated by the learner as captured by the second element. The third element emphasises that social and contextual aspects are important contributors to the motivation of the learner. Motivation then becomes a norm of the classroom as a cultural environment, and in this role, it aids in defining appropriate and desirable classroom behaviour in concert with other classroom norms. The next section focuses further on how motivation manifests itself to the observer during the process of learning.

3.2.4 Manifestations of Motivation

Interest

Schiefele (1991) and Krapp (1999) map the history of the concept of interest from its psychological roots in the 1800s to its central role in motivation during a learning process. Schiefele (1991) further emphasises a number of key empirical findings which highlight its significance in different aspects of the learning process, notably: (i) the quality of learning results; (ii) the use of learning strategies; and (iii) the quality of the learning experience (Schiefele, 1991, p. 304).

Central in the context of motivation and interest are three related conceptual dimensions that underpin interest within a learning environment (Krapp, 1999, p. 24): (i) interest as a dispositional characteristic of the person; (ii) interest as a characteristic of the learning environment (interestingness); and (iii) interest as a psychological state. Krapp (1999) articulates that the third dimension, that of psychological state, is a consequence of the interplay between the other

two; in other words, the psychological state of interest can be characterised by an individual's dispositional characteristic within a learning environment (based on the interestingness of the learning environment). Goudas et al. (2000) further infer that this psychological state of interest bears some conceptual similarities to intrinsic motivation, as defined by Ryan and Deci (2000a).

At a more granular level, interest can be stratified into two types when it comes to educational research: (i) situational interest; and (ii) individual interest (Hidi & Renninger, 2006; Krapp, 1999; Schiefele, 1991). On the one hand, situational interest is brought about by external or environmental stimuli, with many research studies, as summarised by Hidi and Renninger (2006), showing situational interest to positively influence cognitive performance, including enhancing levels of learning (Hidi & Renninger, 2006; Krapp, 1999; Schiefele, 1991). On the other hand, individual interest is concerned with a person's enduring preference to engage particular content, activities or subject areas over time, as well as the person's immediate psychological state once this process of engagement has been activated (Hidi & Renninger, 2006; Krapp, 1999; Schiefele, 1991). For individual interest, empirical evidence exists, as similarly summarised by Hidi and Renninger (2006), which shows it to have a positive impact on academic performance and levels of learning amongst other psychological constructs. Collectively, "the positive affect associated with the levels of interest generated from both situational and individual factors has been found to contribute to cognitive performance" (Hidi & Renninger, 2006, p. 113).

Engagement

In its broadest sense, engagement in the context of learning is concerned with a learner's effort, interest, willingness, agency, and enthusiasm observable when pursuing tasks, activities or interactions related to learning (Christenson et al., 2012; Oncu & Cakir, 2011). Lam et al. (2016) attest that it has "attracted increasing attention from researchers and educators because of its comprehensiveness in describing student motivation" (p. 138). Recent research efforts on learner engagement have been concerned with streamlining its definition in order to depart from the historical fragmented conceptualisations of learner engagement. To this end, learner engagement has emerged as a multidimensional construct, comprising four dimensions: (i) behavioural engagement; (ii) affective engagement; (iii) cognitive engagement; and (iv) agentic engagement (Archambault et al., 2009; Green et al., 2012; Reeve & Tseng, 2011; Reschly & Christenson, 2012).

Behavioural engagement is concerned with the behaviours learners portray in undertaking both the social and academic aspects of school (Archambault et al., 2009; Rumberger & Rotermund, 2012). This persists beyond the boundaries of the school into spaces where learners continue to engage with school activities, for instance, engaging in homework at home, at an after-school care facility, or at a public library. Affective engagement is concerned with the learner's emotional state, which encompasses "feelings, interests, perceptions, and attitudes toward school" (Archambault et al., 2009, p. 654). Cognitive engagement encompasses a learner's participation in academic tasks and "incorporates thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills" (Mahatmya et al., 2012, p. 47). Agentic engagement refers to the extent of "students' constructive contribution to the flow of instruction they receive" (Reeve & Tseng, 2011, p. 257). It is different to the other three types of engagement in that it is uniquely proactive, intentional, and teacher-collaborative.

Overall, engagement is characterised by observable and action-oriented behaviours, which stem from its cognitive and affective dimensions, with a number of studies asserting a connection between engagement and learner performance and achievement (as elaborated in Christenson et al., 2012). Reschly and Christenson (2012) further draw on the relationship between engagement and motivation, which resonates with that of Sivan (1986), stating that motivation is an intent manifesting itself through engagement. Although back in 1986 Sivan only contemplated the cognitive and affective dimensions of engagement as observable manifestations of motivation, the behavioural and agentic dimensions have since been incorporated into the multidimensionality of engagement without upsetting the inherent relationship between engagement as a unit and motivation. Numerous studies have explored the use of various learning strategies, including using ICTs, and how these impact or relate to the engagement (or specific dimensions of engagement) of learners during the learning process (Ang et al., 2012; Eyyam & Yaratan, 2014; Hanus & Fox, 2015; Rappa et al., 2009; Reading, 2008; Schacter, 1999; Wenglinsky, 1998; Wilson & Boldeman, 2012; Yang & Wu, 2012). It is imperative to emphasise that ICT "in and of itself is not engaging, though it can provide opportunities to engage [learners] in learning" (Yazzie-Mintz & McCormick, 2012, p. 745).

3.2.5 Measures of Motivation Attributes

Interest

Situational Interest

Various measures of situational interest exist, each appropriate to measure situational interest under various conditions owing to its multidimensionality. The most notable of these are the *interest survey* (Mitchell, 1993), the Situational Interest Scale (SIS) (A. Chen et al., 1999), the Situational Interest Survey (SIS) (Linnenbrink-Garcia et al., 2010), and the Situational Interest Questionnaire (SIQ) (Rotgans & Schmidt, 2011a, 2011b, 2014), all of which have been validated and are reliable.

Mitchell's *interest survey* (which was initially named the Situational Interest Survey) is a composite measure of interest, which was designed to measure aspects of personal (individual) and situational interest across some five dimensions in mathematics classrooms. The situational interest aspect of the *interest survey* is a six-item subscale which became instrumental in how situational interest would later be measured.

The SIS (A. Chen et al., 1999) was developed as a five-dimension scale to measure situational interest in a physical education subject setting. In this instance, the grounding of situational interest was strongly on "personal subjectivity" (p. 160), guided by the work of Deci (1992), and marked a departure from earlier conceptualisations (for instance, Mitchell, 1993).

Linnenbrink-Garcia et al. (2010) sought to capture the deeper aspects of situational interest, which were previously not interrogated by prior measures of situational interest. Through their research efforts, they developed a three-factor structure of measuring situational interest which is encapsulated in their SIS framework. This structure is amenable to a wide range of contexts within classroom settings.

Rotgans and Schmidt (2011a, 2011b, 2014) modelled a conceptualisation of situational interest based on what they referred to as a "thirst for knowledge" (Rotgans & Schmidt, 2014, p. 38). Through what they hypothesised as the knowledge-deprivation principle (the thirst for knowledge), they developed and tested the SIQ in a number of iterations over a number of years. This allowed for the development of a measure to ascertain circumstances under which situational interest is triggered and how it ultimately leads to learning.

Despite the availability of multiple measures such as those mentioned above, as well as others not specified, ongoing research efforts continue to strive for the creation of a single, all-encompassing measure of situational interest that truly captures its entirety. In this regard, having conducted a comprehensive analysis of various existing measures of situational interest, including those discussed above, Potvin et al. (2023) identified crucial characteristics that a comprehensive measure should embody. These include conciseness, coverage, the object of interest, specificity, and adaptability. Additionally, they posit that any measure of situational interest should take into account the multidimensional nature of the construct, including its affective, cognitive, behavioural, and value-related aspects. To further demonstrate their hypothesis, they developed and partially validated two versions of the International Situational interest Questionnaire (ISiQ): a comprehensive twenty-item measure, and a briefer version of the same, comprising seven items. The twenty-item version is suitable for measuring situational interest as an isolated phenomenon, while the seven-item version is suitable to be incorporated as a subscale into surveys measuring situational interest and other constructs. The ISiQ was however not considered as a potential measure of situational interest for this research study because it was still in its early stages of development during the instrument design stage of this research study. Nevertheless, the key characteristics and multidimensionality aspects of an ideal situational interest measure were considered in retrospect in identifying the SIQ (Rotgans & Schmidt, 2011a, 2011b, 2014) as a workable measure of situational interest in the context of this research study.

The SIQ was introduced as a self-report instrument comprising six Likert-type items and rated on a five-point scale to be administered to learners. For this research study, each item underwent a contextualisation to align with the overall research problem, purpose, and questions. Thereafter, each item was evaluated individually and for its part in the main instrument to ascertain fitness to context. The contextualised versions of all six items were retained to form the situational interest subscale that was ultimately used. Table 3.1 shows how the contextualisation was undertaken.

Individual Interest

Rotgans (2015) introduced the Individual Interest Questionnaire (IIQ) as an overdue measure of individual interest. He argued that interest, and specifically individual interest, had over time become a "construct of considerable educational significance" (p. 68), and for it to not have a valid and reliable measurement instrument suitable for use across different disciplines was an academic oversight. Part of the reason for this, he argues, is that interest as an educational construct has endured a fragmented history of conceptualisations and practicalisations, leading to this impasse. Renninger and Hidi (2011) had earlier demonstrated the same argument. Thus, the IIQ was considered an appropriate basis for measuring individual interest in the context of

Table 3.1: Contextualisation of the Situational Interest Questionnaire for use as a situational interest measure.[1]

Item	Situational Interest Questionnaire Items	Contextualised Situational Interest Items
1	I enjoy working on this topic	My learners enjoy working on mathematics topics
2	I want to know more about this topic	My learners want to know more about mathematics
3	I think this topic is interesting	My learners think that mathematics is interesting
4	I expect to master this topic well	My learners expect to master mathematics well
5	I am fully focused on this topic; I am not distracted by other things	My learners are often fully focused on mathematics; they are not distracted by other things
6	Presently, I feel bored (reversed)	My learners are often bored

this research study.

The IIQ was introduced as a self-report instrument comprising seven Likert-type items and rated on a five-point scale to be administered to learners. For this research study, each item underwent a contextualisation to align with the overall research problem, purpose, and questions. Thereafter, each item was evaluated individually and for its part in the main instrument to ascertain fitness to context. The contextualised versions of six out of the seven items were retained to form the individual interest subscale that was ultimately used. Table 3.2 shows how the contextualisation was undertaken.

As highlighted in Table 3.2, one item (4) was not retained into the final individual interest measure for this research study. This was chiefly because it might have been difficult for a teacher to make such an observation as encompassed by this item once it was built into the individual interest subscale.

Engagement

Efforts to measure learner engagement have been on the rise in the last three decades. The primary driver for these efforts was the mission to unify the conceptualisation of engagement as a multidimensional construct, and to develop and refine a universal measure that captures the essence of learner engagement, grounded on existing literature and theory. The most notable of these efforts saw researchers from close to twenty countries collaborate in the development of two comprehensive tools, the Student Engagement in Schools Questionnaire (SESQ) and the Teacher Engagement Report Form - New (TERF-N) (S. R. Hart et al., 2011; Lam et al.,

[1] Source: Rotgans and Schmidt (2011a, 2011b, 2014).

Table 3.2: Contextualisation of the Individual Interest Questionnaire for use as an individual interest measure.[2]

Item	Individual Interest Questionnaire Items	Contextualised Individual Interest Items
1	I am very interested in biochemistry	My learners are very interested in learning mathematics
2	Outside of school I read a lot about biochemistry	Outside of school, my learners practice a lot of mathematics
3	I always look forward to my biochemistry lessons, because I enjoy them a lot	My learners always look forward to their mathematics lessons, because they enjoy them a lot
4	I am interested in biochemistry since I was young	My learners are interested in mathematics since they were young
5	I watch a lot of biochemistry-related TV programs (e.g., Discovery Channel)	My learners watch a lot of mathematics-related TV programs
6	Later in my life I want to pursue a career in biochemistry or a biochemistry-related discipline	Later in life, my learners want to pursue careers in mathematics or mathematics-related disciplines
7	When I am reading something about biochemistry, or watch something about biochemistry on TV, I am fully focused and forget everything around me	When my learners read or watch something mathematics-related, they are fully focused and they forget everything else around them

2014, 2016). These tools are premised on learner engagement described as a three-dimensional construct comprising behavioural, emotional (affective), and cognitive aspects, drawing largely from the work of Fredricks et al. (2004). The SESQ is an elaborate 109-item learner self-report questionnaire aimed at interrogating multiple dimensions across multiple domains of learner engagement, and has a simplified 33-item version specific to learner engagement only in schools (S. R. Hart et al., 2011). The TERF-N is a 10-item teacher observation chart, purposed to supplement the SESQ, which the teacher completes for each learner in their classroom while the class is in session, or as soon as the class session ends.

With the introduction of agency as a fourth dimension of learner engagement (Reeve & Tseng, 2011), the Agentic Engagement Scale (AES) soon followed as a reliable and validated measure of agentic engagement (Reeve, 2013).

In sum, the briefer version of the SESQ, which comprises the behavioural engagement, affective engagement, and cognitive engagement subscales, the TERF-N, and the AES formed the basis of the respective engagement measures for this research study, and the following subsections elaborate further on the formation of these measures.

[2]Source: Rotgans (2015, pp. 73–74).

Behavioural Engagement

The Behavioural Engagement Subscale (Lam et al., 2014) introduced as part of the abridged SESQ is a self-report instrument comprising twelve Likert-type items, all of which are rated on a five-point scale, to be administered to learners. In its application, it is complemented by four Likert-type items embedded within the TERF-N, all of which are also rated on a five-point scale. For this research study, each item from these two sources underwent a contextualisation to align with the overall research problem, purpose, and questions. Thereafter, each item was evaluated individually and for its part in the main instrument to ascertain fitness to context. The contextualised versions of six out of the twelve items of the abridged SESQ Behavioural Engagement Subscale, and one out of the four items of the behavioural engagement component of the TERF-N, were retained to form the behavioural engagement subscale that was ultimately used. Table 3.3 shows how the contextualisation was undertaken.

As highlighted in Table 3.3, six items (1.1, 1.6, and 1.9 to 1.12) from the Behavioural Engagement Subscale of the abridged SESQ were not retained into the final behavioural engagement measure for this research study. This was because these items were capturing school-based, home-based, or other extra-curricular engagement behaviours, whereas the primary focus of this research study was purely on class-based activities that illustrate behavioural engagement. Furthermore, three items (2.2 to 2.4) from the behavioural engagement component of the TERF-N were not retained into the final behavioural engagement measure for this research study because they were either already captured by the retained items, or fell outside the scope of the inquiry.

Affective Engagement

The Affective Engagement Subscale (Lam et al., 2014) introduced as part of the abridged SESQ is a self-report instrument comprising nine Likert-type items, all of which are rated on a five-point scale to be administered to learners. In its application, it is complemented by three Likert-type items embedded within the TERF-N, all of which are also rated on a five-point scale. For this research study, each item from these two sources underwent a contextualisation to align with the overall research problem, purpose, and questions. Thereafter, each item was evaluated individually and for its part in the main instrument to ascertain fitness to context. The contextualised versions of five out of the nine items of the abridged SESQ Affective Engagement Subscale were retained to form the affective engagement subscale that was ultimately used. Table 3.4 shows how the contextualisation was undertaken.

Table 3.4 highlights that four items (1.6 to 1.9) from the Affective Engagement Subscale of the abridged SESQ were not retained into the final affective engagement measure for this research study. This was because these items were capturing school-based engagement behaviours, whereas the primary focus of this research study was purely on class-based activities that illustrate affective engagement. Furthermore, none of the three items from the affective engagement component of the TERF-N were retained into the final affective engagement measure for this research study because they did not align with the scope of inquiry as set out by the research problem, purpose, and questions.

Table 3.3: Contextualisation of the Behavioural Engagement Subscale of the abridged SESQ and the corresponding TERF-N items for use as a behavioural engagement measure.[3]

Item	Behavioural Engagement Subscale and TERF-N Items	Contextualised Behavioural Engagement Items
1.1	I try hard to do well in school	—
1.2	In class, I work as hard as I can	In class, my learners work as hard as they can
1.3	When I'm in class, I participate in class activities	When my learners are in class, they actively participate in class activities
1.4	I pay attention in class	My learners pay attention in class
1.5	When I'm in class, I just act like I am working (R)	When my learners are in class, they just act like they are working
1.6	In school, I do just enough to get by (R)	—
1.7	When I'm in class, my mind wanders (R)	When my learners are in class, their minds often wander
1.8	If I have trouble understanding a problem, I go over it again until I understand it	If my learners have trouble understanding a problem, they go over it again until they understand it
1.9	When I run into a difficult homework problem, I keep working at it until I think I've solved it	—
1.10	I am an active participant of school activities such as sport day and school picnic	—
1.11	I volunteer to help with school activities such as sport day and parent day	—
1.12	I take an active role in extra-curricular activities in my school	—
2.1	Has good attendance	My class attendance is good
2.2	Participates in class discussions/activities	—
2.3	Is referred for out-of-class disciplinary procedures	—
2.4	Is respectful to staff	—

Note: Items 1.1 to 1.12 are from the Behavioural Engagement Subscale of the abridged SESQ and Items 2.1 to 2.4 are from the behavioural engagement component of the TERF-N.

[3] Source: S. R. Hart et al. (2011) and Lam et al. (2014).

Table 3.4: Contextualisation of the Affective Engagement Subscale of the abridged SESQ and the corresponding TERF-N items for use as an affective engagement measure.[4]

Item	Affective Engagement Subscale and TERF-N Items	Contextualised Affective Engagement Items
1.1	I am very interested in learning	My learners are very interested in learning
1.2	I think what we are learning in school is interesting	My learners think what they are learning in class is interesting
1.3	I like what I am learning in school	My learners like what they are learning in class
1.4	I enjoy learning new things in class	My learners enjoy learning new things in class
1.5	I think learning is boring (R)	My learners think learning is boring
1.6	I like my school	—
1.7	I am proud to be at this school	—
1.8	Most mornings, I look forward to going to school	—
1.9	I am happy to be at this school	—
2.1	Seems interested in school	—
2.2	Gets along with peers	—
2.3	Seems to care about grades	—

Note: Items 1.1 to 1.9 are from the Affective Engagement Subscale of the abridged SESQ and Items 2.1 to 2.3 are from the affective engagement component of the TERF-N.

Cognitive Engagement

The Cognitive Engagement Subscale (Lam et al., 2014) introduced as part of the abridged SESQ is a self-report instrument comprising twelve Likert-type items, all of which are rated on a five-point scale to be administered to learners. In its application, it is complemented by three Likert-type items embedded within the TERF-N, all of which are also rated on a five-point scale. For this research study, each item from these two sources underwent a contextualisation to align with the overall research problem, purpose, and questions. Thereafter, each item was evaluated individually and for its part in the main instrument to ascertain fitness to context. The contextualised versions of two out of the twelve items of the abridged SESQ Cognitive Engagement Subscale, and all three items of the cognitive engagement component of the TERF-N, were retained to form the cognitive engagement subscale that was ultimately used. Table 3.5 shows how the contextualisation was undertaken.

[4]Source: S. R. Hart et al. (2011) and Lam et al. (2014).

Table 3.5: Contextualisation of the Cognitive Engagement Subscale of the abridged SESQ and the corresponding TERF-N items for use as a cognitive engagement measure.[5]

Item	Cognitive Engagement Subscale and TERF-N Items	Contextualised Cognitive Engagement Items
1.1	When I study, I try to understand the material better by relating it to things I already know	—
1.2	When I study, I figure out how the information might be useful in the real world	—
1.3	When learning new information, I try to put the ideas in my own words	When my learners learn new information, they try to put the ideas in their own words
1.4	When I study, I try to connect what I am learning with my own experiences	—
1.5	I make up my own examples to help me understand the important concepts I learn from school	My learners make up their own examples to help them understand the important concepts they learn from my class
1.6	When learning things for school, I try to see how they fit together with other things I already know	—
1.7	When learning things for school, I often try to associate them with what I learnt in other classes about the same or similar things	—
1.8	I try to see the similarities and differences between things I am learning for school and things I know already	—
1.9	I try to understand how the things I learn in school fit together with each other	—
1.10	I try to match what I already know with things I am trying to learn for school	—
1.11	I try to think through topics and decide what I'm supposed to learn from them, rather than studying topics by just reading them over	—
1.12	When studying, I try to combine different pieces of information from course material in new ways	—

Continues on next page...

[5] Source: S. R. Hart et al. (2011) and Lam et al. (2014).

Table 3.5: Contextualisation of the Cognitive Engagement Subscale of the abridged SESQ and the corresponding TERF-N items for use as a cognitive engagement measure. *(Continued)*

Item	Cognitive Engagement Subscale and TERF-N Items	Contextualised Cognitive Engagement Items
2.1	Persists on more challenging tasks	My learners persist on more challenging tasks
2.2	Demonstrate appropriate effort for task	My learners demonstrate appropriate effort to task
2.3	Is self-motivated	My learners are self-motivated

Note: Items 1.1 to 1.9 are from the Affective Engagement Subscale of the abridged SESQ and Items 2.1 to 2.3 are from the affective engagement component of the TERF-N.

The ten items (1.1 to 1.2, 1.4, and 1.6 to 1.12) from the Cognitive Engagement Subscale of the abridged SESQ that were not retained into the final cognitive engagement measure for this research study are highlighted in Table 3.5. This was because these items were capturing home-based engagement behaviours specifically related to school activities (for instance: "when I study" or "when learning things for school"), whereas the primary focus of this research study was purely on class-based activities that illustrate cognitive engagement.

Table 3.6: Contextualisation of the Agentic Engagement Scale for use as an agentic engagement measure.[6]

Item	Agentic Engagement Scale Items	Contextualised Agentic Engagement Items
1	I let my teacher know what I need and want	My learners let me know what they need and want
2	During class, I express my preferences and opinions	During the lesson, my learners express their preferences and opinions
3	When I need something in class, I'll ask the teacher for it	When my learners need something in class, they ask me for it
4	During class, I ask questions to help me learn	During the lesson, my learners ask questions to assist them to learn
5	I let my teacher know what I am interested in	My learners let me know what they are interested in

Agentic Engagement

The AES was introduced as a self-report instrument comprising five Likert-type items, all of which are rated on a five-point scale to be administered to learners. In a similar manner as with

[6]Source: Reeve (2013).

other measures already discussed for this research study, each item underwent a contextualisation to align with the overall research problem, purpose, and questions. Thereafter, each item was evaluated individually and for its part in the main instrument to ascertain fitness to context. The contextualised versions of all five items were retained to form the agentic engagement subscale that was ultimately used. Table 3.6 shows how the contextualisation was undertaken.

3.3 RESEARCH PHILOSOPHY

3.3.1 Research Paradigms: Definition and Importance

The term *paradigm* has been subjected to a lot of controversy and scrutiny since it was first introduced into the research discourse by American philosopher Thomas Kuhn in the early 1960s (Kivunja & Kuyini, 2017; Morgan, 2007; Sefotho, 2015). Morgan (2007) interrogates the historical aspects of a paradigm, and propounds that in its most general sense, a paradigm is a "shared belief system[s] that influence[s] the kinds of knowledge researchers seek and how they interpret the evidence they collect" (p. 50). Morgan goes on to advance four descriptions or versions of a paradigm, each specific to a certain research approach (or a combination thereof). These versions of the term, from most general to most specific, include viewing a paradigm as: (i) a worldview; (ii) an epistemological stance; (iii) shared beliefs in a research field; and (iv) model examples (or exemplars). Notwithstanding, many other social science researchers have advanced many other definitions and critical thought on paradigms. Collectively, these definitions have often overlapped with or have been found to be in conflict with how the term is perceived and used, especially by natural science researchers. This has led to a number of *research paradigms* emerging over the years.

This research study adopted the definition by Mertens (2023), which states that a paradigm is "a way of looking at the world" and that "it is composed of certain philosophical assumptions that guide and direct thinking and action" (p. 2). While maintaining its specificity, this definition fully embodies the essence of Morgan's (2007) four descriptors of the term. Furthermore, it acknowledges the importance for a research study to adopt and be guided by such established philosophical assumptions as this serves to support, direct, explain, and contextualise all the decisions and outcomes of the research study as it unfolds. Over the years, researchers have identified and elaborated on four key elements, or basic beliefs, that are at the core of a paradigm. These elements are the (i) epistemology, (ii) ontology, (iii) methodology, and (iv) axiology of a paradigm (Guba & Lincoln, 2005; Kivunja & Kuyini, 2017; Lincoln & Guba, 1985; Mertens, 2023; Morgan, 2007; Sefotho, 2015), and the following subsections define what each of these terms mean and emphasise their importance within a research paradigm.

Epistemology

The epistemology of a paradigm describes the nature of knowledge in relation to the way of looking at the world. Crotty (1998) succinctly defines it as the "theory of knowledge embedded in the theoretical perspective" (p. 3). In broad terms, epistemology is concerned with the various forms and sources of knowledge, together with how researchers and research participants can participate in the processes of acquiring, comprehending, broadening, deepening, extending and disseminating knowledge for the benefit of themselves and the associated fields of research

(Kivunja & Kuyini, 2017; Moser, 2002).

Epistemology is thus very important within a research paradigm because it affects how researchers reason about knowledge, and within each epistemological stance is an embedding of ways with which to understand the natural and social worlds.

Ontology

The ontology of a paradigm is concerned with the nature of reality in relation to the way of looking at the world. In the words of Tai and Ajjawi (2016), it describes "the existence of things, objects and experiences" (p. 176), and asks of researchers the question of whether or not the things humans perceive in the world are actually there or real (Kivunja & Kuyini, 2017; Mertens, 2023; Tai & Ajjawi, 2016).

Ontology is especially important within a research paradigm because it informs and orientates researchers on how to make meaning of the data collected during the research process, and further helps them understand the very essence of the problem and significance of the research under study (Kivunja & Kuyini, 2017).

Methodology

The third key element at the core of a paradigm, methodology, is concerned with the systematic approach that the researcher adopts in pursuit of the answers sought by the research questions (or to prove or nullify any hypotheses set forth) (Mertens, 2023; Neuman, 2014).

Kivunja and Kuyini (2017) suggest that methodology, above working in tandem with the other three key elements of a paradigm, is directly linked to the contribution to knowledge dimension, which is the ultimate goal of any research study. It is therefore important for a researcher to craft an unambiguous research methodology, characterised by high standards, as it is through the methodology that the study gains merit in the research world.

Axiology

Axiology is the final and equally important key element of a research paradigm. It is concerned with the "nature of ethical behaviour" during a research study (Mertens, 2023, p. 5). Furthermore, it encompasses "an awareness of our values, attitudes, and biases" as researchers, and further acknowledges how these attributes might influence the nature of our research in its entirety (Hesse-Biber & Griffin, 2015, p. 79).

Over the years, researchers have highlighted the importance of ethical and moral conduct when conducting research. They have emphasised the need for researchers to ensure that the interests, dignity, and morality of all those participating in their research studies are recognised and protected on the one hand, while also exercising sound ethical and moral behaviour in reporting the research findings on the other hand (Hedrick et al., 1993; Mertens, 2023; Neuman, 2014).

3.3.2 Dominant Paradigms in Educational Research

There are four dominant paradigms in educational research. According to Mertens (2023), the oldest of these paradigms is the *Positivist* paradigm, which is followed chronologically by the *Interpretivist*, *Transformative* and *Pragmatic* paradigms. General consensus in educational research suggests that many of the existing paradigms can be classified into one of these four (Guba & Lincoln, 2005; Kivunja & Kuyini, 2017). The following subsections outline the characteristics of each.

Positivist Paradigm

Positivism (and its successor, postpositivism) is a way of looking at the world that is dominantly adopted by the natural science discipline. Its underlying assumptions, according to Mertens (2023, p. 4), "include the belief that the social world can be studied in the same way as the natural world". Researchers in this paradigm exercise the use of traditionally scientific methods of inquiry in conducting their research (such as calculations, experiments, extrapolations, statistics, mathematical equations, and so on), and often prefer precise quantitative data (Kivunja & Kuyini, 2017; Mertens, 2023; Neuman, 2014).

Interpretivist Paradigm

The Interpretivist paradigm, also referred to as the Constructivist paradigm, holds the underlying assumption that individuals develop subjective meanings of their experiences (Creswell, 2014). Researchers in this paradigm endeavour to seek and interpret the experiences of research participants, based on the social contexts within which such experiences are had (Creswell, 2014; Kivunja & Kuyini, 2017; Mertens, 2023).

Transformative Paradigm

Researchers who are at the forefront of any of socio-political, socio-cultural, socio-ethnic, or socio-economical research situate their research within the Transformative paradigm. Sometimes called the Critical paradigm, this paradigm consolidates various diverse philosophical assumptions that aim to address issues concerned with, in the deepest and broadest sense, human rights, social justice, and decolonisation, thereby transforming society (Cram & Mertens, 2015; Kivunja & Kuyini, 2017; Mertens, 2023; Neuman, 2014).

Pragmatic Paradigm

Morgan (2007) explains in great depth the paradigmatic tapestry which has led to the recognition of an alternative paradigm underpinned by pragmatism as a philosophical viewpoint. Research efforts situated in this paradigm are centred around the methodology key element, following the advocacy that only those methods of inquiry which would best offer insight into the research phenomenon being studied should be selected (Mertens, 2023; Morgan, 2007).

3.3.3 Research Paradigm for this Study

The preceding sections have: (i) defined, albeit briefly, what is meant by *paradigm* in the context of research; (ii) highlighted the importance of situating a research study within a specific

paradigm; (iii) adopted a specific definition of a paradigm for the context of this research study; and (iv) introduced the dominant paradigms in the discipline of educational research. This has provided the impetus for situating this research study within the Pragmatic paradigm.

The remainder of this section looks at the four key elements at the core of a paradigm in relation to the problem statement (Section 1.2), purpose statement (Section 1.3), and research questions (Section 1.4) underpinning this study in arguing and justifying why the Pragmatic paradigm was an apt choice for this research study. The methodology key element, as the centre point of the Pragmatic paradigm, is explored first.

Methodology

The primary purpose of this study, as outlined in Section 1.3, was to explore teachers' perceptions of learner motivation as it relates to the use of ICTs to teach and learn mathematics in the context of the theoretical conceptualisation of motivation in a social constructivist setting as set out by Sivan (1986). Pursuant to this primary purpose, this exploration was conducted through an online survey questionnaire, which was designed and developed through a mix of insights from literature and the characteristics of motivation in social constructivist theory. This survey questionnaire was administered to conveniently selected teachers across all school districts and educational phases of the Gauteng province of South Africa.

The secondary purpose of this study was to further explore the nuances of learner motivation and the different discourse practices in the use of ICTs in teaching and learning mathematics. This was undertaken so as to explain and explicate the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics. Pursuant to this secondary purpose, this further exploration adopted semi-structured interviews as a method of inquiry, conducted with teachers who volunteered to participate in this research study. This method of inquiry afforded a rich, exploratory, and interactive process between the researcher and the research participants, which assisted in uncovering the different discourse practices prevalent in the use of ICTs in classrooms.

At an abstract level, pursuing the aggregate purpose of this research study, as set out above, required a *quantitative phase* (concerned with pursuing the primary purpose of this study) followed sequentially by a *qualitative phase* (concerned with pursuing the secondary purpose of this study), and included an integration (through the two forms of data and their results) of these two phases at various stages along the research process. This was necessary in order to gain a more complete understanding of the phenomenon that this research study investigated (as problematised in Section 1.2). Thus, this aligned with Creswell's (2014, pp. 15–16) "explanatory sequential mixed methods" design, and conformed to the Pragmatic paradigmatic view which holds that "[methods of inquiry] should be decided by the purpose of the research" (Mertens, 2023, p. 28). Sections 4.2 and 4.3 further unpack the methodology and design choices that guided this research study.

An attempt to situate this study within the Positivist paradigm would limit the insights that would otherwise be garnered, since the methodological stance of this paradigm is strongly experimental. Similarly, the Interpretivist paradigm's strong humanist or naturalist methodological assumptions would limit the study's potential to further interrogate the views of the partici-

pants. While there might be traces of socio-political aspects in the problem statement, the heart of this research study is in the classroom, and situating it within the Transformative paradigm would not align to its purpose. The Pragmatic paradigm affords the researcher the flexibility to choose the most appropriate approach to address the research purpose at hand (Mertens, 2023; Morgan, 2007), and the mixed methods design is quintessentially pragmatic (Creswell, 2014; Creswell & Plano Clark, 2017; Hanson et al., 2005; Tashakkori et al., 2020).

Epistemology

The "valuing [of] both objective and subjective knowledge" (Hanson et al., 2005, p. 226) is an inherent and reconciliatory perspective of the Pragmatic paradigm, which assists pragmatic researchers with navigating the contrasting epistemological stances of the Positivist and Interpretivist paradigms. Morgan (2007) further attests to the importance of a "practicing researcher [having] to work back and forth between various frames of reference" (p. 71). By design, this research study sought to uncover, understand, and reason about both the objective and subjective knowledge, while being cognisant of the nature and assumptions surrounding how these knowledges have come to being.

During the quantitative strand of this research study, quantitative data were collected and objectively analysed through established statistical methods and procedures pursuant to the study's primary purpose. This implied an objectivist epistemological stance, characteristic of the Positivist paradigm.

In contrast, the qualitative strand of this research study was characterised by a rich interactive process between the researcher and the research participants in order to uncover knowledge pursuant to the study's secondary purpose. The resultant knowledge was a subjective account of participants' insights interpreted by the researcher. This implied a subjectivist epistemological stance, characteristic of the Interpretivist paradigm.

The integrated interpretation of the outcome of these two strands (the so-called 'mixing' of the methods), from which key insights were drawn, carefully recognised, valued, and protected both these epistemological stances, true to the epistemological perspective of the Pragmatic paradigm.

Ontology

Researchers who situate their research within the Positivist paradigm are guided by the ontological assumption that the nature of reality is singular and that this reality is "knowable within a specified level of probability" (Mertens, 2023, p. 5). In stark contrast, researchers whose research is situated within the Interpretivist paradigm subscribe to the ontological assumption that there are multiple realities, and that these realities are socially constructed (Mertens, 2023; Mertens & Tarsilla, 2015). The ontological assumptions within the Transformative paradigm suggest multiple versions of reality which are informed by the social positioning of the perceiver of the reality (Mertens, 2023; Mertens & Tarsilla, 2015) and are also "consequences of privilege" (Mertens & Tarsilla, 2015, p. 439). The ontological assumptions within the Pragmatic paradigm "[assert] that there is single reality and that all individuals have their own unique interpretation of reality" (Mertens, 2023, p. 5).

Given the political history of South Africa, and how it has a direct and telling influence on the current education system of the country, it was inevitable that hints of historical imbalances would surface across all the data collection phases of this research study (Howie et al., 2005; Mestry, 2014). According to Mestry (2014), "unequal and separate funding of public education under the apartheid regime created huge disparities between white and black schools and this had serious implications for the provision of quality education, learner performance and educational outcomes in historically disadvantaged schools" (p. 500). This reality extends beyond the schools into the communities, where the very learners that attend these historically disadvantaged schools reside and are constantly grappling with socio-economical issues such as poverty, access to basic human rights, access to information and access to technology, amongst many other critical social and cultural issues (Chigona et al., 2014; Mestry, 2014; Mestry & Ndhlovu, 2014). This pre-existing reality laid an important ontological base leading into the data collection phases of this research study.

Indeed, the quantitative phase of this research study, which sought to explore the use of ICTs in teaching and learning mathematics, and what influence that use had in the motivation of learners to learn mathematics, adopted a quantitative method of inquiry, and thus leaned towards the Positivist worldview. However, the analysis of the data from this phase of the study had to be conducted in tandem with the understanding of the contextual nature of reality, thus acknowledging the Pragmatic paradigm's ontological assumptions.

The qualitative phase of this study sought to explain and understand some of the relationships derived from the quantitative phase through exploring and uncovering the views of the participants on how ICTs are used in classroom discourse, and what characterises a motivated learner. This was accomplished through semi-structured interviews as a method of inquiry. As was the expectation, these views, or realities, were subjective upon the experiences of the perceivers and varied from participant to participant. A key assumption leading into this phase of the study was that there is one reality on how ICTs are used in classroom discourse and that there are common traits that identify a motivated learner. Its ontological purpose was thus to unearth this reality by piecing it together from the participants' accounts of their reality.

In sum, this was incompatible with the Positivist paradigm's ontological assumptions as it acknowledged the possible multiplicity of realities perceived by the participants, whereas the Positivist paradigm advocates for a single reality only. In considering the Interpretivist paradigm's ontological assumptions, which allude to there being multiple socially constructed realities, this study grounded itself on the assumption of there being a single reality with multiple perceptions of this reality—and not actual multiple realities—by the participants. The two assumptions were thus also incompatible. The nature of reality within the Transformative paradigm is underlined principally by historical experiences linked to privilege and equality, whereas that within the Pragmatic paradigm is an individualistic interpretation or perception of a single reality. These two ontological assumptions from both these paradigms were at the centre of the qualitative phase of this research study as a consequence of the historical legacy of South Africa: while there might be a singular reality on how ICTs are used in classroom discourse, this reality is in itself derived from the realities reflecting historical inequalities of the country, as earlier highlighted, which are perceived uniquely by each member of the classroom environment.

Axiology

Morgan (2014) argues that the axiological assumptions of the Pragmatic paradigm naturally place ethics in a central role "in every aspect of human experience" (p. 1051). This means that unlike within the other paradigms where axiological assumptions have specific labels or basic terminology that describe such assumptions[7], research situated within the Pragmatic paradigm acknowledges and values all aspects concerned with ethical and moral behaviour prevalent during a research study. Mertens and Tarsilla (2015) concur with this view, and further highlight that the researcher's values, and other related aspects such as politics and experiences, play an important role during the research process.

The quantitative and qualitative strands of this research study saw participation from humans through the various methods of inquiry which were adopted for each strand. These methods of inquiry yielded sets of data that were carefully analysed and interpreted, and from which key insights were drawn. In carrying out these processes, it was important to respect the views expressed by the research participants, while also demonstrating high standards of ethical and moral conduct from a researcher's point of view. This was important throughout the execution of the methods of inquiry and in the reporting of, and communicating about, the key findings that this research study arrived at. This was in line with the Pragmatic paradigm's basic belief of how ethical and moral issues ought to be approached when conducting research. Section 4.5 expands on the ethical considerations that were key during the undertaking of this research study.

3.4 SUMMARY

This chapter delineated the theoretical and philosophical underpinnings that were foundational in the undertaking of this research study. It commenced with an exploration of constructivism, particularly social constructivism, as the principal theoretical lens through which the dynamics of ICT use in mathematics education and its influence on learner motivation were examined. The chapter provided a robust argument for this choice, anchored in social constructivism's three fundamental tenets: the emphasis on cognitive activity as the essence of learning processes, the significance of cultural knowledge, tools, and signs in constructing meaning and shaping understanding, and the crucial role of assisted learning through social interactions and collaboration. These principles collectively offered a robust lens for viewing learner motivation within technology-enhanced learning environments, underscoring the interactive, culturally situated, and supportive aspects of learning that are critical for fostering motivation.

In discussing motivation, the chapter traversed several pivotal theories, including the expectancy-value theory and the self-determination theory, synthesising these perspectives to forge a nuanced understanding of motivation as it pertains to this study. This led to a distinctive conceptualisation of motivation, informed by Sivan's (1986) work and framed within a social constructivist context, as a nested, multidimensional construct comprising interest and engagement. This

[7]For instance, Mertens and Tarsilla (2015) summarise the axiological assumptions within the Positivist paradigm as those characterised by "respect", "privacy", "beneficence", "nonmaleficence" and "justice" (p. 433); within the Interpretivist paradigm as those characterised by "balanced representation", "rapport" and "multicultural respect" (p. 434); and within the Transformative paradigm as those characterised by "cultural respect", "[the promotion of] social justice and human rights", "[the addressing of] inequities", as well as "reciprocity" (p. 439).

conceptual framework depicted motivation as an observable manifestation of interest and engagement within educational settings. Additionally, the chapter detailed the operationalisation of these constructs, including measures of motivation attributes, thereby laying the groundwork for the methodological approaches elaborated upon in the following chapter.

On the philosophical front, the chapter ventured into the significance of research paradigms and their respective philosophical assumptions, underscoring their centrality in shaping scholarly inquiry. After examining four prevalent paradigms within educational research, the chapter provided a detailed rationale for selecting the Pragmatic paradigm as the most appropriate for this study. This choice was predicated on its alignment with the study's problem statement, purpose statement, and research questions, in addition to the theoretical discourse previously established. The Pragmatic paradigm, which centres on robust yet reflexive methodological approaches, was portrayed as ideally suited to the study's objectives, seamlessly connecting the theoretical and philosophical discussions to the methodological aspects outlined in the next chapter.

CHAPTER 4

RESEARCH METHODOLOGY AND DESIGN

4.1 INTRODUCTION

4.1.1 Chapter Purpose

Building upon the theoretical and philosophical foundations established in the preceding chapter, this chapter presents the methodological framework that guided this research. Having justified the use of a social constructivist lens and the Pragmatic paradigm, along with a detailed conceptualisation of motivation, the focus now shifts to the methodological aspects that were taken into account for investigating ICT use in teaching and learning mathematics and its implications for learner motivation. This chapter is central to this thesis, as it delineates the chosen methodological stance, including the specific research design, data collection and analysis techniques, and ethical considerations, all carefully chosen to complement the study's theoretical perspectives, purpose, and research questions. It serves as a detailed exposition of how each methodological element contributed to a coherent and effective research strategy.

4.1.2 Chapter Outline and Organisation

This chapter unfolds through several key sections. It begins with Section 4.2, which discusses the research methodology, comparing various methodological approaches, subsequently detailing the rationale for having selected a mixed methods approach as most suited for this study. Section 4.3 proceeds to research design specifics, initially reviewing common designs within mixed methods research, before justifying the adoption of an explanatory sequential mixed methods design. This section also elaborates on this design's defining features and its fit with the study's broader aims.

Continuing, Section 4.4 delves into the specifics of the research methods employed, spanning sampling strategies, data collection and generation techniques, and data analysis approaches, thus ensuring a comprehensive overview of the empirical process. Ethical considerations are addressed in Section 4.5, where the ethical framework and procedural ethics that underpinned the study's execution, including institutional approvals and participant consent, are discussed.

Finally, Section 4.6 summarises the chapter's main points, bridging to the presentation of results and findings in the chapters that follow.

4.2 Research Methodology

The Pragmatic paradigm provided the philosophical underpinnings of this research study as so articulated in the previous in Section 3.3. Of the four key elements at the core of a paradigm, and without undermining the equal importance of all four, this paradigm centres around the methodology element, as it is through a sound and meticulous methodology that the outcomes of a research study can be credible. To re-articulate, methodology is concerned with the systematic approach that the researcher adopts in pursuit of the answers sought by the research questions (Mertens, 2023; Neuman, 2014). Creswell (2014), who refers to methodology as a *research approach*, further advances that it consists of "plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation" (p. 3).

There are three research approaches from which to choose when conducting a research study. These are the (i) qualitative, (ii) quantitative, and (iii) mixed methods research approaches (Creswell, 2014; Edmonds & Kennedy, 2017). The qualitative research approach is situated on the one extreme end of a continuum of approaches and it is adopted in order to explore and understand the meaning individuals or groups of individuals ascribe to various social phenomena (Creswell, 2014). This approach is characterised by structured and unstructured open-ended sets of data (qualitative data) that are collected, analysed and interpreted by the researcher. The quantitative research approach is situated on the other extreme end of this continuum and it is adopted when there is a need to test objective theories by looking at the various relationships between variables concerned (Creswell, 2014). This approach is characterised by numerical data (quantitative data), and the manipulation and analysis thereof using statistical procedures and tools. The mixed methods approach is positioned in the middle of this research approach continuum, as it is concerned with "collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks" (Creswell, 2014, p. 6).

The choice of which approach to adopt is informed by the philosophical assumptions that guide the research paradigm in which the research study is situated. Research in the Positivist paradigm often adopts the quantitative research approach while that in the Interpretivist paradigm often adopts the qualitative research approach. The inherent philosophical assumptions of both the Transformative and Pragmatism paradigms often necessitate that research efforts within these paradigms adopt the mixed methods research approach (Hanson et al., 2005; Mertens, 2023). Accordingly, this research study adopted the mixed methods research approach.

Over the years, researchers at the forefront of the mixed methods research field have contributed towards defining what the mixed methods research approach really is. R. B. Johnson et al. (2007) examined a number of these definitions across their varying levels of specificity, and emerged with a reconfigured definition which captures the essence of this research approach: "mixed methods research is an intellectual and practical synthesis based on qualitative and

quantitative research" (p. 129). They further asserted that the mixed methods approach recognises the fundamentals of the traditional qualitative and quantitative research approaches, and that it is a powerful approach that "often will provide the most informative, complete, balanced, and useful research results" (p. 129). In a recent publication, Creswell and Plano Clark (2017) followed a similar process in synthesising this definition, arriving at a consistent definition of the mixed methods approach.

Creswell and Plano Clark (2017) went on to outline the core characteristics that describe mixed methods, which include: (i) the collection and analysis of both quantitative and qualitative data in a rigorous manner pursuant to the research questions; (ii) the systematic integration (or mixing or combining) of the two forms of data and their results; (iii) the use of specific research designs that provide the logic and procedures for conducting a research study; and (iv) the framing of these research designs within theory or underpinning philosophy.

Given these characteristics, there are several reasons why the mixed methods approach would be employed when conducting research. Hanson et al. (2005) synthesised and consolidated several of these reasons from prominent researchers in the field into the following four:

> to (a) better understand a research problem by converging numeric trends from quantitative data and specific details from qualitative data; (b) identify variables/constructs that may be measured subsequently through the use of existing instruments or the development of new ones; (c) obtain statistical, quantitative data and results from a sample of a population and use them to identify individuals who may expand on the results through qualitative data and results; and (d) convey the needs of individuals or groups of individuals who are marginalized or underrepresented. (p. 226)

In this research study, the mixed methods approach was adopted to, in the first instance, explore teachers' perceptions of learner motivation as it relates to the use of ICTs to teach and learn mathematics and, in the second instance, to explain and explicate the relationship between the use of ICTs in teaching and learning mathematics, as well as the motivation of learners to learn mathematics, by further exploring the nuances of learner motivation and the different discourse practices in the use of ICTs in teaching and learning mathematics. This inquiry was guided by the theoretical conceptualisation of motivation in a social constructivist setting as set out by Sivan (1986). This was in line with the third reason for adopting a mixed methods approach, as given by Hanson et al. (2005). The next section presents the research design that this study adopted, first by looking at the three core mixed methods research designs, and then by drawing specific focus to the design that this research study adopted.

4.3 Research Design

A research design represents a template or a model that can be adopted for structuring a research study, along with the associated procedures for collecting, analysing, interpreting and reporting data as part of the research study. As a function of a research study's methodology, a research design needs to align with the key elements of the study, notably the research questions (and by extension, the purpose and problem statements), in order to achieve a consistent flow in the study's analysis, interpretation and reporting stages (Creswell, 2012, 2014; Gorard, 2017). The

remainder of this section introduces the principal designs within the mixed methods research approach and subsequently from these designs, the specific design of choice for this research study.

4.3.1 Mixed Methods Research Designs

Creswell and Plano Clark (2017) describe three core research designs in the mixed methods research approach which have emerged and have been refined over time. These are: (i) the convergent design; (ii) the explanatory sequential design; and (iii) the exploratory sequential design. These are explained further in the immediate subsections.

Convergent Design

The primary intent of the convergent mixed methods design is to "bring together the strengths and weaknesses of quantitative and qualitative methods" (Creswell & Plano Clark, 2017, p. 68). This is achieved through combining or comparing the results that come from the independent analysis of both sets of data. The rationale behind using this design is to obtain a more complete understanding of a problem or to validate one set of findings with the other (Creswell & Plano Clark, 2017). This mixed methods design conforms to the first reason for adopting a mixed methods approach, as given by Hanson et al. (2005).

Explanatory Sequential Design

The explanatory sequential mixed methods design has two distinct phases that follow each other sequentially (Creswell, 2014; Creswell & Plano Clark, 2017). The first phase of this design is concerned with collecting quantitative data. These data are then analysed accordingly, yielding results that will inform how the second qualitative phase of this design should be structured. The primary intent of this mixed methods design is to use the results of the second qualitative phase of this design to explain the results from the first quantitative phase (Creswell, 2014; Creswell & Plano Clark, 2017). The rationale behind using this design is to limit focus to a specific subset of the sample, in order to follow up and gain a richer understanding and explanation of the initial quantitative results. This mixed methods design conforms to the third reason for adopting a mixed methods approach, as given by Hanson et al. (2005).

Exploratory Sequential Design

The third mixed methods research design is the exploratory sequential design. To a certain extent, this design is the inverse of the explanatory sequential design, but has three distinct sequential phases (Creswell, 2014; Creswell & Plano Clark, 2017). The first phase of this design is concerned with collecting qualitative data. These data are then analysed accordingly, yielding results that feed into the second intermediary (or developmental) phase of this design. This phase is characterised by the designing of a "quantitative feature based on the qualitative results" (Creswell & Plano Clark, 2017, p. 67) and any existing theory. This feature is then administered during the third quantitative phase of this design. The primary intent of this design is to ground the quantitative feature of the intermediary phase and the quantitative results of the quantitative phase on the views and findings uncovered in the qualitative phase. Creswell and Plano Clark (2017) emphasise that "the quantitative feature is based on the culture or setting

of participants rather than pulled 'off the shelf' for use" (p. 84). The rationale behind using this design is to create and adopt a culture-specific feature in exploring the phenomenon under study. This mixed methods design conforms to the second reason for adopting a mixed methods approach, as given by Hanson et al. (2005).

4.3.2 Research Design for this Study

The previous section has introduced the three core research designs available in the mixed methods research approach. Creswell and Plano Clark (2017) stress the importance of selecting a core design based on its alignment to the research problem, research purpose, research questions, and reason(s) for mixing. Taking this into consideration, and as expressed in the earlier parts of this thesis, the explanatory sequential mixed methods design was deemed a suitable fit for this research study and was therefore adopted. Figure 4.1 depicts this research design.

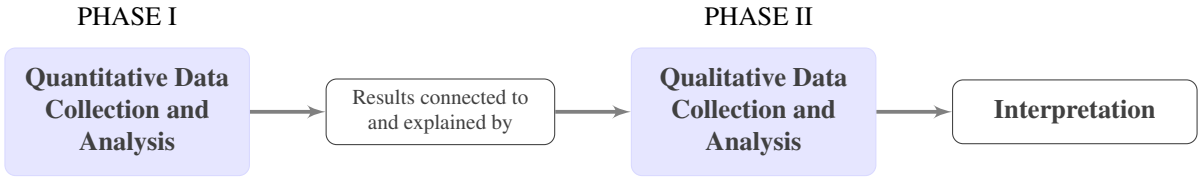


Figure 4.1: Explanatory sequential mixed methods research design.[1]

There are four key steps or procedures that need to be followed when using the explanatory sequential mixed methods design (Creswell & Plano Clark, 2017). Embedded in these steps are the actual points in the design at which the mixing occurs. These are detailed in the next subsection.

Design Procedures and the Mixing of Data Sets

The first step of the explanatory sequential mixed methods design is concerned with the design and implementation of the necessary instruments and procedures to aid in the collection and analysis of quantitative data in order to explore the phenomenon under study (Creswell & Plano Clark, 2017). This includes the identification of a quantitative sample from which to collect the data, as well as obtaining the institutional and individual permissions necessary to proceed with the research study. This corresponds with PHASE I of this design, as depicted in Figure 4.1. Additionally, this step of the design is crucial in identifying those participants interested in participating in the subsequent phase. For this research study, quantitative data were collected from the teacher participants who use ICTs to teach mathematics in their classrooms within the GDE provincial schooling system. These quantitative data were analysed using various statistics techniques in order to answer the quantitative research questions presented in Section 1.4.1.

The second step of this design, which also represents the point at which the mixing occurs, is concerned with identifying the results from the quantitative phase which will need to be further explored and explained by the qualitative phase (Creswell & Plano Clark, 2017). This is a significant intermediary phase which connects the quantitative phase (PHASE I) and the

[1] Source: Adapted from Creswell and Plano Clark (2017, pp. 66, 79).

qualitative phase (PHASE II) of the design, as depicted in Figure 4.1. For this research study, the results of the quantitative phase were used in conjunction with the contextual framing of motivation as guided by Sivan's (1986) conceptualisation of motivation in social constructivist theory in order to finalise the development of a qualitative data generation protocol that was used in the qualitative phase of this study. Furthermore, this step presented an opportunity, as contemplated by Creswell and Plano Clark (2017), to refine the qualitative and mixed methods research questions (presented in Sections 1.4.2 and 1.4.3) given the foresight of the quantitative phase results.

The third step of the explanatory sequential mixed methods design, which is depicted as PHASE II in Figure 4.1, is where the qualitative phase of the design is implemented (Creswell & Plano Clark, 2017). This step is guided by the quantitative results obtained in the first step, and the refined research questions and data generation protocol achieved in the preceding step. Similar to the first step, tasks in this step include the ratification of a qualitative sample from which data will be generated, and obtaining permission from consenting participants in order to continue with the research study. For this research study, qualitative data were generated from the teacher participants who, during the first step, indicated their interest in taking part in subsequent phases of the research study. These data were analysed using reflexive thematic analysis in order to answer the refined qualitative research questions, as presented in Section 1.4.2.

The fourth and final step of this design, representing the second point at which the mixing occurs, is concerned with the interpretation of the connected results. In broad terms, this step allows for the discussion of the extent and ways that the qualitative results assist with the explanation and understanding of the quantitative results (Creswell & Plano Clark, 2017). For this research study, the integrated interpretation of the results from PHASE I and PHASE II allowed for a discussion to answer the mixed methods research questions, as posed in Section 1.4.3, in order to gain an understanding of the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics from an observational account of teachers.

The Rationale for Adopting this Research Design

There are three main reasons why the explanatory sequential mixed methods research design was considered the research design of choice for this research study. The first reason is that of contextual fit: the problem statement, the purpose statement, and the research questions underlining this research study all aligned well with the core structure of this research design. The second reason is that of theoretical fit: the procedures and intent of this research design put specific emphasis on recognising the cultural context within which a research study takes place; this aligns with one of the three fundamental elements underpinning social constructivism, as articulated in Section 3.2.1, and allows for framing this design within this theoretical point of view. The third reason entails methodological soundness, and Ivankova et al. (2006) capture this by stating that "the quantitative data and their subsequent analysis provide a general understanding of the research problem", and that "the qualitative data and their analysis refine and explain those statistical results by exploring participants' views in more depth" (p. 5). This links to the prioritisation of the phases of this research design, as emphasised in the next subsection.

Priority of the Research Methods

In the explanatory sequential mixed methods design, the quantitative phase can take priority[2] over the qualitative phase (most typical case), the qualitative phase can take priority over the quantitative phase (least typical case), or both phases can have equal priority (Creswell, 2014; Creswell & Plano Clark, 2017; Edmonds & Kennedy, 2017; R. B. Johnson & Christensen, 2019). For this research study, it was decided a priori that both phases were to have equal priority. This was important in order to eliminate the possibility of showing bias towards one method over the other during the actual undertaking of the research study. Additionally, placing equal emphasis on both phases signified that while the statistical results of the first phase were important in addressing the research problem and associated research questions, so too were the views expressed by the participants in forming a holistic picture of the use of ICTs in teaching and learning mathematics in classroom settings. Furthermore, this approach aimed to recognise the importance of the cultural context within which this research study took place.

Strengths of the Research Design

Beyond the reasons specific to this research study, as highlighted in the rationale above, Creswell (2014) and Creswell and Plano Clark (2017) cite a number of strengths associated with this research design. The most notable is that because it is sequential with distinct phases, it makes it straightforward to describe, implement, and adopt. The distinct phases are also manageable, which favour sole researchers, unlike having to implement both phases simultaneously, as in the convergent design. Another strength associated with this design is the seamless integration of a qualitative phase that follows the quantitative phase, where the results of the quantitative phase are used to shape and optimise the design and execution of the qualitative phase. This neutralises the bias in audiences that are pro-quantitative or pro-qualitative methods, and further serves to provide a clear approach to reporting and delineating results and findings of the research study. The strengths outlined here, as well as others, were consistently evident throughout the duration of this research study.

Adopting an explanatory sequential mixed methods research design can present a range of challenges, as noted in literature. The following subsection highlights some of the key challenges encountered during the conduct of this research study specific to this research design.

Challenges with this Research Design

The sequential nature of this design, while a key strength, also presents a significant challenge when adopted. The implementation of both the quantitative and qualitative phases of this research design, as Creswell (2014) and Creswell and Plano Clark (2017) stress, often takes considerably longer to implement than other approaches. This further extends to the availability

[2]Specific notation exists which denotes the order of priority for all mixed methods designs (Creswell, 2014; Creswell and Plano Clark, 2017; Edmonds and Kennedy, 2017; R. B. Johnson and Christensen, 2019). This notation uses QUAN/QUAL (expressed in all uppercase letters) to emphasise that the quantitative phase (QUAN) or the qualitative phase (QUAL) takes higher priority, and quan/qual (expressed in all lowercase letters) to emphasise that the quantitative phase (quan) or the qualitative phase (qual) takes lower priority. For the explanatory sequential mixed methods design, the three possible orders of priority can be expressed as: (i) QUAN $\rightarrow$ qual (quantitatively driven sequential design); (ii) quan $\rightarrow$ QUAL (qualitatively driven sequential design); or (iii) QUAN $\rightarrow$ QUAL (equal-status sequential design).

and accessibility of participants. This was no different for this research study, and the duration was further exacerbated by other factors, as outlined later in Section 4.4.2.

Another less nuanced challenge inherent in this design is the ability to design for a seamless transition from the quantitative phase to the qualitative phase. This is due to the following sequence of reasons advanced by Creswell and Plano Clark (2017): firstly, the quantitative phase needs to be fully completed; secondly, the completion of the quantitative phase may result in several results needing to be further explored and explained through the qualitative phase; thirdly, the researcher must thus choose the most apt of these results to follow up on, while staying true to the research problem, research purpose, research questions, and reason(s) for mixing; fourthly, depending on which results are chosen for the qualitative phase, it might be necessary to re-select an appropriate sample best positioned to give valuable insights. Achieving a seamless transition between phases means carefully aligning these four instances such that the research study remains feasible, which inadvertently contributes to the overall lengthiness associated with this research design. The quantitative phase of this research study required a significant amount of attention and dedication, and took considerably longer to complete than was initially anticipated. Notwithstanding, the results made the remaining three instances reasonably straightforward.

4.4 Research Methods

4.4.1 Sampling Strategies

Sampling is a systematic process that employs specific techniques in order to select units from a larger population for conducting research. Mertens (2023) stresses the importance of sampling in research, stating that the strategy used for selecting a sample has a direct influence on the quality of the data that will be collected, and the inferences that can be made after analysing those data. According to Teddlie and Yu (2007), there are four broad categories of sampling procedures or strategies in the social and behavioural sciences disciplines. These are: (i) probability sampling; (ii) purposive sampling; (iii) convenience sampling; and (iv) mixed methods sampling.

Probability sampling procedures are predominately used in research studies employing the quantitative research approach. Sampling procedures in this category are primarily concerned with selecting a large number of units from a population in a random manner. The ultimate goal for these procedures is to select a sample that is representative of the population (Teddlie & Yu, 2007).

Purposive sampling procedures are predominately used in research studies employing the qualitative research approach. Sampling procedures in this category are primarily concerned with selecting units based on specific purposes aligned with answering the research questions posed by the research study (Teddlie & Yu, 2007). The ultimate goal for these procedures is to identify units that can yield information-rich cases that will allow for in-depth analysis of the phenomenon under study (Mertens, 2023; Palinkas et al., 2013).

Convenience sampling procedures aim to select units based on convenience and availability (Mertens, 2023; Teddlie & Yu, 2007). Although quite popular, convenience sampling proce-

dures are least desirable and are regarded as risky in the research world since they lack creativity and thorough logic (Mertens, 2023).

The final category of sampling procedures is mixed methods sampling. Similar to mixed methods research designs, this category is characterised by the use of both probability and purposive sampling techniques to select units (Mertens, 2023; Teddlie & Yu, 2007). Mixed methods sampling procedures are particularly suited for studies using a mixed methods research approach, as in this research study. Although several typologies of mixed methods sampling strategies exist, all of which share similar underlying concepts (Collins et al., 2006; Onwuegbuzie & Collins, 2007; Teddlie & Yu, 2007), Teddlie and Yu (2007) provide an intuitive categorisation into four distinct procedures, which was adopted for this study. These procedures include: (i) basic mixed methods sampling; (ii) sequential mixed methods sampling; (iii) concurrent mixed methods sampling; and (iv) multilevel mixed methods sampling. They also mention a fifth procedure that is a combination of these four. The remainder of this section briefly discusses these sampling procedures, and concludes with a discussion of the integrated sampling strategy adopted for this research study.

Basic Mixed Methods Sampling

The basic mixed methods sampling procedure comprises two techniques, stratified purposive sampling and purposive random sampling, which traditionally are types of purposive sampling. Because these techniques include elements of probability sampling, they automatically fall within the mixed methods sampling category of procedures. Basic mixed methods sampling techniques are useful for generating narrative data, specifically in qualitative-oriented research in the case of stratified purposive sampling, or for generating both qualitative and quantitative results in the case of purposive random sampling (Tashakkori et al., 2020; Teddlie & Yu, 2007). The basic mixed methods sampling procedure alone did not align with the design of this research study. However, specific techniques within this approach were combined with other mixed methods sampling procedures to develop the final sampling strategy for the study.

Sequential Mixed Methods Sampling

The sequential mixed methods sampling procedure, as the name suggests, directly aligns with the sequential mixed methods research designs (explanatory and exploratory) introduced in Section 4.3.1. It involves selecting units sequentially, using probability and purposive sampling procedures in the direction dictated by the research design. This sampling procedure is predominately used in studies employing the explanatory sequential mixed methods research design, where the final sample from the quantitative strand serves as the sampling frame for the subsequent qualitative strand (Tashakkori et al., 2020; Teddlie & Yu, 2007). In this research study, this sampling procedure was combined with other mixed methods sampling procedures to form the study's integrated sampling strategy.

Concurrent Mixed Methods Sampling

The concurrent mixed methods sampling procedure is directly aligned with the convergent mixed methods research design introduced in Section 4.3.1. Much like the sequential mixed methods sampling procedure, it is concerned with selecting units concurrently using probabil-

ity and purposive sampling procedures for the qualitative and quantitative parts of the research design respectively (Tashakkori et al., 2020; Teddlie & Yu, 2007). This sampling procedure was incompatible with the research design for this study and was therefore considered not applicable.

Multilevel Mixed Methods Sampling

Multilevel mixed methods sampling is characterised by multiple levels at which probability and purposive sampling procedures are used to select units (Tashakkori et al., 2020; Teddlie & Yu, 2007). This procedure is particularly useful for navigating complex and bureaucratic structures such as schools, government departments, and other highly hierarchical entities. Although this method may appear complex and involved, it offers researchers the flexibility to tailor their sampling strategy to the specific needs of their study across multiple hierarchical levels. In this research study, the multilevel mixed methods sampling procedure was combined with other mixed methods sampling procedures to develop the final sampling strategy.

Sampling Strategy for this Study

This research study employed a combination of multilevel and sequential mixed methods sampling procedures. This approach was guided by Teddlie and Yu (2007, p. 94), who described a typical case, similar to this study, where multilevel mixed methods sampling is appropriate (see Table 4.1).

Table 4.1: Multilevel mixed methods sampling as adopted by this research study.[3]

Level	Sampling Frames	Sampling Procedure
L4	Provincial school systems	Purposive sampling based on practical issues
L3	School districts	Probability sampling using random sampling
L2	Schools within districts	Probability sampling using random sampling
L1	Teachers or classrooms within schools	Probability sampling using random sampling followed by self-selection sampling
L0	Learners within classrooms	Not applicable

In Table 4.1, there are five hierarchical levels labelled L0 to L4 which represent a typical public schooling system hierarchy in the South African context. At each level, a sampling frame is presented, together with the sampling procedure and technique that this study used. As highlighted in the table, the focal point of this research study was at level L1, with teachers as participants for both the quantitative and qualitative phases of this research study.

The multilevel mixed methods sampling procedure enabled the selection of a sampling frame, from which participants for the quantitative phase were obtained using probability sampling through random selection. Thereafter, the sequential mixed methods sampling procedure allowed for the selection of qualitative participants from the quantitative sample (a nested sample)

[3]Source: Adopted from Teddlie and Yu (2007, p. 94)

through self-selection sampling. This approach aligns with "Design 7" of the two-dimensional mixed methods sampling model proposed by Onwuegbuzie and Collins (2007), which provides a typology of mixed methods sampling designs.

4.4.2 Data Collection Methods

In line with the explanatory sequential mixed methods research design of this study, data were collected sequentially at two instances during the course of this research study. These instances were during the quantitative phase (PHASE I of Figure 4.1) and the qualitative phase (PHASE II of Figure 4.1).

One of the biggest challenges of this research study was that the data collection stages of both PHASE I and PHASE II coincided with the prevalence of the COVID-19 pandemic. During this period, there was a global shutdown of socioeconomic activities, including those in the education sector, with over 195 countries instituting school closures in an attempt to contain the spread of the highly infectious severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes the COVID-19 (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2020). The COVID-19 pandemic also ushered in government-imposed restrictions in people movement, which necessitated a fundamental shift in the overall approach to research initiatives that relied on data collection, especially involving fieldwork and human participants (Lumeng et al., 2020; Torrentira, 2020). Chatha and Bretz (2020) emphasised the plight of this global research dilemma by highlighting that "researchers who wanted to continue data collection were confronted by many challenges, including research designs and data collection methods that had presumed local access to student participants, such as interactive tasks for students to complete during face-to-face interviews" (p. 4196). Indeed, in the case of educational research, local access extended beyond just to the students. It incorporated access to the entire value chain of a schooling system, including school districts, schools, classrooms, teachers, and the greater schooling community as represented by the sampling frames in Table 4.1 (DeMatthews et al., 2020).

In mitigating this challenge for this research study, alternative means were sought through leveraging modern technology-based strategies suitable for the collection of both quantitative and qualitative data. While the utility of these strategies predates the COVID-19 pandemic period (Couper, 2017; Granello & Wheaton, 2004; Lefever et al., 2007; Topp & Pawloski, 2002; Ward et al., 2014), their uptake was considerably accelerated since its advent (DeMatthews et al., 2020; Torrentira, 2020). The following two subsections elaborate further on the data collection methods that this research study adopted for both PHASE I and PHASE II.

Quantitative Data Collection

The primary purpose of this research study was to explore teachers' perceptions of learner motivation as it relates to the use of ICTs to teach and learn mathematics in the context of the theoretical conceptualisation of motivation in a social constructivist setting, as set out by Sivan (1986). Aligned to this primary purpose were research questions RQ_{1a}, RQ_{1b}, and RQ_{1c} (the quantitative research questions) that needed to be answered as part of the quantitative phase of this research study. To answer these questions, a quantitative feature (survey questionnaire) was designed and developed. At the core of this survey questionnaire were six subscales that were

curated through a mix of insights from literature and the characteristics of motivation in social constructivist theory.

Instrument Design

The data collection instrument for the quantitative phase of this research study was a survey questionnaire comprising twelve sections. These are summarised in Table 4.2. The first two sections were the participant information sheet and the participant consent form. The participant information sheet served two purposes: first, to inform the potential participants, in precise terms, about the purpose of the research study, as well as everything that stands to happen should the participant choose to partake; second, to assist the potential participants in deciding whether to be part of the research process or not. The intent of this process, above being an information base, is to protect the privacy, confidentiality, and other human rights elements of those participants wishing to partake in the research process, and also give them an explicit opportunity, through the participant consent form, to give their consent to participate (Creswell, 2014; Drew et al., 2007). Both the participant information sheet and the participant consent form served at, and were approved by the university's ethics review body during the early stages of this research study, prior to the data collection stages.

The third section of the survey questionnaire was put in place to gather demographic information crucial for the analysis stages of this research study. Importantly, this section also incorporated the main inclusion criterion for participation in this research study (Velasco, 2022), which was set to establish whether or not the potential participant taught mathematics using technology at their school.

Section four of the survey questionnaire was a preamble to the core of the instrument. It included instructions of how to interpret the requirements and rate the subscale items for each of the motivation dimensions' subscales contained in the subsequent sections five through ten. Guided by these subscales, the survey questionnaire aimed to elicit self-reported observations from participants on the use of technology for teaching and learning mathematics in their classrooms.

Overall, the construction of the six subscales was similar and built on the theoretical concepts of measuring their corresponding attributes, as outlined in Section 3.2.5. They were all Likert-type subscales comprising a varying number of Likert-type items each rated on a five-point scale with response anchors ranging from '*Strongly Agree*' to '*Strongly Disagree*'. Table 4.3 lists the complete set of these response anchors with their numerical value coding.

For all the subscales, with the exception of the agentic engagement subscale, the subscale items were a statement or a predicate, anchored on the subject: *Because of the use of technology in teaching and learning in my classroom....* To illustrate using the first item of the situational interest subscale, the complete statement would be: *Because of the use of technology in teaching and learning in my classroom, my learners enjoy working on mathematics topics*. The participant was then to state the extent to which they agreed or disagreed with this complete statement based on what they had observed in their classrooms using the response anchors shown in Table 4.3.

Table 4.2: Summary of the final survey questionnaire for this research study.

Section	Content	Short Description
1	Information sheet	Introduction to the research study, the purpose of the study, the research team, as well as contact information for any ethics-related queries.
2	Consent form	Informed consent for the participant to give their permission to participate in this research study, and to affirm their understanding of voluntariness, their rights, as well as how their data will be handled.
3	Demographic information	Basic demographic details comprising inclusion criterion, schooling phase, and GDE schooling district.
4	Survey instructions	Instructions for how to interpret and respond to the subscales in sections 5 through 10.
5–10	Subscales	The six subscales of the interest and engagement motivation dimensions appearing sequentially in the order: behavioural engagement, affective engagement, cognitive engagement, agentic engagement, situational interest, and individual interest.
11	Interview invitation and consent	An invitation to take part in the next phase of the research study, the related consent, and contact information.
12	End of survey	The end of the survey comprising a message thanking the participant for taking part in this research study and an indication that all the responses have been captured and saved.

Source: Author.

For the agentic engagement subscale, the subject of the scale was slightly different, and instead stated: *Answer the following with respect to what you have observed in your classroom.* This was followed by the five items of the agentic engagement subscale, for which the participant was then to state the extent to which they agreed or disagreed with each in an identical manner as with the other five subscales. There was an additional Likert-type item (rated on the same scale) that served to contextualise the agentic engagement subscale, anchored on the subject: *Answer the following based on your responses you have given above.* The item itself read: *The use of technology in teaching and learning mathematics in my classroom contributes to the observations I have noted above*. This is succinctly illustrated in Table 5.12 in the next chapter.

In total, there were 34 items across the six subscales broken down in the following manner:

Table 4.3: Response anchors and their numerical values for the five-point Likert-type scale used in this research study.

Numerical Value	Interpretation
1	Strongly Agree
2	Agree
3	Neither Agree nor Disagree
4	Disagree
5	Strongly Disagree

Source: Author.

situational interest (six items), individual interest (six items), behavioural engagement (seven items), affective engagement (five items), cognitive engagement (five items), and agentic engagement (five items). These included a total of four negatively worded items, which were important in minimising acquiescence bias, nay-saying, and otherwise extreme responses (Chyung et al., 2018; Dalal & Carter, 2014). Notwithstanding, the number of negatively worded items was deliberately kept at a minimum so not to impair the properties of the subscales (Dalal & Carter, 2014; Józsa & Morgan, 2017).

The eleventh section of the survey questionnaire contained an invitation for the participant to partake in the next phase (the qualitative phase) of this research study. If interested, the participant would give the necessary consent and leave their contact information to be contacted at a later stage.

The final section of the survey questionnaire presented the participant with an expression of appreciation from the research team for having assisted with the research study at hand. This section was later enhanced to include a confirmatory note that all responses had been captured and securely saved, as explained further in the next subsection.

Collection Procedure

The instrument design process was undertaken with the foresight that data collection would be conducted through the utilisation of online tools. This allowed for a seamless transition from paper to online. The entirety of the survey questionnaire, as described in the preceding subsection, was transcribed into Qualtrics [4]. After testing and adjusting for minor aesthetics and overall flow, the online survey questionnaire was deployed and was ready to receive responses through a unique web address. Section D.1 shows the complete version of the online survey questionnaire as loaded on Qualtrics.

[4]The Qualtrics Experience Management Platform (Qualtrics XM Platform or simply Qualtrics) is a versatile online cloud-based platform most popularly used for building and distributing online surveys, as well as for collecting, organising, storing, and understanding data from deployed online surveys. Data that are stored in Qualtrics can be exported in a variety of formats to allow for, amongst other processes, further analysis by more powerful statistical tools. In the period during which this research took place, the University of the Witwatersrand (Wits) had a dedicated and licensed Qualtrics environment for the Wits community to use for research purposes that was accessible via login at: https://wits.eu.qualtrics.com/login.

The utility of modern technology, primarily through the medium of WhatsApp and Telegram messaging applications, facilitated the distribution of the online survey questionnaire's unique web link, ensuring that it reached a broad and diverse audience with ease. Furthermore, the Qualtrics platform proved to be highly versatile, enabling the online survey questionnaire to be easily accessed and completed using a wide range of digital devices including mobile phones, tablets, laptops, and desktop computers—all of which just required internet connectivity and a web browser.

The survey questionnaire received a total of 55 responses between 23 May 2021 and 6 September 2021 (107 days), with a median completion time of 504 seconds (or 8 minutes and 24 seconds) for the valid responses. Chapter 5 presents a detailed analysis of these responses. Eight participants expressed their willingness to partake in the subsequent phase of the research study. The following section details the procedure that was adopted for collecting qualitative data in this research study.

Qualitative Data Collection

The secondary purpose of this research study was to further explore the nuances of learner motivation and the different discourse practices related to the use of ICTs in the teaching and learning of mathematics. This was primarily driven by the need to explain and explicate the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics, as uncovered in the quantitative strand of this research study. The primary research question that addressed this secondary purpose was RQ_{2a}, complemented by additional research questions RQ_{2b}, RQ_{2c}, and RQ_{2d}. Together, these qualitative research questions formed the foundation of the inquiry in the qualitative phase of the study. To address these questions, a qualitative instrument (or data generation protocol) in the form of an interview schedule was designed and developed to facilitate the generation of data through semi-structured interviews. The subsequent subsection provides a detailed explanation of the interview schedule's design.

Instrument Design

The qualitative phase of this research study employed an interview schedule as the data generation protocol. The interview schedule consisted of 22 carefully designed questions, organised into eight sections. These sections, along with their content, are summarised in Table 4.4, while the complete set of questions can be found in Section D.2. These questions were strategically crafted to guide and structure the in-depth discussions with the participating teachers, ensuring that all the necessary qualitative data required to address the research questions were obtained (Adams, 2015; Creswell, 2014; Creswell & Plano Clark, 2017; Kallio et al., 2016). Before proceeding to the interview questions, an explanatory section was provided at the beginning of the interview schedule. This section aimed to provide a clear understanding of the purpose and objectives of the in-depth semi-structured interview, setting the stage for the ensuing discussions with the participating teachers.

Now, moving on to the interview schedule sections, the first section consisted of four introductory and background questions. These questions aimed to elicit information regarding the participating teacher's experience in teaching mathematics with the aid of technology, including

Table 4.4: Summary of the final interview schedule for this research study.

Section	Content	Short Description
A	Introduction and background	Introductory and background questions to establish a basic profile of the participating teacher.
B	Technology tools and their use (teacher)	Teacher-specific questions to solicit the technology tools that the teacher has access to and uses.
C	Technology tools and their use (learner)	Learner-specific questions to solicit the technology tools that the learners have access to and use.
D	Motivation	Questions to establish the participating teacher's perspective of: (i) motivation; (ii) the characteristics of a motivated learner; and (iii) the role technology plays in the motivation of learners.
E	Engagement	Questions to establish the participating teacher's perspective of: (i) engagement; (ii) the characteristics of an engaged learner; and (iii) the behaviour of learners in the context of technology use.
F	Interest	Questions to establish the participating teacher's perspective of: (i) interest; (ii) the characteristics of an interested learner; and (iii) the triggers of interest in learners in relation to technology use.
G	Quantitative phase clarification	Clarification questions seeking insights into and explanations of some of the interesting outcomes of the quantitative phase of the research study.
H	Conclusion	Concluding questions seeking the participating teacher's overall perspective on how the concepts of motivation, engagement, and interest might be related, as well as an opportunity for any further comments or insights from the participating teacher.

Source: Author.

the duration of their engagement and the specific grade levels where technology was utilised. Additionally, these questions sought to determine whether the participating teacher had received sufficient training to effectively leverage technology for teaching mathematics. Lastly, this section provided an opportunity for the teacher to describe their typical preparation process for a mathematics lesson incorporating technology. This section played a crucial role in establishing

the context and situating the generated data (Braun & Clarke, 2019, 2021b; Braun et al., 2019).

The second and third sections of the interview schedule focused on gathering data related to the technology tools used by teachers and learners, respectively. Each of these sections comprised three guiding questions aimed at understanding the tools accessible to the participating teacher and learners, how these tools were employed in the teaching and learning processes, and whether they were utilised to their fullest potential.

The core sections of the in-depth semi-structured interview, namely the fourth, fifth, and sixth sections, consisted of two guiding questions each. These sections aimed to capture the participating teacher's perspective and perception of learner motivation, as well as its conceptualised dimensions of engagement and interest (Sivan, 1986) in the context of using technology for teaching and learning mathematics.

Section seven of the interview schedule comprised four guiding questions specifically designed to explain and elucidate some of the interesting results obtained from the quantitative phase of this research study. It represented the first instance where the integration of datasets occurred (Creswell & Plano Clark, 2017).

The final section of the interview schedule served as the concluding part of the discussion. It encompassed two guiding questions. The first question sought the participating teacher's insights on the relationship between motivation, engagement, and interest in the context of utilising technology for teaching and learning mathematics in their classroom. The second question invited the participating teacher to provide any additional comments, questions, or concluding remarks before concluding the interview.

Collection Procedure

Once the data generation protocol was designed and finalised, a crucial step involved conducting a single mock interview session. According to Kallio et al. (2016), different techniques can be adopted to test an interview schedule, such as internal testing, expert testing, and field-testing. In this study, internal testing was chosen, and it was conducted online via the Microsoft Teams platform. This was undertaken to ensure the semantic flow, appropriateness, coverage, relevance, and practicality of the interview questions specifically in an online setting (Adams, 2015; Kallio et al., 2016). Furthermore, the mock interview session provided valuable insights into effectively managing the overall conversation and estimating the duration of the interviews. Minor adjustments were made to the phrasing of certain questions, while no questions were added or removed.

After the pilot phase of the data generation protocol, contact was made with the eight participants who, during the quantitative phase of the research study, had expressed their willingness to participate in the qualitative phase. Attempts were made to schedule interview appointments at their convenience. However, only six participants could be reached and remained willing to partake in the qualitative phase. Out of these six, four appointments were scheduled to be conducted online using either the Microsoft Teams or Google Meet platforms, one appointment was scheduled to take place telephonically, and the remaining appointment was scheduled to be conducted in-person at the participant's school. Although consent for the qualitative phase

had been obtained during the quantitative phase, additional verbal consent was sought before each interview session, and was subsequently granted, ensuring compliance with ethical considerations. The online sessions were recorded using the native recording functionality within the respective platforms, while the in-person and telephonic sessions were recorded using two stand-alone audio recording devices for redundancy.

On average, the interview sessions lasted 24 minutes and 07 seconds. Additionally, detailed notes were taken on the printed interview schedule for all six sessions. These supplementary notes played a vital role in capturing the subtle nuances of the interview sessions and proved instrumental in the subsequent analysis of the collected data. Further discussion on this aspect is provided in the latter part of the upcoming section.

4.4.3 Data Analysis Methods

Quantitative Data Analysis

Data collected from the quantitative phase of this research study were analysed using IBM® SPSS® Statistics[5] version 28.0.1.0 (142) for Microsoft® Windows®. Additional visualisations of these data were created, and cross-verification of some statistics produced using IBM® SPSS® Statistics to verify their accuracy and consistency was conducted using the R open-source programming language version 4.0.2 (2020-06-22) through its integrated development environment RStudio® version 2022.02.0 (443) for Microsoft® Windows®.

To begin the analysis process, data were exported from Qualtrics in a format suitable for IBM® SPSS® Statistics, enabling a smooth import into the statistical software suite. The dataset underwent preliminary preparation steps before the actual analysis started. These steps included: (i) cleaning and preparing the data for analysis; (ii) transforming reverse-coded variables; and (iii) computing or creating composite variables for the interest and engagement motivation dimensions under study. These steps are detailed further in the following subsections.

Cleaning and Preparation

IBM SPSS Statistics presents data in a tabular structure, with a layout resembling that of a common spreadsheet, using rows and columns. Each row represents a case (which is a contextual unit of analysis for a given study) and each column represents a variable or an attribute of a case. The data import resulted in a total of 55 cases and 61 variables. The variables comprised case metadata variables and actual study variables. The metadata variables comprised details on the start and end date and time of the response, response completion time, a unique case identifier, a completion progress percentage, and various other administrative variables. The study variables were inherited from the data collection instrument.

[5] IBM® SPSS® Statistics is a licensed software suite for statistical analysis. Formerly known as the Statistical Package for the Social Sciences (SPSS), it is a widely used statistical software in the social sciences, health sciences, and other fields. Furthermore, it provides data analysis, data management, and data visualisation tools which assist to better understand and present results. The software allows users to perform complex data analysis tasks such as descriptive statistics, inferential statistics, and predictive analytics through an intuitive graphical user interface, and supports data import from a wide range of sources. The version of the IBM® SPSS® Statistics software suite that was used for statistical analysis in this research study, version 28.0.1.0 (142), was licensed through the University of the Witwatersrand.

Once the data were successfully imported into IBM® SPSS® Statistics, the next step was to visually inspect the dataset for any incomplete cases, in consultation with relevant metadata variables. These cases were incomplete for one of three reasons: (i) the participant did not consent to proceed with partaking in the survey questionnaire; (ii) the participant did not meet the inclusion criterion of "using technology to teach mathematics"; or (iii) the participant faced connectivity issues while completing the survey questionnaire and did not later return to complete it. These incomplete cases were excluded from the analysis that would follow. Additional checks were performed to detect any outliers, instances of unengaged participants, or otherwise anomalous cases in the dataset. No such instances were identified.

The next and final step focused on the verification of study variables to ascertain consistency and correctness. The first layer in this verification was to look at the coding for each variable to ensure consistency. For instance, for the subscale items, it was checked whether or not the response anchors were correctly coded according to Table 4.3, and similarly for other variables. The second layer concerned ensuring the correct level of measurement for each variable. In 1946, Stanley Smith Stevens (1906–1973) advanced a typology of scales (or levels) of measurement which comprised four different types of scales. These were the (i) nominal, (ii) ordinal, (iii) interval, and (iv) ratio scales (Stevens, 1946). There has been much discourse within the academic community regarding the relevance of the classification of scales of measurement, with some considering it a dated concept that should be relegated to history. To this point, Howell (2013, p. 6) attests that "[t]he topic of measurement scales is one that some writers think is crucial and others think is irrelevant". Nevertheless, this research study acknowledged the crucial role of levels of measurement as the type of statistical tests and empirical operations that can be performed on a variable is contingent upon the level at which the data are being measured (Stevens, 1946). Thus, it was important in this step to verify that each variable was correctly classified during the import process. IBM SPSS Statistics categorises variables into three levels of measurement, which are: (i) nominal; (ii) ordinal; and (iii) scale (which combines the interval and ratio levels), and the verification ensured that all study variables we correctly classified into one of these three categories.

Upon the successful completion of the data cleaning phase, the focus then shifted towards the process for handling items that were negatively worded. The subsequent subsection elaborates on the approach taken in this regard.

Negatively Worded Items

The data collection instrument for the quantitative phase comprised four negatively worded items, across the situational interest (one item), behavioural engagement (two items), and affective engagement (one item) subscales. To handle these four subscale items, four new variables were created to contain the reverse-scored values. This recoding procedure was performed utilising the in-built data transformation capability within IBM® SPSS® Statistics, which provides the option to recode a variable into either the same or a different variable (Abu-Bader, 2021; Field, 2017). As the former option modifies the original variable, the latter option was preferred to preserve the original data. These four new variables were subsequently used in the data analysis stages.

Creating Composite Variables

The last step in the preliminary preparation process involved the creation of the six composite variables corresponding to each of the subscales of the data collection instrument. The essence of a composite variable is that it summarises or combines several individual variables used to represent a broader concept or construct (Abu-Bader, 2021). This allows for the easier identification of patterns and relationships in the data, thus aiding in making more informed conclusions about the underlying phenomena being studied.

When creating composite variables, a number of mathematical methods can be utilised, each with its own unique considerations. The choice of method depends on the level of measurement of the input variables, the intended interpretation of the composite score, and the envisaged statistical tests that would later be applied to the resultant composite variable. For instance, one commonly used method is to sum all the scores from each subscale item to yield a single total score for the underlying construct. Another approach entails computing an average[6] of all the subscale item scores, and using the computed score to represent and reason about the underlying construct.

When dealing with ordinal data (that is, data resultant from a variable measured at an ordinal level of measurement), particularly data collected using Likert or Likert-type scales as in the case of the six subscales of the data collection instrument for this research study, researchers have different perspectives on the appropriate method to use. There is ongoing debate about whether Likert data should be treated as interval data and analysed using methods such as regression or analysis of variance (ANOVA), or as ordinal data and analysed using methods such as chi-square tests, contingency table analysis, or nonparametric tests like the Wilcoxon rank-sum test (Bishop & Herron, 2015; Carifio & Perla, 2008; Carifio & Perla, 2007; Harpe, 2015; Kuzon et al., 1996; Wu & Leung, 2017). This debate extends to the way in which composite variables from ordinal data are created. For instance, on the one hand, some scholars suggest that composite scores for Likert or Likert-type scales should be created by either summing the individual item scores or calculating the mean of them, resulting in a composite score that should then be analysed at the interval level of measurement (Boone & Boone, 2012; Subedi, 2016). On the other hand, there are credible counter-arguments for the treatment of Likert or Likert-type scales as ordinal scales, which produce ordinal data, which ought to be analysed at the ordinal level of measurement (Jamieson, 2004; Knapp, 1990). These counter-arguments go on to affirm that "arithmetical manipulations required to calculate the mean (and standard deviation) are inappropriate for ordinal data" (Jamieson, 2004, p. 1217). This is chiefly because the distances between the categories on the scale are not equal, and it is not meaningful to perform arithmetic operations between them. It was because of this line of reasoning, and being guided by the research objectives and the specific questions being addressed, that the computation of the composite variables for the six subscales adopted the calculation of the median of each subscale item scores to compute the composite scores. This was particularly useful for cases where the distribution of the data was skewed or not symmetrical, as it provided a better and more accurate representation of the central tendency of the data compared to the other types of averages. Furthermore, using the median ensured that the composite scores accurately reflected the underlying patterns in the data and that any outliers or extreme values

[6]There are several types of averages, each with its own philosophical underpinnings. These include the arithmetic average (or mean), which is the most commonly used type of average, the median, the mode, as well as the weighted average, amongst many others.

were not unduly influencing the results.

The creation of these composite variables was performed utilising the in-built data transformation capability within IBM® SPSS® Statistics through a straightforward interface using the procedures outlined by Abu-Bader (2021) and Field (2017). Furthermore, this process was guided by examining the internal consistency of the resultant scale, ensuring that the composite variables created are measuring the same construct in a consistent and reliable manner. Internal consistency is discussed further in later sections of this chapter. Following this final preliminary preparation step, the remainder of the quantitative data analysis process focused on the statistical measures to address the quantitative research questions, starting with descriptive statistical measures.

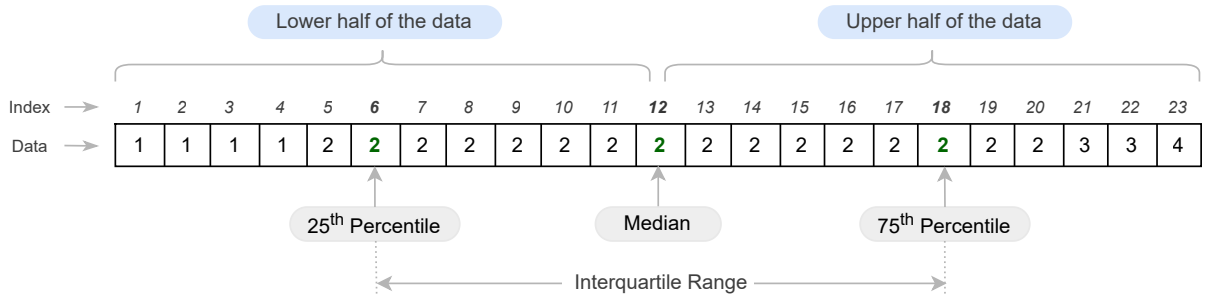
Descriptive Statistical Measures

Descriptive statistics consist of methods and tools that are useful in providing insights from numerical data. These methods and tools describe, characterise, and summarise data into understandable and meaningful patterns or trends with little to no loss or distortion of information (Abu-Bader, 2021; Field, 2017). Descriptive statistics generally come in three types: (i) measures of distribution; (ii) measures of central tendency; and (iii) measures of variability. All of these three types of measures are essential in forming a complete picture of the data that are being analysed, and they can all be presented visually using a combination of summary tables and graphs.

Measures of distribution are usually presented as absolute frequency values or percentages. For instance, in the context of this research study, a summary of the study participants across different school districts and different educational phases under the GDE is presented in Table 5.1. Likewise, the response frequencies for the different dimensions investigated through this research study are presented visually using bar graphs in Figures 5.1 through 5.6. A bar graph is a powerful and appropriate visual tool for presenting frequencies of variables with intrinsic ranking such as those measured on a Likert-type scale, as was the case in this research study (Abu-Bader, 2021; Mishra et al., 2018).

Measures of central tendency provide additional information that supplements what is already known from the distribution (frequency) measures of the data. These measures "provide information about the point around which a distribution's scores are clustered" (Abu-Bader, 2021, p. 106). Three common measures of central tendency in a distribution are the: (i) median—which is the fiftieth percentile, the centre point, or middle score of a distribution; (ii) mode—which is the most frequent occurring score in a distribution; and (iii) mean—which is the arithmetic average of all scores in a distribution (Abu-Bader, 2021; Field, 2017). The choice of which measure to adopt depends on the type of data that were collected, which in itself is a result of the research problem, research purpose, and research questions that guided the inquiry. For ordinal data, the median and mode are the most appropriate measures of central tendency (Weisberg, 1992), and these two measures formed the basis of the presentation and analysis of quantitative data for this research study as presented in Chapter 5. Figure 4.2 illustrates the median ($Mdn = 2.0$) of a distribution of responses to one of the subscale items of this research study, and from the same data, the mode ($Mode = 2.0$) can also be computed.

Measures of variability are generally concerned with the dispersion or the spread of the data. This could be in relation to each data point in a distribution, or relative to a centre and therefore working in concert with the measures of central tendency. There are four common measures of dispersion, which are the: (i) standard deviation—which is an average expression of how far each of the data points in a distribution is from the mean; (ii) variance—which, in simple terms, is defined as the square of the standard deviation; (iii) range—which depicts the spread of data from the lowest to the highest value in a distribution; and (iv) interquartile range—which is the spread of the middle half of a distribution, or put differently, the difference between the seventy-fifth and the twenty-fifth percentiles (Abu-Bader, 2021; Field, 2017; Muijs, 2022; Weisberg, 1992). The first two common measures of dispersion (the standard deviation and variance) are inherently defined with reference to the mean of a distribution, which make them unsuitable measures for ordinal data (or data whose centre is not represented by the mean). The range is a simple measure of variability that is suitable for ordinal data, however, it is not a robust measure as it is affected by extreme cases, making it a nonresistant measure of variability (Weisberg, 1992). The interquartile range is an intuitive, suitable, and preferred resistant measure of variability, which has been widely adopted throughout the presentation and analysis of quantitative data for this research study as presented in Chapter 5. Furthermore, in terms of descriptive statistics, it works hand-in-hand with the median.



Source: Author.
Note: $n = 23$.

Figure 4.2: An illustration of some descriptive statistics measures used in this research study.

Figure 4.2 also illustrates the interquartile range ($IQR = 0.0$) of a distribution of responses to one of the subscale items of this research study, which can be computed as depicted in Equation 4.1.

$$\begin{aligned} Interquartile\ range &= [75^{th}\ percentile] - [25^{th}\ percentile] \\ &= 2 - 2 \\ &= 0.0 \end{aligned} \tag{4.1}$$

In general, the value of the interquartile range is limited by the possible values that a variable can be assigned, and also depends on the units in which the variable is measured. For instance, if there is no upper limit (or maximum value) that a variable can assume, the interquartile range can then take on any value from 0.0 upwards. In the context of this research study however, the minimum and maximum values that could be assigned to a variable were the numerical values

1 and 5, which respectively correspond with the *'Strongly Agree'* and the *'Strongly Disagree'* response anchors (as shown in Table 4.3). Thus, the possible interquartile range values for this research study were between 0.0 (in the cases where the 75^{th} and 25^{th} percentiles were the same, in other words, there was no spread on the variable) and 4.0 (in the cases where the 75^{th} percentile was the maximum value, and the 25^{th} percentile was the minimum value). Table 4.5 illustrates these possible interquartile range values, together with their contextual interpretation.

Table 4.5: Interpretation of the interquartile range value in the context of this research study.

IQR Value	Interpretation
0.0	Very tightly clustered
1.0	Tightly clustered
2.0	Somewhat dispersed
3.0	Quite dispersed
4.0	Highly dispersed

Source: Author.

Inferential Statistical Measures

Inferential statistics are concerned with using random sample data and associated statistics to make generalisations about (for, or of) a population from which the sample has been drawn. Such generalisations may include drawing inferences, reaching conclusions, or making statements (predictive, estimative, or hypothetical statements). Inferential statistics, in much the same way as descriptive statistics, consists of statistical techniques (incorporating a variety of tools and procedures) that are primed at delivering on the core purpose of statistical inference. These techniques can be broadly classified into parametric and nonparametric techniques, with the former being the more popular and widely utilised of the two. Notwithstanding, there continues to be a rich scholarly debate on the appropriateness of one type of technique over the other, with substantive merit to both sides of the argument. The ultimate choice on which technique to adopt, however, rests on one or a combination of: (i) the type of sample data being analysed (the level of measurement); (ii) the purpose for the analysis of the data; (iii) the size of the sample from which the data have been generated; and (iv) on some assumptions about the population from which the sample generating these data has been drawn. Such assumptions encompass the probability distribution[7] of the population and the parameters that best describe the properties of this population.

Table 4.6 lists some of the common parametric and nonparametric techniques, stratified on the purpose for the data analysis process, which is directly related to the research problem, research purpose, and research questions guiding the inquiry process. In the context of this research study, research questions RQ_{1a}, RQ_{1b}, and RQ_{1c} (the quantitative research questions as outlined in Section 1.4.1) were partially or fully answered through the use of nonparametric techniques. For RQ_{1b} and RQ_{1c}, the differences between the dependent and independent variables (for each

[7] Sprent and Smeeton (2016, p. 2) cites that "well-known families of distributions include the uniform (or rectangular), multinomial, Poisson, exponential, gamma, beta, Cauchy and Weibull distributions", and this is by no means an exhaustive list of possible families of probability distributions.

Table 4.6: Classification of inferential statistics by technique type and purpose.

Purpose	**Technique Type**	
	Parametric	Nonparametric
Evaluating differences	*Within a single group*	
	One-sample t-test	One-sample Wilcoxon signed ranks test
	Between two independent / dependent groups	
	Independent t-test	Mann-Whitney U test Wilcoxon rank sum test Kolmogorov-Smirnov two-sample test
	Dependent t-test	Wilcoxon signed ranks test
	Between three or more independent / dependent groups	
	One-way ANOVA	Kruskal-Wallis H test
	Repeated measures ANOVA	Friedman test
Examining relationships	Pearson's correlation	Spearman's rank correlation Kendall's rank correlation

Source: Author.

of the motivation dimensions) were evaluated through the use of the Kruskal-Wallis H test, which was conducted for each of the subscales. This was the appropriate nonparametric test because: (i) the data were at an ordinal level of measurement; (ii) there were more than three independent groups from which the data were generated; (iii) the size of the sample from which the data were generated was relatively small (that is, $n < 30$); and (iv) the population parameter of interest was the median, and there was no assumption on the specificity of the population distribution. Answering RQ_{1b} and RQ_{1c} was important in establishing that there was no difference in the way in which respondents self-reported to have observed certain motivation elements or traits. This allowed for the data to be treated as a homogenous set with confidence that it was generated from a sample representative of the population, and served as a precursor to answering RQ_{1a}.

The process for answering RQ_{1a} started with the analysis of the subscale items for each of the motivation dimensions using descriptive statistics, as earlier outlined. Thereafter, the composite or latent variables were computed using the median statistic for each of the subscale items. This was supplemented by the calculation of the *confidence interval* on the median. A further examination of the relationship between the motivation dimensions was conducted using Kendall's rank *correlation coefficient*, which was also supplemented by the calculation of the confidence interval on the rank correlational coefficient. In totality, this process aided not only in answering RQ_{1a}, but also in making predictions about some population parameters from the sample statistics. Key to this were the notions of *statistical significance* (which was equally important for RQ_{1b} and RQ_{1c} as well) and a confidence interval, which are discussed further in the next sections.

Examining Relationships: The Correlation Coefficient

Examining relationships between variables, which is one of the purposes of inferential statistics (see Table 4.6), concerns quantifying the strength of the relationship between variables concerned. This strength, or degree of association, is commonly measured by a bivariate statistic called a correlation coefficient (symbolised by the letter *r*). This statistic is considered a descriptive statistic if its purpose is only to describe a relationship, however, if this purpose is extended to infer a relationship in the population it thus becomes an inferential statistic (Allua & Thompson, 2009). Beyond describing the strength of the relationship, the correlation coefficient also informs the direction of the relationship. Since *r* can take on any value between -1.00 and $+1.00$: (i) any value between -1.00 and 0.00 (that is, $-1.00 \leq r < 0.00$) represents a negative (or inverse) correlation; (ii) any value between 0.00 and 1.00 (that is, $0.00 < r \leq 1.00$) represents a positive (or direct) correlation; and (iii) any value equalling 0.00 (that is, $r = 0$) represents no correlation whatsoever between the variables concerned (Abu-Bader, 2021; Dancey & Reidy, 2020). The strength of the relationship (whether direct or inverse) is said to be strong as the absolute value of *r* (that is, $|r|$) approaches 1.00, and weak as the absolute value of *r* approaches 0.00, however, the exact degree of strength (or the qualitative or verbal interpretation thereof) is subjective and has tight disciplinary links (Akoglu, 2018). This research study adopted the interpretation of the correlation coefficient advanced by Dancey and Reidy (2020) as detailed in Table 4.7. This interpretation has been widely used and accepted within the disciplines of psychology and education (and indeed the broader behavioural sciences), disciplines within which this research study is largely situated.

Table 4.7: Interpretation of the strength of the correlation coefficient in the context of this research study.[8]

Coefficient Value	Interpretation
$\|r\| = 1.0$	Perfect
$0.7 \leq \|r\| < 1.0$	Strong
$0.4 \leq \|r\| < 0.7$	Moderate
$0.1 \leq \|r\| < 0.4$	Weak
$0.0 \leq \|r\| < 0.1$	Zero

Note: $|r|$ denotes the absolute value of the correlation coefficient *r*.

Listed in Table 4.6 are three common techniques for deriving a correlation coefficient. Pearson's correlation, which is a bivariate parametric test that derives the *Pearson's product-moment correlation coefficient* (*r* or Pearson's *r*), is arguably the most common technique for examining relationships between variables (Abu-Bader, 2021; Dancey & Reidy, 2020). Like other parametric techniques, the Pearson's correlation test rests mainly on the assumptions of normality in the population distribution and that the sample size is "large enough [i.e. ≥ 30] to conduct [parametric] bivariate tests" (Abu-Bader, 2021, p. 200). Additionally, the Pearson's correlation test assumes linearity between the variables concerned, and that these variables are measured on an interval or ratio level of measurement. Thus, it was not an appropriate test to adopt for examining relationships between variables in this research study.

Spearman's rank correlation (Spearman, 1904, 1906) and Kendall's rank correlation (Kendall,

[8] Source: Adapted from Dancey and Reidy (2020, p. 183).

1938) are considered the nonparametric equivalents of Pearson's correlation. As bivariate nonparametric tests, they differ from Pearson's correlation in that they evaluate the monotonic relationship (as opposed to the linear relationship) between the variables concerned (de Winter et al., 2016; Hauke & Kossowski, 2011). This is possible because they both work with rank-ordered values for each variable rather than the raw data. Outliers severely impact the calculation, and therefore the functionality of Pearson's *r*, and the nonparametric approach of working with rank-ordered values instead overcomes this limitation (Field, 2017). Notwithstanding, the underlying mechanics of how these nonparametric techniques compute their correlation coefficients is markedly different (Puka, 2011; Schimek, 2011). On the one hand, Spearman's correlation, which derives the *Spearman's rank correlation coefficient* (r_S, *rho*, Spearman's *rho*, or Spearman's ρ), is regarded as "the regular Pearson's correlation coefficient in terms of the proportion of variability accounted for" (Hauke & Kossowski, 2011, p. 88). On the other hand, Kendall's correlation, which derives the *Kendall's rank correlation coefficient* (*tau*, Kendall's *tau*, or Kendall's τ), "represents a probability, i.e., the difference between the probability that the observed data are in the same order versus the probability that the observed data are not in the same order" (Hauke & Kossowski, 2011, p. 88).

Several advantages have been cited for using Kendall's τ in preference to Spearman's ρ, some of which are specific to certain use cases (Akoglu, 2018; Colwell & Gillett, 1982; Field, 2017; Howell, 2013; Schaeffer & Levitt, 1956). The most notable of these advantages, which made Kendall's τ appropriate for examining relationships in this research study, were that: (i) it is regarded as a more accurate and a more robust measure of association between two variables measured on the ordinal level of measurement (and thus better estimates the population characteristics); (ii) it is better suited for samples where many observations have the same rankings (or tied ranks, see for instance in Figure 4.2 where it is illustrated that many of the observed cases are associated with the response anchor 2 (*'Agree'*), which would result in many tied ranks during the calculation of the correlation coefficient); and (iii) it is suitable for small sample sizes (that is, $n < 30$).

At a finer level of granularity, Kendall's τ is presented as one of three slightly nuanced τ rank correlation coefficient variants: (i) tau-a (τ_a); (ii) tau-b (τ_b); (iii) or tau-c (τ_c). The first variant, τ_a, is the basic statistic that does not cater for any tied ranks. The second variant, τ_b, is specific for the case of tied ranks, and for square contingency tables. The third variant, τ_c, is similar to τ_b except that its calculation is normalised for non-square contingency tables (Costner, 1965; Kendall, 1938, 1945; Somers, 1962). In fact, τ_c is sometimes referred to as Stuart's τ_c or Stuart-Kendall τ_c (Berry et al., 2009; Puka, 2011) since it is credited to have been introduced by Stuart (1953). Nevertheless, Kendall's τ_b was the apt τ rank correlation coefficient variant based on the data that were generated from the sample, and thus formed the basis of the presentation and analysis of quantitative data for this research study as presented in Chapter 5.

Level of Significance

The level of significance, which is symbolised by the Greek letter α, denotes the "probability of making an error of the first kind" (Rosenthal & Gaito, 1963, p. 33). These errors, commonly known as *Type I errors* or *false positives*, occur when researchers falsely conclude on the observed relationships between variables under study, when in reality, these observed relationships

have occurred only by chance or as a result of sampling error (Abu-Bader, 2021). The level of significance is decided a priori, meaning that it is stated upfront as part of the research planning process (Abu-Bader, 2021; Zhu, 2016).

Indeed, deciding on the level of significance is primarily guided by the research problem, research purpose, and research questions. It is also guided by disciplinary norms and traditions (Abu-Bader, 2021; Skipper et al., 1967). In the social sciences, the common and widely accepted level of significance is 5% (or $\alpha = .05$), while in other disciplines, such as in the medical sciences, it is common to find the level of significance set at 1%, 0.1%, or even lower. Cowles and Davis (1982) presented an elaborate probability and statistical theory history of the adoption of the 5% (or $\alpha = .05$) level of significance (especially in psychology and the social sciences) dating back to the mid seventeenth century, and concluded that "the choice was far from arbitrary and was influenced by previous scientific conventions that themselves were based on the notion of 'chance' and the unlikelihood of an event occurring" (pp. 553–554). Notwithstanding, some researchers still argue that this approach is arbitrary and instead suggest that it should be decided through scientific processes (J. H. Kim & Choi, 2021). For this research study, the level of significance was set at 5% due to the nature of the research and also conforming to the disciplinary norms and traditions. This choice thus informed both the statistical significance determination and the calculation of confidence intervals during the analysis and interpretation of the sample data pursuant to answering the quantitative research questions that were constructed for this research study.

Statistical Significance

To determine statistical significance, the level of significance for the research undertaking must first be set. Thereafter, specific bivariate or multivariate statistical tests (like those mentioned in Table 4.6) involving those variables of interest must be undertaken. These will yield a probability value (or p-value) indicating the probability or likelihood that the observed relationships between the variables of interest occurred only by chance or as a result of sampling error (Abu-Bader, 2021). Only if this p-value is less than the set level of significance (that is, $p < \alpha$) can it be said that the observed relationships are *statistically significant*. In unpacking the notion of statistical significance, Kirk (2007) stresses that "statistical significance only means that chance is an unlikely explanation for an observed result" (p. 483). Furthermore, he underlines that it "does not connote importance or usefulness, and it should not be confused with practical significance" (Kirk, 2007, p. 286).

For this research study, the statistical tests that yielded a p-value were: (i) the calculation of the item-total correlation coefficients for each of the subscale items (as an additional measure of internal consistency) for all the motivation dimensions; (ii) the Kruskal-Wallis H test, which was adopted to evaluate the differences between the dependent and independent variables (for each of the motivation dimensions) specifically for answering RQ_{1b} and RQ_{1c}; and (iii) the calculation of the correlation coefficients to ascertain any inter-scale relationship between the motivation dimensions. In the truest sense, these statistical tests were hypotheses tests[9], and the results of these tests, together with the analyses and interpretation of these results, are pre-

[9] Appendix E presents a more elaborate picture of the hypotheses that were tested, the processes that were followed in conducting these tests, and a complete database of the results.

sented in Chapter 5. Zhu (2016) advises on the appropriate use of (statistical) language when reporting findings based on p-values, and this has been taken into consideration, where relevant, throughout Chapter 5.

Calculating and Interpreting the Confidence Interval

Computing the descriptive statistics of a given sample, for instance, a median for a certain variable or dimension as a measure of central tendency, or a correlation coefficient to ascertain a relationship between two variables or dimensions, yields *point estimate* statistics that purport to estimate the corresponding parameter in the population from which the sample has been drawn. It is often necessary for researchers to conclude with a certain *level of confidence* that these point estimates are indeed accurate representations of the corresponding population parameters. Thus for a given point estimate, a confidence interval (CI) is computed to give a range of values within which this point estimate is likely to fall within the population, and this range is computed with a certain level of confidence which is a direct complement of the level of significance (α). Abu-Bader (2021, p. 179) defines the level of confidence as "the probability, or degree of confidence, that the confidence interval contains the true population's parameter", and advances a simple formula for obtaining the level of confidence:

$$\begin{aligned} Level\ of\ confidence &= 1 - [level\ of\ significance] \\ &= 1 - \alpha \end{aligned} \tag{4.2}$$

For this research study, the level of confidence was thus $.95$ (or 95%) in all the computations of the CI. Because the CI is a range of values, it has a lower limit and an upper limit (collectively, *confidence limits*) that are then referred to (together with the level of confidence) in the interpretation of the CI. So for instance, Table 5.14 shows that the composite median for the situational interest dimension of motivation was computed to be 2.00 (point estimate), with a 95% CI $[2.00, 2.25]$ (lower limit $= 2.00$; upper limit $= 2.25$)[10]. This can then be interpreted in the following manner: it can be concluded with 95% certainty that the population median for the situational interest dimension of motivation falls between 2.00 and 2.25; or put differently, any random sample drawn from the population will yield an estimate composite median for the situational interest dimension falling in the range between 2.00 and 2.25 95% of the time; or put inversely, only 5% of the time will any random sample drawn from the population yield an estimate composite median for the situational interest dimension falling outside the range between 2.00 and 2.25.

Similarly, the statistically significant rank correlation coefficients shown in Table 5.15 and expounded in Section E.4 can be interpreted in a similar manner as above.

Bootstrapping

In certain cases, on its own, a sample drawn from the population does not have sufficient power to generate adequate estimates or sample statistics to be used when estimating population parameters. This then calls for the use of special statistical procedures which can assist in making

[10] To compute the CI for a median, the procedure outlined in *IBM® SPSS® Statistics Help Pages* at https://www.ibm.com/support/pages/obtaining-confidence-interval-median was followed.

better meaning of the sample that has already been drawn, without the need for researchers to go back to the population and draw another sample. One such procedure is bootstrapping, which Mooney and Duval (1993) explain as "a computationally intensive, nonparametric technique ... [which makes use of sample] statistics to make inferences about population parameters" (p. 1). The bootstrapping procedure, or "the bootstrap" (Efron, 1979, p. 1), treats the sample as the population, and from this pseudo-population, draws as many smaller independent random samples (or bootstrap samples) as specified, with each bootstrap sample yielding an estimate statistic (Efron & Tibshirani, 1994; Field, 2017; Mooney & Duval, 1993). This process of drawing bootstrap samples is called *resampling with replacement* (Howell, 2013). Collectively, these estimate statistics are used as an empirical basis for estimating population parameter characteristics (usually, these are the confidence limits, and bias and standard error (SE) of the parameter estimates) (Efron & Tibshirani, 1994; Field, 2017; Mooney & Duval, 1993).

For this research study, the bootstrapping technique was used for the estimation of confidence limits, and bias and SE in the following cases: (i) the calculation of the item-total correlation coefficients for each of the subscale items (as an additional measure of internal consistency) for all the motivation dimensions; (ii) the calculation of the CI for the median of each of the motivation dimensions; and (iii) the calculation of the correlation coefficients to ascertain any inter-scale relationship between the motivation dimensions. Key results from these three cases are presented in Chapter 5, with the full set of the same presented under Appendix E. For all calculations using the bootstrapping technique, the number of bootstrap samples was set at $5,000$, which was a determination guided by the work of Hesterberg (2011, 2015).

Reliability

In statistics, the concept of reliability refers to the extent to which a measurement instrument produces consistent and stable results over time and across different conditions, which is essential in establishing the level of confidence that can be placed in the results (Abu-Bader, 2021; Howell, 2013). Simply put, it pertains to the consistency, dependability, and replicability of the results. However, Abu-Bader (2021) cautions that this does not extend to the correctness or accuracy of the information being communicated by the data. Four main types of reliability exist, namely: (i) inter-observer or inter-rater reliability; (ii) test-retest reliability; (iii) equivalence reliability; and (iv) internal consistency reliability (Abu-Bader, 2021). Inter-observer or inter-rater reliability pertains to measuring the consistency of scores between two or more different observers or raters on the same group of participants. Test-retest reliability is concerned with measuring the consistency of scores over time, whereby the same test is administered to the same or similar sample and under similar conditions on two or more different occasions. Equivalence reliability, which is sometimes referred to as parallel-forms reliability, is concerned with measuring the consistency of scores across different versions of a measure on the same sample. Internal consistency reliability is the most widely reported type of reliability, and it is concerned with measuring the consistency of scores across different items or parts of a measure, wherein the items on a measure are analysed to determine how well they correlate with each other, and this is primarily to ascertain the extent to which the items are measuring the same underlying construct.

Reliability is typically assessed using a reliability coefficient that ranges between 0.00 and 1.00,

similar to the correlation coefficient introduced earlier. A reliability coefficient value closer to 1.00 indicates a more reliable measurement of consistency, while a value closer to 0.00 indicates less reliability in the same. However, there is no universally agreed-upon criterion, standard, or threshold for interpreting the reliability coefficient. Some researchers argue for discipline-specific interpretations (Barbera et al., 2020), others contend that the type of reliability should guide the interpretation (Cicchetti, 1994), and still others suggest using qualitative labels to categorise the reliability coefficient values into specific ranges. For example, a reliability coefficient value below 0.50 may be labelled as "unacceptable", while a value of 0.90 or higher may be labelled as "excellent" (Gliem & Gliem, 2003). Warmbrod (2014) illustrates this non-universality dating back to the 1930s.

In the context of this research study and guided by its design, internal consistency reliability was the only type of reliability assessed, as the instrument was administered only once to a single group of participants, and thus, inter-observer or inter-rater, test-retest, and equivalence reliabilities were not applicable. There are several tests and methods available to assess internal consistency reliability, amongst which the most commonly used are: (i) split-half reliability; (ii) inter-item reliability; (iii) item-total reliability; and (iv) internal consistency reliability (as measured by reliability coefficients such as alpha and omega). For this study, two approaches which are widely used and considered to be more robust than other methods were explicitly considered and assessed. These were the item-total reliability and the internal consistency reliability, as measured by reliability coefficients. The computation of the coefficients for internal consistency reliability implicitly includes inter-item reliability, so this was also taken into account. The split-half method was not considered due to concerns about its potential limitations, such as its sensitivity to the number of items in the measurement scale and its dependence on the method of splitting the dataset.

Calculating the item-total reliability for each of the six subscales involved computing the total for all the subscale items and then calculating Kendall's rank item-to-total correlation coefficient (τ_b) for each of the subscale items. This approach was strengthened by the calculation and reporting of the p-value and the estimation of confidence limits, and bias and SE for Kendall's rank item-to-total correlation coefficients. These are presented in Chapter 5 and in Appendix E under Section E.1.

There are several internal consistency reliability coefficients that can be computed to ascertain internal consistency reliability. In the 1930s, Kuder and Richardson derived a number of formulae to compute estimations or approximations of internal consistency reliability (Kuder & Richardson, 1937). In total, they advanced 22 different formulae, with each suitable to specific situations. Of these, their 20$^{\text{th}}$ formula—popularly known as the Kuder–Richardson Formula 20 (KR20), has since emerged as the most robust and reliable formula for approximating internal consistency reliability, however, it applies only to scales with dichotomous items (Abu-Bader, 2021; Cronbach, 1951; Kuder & Richardson, 1937). Due to this limitation, Cronbach (1951) generalised the KR20 and introduced coefficient alpha (α), which became the most prevalent and commonly reported estimate of internal consistency reliability, especially in studies that adopt the multi-item measurement scale approach (Hayes & Coutts, 2020). Coefficient α, which is commonly referred to as Cronbach's α, is computed using a general α formula (Cronbach, 1951). This coefficient assesses (or estimates) reliability by adopting the components of vari-

ance approach (Cortina, 1993; Cronbach & Shavelson, 2004). However, even with Cronbach's α, certain assumptions about the data need to be satisfied for the formula to provide an accurate estimate of internal consistency reliability. The most important of these assumptions, according to Hayes and Coutts (2020, p. 5), is termed "*essential tau-equivalence*" and it is "often unknown to or neglected by users of Cronbach's α". In simple terms, essential tau-equivalence is a statistical assumption that pertains to the population being studied, stating that all items in a measurement instrument have the exact same relationship with the underlying construct being measured, as represented by a latent variable. Some researchers argue that it is practically unrealistic to ascertain essential tau-equivalence in the real world. Because of this, McDonald (1999) proposed a more general formula for estimating internal consistency reliability that is not sensitive to the assumption of essential tau-equivalence, as well as other assumptions used in computing Cronbach's α. McDonald's general formula computes coefficient omega (ω), also known as McDonald's coefficient ω or simply McDonald's ω, which has been proven to be a more flexible and robust approximation of internal consistency reliability than Cronbach's α. Under ideal conditions, including when the assumption of essential tau-equivalence is met, the computed values of coefficient α and coefficient ω should converge (Hayes & Coutts, 2020; McDonald, 1999).

Taking the above into consideration, as well as other recommendations grounded on analytical and empirical work (Flora, 2020; Hayes & Coutts, 2020; Revelle & Zinbarg, 2009; Trizano-Hermosilla & Alvarado, 2016), McDonald's coefficient ω was the preferred approach for assessing and reporting estimates of internal consistency reliability for this research study. The calculations for McDonald's coefficient ω were carried out in IBM® SPSS® Statistics through an extension macro[11], as described by Hayes and Coutts (2020). These calculations yielded estimate values ranging from .566 to .866, and were cross-verified using the R open-source programming language. Further details on these computed estimates of internal consistency reliability are provided in Chapter 5.

Qualitative Data Analysis

The qualitative data generated during the qualitative phase of this research study were subjected to analysis using the reflexive thematic analysis method (Braun & Clarke, 2019, 2021b; Braun et al., 2019). Thematic analysis encompasses a range of comprehensive methods that share a common focus on coding and developing themes. It provides a flexible and iterative analytic process that allows researchers to explore the rich and nuanced aspects of the data, uncover patterns embedded within these data, and interpret their meanings. Within this methodological family, three main types of approaches can be identified: coding reliability, codebook, and reflexive thematic analysis approaches. Coding reliability approaches align with a quantitative paradigm, while reflexive approaches align with a qualitative paradigm, with codebook approaches falling somewhere in between (Braun & Clarke, 2019, 2021b; Braun et al., 2019).

[11] The version of IBM® SPSS® Statistics that was used for the analysis of quantitative data for this research study did not have a built-in procedure for computing McDonald's coefficient ω. Thus, a free-to-use computational tool packaged as an extension to IBM® SPSS® Statistics, and as described by Hayes and Coutts (2020), was downloaded from http://www.afhayes.com/index.html and used for the computation of coefficient ω for each of the six subscales. From a technical point of view, the results indicate that the estimates of ω are *based on the factor loadings of a forced single-factor maximum likelihood factor analysis* (that is, unstandardised factor loadings) using the built-in FACTOR procedure in IBM® SPSS® Statistics.

Amongst these approaches, the reflexive thematic analysis method, introduced by Braun and Clarke (2006, 2012, 2013), holds significant prominence and has emerged as a widely recognised approach within the field of qualitative research. Importantly, it acknowledges "the *active* role of the researcher in **coding** and theme development, the inevitable **subjectivity** of these processes, and the importance of the researcher reflecting on their assumptions and practices, and how these might shape and delimit their data analysis" (Braun & Clarke, 2021b, p. 294). It involves a systematic and rigorous six-phase process for engaging with qualitative data, allowing for the exploration and interpretation of patterns embedded within the data. These phases include: (i) familiarisation with the data; (ii) coding the data; (iii) generating initial themes; (iv) developing and reviewing themes; (v) refining, defining, and naming themes; and (vi) writing up (Braun & Clarke, 2021b). Each phase demonstrates the systematic and reflexive nature of the analysis process, while also contributing to a deeper understanding of the data and facilitating the development of meaningful and coherent themes that capture the essence of the participants' experiences and perspectives.

The following subsections delve into each of these phases of the reflexive thematic analysis method and describe how it was applied during the qualitative data analysis stage of this research study.

Familiarisation

The initial phase of the reflexive thematic analysis approach centres around becoming familiar with the data. This phase encompasses three key practices that drive the reflexive nature of the approach: (i) immersion in the dataset; (ii) critical distancing and questioning; and (iii) note-making (Braun & Clarke, 2021b). Immersion involves fully engaging with the dataset in all its aspects to gain a deep and intimate understanding of its content. Critical distancing and questioning encourage an analytical mindset, where the researcher actively explores and makes sense of the data beyond its surface-level meaning. These two practices can unfold sequentially or in parallel, facilitated by the practice of note-making. Note-making entails capturing informal ideas and reflections during the critical engagement with the data items, and systematically documenting formal and structured familiarisation notes that encompass the entire dataset.

In this research study, the familiarisation phase was approached using a multifaceted approach. To begin with, each interview session was recorded and subsequently transcribed into written text. Alongside the recordings, notes were taken during or immediately after the interview sessions to capture important details and observations. The transcription process involved multiple iterations to ensure accuracy and enhance the quality of the transcriptions. During the first iteration, the recorded content was transcribed verbatim. Subsequent iterations involved carefully listening to the recordings multiple times to refine the transcript and ensure alignment between the recordings and transcribed text. Concurrently, detailed notes were continuously recorded and integrated with the existing ones. Once the transcripts were finalised, they were thoroughly explored in an active, critical, and comprehensive manner to develop a deep understanding of their content. This exploration aimed to uncover the intricacies and richness of the data, and begin the process of identifying contextual connections amongst different elements within the dataset, existing literature, and established theoretical concepts. Additionally, in select instances, the recordings were revisited to extract further contextual information and ensure

a thorough exploration of the data.

This multifaceted approach taken during the familiarisation phase ensured a thorough immersion in and critical engagement with the data, and laid the foundation for subsequent phases of the reflexive thematic analysis.

Coding

The second phase of the reflexive thematic analysis approach focuses on the process of coding. This process can be conducted manually (with pen and paper, or using word processing or spreadsheet software), through the use of computer-assisted (or aided) qualitative data analysis software (CAQDAS), or by combining these methods. Braun and Clarke (2021b) emphasise that coding is a systematic and rigorous process that yields two distinct outputs: (i) a code, which represents "an analytically interesting idea, concept or meaning associated with particular segments of data"; and (ii) a code label, which serves as a "succinct phrase attached to a segment of data, as a shorthand tag for a code" (Braun & Clarke, 2021b, p. 53). The coding process is organic and evolving, allowing for the continuous development and refinement of both codes and code labels throughout the analytic engagement. It is also inherently subjective, relying on the researcher's subjectivity and the depth and rigour of the analytic engagement. Another crucial aspect of coding is understanding the orientation to the data, which determines whether the process is approached inductively (data-driven) or deductively (researcher- or theory-driven). In practice, the reflexive thematic analysis approach allows for a combination of both orientations, as long as they remain aligned with the research problem, research purpose, and research questions of the study. Additionally, the coding process involves deciding the level at which meaning is coded. This can be at the semantic level, where coding is explicit and descriptive at the surface-level of the data, or at the latent level, where coding is implicit and conceptual at a higher level of abstraction, or a combination of both. Again, the choice of coding level is guided by the research problem, purpose, and questions underpinning the study.

In the context of this research study, the coding process was conducted manually using a combination of hard-copy documents and software tools such as Microsoft Word, Microsoft OneNote, and Microsoft Excel. This approach facilitated a deeper engagement with the dataset, allowing the researcher to continue immersing themselves in the data without the use of CAQDAS as a means of analysis. Initially, it took an inductive approach at a semantic level. However, as the process unfolded and the researcher's immersion in the data deepened, a natural evolution occurred, incorporating deductive elements and generating codes at a latent level. This evolution in the coding process allowed for a comprehensive analysis that encompassed both the surface-level and underlying meanings of the data. Moreover, the coding process followed a semi-iterative pattern, necessitating periodic revisiting and refinement of previously assigned codes and code labels. This fluid evolution and iterative refinement exemplifies the dynamic and reflexive nature of the thematic analysis approach, accommodating the shifting demands of the data and the researcher's analytic engagement (Braun & Clarke, 2021b).

In total, the coding process yielded 367 codes, serving as the basic units of analysis for the reflexive thematic analysis approach. Section F.1 provides a snapshot of all the code labels associated with each data item of the dataset for this qualitative phase of this research study. These code labels and associated codes not only provided insights into the data, but also formed

the input for the subsequent phase of the approach.

Generating Initial Themes

The third phase of the reflexive thematic analysis approach signifies a pivotal shift in focus, transitioning from a micro-level generation and examination of codes and code labels within the dataset to a macro-level exploration of shared meaning and conceptual coherence (Braun & Clarke, 2021b). This phase represents the exploratory stage of the theme development process, which extends across this phase and the subsequent ones, where clusters of potentially interconnected codes from the entire dataset are identified as candidate themes for further development and refinement. In the context of reflexive thematic analysis, a theme is not simply a summary of topics, but rather an embodiment of "shared, multi-faceted meaning, patterned across at least some of a qualitative dataset" (Braun & Clarke, 2021b, p. 350). It encompasses a collection of "related analytical insights, unified by a central organising concept or idea" (Braun & Clarke, 2021b, p. 296). Thus, this phase plays a crucial role in identifying initial patterns in the dataset that align closely with the research problem, research purpose, and research questions of the study. Braun and Clarke (2021b) emphasise the provisional nature of this phase, allowing researchers to experiment with different clustering permutations to deeply engage with the dataset's meaning, the interrelatedness of candidate themes, and to begin constructing a coherent narrative through these candidate themes.

In the context of this research study, the macro-level exploration of the dataset resulted in the generation of a total of 29 candidate themes, illuminating initial conceptual cohesion as well as diverse and interconnected meanings within the data. The number of codes within each candidate theme varied, ranging from 2 codes to 82 codes. These candidate themes provided a provisional framework for understanding the interconnected meanings and patterns within the dataset, and served as an initial response to the research questions for the qualitative phase of this research study. Section F.2 provides a visual representation of these candidate themes and their constituent codes, which subsequently served as input to the next phase of the reflexive thematic analysis approach.

Developing and Reviewing Themes

The fourth phase of the reflexive thematic analysis approach serves as a quality assurance checkpoint of the entire analysis process. It is a heavily recursive phase, which entails looking at multiple facets of the research process at the same time, including: verifying the appropriateness, suitability, viability, or fit of the codes and their corresponding extracts from the dataset into the cluster within which they have been grouped; looking at the candidate themes in relation to the study's research problem, research purpose, and research questions, and the narrative that they can potentially convey; probing whether or not each candidate theme embodies a singular concept or idea and whether or not it is cohesive; and considering the candidate themes in light of the contextual and epistemological aspects of and about the dataset. All of this effort is part of (re)developing and (re)reviewing and fine-tuning the candidate themes, and the worst-case scenario is for a researcher to have to go back to phase two of the reflexive thematic analysis process and re-engage with the coding process, which again demonstrates the reflexive nature of the analysis. Braun and Clarke (2021b) estimate that usually after two recursive cycles, it becomes clear the direction that the researcher needs to take: whether tracking back several

phases; or proceeding onto the next phase. They further express, however, that the analysis process is organic and non-linear, and relies on the scholarliness of the researcher.

In this research study, the initial 29 candidate themes generated in the previous phase were systematically reviewed. Each of the 376 codes from the coding phase, along with their related data extracts, were reviewed to determine if they fit well within their respective candidate themes, and if they contributed effectively to the narrative each candidate theme was likely to convey. This step was important for ensuring that each candidate theme was relevant to the study's research problem, research purpose, and research questions, and specifically, to the research questions for the qualitative phase of this research study. This examination led to notable adjustments. Some codes were repositioned to other candidate themes where they found a more suitable fit, while others were excluded entirely. This process led to the elimination of five candidate themes that were not as relevant, and the merging and reorganising of others into new thematic clusters. Ultimately, this process distilled the candidate themes down to 22, which were then carried forward to the subsequent phase of the analysis. This phase demonstrated the iterative and reflexive nature of thematic analysis, emphasising the importance of careful evaluation and adjustment of candidate themes to align with the research goals.

Refining, Defining, and Naming Themes

The fifth phase of the reflexive thematic analysis approach is the final stage of the theme development process, which encompasses three essential processes that facilitate the concluding phase of the reflexive thematic analysis approach. The first process involves a thorough analytic refinement of the themes developed in the previous phase. This refinement includes mapping out and fine-tuning the narrative or argument that will be presented in the final phase of the analysis. Carefully examining, adjusting, and refining the themes is essential to ensure their coherence, relevance, and alignment with the research problem, research purpose, and research questions. The second process focuses on the formal writing of concise and precise definitions for each refined theme. These definitions serve as anchor points, encapsulating the central organising concept, boundaries, and distinct characteristics of each theme. They are crucial tools in testing and validating the robustness, coherence, and integrity—or "themeyness" (Braun & Clarke, 2021b, p. 108)—of the developed themes. If any theme definition falls short or fails to accurately capture the core concept and other key characteristics of a theme, further refinement or revisitation of earlier phases may be necessary. The third process within this phase involves thoughtfully naming the themes. Braun and Clarke (2021b) emphasise the importance of selecting appropriate and meaningful theme names. These names should be concise phrases that effectively capture the essence of the theme, avoid misleading the reader, and accurately represent the analytic effort invested. They further underscore that a well-chosen theme name serves as a signal guiding the reader's understanding of the theme's contextual "*meaning* and *analytic direction*" (Braun & Clarke, 2021b, p. 112).

In this final stage of theme development, the 22 candidate themes identified in the preceding phase underwent a detailed analytic refinement. This refinement process aimed to ensure their coherence with the unfolding story told by the data and their relevance to the overall objectives of the research study, particularly in addressing the research questions specific to this phase of the research study. Following this, the themes were formally defined, marking their transition

from candidate status to fully established themes.

The refining and naming processes resulted in the exclusion of one theme for not meeting the criteria of "themeyness," bringing the total down to 21 themes. Additionally, due to the extensive range of codes it encompassed, one theme was divided into three distinct subthemes, enhancing its alignment with the overall narrative.

In the final step of this phase, the 21 themes, along with the three subthemes, were thoughtfully named. These names were carefully chosen to encapsulate the essence of their contextual meaning and analytic direction. This step highlighted the analytical depth and rigour of this phase of the research study.

These thematic findings were then systematically prepared for presentation in the final phase of the reflexive thematic analysis approach, ensuring a coherent and meaningful representation of the research insights.

Writing Up

The final phase of the reflexive thematic analysis approach signifies the culmination of the analysis process, involving the creation of a comprehensive and coherent formal analytic narrative. This phase is dedicated to unambiguously communicating the rich meaning derived from the data, specifically in relation to the research problem, research purpose, and research questions. Braun and Clarke (2021b) emphasise that this phase is not separate or detached from the preceding phases; instead, it builds upon the analytic engagement established throughout the reflexive thematic analysis and draws upon the overarching theoretical and philosophical foundations of the research study. While the presentation and interpretation of findings form a central component of the qualitative analysis write-up, Braun and Clarke (2021b) emphasise the need for a coherent thread that rationalises the reflexive thematic analysis approach throughout the entire body of work. Moreover, they provide valuable guidance on key considerations to be mindful of throughout the entire reflexive thematic analysis approach, with particular importance during this final phase (Braun & Clarke, 2021a).

Within the context of this research study, the reflexive thematic analysis approach is briefly introduced in Chapter 1 as the chosen method for analysing data during the qualitative phase. This chapter further articulates the rationale for its use and demonstrates how it integrates into the overall methodological approach of the study. The final phase of the analysis, representing the culmination of the reflexive thematic analysis approach, is presented in Chapters 6 and 7. In Chapter 6, an initial, but comprehensive interpretive account of the themes derived from the analysis is provided. Chapter 7 integrates the findings from the reflexive thematic analysis with the results of the quantitative phase, following the study's mixed methods design, and offers detailed discussion and interpretation of the same. These chapters collectively offer a comprehensive and cohesive narrative that showcases the significance and value of the reflexive thematic analysis approach in addressing the research problem, purpose, and questions.

4.5 ETHICAL CONSIDERATIONS

Upholding ethical principles in research is essential, not just for maintaining academic integrity, but also for ensuring that the inquiry is conducted meaningfully and responsibly. This section outlines the ethical considerations observed in conducting this research, especially pertinent due to the involvement of human participants. Emphasis was placed on compliance with established ethical standards to safeguard the rights, well-being, and dignity of all potential and would-be participants. It details the adherence to these standards throughout various stages, from initial planning to the dissemination of outcomes. Covered herein are critical areas including securing institutional approvals, ensuring informed consent, and protecting participant confidentiality and privacy, amongst other rights. This ethical approach aligns with the guidelines set forth by authorities like Creswell (2014), Drew et al. (2007), and Preissle et al. (2015), and adheres to the specific requirements of the Wits and the GDE.

4.5.1 Ethical Conduct and Principles

There are several research ethics approaches that researchers consider as best practices when conducting research. Kivunja and Kuyini (2017), for example, highlight four criteria derived from the works of John Stuart Mill (a British philosopher, 1806–1873), which assist researchers in addressing important ethical and moral questions during their research endeavours. These criteria are as follows: (i) teleology, which advocates that researchers should prioritise actions that are inherently right as their moral obligation; (ii) deontology, which recognises that every action taken in the course of research carries its own consequences; (iii) morality, referring to the intrinsic moral values that researchers should uphold throughout their research; and (iv) fairness, emphasising the researcher's responsibility to treat all research participants fairly and equitably.

Other researchers have embraced Mason's (1986) four ethical principles as guiding principles in their research endeavours. These principles encompass: (i) privacy, which addresses the voluntary disclosure of information by participants, including the grounds and guarantees surrounding such disclosure; (ii) accuracy, emphasising the researcher's responsibility for ensuring the authenticity, fidelity, and accuracy of the information gathered; (iii) property, referring to the ownership of information and the channels through which it is disseminated; and (iv) accessibility, encompassing the rights governing access to and the conditions of use for the information.

All of these approaches, criteria, or principles embody ethical compliance and integrity, as Preissle et al. (2015) assert, although they only form a subset of what research ethics, particularly in the context of mixed methods research, encompass. Achieving a comprehensive understanding of research ethics necessitates ongoing reflection and discernment tailored to each individual research project (Preissle et al., 2015).

An alternative approach to research ethics, advocated by proponents in the field of mixed methods research, involves anticipating and addressing ethical considerations at various stages of the research process. These stages include during: (i) formulating the problem statement; (ii) developing the purpose statement and research questions; (iii) conducting data collection; (iv) analysing and interpreting the data; and (v) writing and disseminating the research findings (Creswell, 2014; Preissle et al., 2015). This approach allows researchers to flexibly anticipate

and plan for ethical concerns at each stage, recognising that certain principles or criteria may not be universally applicable throughout the entire study, particularly when human participants are involved. According to Preissle et al. (2015), maintaining reflexivity and transparency are crucial components of research ethics and should be interwoven throughout the entire research study.

This suggested alternative approach aligns with the axiological assumptions of the Pragmatic paradigm, which place a central focus on human experience, and was thus adopted during this research study. The remaining part of this subsection provides a brief description of how ethical considerations were addressed during the aforementioned stages of the research process in the context of this study.

Ethical Concerns at Problem Statement Formulation

In formulating the problem statement, ethical considerations were carefully addressed. The research was anchored in South Africa's NDP, targeting key educational objectives by 2030. This study critically explored the use of technology in mathematics education within the South African NCS Grades R–12 schooling system, assessing its influence on learner motivation and its alignment with the NDP's educational targets.

While immediate benefits to the participant teachers (and by extension, the learners in their classrooms) may not be evident, the study emphasises long-term gains in educational quality and performance. Additionally, it enriches academic discussions on the interplay between ICTs and education, underscoring the potential for systemic improvements. This approach adheres to the ethical standards of benefiting participants and advancing the field, as emphasised by Creswell (2014) and Preissle et al. (2015).

Ethical Concerns at Purpose Statement and Research Questions Formulation

The development of a clear purpose statement is vital for ethical transparency in research, as emphasised by Creswell (2014). This clarity is crucial for conveying the study's intent to participants, aligning with the ethical imperative of transparency highlighted by Preissle et al. (2015). It establishes a shared understanding and eradicates potential misunderstandings.

In this research, the purpose statement and accompanying research questions, elaborated in Sections 1.3 and 1.4, incorporate crucial aspects like study design and theoretical approach. This information was shared with gatekeepers and potential participants using straightforward, accessible language to ensure maximum transparency. Creswell (2014) highlights the ethical risk of deception, which arises when there is a discrepancy between the participant's understanding and the researcher's actual intent. Thus, adopting this approach ensured participants were fully aware of the study's objectives, aligning their understanding with the researcher's intentions, thereby mitigating this risk.

Ethical Concerns During Data Collection

The data collection stage is critical in any research study, particularly in mixed methods research where interaction with participants is pivotal. Respecting participants and research sites

is central, as outlined by Creswell (2014). This research required obtaining necessary permissions and consents, detailed in Sections 4.5.2 and 4.5.3, covering institutional approvals and participants' consent.

The complexity inherent in mixed methods research, particularly in this study's explanatory sequential design, brings unique ethical challenges (Preissle et al., 2015). This approach entailed a quantitative phase followed by a qualitative phase, each requiring distinct methodological expertise, as noted by Creswell (2014) and others. Preissle et al. (2015) identify two key ethical obligations for researchers employing mixed methods designs: firstly, maintaining technical proficiency across all aspects of the study, and secondly, the proactive identification and management of ethical issues that may arise during data collection and generation.

To meet the first ethical obligation, this study employed well-established qualitative and quantitative methods appropriate for each phase, as articulated earlier in this chapter, ensuring methodological rigour. The Pragmatism paradigm's epistemological assumptions guided the selection of methods best suited to address the research questions, involving a thorough evaluation of various alternatives.

For the second ethical obligation, anticipating and addressing potential ethical concerns throughout the actual data collection and generation processes was essential. In the quantitative phase, a custom-designed survey questionnaire was employed, and care was taken to ensure ethical considerations such as informed consent, privacy, confidentiality, and data protection. Similarly, the qualitative phase utilised semi-structured interviews, giving additional attention to concerns like participant burden and respect.

Ethical Concerns During Data Analysis and Interpretation

During the data analysis and interpretation stages, mixed methods researchers face two critical ethical challenges as identified by Preissle et al. (2015). The first is avoiding bias towards any one method, and the second is exercising care in the mixing of data from different phases to maintain data quality and integrity. Creswell (2014) further reinforces this perspective by advising against any partiality in representing participant views, particularly the selective portrayal of results or findings that might skew the study's outcomes. This ethical guidance is especially pertinent in mixed methods research where the interplay between quantitative and qualitative data can present complex interpretive challenges.

Characteristic of the explanatory sequential mixed methods design used in this study, as outlined in Section 4.3.2, is the clear upfront declaration of the phase priorities, which aids in safeguarding against retrospective method bias. The strategic integration of data occurred at two key junctures: firstly, using the quantitative phase results to refine the data generation protocol for the qualitative phase, and secondly, in the synthesis of both quantitative results and qualitative findings for the overall interpretation. Anchoring this approach were the ontological assumptions of the Pragmatic paradigm, valuing the diverse realities of participants. This paradigmatic stance functioned as a safeguard, ensuring balanced consideration of all participant perspectives and preventing any bias towards particular views.

Ethical Concerns During Writing and Disseminating the Research

The final stage of the research process, which involves writing and disseminating outcomes, is pivotal as it serves as the key interface with the scholarly community and other interested audiences. Creswell (2014) and Preissle et al. (2015) emphasise several ethical considerations in this phase, which have been thoughtfully prioritised in this study. A primary focus was placed on accuracy and truthfulness to ensure that the outcomes presented a genuine and precise reflection of the gathered data. This commitment extended beyond preventing falsification or misrepresentation of data to implementing thorough cross-checking and validation procedures, thereby upholding the integrity of the research throughout.

Equally crucial was the judicious management of sensitive information. In line with the guidelines detailed in Section 4.5.3, care was taken to maintain participant privacy and confidentiality, specifically avoiding the disclosure of any information that could harm participants or infringe upon others' rights. This protective measure was a constant throughout the research process. In terms of communication, clear and unambiguous language was consistently used, as will be the case in future publications, to ensure inclusivity and unbiased representation across diverse demographics, including gender, ethnicity, sexual orientation, disability, and age, following the advice of Preissle et al. (2015).

Addressing the issue of plagiarism was another significant aspect of this research. In adherence to the anti-plagiarism policies of Wits, every effort was made to properly attribute all sources, thereby upholding academic honesty and integrity. Finally, the selection of dissemination platforms, both current and future, has been and will continue to be made with careful consideration to align with the ethical standards of writing and dissemination. This thesis represents the primary documentation of the research, prepared in accordance with Wits' guidelines. Plans for further dissemination include publications in reputable journals and presentations at prominent conferences, thereby extending the reach of the study's outcomes while maintaining the ethical commitments outlined in this thesis, and building upon the publications already presented in the preliminary sections of this thesis.

4.5.2 Institutional Approvals

The Gauteng Department of Education

Obtaining the GDE approval was a fundamental prerequisite for conducting this research, which involved teachers across various educational districts in the Gauteng province. The process, in line with protocols similar to those described in previous studies (e.g., Alibali & Nathan, 2010; Wanat, 2008), entailed obtaining permissions from district officials, school principals, and the GDE for each school involved. Although this part of the research methodology was initially planned for on-site execution, the COVID-19 pandemic necessitated a shift to an online format, as detailed in Section 4.4.2. Nonetheless, certain aspects of the research still required in-person school visits.

In compliance with the GDE guidelines, an application was submitted to the Director: Education Research and Knowledge Management at the GDE, and was duly approved. This approval was a precondition for beginning the data collection and generation phases of the study. As the

research timeline extended beyond initial expectations, a subsequent application for an extension of the research period was also granted by the GDE, ensuring continued compliance with their regulations. The original approval, its extension, and related documentation are included in Sections A.1, A.2, and B.1 of the appendix for reference.

Furthermore, for each school visited, specific permission was sought from the school principal. This involved presenting the GDE's permission letter alongside an invitation letter detailing the research's scope (a sample of which is in Section B.2 of the appendix). Upon agreeing to participate, principals were required to formally provide their consent, indicated through a signed and stamped consent form (a sample can be found in Section B.3). All signed and stamped consent forms were securely stored, adhering to ethical guidelines.

The University of the Witwatersrand

In line with the guidelines highlighted by Creswell (2014) for ethical research conduct, this study's proposal was submitted for review and approval to the Wits' Human Research Ethics Committee (HREC): Non-Medical. This committee, established as per regulatory requirements, is tasked with ensuring the protection and just treatment of human participants in non-medical research, as well as overseeing the ethical aspects of such studies in the university.

Before initiating the data collection and generation phases, a comprehensive ethical approval application was made to the Wits' HREC: Non-Medical. This application adhered to all specified requirements and conditions. Approval was granted under protocol number H19/08/22. The official approval certificate is available in Section A.3 of the appendix.

4.5.3 Informed Consent of Participants

Informed consent is a critical process in research, ensuring that potential participants are thoroughly informed about the study's objectives and what their participation might entail should they opt-in. This process is essential not only for providing information that aids participants in making informed decisions, but also for safeguarding their privacy, confidentiality, and other human rights, as underscored by Creswell (2014) and Drew et al. (2007). Drew et al. (2007) delineate three key elements of an ethical informed consent process: (i) capacity; (ii) information; and (iii) voluntariness. These elements are further explored in relation to this study in the subsequent subsections.

Capacity

Understanding the capacity of participants is integral to the informed consent process. As Drew et al. (2007) articulate, it involves assessing whether individuals have the competence "to acquire, retain, and evaluate information" (p. 57) to make an informed decision about their involvement in research. This involves ensuring that potential participants possess the competence necessary to evaluate and to knowingly choose to participate in the study.

In this study, teachers were the primary participants in both the quantitative and qualitative phases. The quantitative phase involved disseminating a survey questionnaire, while the qualitative phase included semi-structured interviews with interested teachers from the earlier phase.

To obtain consent, teachers were presented with a detailed informed consent form, available in full in Section C.2 of the appendix. An abbreviated version was also provided in the online questionnaire for the quantitative phase (see Section D.1). In addition, verbal consent was sought at the start of each interview in the qualitative phase, confirming each participant's informed and voluntary agreement to partake in the research.

Information

The information component of informed consent, closely related to the capacity element, involves providing potential participants with comprehensive details necessary to make an informed decision about their participation. As emphasised by Drew et al. (2007), this information must be presented clearly and comprehensively for potential participants to fully understand. The responsibility lies with the researcher to provide detailed information about the research's purpose, nature, and possible outcomes (Creswell, 2014; Drew et al., 2007; Gallagher et al., 2009).

In this study, the method of conveying information to participants was primarily through formal, written channels, using informed consent forms and detailed participant information sheets, following the approach recommended by Creswell (2012). These materials were used across both the quantitative and qualitative phases. The complete participant information sheet is included in Section C.1 of the appendix, with a summarised version integrated into the online questionnaire for the quantitative phase (as seen in Section D.1). Additionally, in the qualitative phase, a verbal summary of this information was provided at the beginning of each interview. Table 4.8 provides a summary of the key information that was communicated in this process.

Table 4.8: Key information communicated to potential participants as part of the informed consent process.

Key Information for Participant Consent
Voluntary participation
Right to withdraw at any time
Purpose of the research study
Procedures for data collection
Right and guarantee of confidentiality
Right and guarantee of privacy
Right and guarantee of anonymity
Benefits for participating
Information about the researcher

Source: Author.

Voluntariness

Voluntariness is a critical component of the informed consent process, underscoring the necessity of consent being freely given without any form of coercion. Creswell (2014) stresses the ethical obligation to avoid forcing or manipulating potential participants into consenting to partake in a study. As Drew et al. (2007) point out, it is the researcher's responsibility to provide clear and sufficient information about the study to allow potential participants to make an

informed decision without feeling pressured.

In this research study, voluntariness was upheld by respecting the potential participants' right to decide whether to partake in the study. Once consent was given, participants were assured of their autonomy throughout their involvement, with the understanding that they had the ongoing option to withdraw from the study at any stage without any repercussions. This commitment to participant autonomy and voluntariness was reinforced through the information component of the informed consent process, the key details of which are summarised in Table 4.8. By ensuring that participants understood their rights and the nature of their participation, the study upheld the essential element of voluntary consent throughout the research process.

4.6 SUMMARY

This chapter has provided a detailed account of the methodological framework adopted for this research study, beginning with an in-depth discussion on the spectrum of methodological approaches. It highlighted the positioning of mixed methods research as a bridge between qualitative and quantitative approaches, articulating a strong rationale for its selection. This rationale was rooted in the study's theoretical and paradigmatic underpinnings, with a particular emphasis on the unique ability of mixed methods to address the study's research problem effectively.

The chapter then delved into the specifics of research design within the mixed methods domain, advocating for the explanatory sequential mixed methods design. Drawing on the authoritative work of Creswell and Plano Clark (2017), it provided a thorough justification for this design choice, highlighting its key features and its alignment with the study's broader aims.

Central to this chapter was the exploration of the research methods implemented throughout the study. The selection of participants was guided by the mixed methods sampling procedures recommended by Teddlie and Yu (2007), with a combination of multilevel and sequential mixed methods sampling procedures forming the study's integrated sampling strategy. The chapter also tackled the challenges introduced by the COVID-19 pandemic, detailing the adaptations made for data collection and generation in both the quantitative and qualitative phases. This included leveraging online platforms to maintain the continuity and integrity of the research process. Furthermore, it described the systematic processes undertaken, from designing the instruments to executing the collection and generation procedures.

The chapter provided a detailed overview of the data analysis processes for both quantitative and qualitative data. For quantitative data, it elaborated on the preprocessing and analysis phases conducted using IBM® SPSS® Statistics, and the specific descriptive and inferential statistical measures employed. Emphasis was placed on the careful selection of quantitative techniques and statistical measures, ensuring they were well-suited to the data at hand and capable of addressing the quantitative research questions effectively. For qualitative data, the chapter described the approach to analysis through reflexive thematic analysis, detailing its six phases and their execution in addressing the qualitative research questions.

Ethical considerations were thoroughly addressed within the chapter, underscoring the importance of ethical compliance in research. By integrating the ethical framework proposed by

Creswell (2014) and Preissle et al. (2015) for mixed methods research, the chapter carefully delineated ethical considerations applied at each significant stage of the study. Furthermore, it detailed the process for obtaining requisite institutional approvals from Wits and the GDE, and described the informed consent process with a focus on ensuring participants' information, capacity, and voluntariness, underlining the ethical rigour with which the study was conducted.

This chapter has established a robust foundation by offering a comprehensive overview of the methodological considerations, choices, and execution. It effectively sets the stage for the detailed presentation of results and findings in the forthcoming chapters, ensuring a seamless transition from methodology to empirical evidence.

CHAPTER 5

QUANTITATIVE RESULTS

5.1 INTRODUCTION

5.1.1 Chapter Purpose

The previous chapter outlined the research methodology and design of this study, demonstrating the systematic approach adopted to address the research questions, which are closely aligned with the research purpose and problem. As detailed in Section 4.3.2 and illustrated in Figure 4.1, this study employed an explanatory sequential mixed methods design, comprising two distinct phases.

The focus of this chapter is to present the results from the analysis of the quantitative data collected in the first phase of the study. This aligns with the primary purpose of this research study, which was to quantitatively investigate teachers' perceptions of learner motivation in relation to the use of ICTs in mathematics education. The specific quantitative research questions guiding this investigation were introduced in Section 1.4.1.

5.1.2 Overview of Participants

For the quantitative phase of this study, a total of 55 unique responses to the survey questionnaire were received. Out of these responses, a total of 14 participants (25% of the total responses) did not see the survey questionnaire to completion, and thus were subsequently excluded from the analysis. Out of the 41 participants who completed the survey questionnaire, 2 participants (4% of the total responses) did not consent to proceed with the process, while 16 participants (29% of the total responses) did not meet the inclusion criterion of "using technology to teach mathematics." These responses were also subsequently excluded from the analysis. This left a total survey questionnaire sample of 23 participants (42% of the total responses). Table 5.1 shows the spread of these valid responses across the GDE school districts and educational phases.

5.1.3 Chapter Outline and Organisation

The remainder of this chapter presents the results of the quantitative analysis of the data gathered on teacher perceptions of learner motivation in relation to the use of ICTs in mathematics classrooms. As outlined in Section 3.2, this study adopted the reconceptualised definition of

Table 5.1: Spread of participants across school districts and educational phases.

District	Phase				Total
	Foundation	Intermediate	Senior	FET	
Ekurhuleni North	1	·	1	1	3
Ekurhuleni South	1	3	3	4	11
Johannesburg East	·	1	2	1	4
Johannesburg South	·	·	·	3	3
Johannesburg West	·	·	·	1	1
Sedibeng West	1	·	·	·	1
Total	3	4	6	10	23

Source: Author.

motivation from a social constructivist perspective, characterising motivation as manifesting in forms of observable interest and engagement (Sivan, 1986).

Accordingly, the subsequent section, Section 5.2, focuses on quantitative results that explore the interplay between the use of ICTs in mathematics teaching and learning, and the interest dimensions of motivation. Section 5.3 then shifts the focus to similar explorations, but within the engagement dimensions of motivation. Following this, Section 5.4 synthesises these results, offering an integrated analysis of the quantitative data. Finally, Section 5.5 summarises the chapter, emphasising key results that connect to the second phase of this research study.

5.2 INTEREST

5.2.1 Situational Interest

Situational interest was measured on a Likert-type subscale comprising six Likert-type items. Each subscale item was rated on a five-point scale with response anchors ranging from *'Strongly Agree'* (coded with the numerical value of 1) to *'Strongly Disagree'* (coded with the numerical value of 5). Of the six items, one was negatively worded (SI6). Each item was a statement (or a predicate) anchored on the subject: *Because of the use of technology in teaching and learning in my classroom....* Table 5.2 depicts the situational interest Likert-type subscale as described above.

The internal consistency of the situational interest subscale, as measured by McDonald's coefficient omega (ω), was computed to be .866. Kendall's rank correlation coefficients (τ_b) were calculated to ascertain item-total correlations between each subscale item and the corresponding item total as an additional measure of internal consistency of the situational interest subscale. These were all found to be statistically significant (with $p < .05$ or $p < .01$), above the recommended value of .300, and ranged from .421 to .808 as reported in Table 5.3.

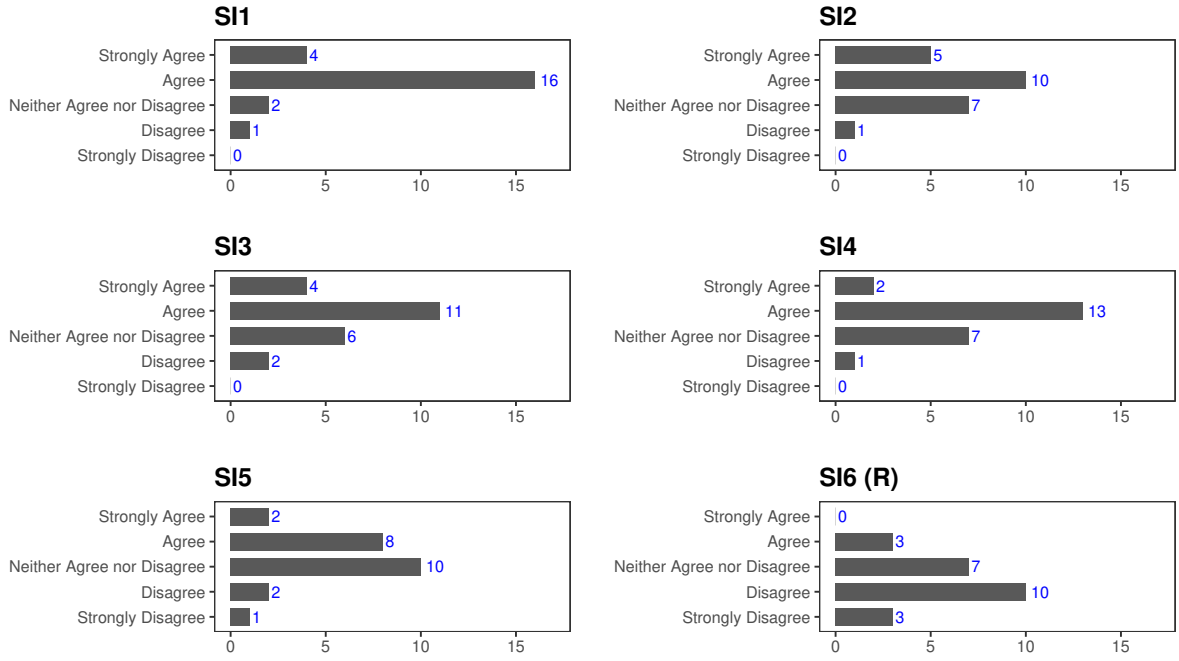
The response frequencies for the situational interest subscale are illustrated in Figure 5.1, which show how the respondents self-reported their observations of situational interest elements in their classrooms. These are complemented by the descriptive statistics values of the situational

Table 5.2: Situational interest statements.

Label	Statement *Because of the use of technology in teaching and learning in my classroom...*
SI1	My learners enjoy working on mathematics topics
SI2	My learners want to know more about mathematics
SI3	My learners think that mathematics is interesting
SI4	My learners expect to master mathematics well
SI5	My learners are often fully focused on mathematics; they are not distracted by other things
SI6 (R)	My learners are often bored

Source: Author.

interest subscale as reported in Table 5.3.



Source: Author.
Note: $n = 23$.

Figure 5.1: Response frequencies for situational interest statements.

The first statement (SI1) asserted that *learners enjoy working on mathematics topics* as a direct result of the use of technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and interquartile range (IQR) ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement SI1 was *'Agree'*, coded with the numerical value of 2, with 16 of the 23 respondents (70%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 4 of

the 23 respondents (17%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers agreed that using technology to teach and learn mathematics leads to learners enjoying working on mathematics topics. Only 1 of the 23 respondents (4%) disagreed with statement SI1, while the remaining respondents (9%) were tentative about statement SI1.

The second statement (SI2) asserted that the use of technology in teaching and learning mathematics in a classroom setting drives *learners [to] want to know more about mathematics*. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement SI2 was again *'Agree'*, coded with the numerical value of 2, with 10 of the 23 respondents (44%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 5 of the 23 respondents (22%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers were positive that using technology to teach and learn mathematics leads to learners wanting to know more about mathematics. Only 1 of the 23 respondents (4%) disagreed with statement SI2, while the remainder of the respondents (30%) were tentative about statement SI2.

The third statement (SI3) asserted that the use of technology in teaching and learning mathematics in a classroom setting makes *learners think that mathematics is interesting*. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement SI3 was again *'Agree'*, coded with the numerical value of 2, with 11 of the 23 respondents (48%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 4 of the 23 respondents (17%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers were positive that using technology to teach and learn mathematics leads to learners believing that mathematics is interesting. Only 2 of the 23 respondents (9%) disagreed with statement SI3, while the remainder of the respondents (26%) were tentative about statement SI3.

The fourth statement (SI4) asserted that the use of technology in teaching and learning mathematics in a classroom setting fosters the belief that *learners expect to master mathematics well*. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement SI4 was again *'Agree'*, coded with the numerical value of 2, with 13 of the 23 respondents (57%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 2 of the 23 respondents (9%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers agreed that using technology to teach and learn mathematics, learners have an expectation of mastering mathematics. Only 1 of the 23 respondents (4%) disagreed with statement SI4, while the remainder of the respondents (30%) were tentative

about statement SI4.

Statement five (SI5) asserted that *learners are often fully focused on mathematics* and that *they are not distracted by other things* primarily because of the use of technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 23$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement SI5 was *'Neither Agree nor Disagree'*, coded with the numerical value of 3, with 10 of the 23 respondents (44%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Neither Agree nor Disagree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. Notwithstanding, 8 of the 23 respondents (35%) aligned with the *'Agree'* response anchor, and 2 of the 23 respondents (9%) aligned with the *'Strongly Agree'* response anchor. This was an interesting result as it meant that from their observations, there was an equal split between those teachers who were tentative and those teachers who were positive about the assertion of statement SI5. Only 1 of the 23 respondents (4%) strongly disagreed with statement SI5, while the remainder of the respondents (9%) disagreed with statement SI5.

The last statement of the situational interest subscale (SI6) was negatively worded. It asserted that *learners are often bored* as a direct result of using technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 23$), the median ($Mdn = 4.0$), mode ($Mode = 4.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement SI6 was *'Disagree'*, coded with the numerical value of 4, with 10 of the 23 respondents (44%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Disagree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 3 of the 23 respondents (13%) aligned with the *'Strongly Disagree'* response anchor. This meant that from their observations, the majority of the teachers did not think that using technology to teach and learn mathematics bores learners in their mathematics classrooms. Only 3 of the 23 respondents (13%) agreed with statement SI6, with the remainder of the respondents (30%) being tentative about statement SI6.

A Kruskal-Wallis H test was conducted, comparing the teachers' observations of situational interest amongst the learners in their classrooms across both school districts and educational phases. No statistically significant result was found across both the educational phases, $H(3) = .407$, $p > .05$, and the school districts, $H(5) = 4.831$, $p > .05$. This indicated that the participants across the four educational phases and across the six school districts did not differ significantly in their observation of situational interest from one another.

5.2.2 Individual Interest

Individual interest was measured on a Likert-type subscale comprising six Likert-type items. Each subscale item was rated on a five-point scale with response anchors ranging from *'Strongly Agree'* (coded with the numerical value of 1) to *'Strongly Disagree'* (coded with the numerical value of 5). Each item was a statement (or a predicate) anchored on the subject: *Because of the use of technology in teaching and learning in my classroom....* Table 5.4 depicts the individual interest Likert-type subscale as described above.

Table 5.3: Statistical values for situational interest statements.

Scale Item	Statistical Measures			
	Median	Mode	IQR	Item-Total Correlation (τ_b)
SI1	2.0	2.0	0.0	.717**
SI2	2.0	2.0	1.0	.808**
SI3	2.0	2.0	1.0	.641**
SI4	2.0	2.0	1.0	.709**
SI5	3.0	3.0	1.0	.554**
SI6 (R)	4.0	4.0	1.0	.421*

Source: Author.

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Table 5.4: Individual interest statements.

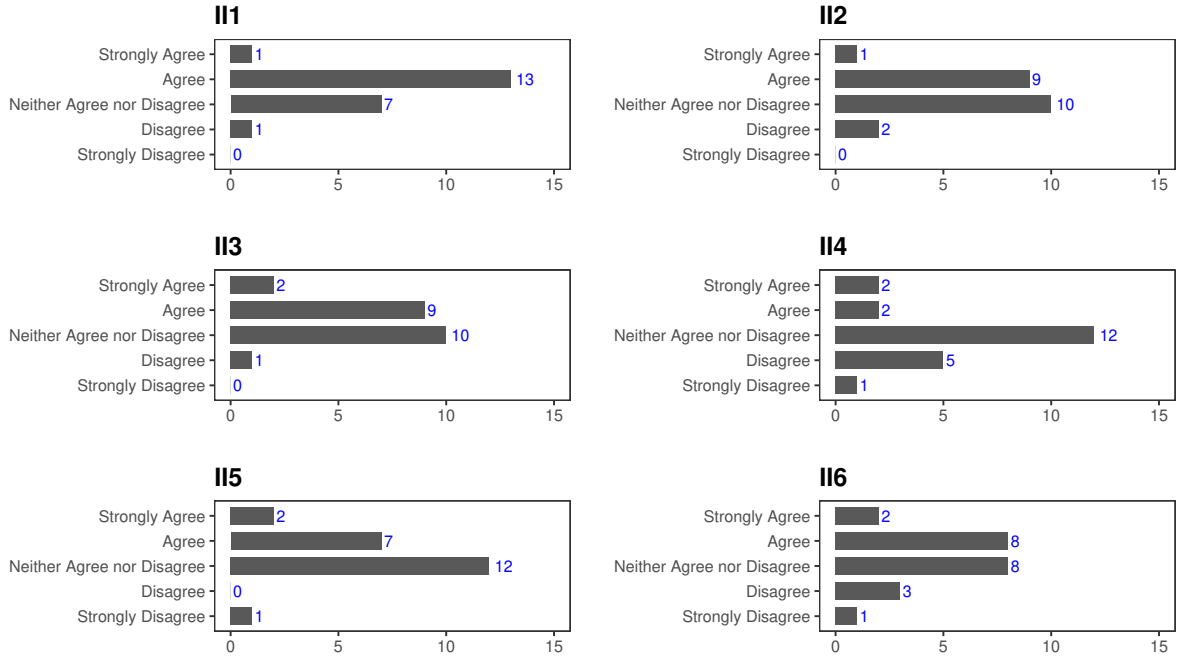
Label	Statement *Because of the use of technology in teaching and learning in my classroom...*
II1	My learners are very interested in learning mathematics
II2	My learners practice a lot of mathematics outside of school
II3	My learners always look forward to their mathematics lessons because they enjoy them a lot
II4	My learners watch a lot of mathematics-related TV programs
II5	My learners want to pursue careers in mathematics or mathematics-related disciplines later in life
II6	When my learners read or watch something mathematics-related, they are fully focused, and they forget everything else around them

Source: Author.

The internal consistency of the individual interest subscale, as measured by McDonald's coefficient omega (ω), was computed to be .825. Kendall's rank correlation coefficients (τ_b) were calculated to ascertain item-total correlations between each subscale item and the corresponding item total as an additional measure of internal consistency of the individual interest subscale. These were all found to be statistically significant (with $p < .05$ or $p < .01$), above the recommended value of .300, and ranged from .375 to .765, as reported in Table 5.5.

The response frequencies for the individual interest subscale are illustrated in Figure 5.2, which show how the respondents self-reported their observations of individual interest elements in their classrooms. These are complemented by the descriptive statistics values of the individual interest subscale, as reported in Table 5.5.

The first statement of the individual interest subscale (II1) asserted that as a direct result of the use of technology in teaching and learning mathematics in a classroom setting, *learners are very interested in learning mathematics*. From the responses ($n = 22$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode



Source: Author.
Note: n = 22.

Figure 5.2: Response frequencies for individual interest statements.

indicated that the most frequent response for statement II1 was *'Agree'*, coded with the numerical value of 2, with 13 of the 22 respondents (59.1%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 1 of the 22 respondents (4.5%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers agreed that using technology to teach and learn mathematics leads to learners who are very interested in learning mathematics. Only 1 of the 22 respondents (4.5%) disagreed with statement II1, while the remaining respondents (31.8%) were tentative about statement II1.

The second statement of the individual interest subscale (II2) asserted that *learners practice a lot of mathematics outside of school* due to the use of technology in teaching and learning mathematics during their classroom sessions. From the responses ($n = 22$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement II2 was again *'Neither Agree nor Disagree'*, coded with the numerical value of 3, with 10 of the 22 respondents (45.5%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Neither Agree nor Disagree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. Notwithstanding, 9 of the 22 respondents (40.9%) aligned with the *'Agree'* response anchor, and 1 of the 22 respondents (4.5%) aligned with the *'Strongly Agree'* response anchor. This was an interesting result, as it meant that from their observations, there was an equal split between those teachers who were

tentative and those teachers who were positive that using technology to teach and learn mathematics compels learners to practice a lot of mathematics even outside of school. Only 2 of the 22 respondents (9.1%) disagreed with statement II2.

The third statement of the individual interest subscale (II3) asserted that the use of technology in teaching and learning mathematics in a classroom setting ensures that *learners always look forward to their mathematics lessons because they enjoy them a lot*. From the responses ($n = 22$), the median ($Mdn = 2.5$), mode ($Mode = 3.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement II3 was again *'Neither Agree nor Disagree'*, coded with the numerical value of 3, with 10 of the 22 respondents (45.5%) aligning with this response anchor. The median, however, indicated that the responses centred at a point between the *'Neither Agree nor Disagree'* and the *'Agree'* response anchors. Interpreting the IQR value further indicated that these responses were tightly clustered around this point. This was supported by a further 9 of the 22 respondents (40.9%) and 2 of the 22 respondents (9.1%) aligning with the *'Agree'* and *'Strongly Agree'* response anchors, respectively. This was yet another interesting result as it meant that from their observations, there was no outright consensus amongst the respondents on whether or not the use of technology to teach and learn mathematics fosters an enjoyment on the learners to a point where learners always look forward to their mathematics lessons. Only 1 of the 22 respondents (4.5%) disagreed with statement II3.

The fourth statement of the individual interest subscale (II4) asserted that *learners watch a lot of mathematics-related TV programs* as a direct result of the use of technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 22$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement II4 was again *'Neither Agree nor Disagree'*, coded with the numerical value of 3, with 12 of the 22 respondents (54.5%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Neither Agree nor Disagree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. This meant that from their observations, the majority of the teachers were tentative that using technology to teach and learn mathematics leads to learners who are very interested in learning mathematics. On the positive side, 2 of the 22 respondents (9.1%) aligned with the *'Agree'* response anchor, with the same number of respondents (9.1%) aligning with the *'Strongly Agree'* response anchor. On the negative side, 5 of the 22 respondents (22.7%) disagreed with statement II4, while the remaining respondent (4.5%) strongly disagreed with statement II4.

Statement five of the individual interest subscale (II5) asserted that *learners want to pursue careers in mathematics or mathematics-related disciplines later in life* primarily because of the use of technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 22$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement II5 was again *'Neither Agree nor Disagree'*, coded with the numerical value of 3, with 12 of the 22 respondents (54.5%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Neither Agree nor Disagree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered.

This meant that from their observations, the majority of the teachers were tentative that using technology to teach and learn mathematics causes learners to want to pursue careers in mathematics or mathematics-related disciplines later on in their lives. On the positive side, 7 of the 22 respondents (31.8%) aligned with the *'Agree'* response anchor, while a further 2 of the 22 respondents (9.1%) aligned with the *'Strongly Agree'* response anchor. On the negative side, only 1 of the 22 respondents (4.5%) strongly disagreed with statement II5.

The last statement of the individual interest subscale (II6) asserted that as a direct result of using technology in teaching and learning mathematics in a classroom setting, when *learners read or watch something mathematics-related, they are fully focused, and they forget everything else around them*. From the responses ($n = 22$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$ and 2.0), and IQR ($IQR = 1.0$) for this statement were computed. There were two modes (that is, the responses to statement II6 were bimodal), indicating that the most frequent responses for statement II6 were both *'Neither Agree nor Disagree'* and *'Agree'*, coded with the numerical values of 3 and 2, respectively. Eight of the 22 respondents (36.4%) aligned with the *'Neither Agree nor Disagree'* response anchor, and another 8 of the 22 respondents (36.4%) aligned with the *'Agree'* response anchor. Notwithstanding, the median indicated that the responses centred more around the *'Neither Agree nor Disagree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 2 of the 22 respondents (9.1%) aligned with the *'Strongly Agree'* response anchor on the positive side. This meant that from their observations, there was again an almost even split between those teachers who self-reported that using technology to teach and learn mathematics compels learners to fully focus and completely zone-in whenever they read or watch something mathematics-related, and those teachers who remained tentative about the same statement. On the negative side, 3 of the 22 respondents (13.6%) disagreed with statement II6, while the remaining respondent (4.5%) strongly disagreed with statement II6.

Table 5.5: Statistical values for individual interest statements.

Scale Item	**Statistical Measures**			
	Median	Mode	IQR	Item-Total Correlation (τ_b)
II1	2.0	2.0	1.0	.375*
II2	3.0	3.0	1.0	.626*
II3	2.5	3.0	1.0	.621**
II4	3.0	3.0	1.0	.596**
II5	3.0	3.0	1.0	.546**
II6	3.0	2.0[a]	1.0	.765**

Source: Author.

[a] Multiple modes exist. The smallest value is shown.

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

A Kruskal-Wallis H test was conducted, comparing the teachers' observations of individual interest amongst the learners in their classrooms across both school districts and educational phases. No statistically significant result was found across both the educational phases, $H(3) =$

1.255, $p > .05$, and the school districts, $H(5) = 5.661$, $p > .05$. This indicated that the participants across the four educational phases and across the six school districts did not differ significantly in their observation of individual interest from one another.

5.3 ENGAGEMENT

5.3.1 Behavioural Engagement

Behavioural engagement was measured on a Likert-type subscale comprising seven Likert-type items. Each subscale item was rated on a five-point scale with response anchors ranging from *'Strongly Agree'* (coded with the numerical value of 1) to *'Strongly Disagree'* (coded with the numerical value of 5). Of the seven items, two were negatively worded (BE4 and BE5). Each item was a statement (or a predicate) anchored on the subject: *Because of the use of technology in teaching and learning in my classroom....* Table 5.6 depicts the behavioural engagement Likert-type subscale, as described above.

Table 5.6: Behavioural engagement statements.

Label	**Statement** *Because of the use of technology in teaching and learning in my classroom...*
BE1	In class, my learners work as hard as they can
BE2	When my learners are in class, they actively participate in class activities
BE3	My learners pay attention in class
BE4 (R)	When my learners are in class, they just act like they are working
BE5 (R)	When my learners are in class, their minds often wander
BE6	If my learners have trouble understanding a problem, they go over it again until they understand it
BE7	My class attendance is good

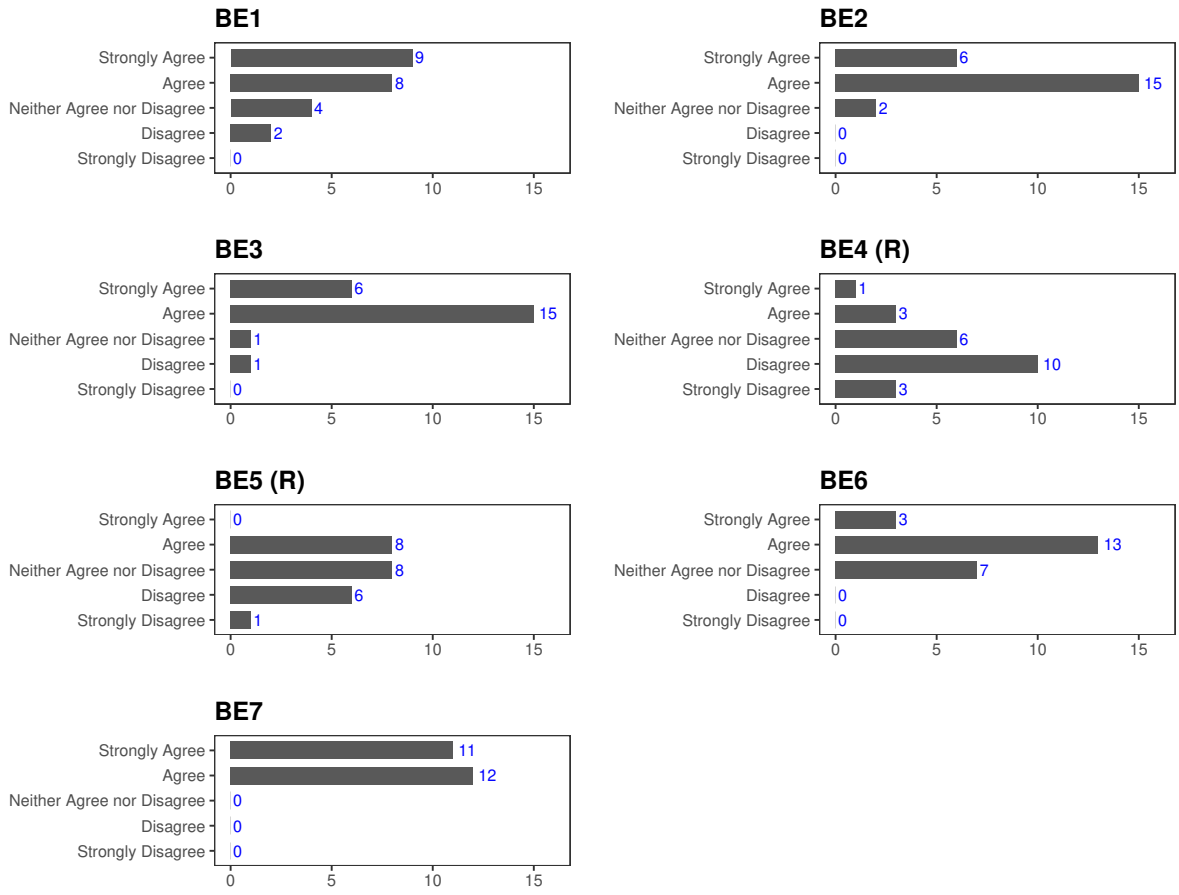
Source: Author.

The internal consistency of the behavioural engagement subscale, as measured by McDonald's coefficient omega (ω), was computed to be .566. Kendall's rank correlation coefficients (τ_b) were calculated to ascertain item-total correlations between each subscale item and the corresponding item total as an additional measure of internal consistency of the behavioural engagement subscale. All but one of these were found to be statistically significant (with $p < .05$ or $p < .01$), above the recommended value of .300, and ranged from .366 to .698, as reported in Table 5.7.

The one item that was statistically not significant corresponded to statement BE3 (*Because of the use of technology in teaching and learning in my classroom, my learners pay attention in class.*). Apart from being statistically not significant, it also had a τ_b value of .272, which was below the recommended value of .300. Removing this subscale item improved McDonald's omega coefficient (ω) to be .636. Furthermore, recalculating Kendall's rank correlation coefficients (τ_b) to ascertain item-total correlations between the remaining subscale items and the corresponding item total as an additional measure of internal consistency revealed that all the τ_b coefficients were statistically significant (with $p < .05$ or $p < .01$), above the recommended value of .300,

and ranged from .358 to .697.

The response frequencies for the behavioural engagement subscale are illustrated in Figure 5.3, which show how the respondents self-reported their observations of behavioural engagement elements in their classrooms. These are complemented by the descriptive statistics values of the behavioural engagement subscale, as reported in Table 5.7.



Source: Author.

Note: $n = 23$.

Figure 5.3: Response frequencies for behavioural engagement statements.

The first statement of the behavioural engagement subscale (BE1) asserted that as a direct result of the use of technology in teaching and learning mathematics in a classroom setting, *learners work as hard as they can [in class]*. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 1.0$), and IQR ($IQR = 2.0$) for this statement were computed. The mode indicated that the most frequent response for statement BE1 was *'Strongly Agree'*, coded with the numerical value of 1, with 9 of the 23 respondents (39%) aligning with this response anchor. The median, however, indicated that the responses centred more around the *'Agree'* response anchor than the most frequent response anchor. Interpreting the IQR value supported this result, as it indicated that the responses for statement BE1 were somewhat dispersed. A further 8 of the 23 respondents (35%) aligned with the *'Agree'* response anchor. This meant that from their

observations, the majority of the teachers were positive that using technology to teach and learn mathematics leads to learners working as hard as they can during their class activities. Only 2 of the 23 respondents (9%) disagreed with statement BE1, while the remaining respondents (17%) were tentative about statement BE1.

The second statement of the behavioural engagement subscale (BE2) asserted that *when learners are in class, they actively participate in class activities*, primarily because of the use of technology in teaching and learning mathematics during their classroom sessions. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement BE2 was *'Agree'*, coded with the numerical value of 2, with 15 of the 23 respondents (65%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 6 of the 23 respondents (26%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that using technology to teach and learn mathematics compels learners to actively participate in class activities. The remainder of the respondents (9%) were tentative about statement BE2.

The third statement of the behavioural engagement subscale (BE3) asserted that the use of technology in teaching and learning mathematics in a classroom setting ensures that *learners pay attention in class*. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement BE3 was again *'Agree'*, coded with the numerical value of 2, with 15 of the 23 respondents (65%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 6 of the 23 respondents (26%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, an overwhelming majority of the teachers agreed that using technology to teach and learn mathematics is instrumental in learners paying attention in class. Only 1 of the 23 respondents (4%) disagreed with statement BE3, while the remaining respondent (4%) was tentative about statement BE3.

The fourth statement of the behavioural engagement subscale (BE4) was negatively worded. It asserted that *when learners are in class, they just act like they are working* as a direct result of using technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 23$), the median ($Mdn = 4.0$), mode ($Mode = 4.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement BE4 was *'Disagree'*, coded with the numerical value of 4, with 10 of the 23 respondents (44%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Disagree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 3 of the 23 respondents (13%) aligned with the *'Strongly Disagree'* response anchor. This meant that from their observations, the majority of the teachers did not think that using technology to teach and learn mathematics makes learners to pretend that they are working on class activities. Only 3 of the 23 respondents (13%) agreed with statement BE4, while 1 of the 23 respondents (4%) strongly disagreed with

statement BE4. The remainder of the respondents (26%) were tentative about statement BE4.

The fifth statement of the behavioural engagement subscale (BE5) was also negatively worded. It asserted that *when learners are in class, their minds often wander* primarily because of the use of technology in teaching and learning mathematics. From the responses ($n = 23$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$ and 2.0), and IQR ($IQR = 2.0$) for this statement were computed. There were two modes (that is, the responses to statement BE5 were bimodal), indicating that the most frequent responses for statement BE5 were *'Neither Agree nor Disagree'* and *'Agree'*, coded with the numerical values of 3 and 2, respectively. Eight of the 23 respondents (35%) aligned with the *'Neither Agree nor Disagree'* response anchor, and another 8 of the 23 respondents (35%) aligned with the *'Agree'* response anchor. Notwithstanding, the median indicated that the responses centred more around the *'Neither Agree nor Disagree'* response anchor than the most frequent response anchor. Interpreting the IQR value supported this result, as it indicated that the responses for statement BE5 were somewhat dispersed across the response anchors. A further 6 of the 23 respondents (26%) aligned with the *'Disagree'* response anchor, with 1 of the 23 respondents (4%) aligning with the *'Strongly Disagree'* response anchor. This was an interesting result as it meant that from their observations, there was no outright consensus amongst the respondents on whether or not the use of technology in teaching and learning mathematics makes the learners' minds wonder when they are in class. There was an almost even three-way split between those teachers who self-reported to (i) agree with, (ii) disagree with, and (iii) remain tentative about the assertion of statement BE5.

Statement six of the behavioural engagement subscale (BE6) asserted that *if learners have trouble understanding a problem, they go over it again until they understand it*, and this is encouraged by the use of technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement BE6 was *'Agree'*, coded with the numerical value of 2, with 13 of the 23 respondents (57%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. Additionally, 3 of the 23 respondents (13%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers agreed that through the use of technology in teaching and learning mathematics in a classroom setting, learners become persistent in dealing with problems or activities that are difficult to understand. The remainder of the respondents (30%) were tentative about statement BE6.

The last statement of the behavioural engagement subscale (BE7) attributed good class attendance to the use of technology in teaching and learning mathematics during classroom sessions. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement BE7 was again *'Agree'*, coded with the numerical value of 2, with 12 of the 23 respondents (52%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. The remaining respondents (48%) aligned with the *'Strongly Agree'* response anchor. This was quite an encouraging result,

as it meant that from their observations, all the teachers were in consensus that the use of technology in teaching and learning mathematics during classroom sessions leads to good learner attendance.

Table 5.7: Statistical values for behavioural engagement statements.

Scale Item	Statistical Measures			
	Median	Mode	IQR	Item-Total Correlation (τ_b)
BE1	2.0	1.0	2.0	.406*
BE2	2.0	2.0	1.0	.698**
BE3	2.0	2.0	1.0	.272
BE4 (R)	4.0	4.0	1.0	.577**
BE5 (R)	3.0	3.0[a]	2.0	.527**
BE6	2.0	2.0	1.0	.366*
BE7	2.0	2.0	1.0	.409*

Source: Author.

[a] Multiple modes exist. The largest value is shown.
** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

A Kruskal-Wallis H test was conducted, comparing the teachers' observations of behavioural engagement amongst the learners in their classrooms across both school districts and educational phases. No statistically significant result was found across both the educational phases, $H(3) = 2.319, p > .05$, and the school districts, $H(5) = 4.438, p > .05$. This indicated that the participants across the four educational phases and across the six school districts did not differ significantly in their observation of behavioural engagement from one another.

5.3.2 Affective Engagement

Affective engagement was measured on a Likert-type subscale comprising five Likert-type items. Each subscale item was rated on a five-point scale with response anchors ranging from *'Strongly Agree'* (coded with the numerical value of 1) to *'Strongly Disagree'* (coded with the numerical value of 5). Of the five items, one was negatively worded (AE5). Each item was a statement (or a predicate) anchored on the subject: *Because of the use of technology in teaching and learning in my classroom....* Table 5.8 depicts the affective engagement Likert-type subscale, as described above.

The internal consistency of the affective engagement subscale, as measured by McDonald's coefficient omega (ω), was computed to be .757. Kendall's rank correlation coefficients (τ_b) were calculated to ascertain item-total correlations between each subscale item and the corresponding item total as an additional measure of internal consistency of the affective engagement subscale. These were all found to be statistically significant (with $p < .05$ or $p < .01$), above the recommended value of .300, and ranged from .456 to .706, as reported in Table 5.9.

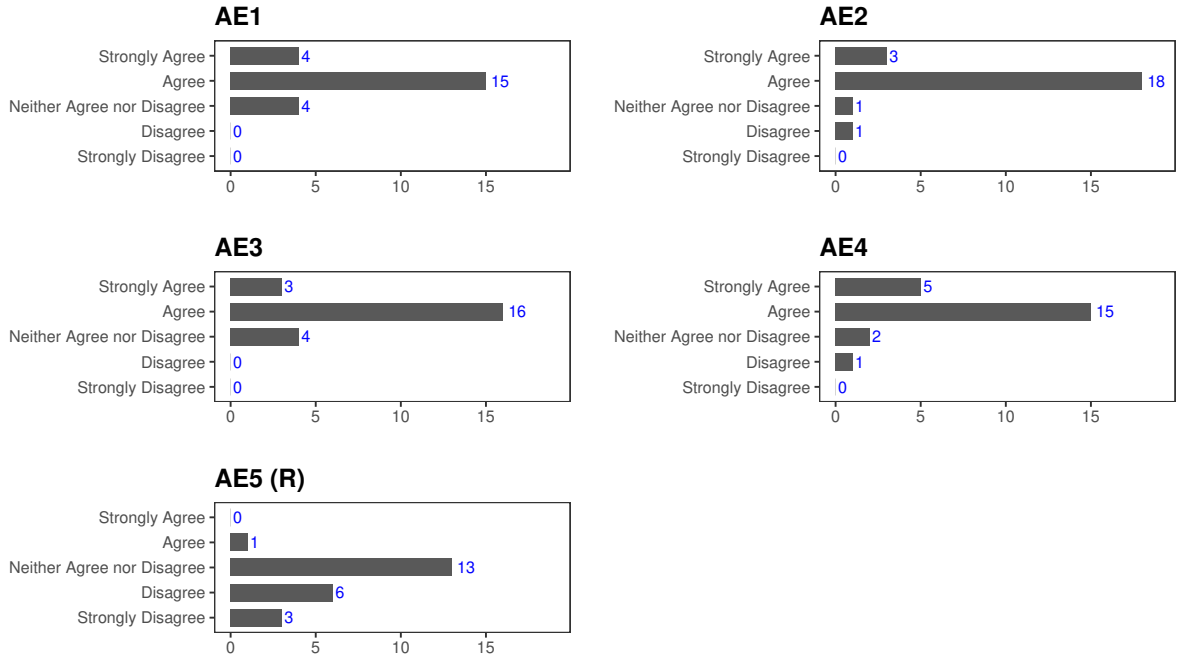
The response frequencies for the affective engagement subscale are illustrated in Figure 5.4, which show how the respondents self-reported their observations of affective engagement ele-

Table 5.8: Affective engagement statements

Label	Statement *Because of the use of technology in teaching and learning in my classroom...*
AE1	My learners are very interested in learning
AE2	My learners think what they are learning in class is interesting
AE3	My learners like what they are learning in class
AE4	My learners enjoy learning new things in class
AE5 (R)	My learners think learning is boring

Source: Author.

ments in their classrooms. These are complemented by the descriptive statistics values of the affective engagement subscale, as reported in Table 5.9.



Source: Author.
Note: n = 23.

Figure 5.4: Response frequencies for affective engagement statements.

The first statement of the affective engagement subscale (AE1) asserted that because of the use of technology in teaching and learning in a classroom setting, *learners are very interested in learning* mathematics. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement AE1 was *'Agree'*, coded with the numerical value of 2, with 15 of the 23 respondents (65%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A

further 4 of the 23 respondents (17%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that the use of technology to teach and learn in a classroom environment leads to learners who are very interested in learning mathematics. The remaining 4 of the 23 respondents (17%) were tentative about statement AE1.

The second statement of the affective engagement subscale (AE2) asserted that *learners think what they are learning in class is interesting* primarily because of the use of technology in teaching and learning mathematics in the classroom. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement AE2 was again *'Agree'*, coded with the numerical value of 2, with 18 of the 23 respondents (78%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 3 of the 23 respondents (13%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that learners think that what they are learning in class is interesting, and they attribute this to the use of technology in the teaching and learning processes. Only 1 of the 23 respondents (4%) disagreed with statement AE2, while the remaining respondent (4%) was tentative about statement AE2.

The third statement of the affective engagement subscale (AE3) asserted that *learners like what they are learning in class* because of the use of technology in teaching and learning mathematics. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement AE3 was again *'Agree'*, coded with the numerical value of 2, with 16 of the 23 respondents (70%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 3 of the 23 respondents (13%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that learners like what they are learning in class because of the use of technology in teaching and learning mathematics. The remaining 4 of the 23 respondents (17%) were tentative about statement AE3.

Statement four of the affective engagement subscale (AE4) asserted that *learners enjoy learning new things in class* as a result of the use of technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement AE4 was again *'Agree'*, coded with the numerical value of 2, with 15 of the 23 respondents (65%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 5 of the 23 respondents (22%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that using technology in the teaching and learning processes leads to learners enjoying learning new things in the classroom. Only 1 of the 23 respondents (4%) disagreed with statement AE4, while the

remainder of the respondents (9%) were tentative about statement AE4.

The final statement of the affective engagement subscale (AE5) was negatively worded. It asserted that making use of technology to teach and learn mathematics in a classroom setting makes *learners think [that] learning is boring*. From the responses ($n = 23$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement AE5 was *'Neither Agree nor Disagree'*, coded with the numerical value of 3, with 13 of the 23 respondents (57%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Neither Agree nor Disagree'* response anchor. This meant that from their observations, the majority of the teachers were tentative on whether or not learners think that learning is boring as a result of using technology to teach and learn mathematics in the classroom. Notwithstanding, 6 of the 23 respondents (26%) and 3 of the 23 respondents (13%) aligned with the *'Agree'* and *'Strongly Disagree'* response anchors, respectively. Only 1 of the 23 respondents (4%) agreed with statement AE5.

Table 5.9: Statistical values for affective engagement statements.

Scale Item	Statistical Measures			
	Median	Mode	IQR	Item-Total Correlation (τ_b)
AE1	2.0	2.0	0.0	.604**
AE2	2.0	2.0	0.0	.666**
AE3	2.0	2.0	0.0	.706**
AE4	2.0	2.0	0.0	.456*
AE5 (R)	3.0	3.0	1.0	.584**

Source: Author.

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

A Kruskal-Wallis H test was conducted, comparing the teachers' observations of affective engagement amongst the learners in their classrooms across both school districts and educational phases. No statistically significant result was found across both the educational phases, $H(3) = .533$, $p > .05$, and the school districts, $H(5) = 8.748$, $p > .05$. This indicated that the participants across the four educational phases and across the six school districts did not differ significantly in their observation of affective engagement from one another.

5.3.3 Cognitive Engagement

Cognitive engagement was measured on a Likert-type subscale comprising five Likert-type items. Each subscale item was rated on a five-point scale with response anchors ranging from *'Strongly Agree'* (coded with the numerical value of 1) to *'Strongly Disagree'* (coded with the numerical value of 5). Each item was a statement (or a predicate) anchored on the subject: *Because of the use of technology in teaching and learning in my classroom....* Table 5.10 depicts the cognitive engagement Likert-type subscale as described above.

Table 5.10: Cognitive engagement statements.

Label	Statement *Because of the use of technology in teaching and learning in my classroom...*
CE1	When my learners learn new information, they try to put the ideas in their own words
CE2	My learners make up their own examples to help them understand the important concepts they learn from my class
CE3	My learners persist on more challenging tasks
CE4	My learners demonstrate appropriate effort to task
CE5	My learners are self-motivated

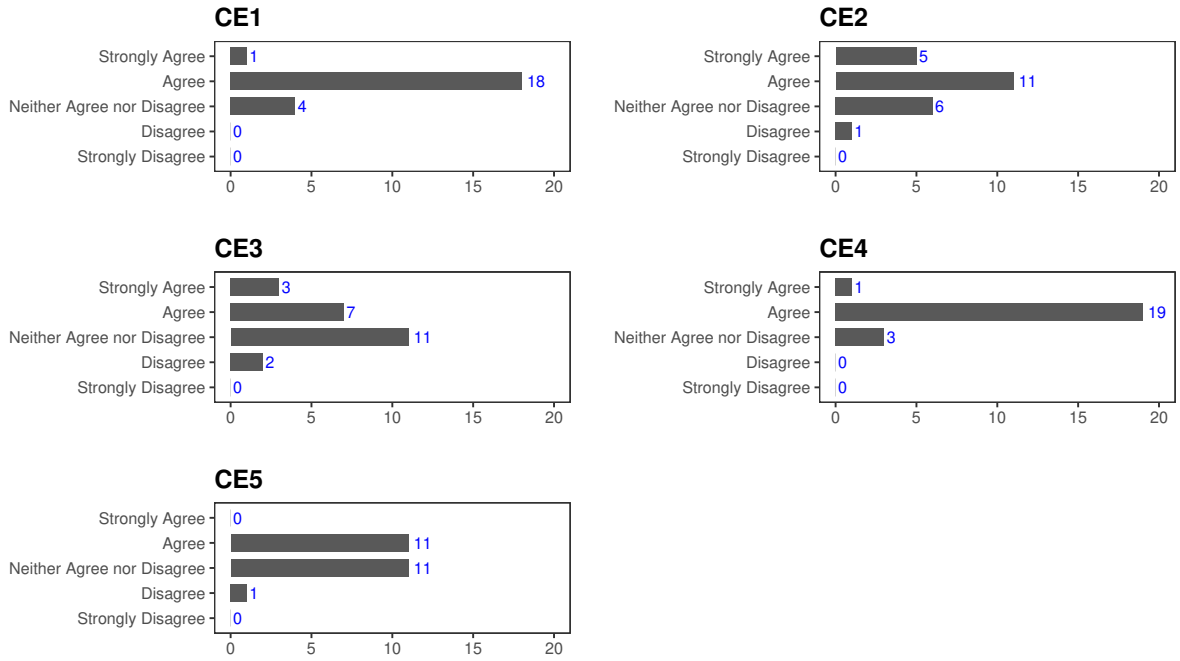
Source: Author.

The internal consistency of the cognitive engagement subscale, as measured by McDonald's coefficient omega (ω), was computed to be .633. Kendall's rank correlation coefficients (τ_b) were calculated to ascertain item-total correlations between each subscale item and the corresponding item total as an additional measure of internal consistency of the cognitive engagement subscale. These were all found to be statistically significant (with $p < .05$ or $p < .01$), above the recommended value of .300, and ranged from .387 to .723, as reported in Table 5.11.

The response frequencies for the cognitive engagement subscale are illustrated in Figure 5.5, which show how the respondents self-reported their observations of cognitive engagement elements in their classrooms. These are complemented by the descriptive statistics values of the cognitive engagement subscale, as reported in Table 5.11.

The first statement of the cognitive engagement subscale (CE1) asserted that as a result of using technology to teach and learn mathematics in a classroom setting, when *learners learn new information, they try to put the ideas in their own words*. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement CE1 was *'Agree'*, coded with the numerical value of 2, with 18 of the 23 respondents (78%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 1 of the 23 respondents (4%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that the use of technology to teach and learn in a classroom environment plays a crucial role in allowing learners to self-ideate based on new information that they learn. The remaining 4 of the 23 respondents (17%) were tentative about statement CE1.

The second statement of the cognitive engagement subscale (CE2) asserted that using technology to teach and learn mathematics allows *learners [to] make up their own examples to help them understand the important concepts they learn* during classroom sessions. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement CE2 was again *'Agree'*, coded with the numerical value of 2, with 11 of the 23 respondents (48%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further in-



Source: Author.

Note: $n = 23$.

Figure 5.5: Response frequencies for cognitive engagement statements.

dicated that these responses were tightly clustered. A further 5 of the 23 respondents (22%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers were positive that using technology to teach and learn mathematics in a classroom setting helps learners explore and understand important concepts through formulating their own examples. Only 1 of the 23 respondents (4%) disagreed with statement CE2, while the remainder of the respondents (26%) were tentative about statement CE2.

The third statement of the cognitive engagement subscale (CE3) asserted that *learners persist on more challenging tasks* primarily because of the use of technology in teaching and learning mathematics in a classroom setting. From the responses ($n = 23$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement CE3 was *'Neither Agree nor Disagree'*, coded with the numerical value of 3, with 11 of the 23 respondents (48%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Neither Agree nor Disagree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. Notwithstanding, 7 of the 23 respondents (30%) aligned with the *'Agree'* response anchor, and 3 of the 23 respondents (13%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, there was an almost even split between those teachers who self-reported that using technology to teach and learn mathematics challenges learners to persist on more challenging tasks, and those teachers who remained tentative about the same statement. The remaining 2 of the 23 respondents (9%) disagreed with statement CE3.

Statement four of the cognitive engagement subscale (CE4) asserted that because of the use of technology in the teaching and learning processes, *learners demonstrate appropriate effort to task* in their mathematics classrooms. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement CE4 was *'Agree'*, coded with the numerical value of 2, with 19 of the 23 respondents (83%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 1 of the 23 respondents (4%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that using technology to teach and learn mathematics in a classroom setting drives learners to demonstrate appropriate effort to task. The remainder of the respondents (13%) were tentative about statement CE4.

The final statement of the cognitive engagement subscale (CE5) asserted that using technology to teach and learn mathematics in a classroom setting leads to *learners [who] are self-motivated.* From the responses ($n = 23$), the median ($Mdn = 3.0$), mode ($Mode = 3.0$ and 2.0), and IQR ($IQR = 1.0$) for this statement were computed. There were two modes (that is, the responses to statement CE5 were bimodal), indicating that the most frequent responses for statement CE5 were both *'Neither Agree nor Disagree'* and *'Agree'*, coded with the numerical values of 3 and 2, respectively. Aligning with each of these two response anchors were 11 of the 23 respondents (48%). Notwithstanding, the median indicated that the responses centred more around the *'Neither Agree nor Disagree'* response anchor than the most frequent response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. This meant that from their observations, there was an even split between those teachers who self-reported that the use of technology in teaching and learning mathematics breeds learners who are self-motivated, and those teachers who remained tentative about the same statement. The remaining respondent (4%) was tentative about statement CE5.

Table 5.11: Statistical values for cognitive engagement statements.

Scale Item	Statistical Measures			
	Median	Mode	IQR	Item-Total Correlation (τ_b)
CE1	2.0	2.0	0.0	.403*
CE2	2.0	2.0	1.0	.492**
CE3	3.0	3.0	1.0	.723**
CE4	2.0	2.0	0.0	.387*
CE5	3.0	2.0[a]	1.0	.395*

Source: Author.

[a] Multiple modes exist. The smallest value is shown.
** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

A Kruskal-Wallis H test was conducted, comparing the teachers' observations of cognitive engagement amongst the learners in their classrooms across both school districts and educa-

tional phases. No statistically significant result was found across both the educational phases, $H(3) = 3.740, p > .05$, and the school districts, $H(5) = 1.520, p > .05$. This indicated that the participants across the four educational phases and across the six school districts did not differ significantly in their observation of cognitive engagement from one another.

5.3.4 Agentic Engagement

Agentic engagement was measured on a Likert-type subscale comprising five Likert-type items. Each subscale item was rated on a five-point scale with response anchors ranging from *'Strongly Agree'* (coded with the numerical value of 1) to *'Strongly Disagree'* (coded with the numerical value of 5). Each item was a statement (or a predicate) grounded on the instruction: *Answer the following with respect to what you have observed in your classroom.* Complementing the agentic engagement subscale was an additional Likert-type item whose purpose was to establish a deliberate link between the observations measured by the subscale and the use of technology in teaching and learning mathematics in a classroom environment. This additional item was also rated on a five-point scale with identical response anchors as the subscale items. Table 5.12 depicts the agentic engagement Likert-type subscale and the additional Likert-type item, as described above.

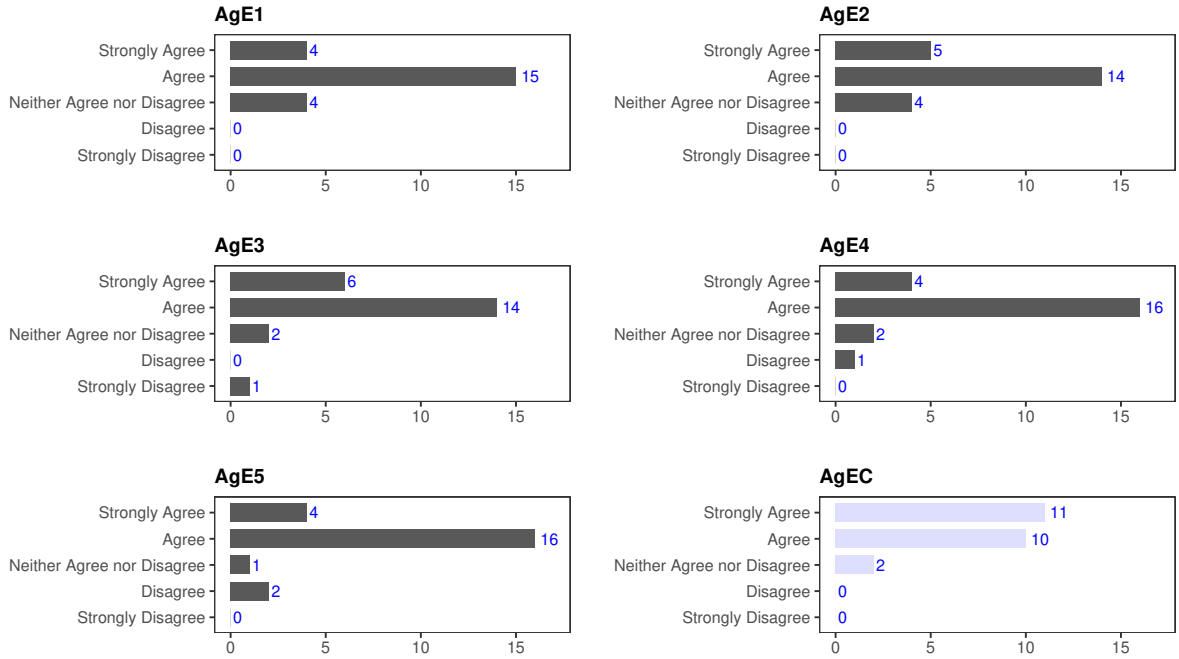
Table 5.12: Agentic engagement statements.

Label	Statement
	Answer the following with respect to what you have observed in your classroom.
AgE1	My learners let me know what they need and want
AgE2	During the lesson, my learners express their preferences and opinions
AgE3	When my learners need something in class, they ask me for it
AgE4	During the lesson, my learners ask questions to assist them to learn
AgE5	My learners let me know what they are interested in
	Answer the following based on your responses you have given above.
AgEC	The use of technology in teaching and learning mathematics in my classroom contributes to the observations I have noted above

Source: Author.

The internal consistency of the agentic engagement subscale, as measured by McDonald's coefficient omega (ω), was computed to be .818. Kendall's rank correlation coefficients (τ_b) were calculated to ascertain item-total correlations between each subscale item and the corresponding item total as an additional measure of internal consistency of the agentic engagement subscale. These were all found to be statistically significant (with $p < .01$), above the recommended value of .300, and ranged from .525 to .724, as reported in Table 5.13.

The response frequencies for the agentic engagement subscale and the additional complementary item are illustrated in Figure 5.6, which show how the respondents self-reported their observations of cognitive engagement elements in their classrooms. These are complemented by the descriptive statistics values of the agentic engagement subscale and the additional complementary item, as reported in Table 5.13.



Source: Author.
Note: n = 23.

Figure 5.6: Response frequencies for agentic engagement statements.

The first statement of the agentic engagement subscale (AgE1), *My learners let me know what they need and want*, sought to uncover the extent to which the learners were observed to be autonomous, and the degree with which teachers supported this autonomy during classroom discourse. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement AgE1 was *'Agree'*, coded with the numerical value of 2, with 15 of the 23 respondents (65%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 4 of the 23 respondents (17%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that during their class sessions, the learners express and communicate their needs and wants to the teacher, which also meant that the teachers themselves were regarded as autonomy supportive by the learners. The remaining respondents (17%) were tentative about statement AgE1.

The second statement of the agentic engagement subscale (AgE2), *During the lesson, my learners express their preferences and opinions*, sought to uncover the extent to which learners were observed to be agents of their preferences and opinions during classroom discourse. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement AgE2 was again *'Agree'*, coded with the numerical value of 2, with 14 of the 23 respondents (61%) aligning with this response anchor. The median corroborated this as it in-

dicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 5 of the 23 respondents (22%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers agreed that during their class sessions, learners are indeed able to express their preferences and opinions. The remaining respondents (17%) were tentative about statement AgE2.

The third statement of the agentic engagement subscale (AgE3), *When my learners need something in class, they ask me for it*, sought to uncover the extent to which learners were observed to take initiative in asking for what they need during classroom discourse. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 1.0$) for this statement were computed. The mode indicated that the most frequent response for statement AgE3 was again *'Agree'*, coded with the numerical value of 2, with 14 of the 23 respondents (61%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were tightly clustered. A further 6 of the 23 respondents (26%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the majority of the teachers agreed that learners do take the initiative of asking the teacher for anything they need during class sessions. Only 1 of the 23 respondents (4%) strongly disagreed with statement AgE3, while the remaining respondents (9%) were tentative about statement AgE3.

Statement four of the agentic engagement subscale (AgE4), *During the lesson, my learners ask questions to assist them to learn*, sought to uncover the extent to which learners were observed to take the initiative in asking crucial questions to assist them in their learning process. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement AgE4 was again *'Agree'*, coded with the numerical value of 2, with 16 of the 23 respondents (70%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. A further 4 of the 23 respondents (17%) aligned with the *'Strongly Agree'* response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that learners do take the initiative of asking crucial questions that assist them in the learning process during class sessions. Only 1 of the 23 respondents (4%) disagreed with statement AgE4, while the remaining respondents (9%) were tentative about statement AgE4.

The final statement of the agentic engagement subscale (AgE5), *My learners let me know what they are interested in*, sought to uncover the extent to which learners were observed to express their interests during classroom discourse. From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 2.0$), and IQR ($IQR = 0.0$) for this statement were computed. The mode indicated that the most frequent response for statement AgE5 was again *'Agree'*, coded with the numerical value of 2, with 16 of the 23 respondents (70%) aligning with this response anchor. The median corroborated this as it indicated that the responses centred around the *'Agree'* response anchor. Interpreting the IQR value further indicated that these responses were very tightly clustered. In addition, 4 of the 23 respondents (17%) aligned with the *'Strongly*

Agree' response anchor. This meant that from their observations, the overwhelming majority of the teachers agreed that learners freely express their interests during class sessions. Only 2 of the 23 respondents (9%) disagreed with statement AgE5, while the remaining respondent (4%) was tentative about statement AgE5.

The additional item (AgEC) sought to contextualise the responses to the agentic engagement subscale by asking respondents to rate the extent to which they agreed or disagreed with the statement: *The use of technology in teaching and learning mathematics in my classroom contributes to the observations I have noted above* (that is, the observations as responded to statements AgE1 through AgE5). From the responses ($n = 23$), the median ($Mdn = 2.0$), mode ($Mode = 1.0$), and IQR ($IQR = 0.0$) for this item were computed. The mode indicated that the most frequent response for item AgEC was *'Strongly Agree'*, coded with the numerical value of 1, with 11 of the 23 respondents (48%) aligning with this response anchor. The median, however, indicated that the responses centred more around the *'Agree'* response anchor than the most frequent response anchor, which had 10 of the 23 responses (44%) aligned to it. Interpreting the IQR value further indicated that these responses were very tightly clustered. This meant that there was overwhelming consensus by the teachers that the use of technology to teach and learn mathematics in their classrooms had a positive contribution to their self-reported observations of agentic engagement. Only 2 of the 23 respondents (9%) remained tentative about the assertion of item AgEC.

Table 5.13: Statistical values for agentic engagement statements.

Scale Item	Statistical Measures			
	Median	Mode	IQR	Item-Total Correlation (τ_b)
AgE1	2.0	2.0	0.0	.679**
AgE2	2.0	2.0	0.0	.695**
AgE3	2.0	2.0	1.0	.656**
AgE4	2.0	2.0	0.0	.525**
AgE5	2.0	2.0	0.0	.724**
AgEC	2.0	1.0	1.0	—

Source: Author.

** Correlation is significant at the .01 level (2-tailed).

A Kruskal-Wallis H test was conducted, comparing the teachers' observations of agentic engagement amongst the learners in their classrooms across both school districts and educational phases. No statistically significant result was found across both the educational phases, $H(3) = 3.618$, $p > .05$, and the school districts, $H(5) = 6.878$, $p > .05$. This indicated that the participants across the four educational phases and across the six school districts did not differ significantly in their observation of agentic engagement from one another.

5.4 INTEGRATED ANALYSIS

For each dimension, the composite median was calculated as the chosen measure of central tendency, and the IQR was computed as the preferred measure of variability. Bootstrap methods were employed to estimate the CIs for both the median and IQR values of each variable. The methodologies and techniques used for these calculations are detailed in Section 4.4.3. Table 5.14 provides a concise summary of these computed values, while Table E.20 offers a more comprehensive presentation.

Table 5.14: Coefficient omega (ω) estimates for internal consistency reliability (McDonald, 1999), median, and confidence interval for the median across scale dimensions for interest and engagement.

Subscale	Number of Items	Omega (ω)	Median	95% Confidence Interval	
				Lower	Upper
Interest					
Situational (SI)	6	.866	2.00	2.00	2.50
Individual (II)	6	.825	2.75	2.25	3.00
Engagement					
Behavioural (BE)	7	.566	2.00	2.00	2.00
Affective (AE)	5	.757	2.00	2.00	2.00
Cognitive (CE)	5	.633	2.00	2.00	2.00
Agentic (AgE)	5	.818	2.00	2.00	2.00

Source: Author.

The results for situational interest revealed a composite median of 2.00, with the 95% CI for the median calculated as $[2.00, 2.50]$ ($bias = .034$, $SE = .129$). In addition, the IQR for situational interest and its CI were computed ($IQR = 0.500$, $95\%\,CI\,[0.000, 1.500]$, $bias = .234$, $SE = .367$). These results suggest a general consensus amongst teachers regarding the positive influence of using ICTs in mathematics teaching and learning on learners' situational interest. The alignment of the composite median with the '*Agree*' response anchor, coupled with the tight clustering of responses around this median value, underscores this consensus.

For individual interest, the results showed a median of 2.75 ($95\%\,CI\,[2.25, 3.00]$, $bias = -.014$, $SE = .262$) and an IQR of 1.000 ($95\%\,CI\,[0.500, 1.125]$, $bias = -.108$, $SE = .209$). These results, with the median tilting towards the '*Neither Agree nor Disagree*' response anchor and the IQR indicating a tight clustering around this median, suggest a somewhat tentative position amongst teachers regarding their observations of individual interest markers in learners when using technology in mathematics education.

Turning to the engagement dimensions, the results presented a uniform picture at first glance. Across all four dimensions, the median was determined to be 2.00, with a consistent 95% CI of $[2.00, 2.00]$. Similarly, the IQR for each dimension was calculated as 0.000 ($95\%\,CI\,[0.000, 1.000]$). Despite these similarities, distinctions were evident in the bias and SE values for the

bootstrap CI calculations, as detailed in Table E.20. These variations indicate nuanced differences and slight biases in the dataset. This analysis suggests that teachers generally concurred on the influence of using ICTs to teach and learn mathematics across each engagement dimension, as evidenced by the median values aligning with the '*Agree*' response anchor, and the responses being consistently clustered around these median values for all four dimensions.

Kendall's rank correlation coefficients (τ_b) were calculated to ascertain any inter-scale relationship between dimensions. The results of these coefficient calculations are summarised in Table 5.15 and detailed in Table E.21. Overall, five statistically significant relationships were identified: four were moderately positive and one was weakly positive. These relationships existed both within the two interest dimensions, and between the interest dimensions and several engagement dimensions.

Table 5.15: Results of Kendall's rank correlation coefficient (τ_b) calculations between all the dimensions of the interest and engagement scales.

Variable	SI	II	BE	AE	CE	AgE
Situational Interest (SI)	–					
Individual Interest (II)	.418*	–				
Behavioural Engagement (BE)	.091	-.007	–			
Affective Engagement (AE)	.531**	.254	-.010	–		
Cognitive Engagement (CE)	.399*	.573**	.331	.229	–	
Agentic Engagement (AgE)	.483*	.067	-.131	.279	.053	–

Source: Author.
Note: $n = 22$.
** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

A moderate positive relationship was found between situational interest and individual interest, $\tau_b = .418$, 95% CI $[.098, .688]$, $p = .022$, indicating a statistically significant relationship between these two variables. This means that where aspects of situational interest were reported to have been observed, it was likely that aspects of individual interest would also be reported to have been observed. The reverse also holds true, meaning that where aspects of individual interest were reported to have been observed, it was likely that aspects of situational interest would also be reported to have been observed. In a similar manner: situational interest was statistically significantly related to affective engagement, $\tau_b = .531$, 95% CI $[.232, .763]$, $p = .006$; situational interest was statistically significantly related to cognitive engagement, $\tau_b = .399$, 95% CI $[.110, .673]$, $p = .041$; situational interest was statistically significantly related to agentic engagement, $\tau_b = .483$, 95% CI $[.089, .776]$, $p = .011$; and individual interest was statistically significantly related to cognitive engagement, $\tau_b = .573$, 95% CI $[.336, .721]$, $p = .003$.

It is interesting to note that the relationships between the engagement dimensions were all statistically not significant. There was a weak positive relationship between behavioural engagement and cognitive engagement ($\tau_b = .331$), while the relationships between behavioural engagement and affective engagement ($\tau_b = -.010$), and behavioural engagement and agenting engagement

($\tau_b = -.131$) were negative and zero to weak. The other relationships between the engagement dimensions were weak positive relationships, as noted in Tables 5.15 and E.21.

5.5 SUMMARY

This chapter presented the results of the quantitative phase of the study, which sought to examine teachers' perceptions of learner motivation within the context of ICT use in mathematics teaching and learning. The investigation focused on analysing the dimensions of interest (situational and individual) and engagement (behavioural, affective, cognitive, and agentic), based on the conceptualisation of motivation within this study.

The chapter began with an overview of the participant teachers, highlighting that of the 55 responses received, 23 were deemed valid for further analysis. This set the stage for addressing the quantitative research questions: RQ_{1a}, the primary question, delved into the interrelationships amongst motivation dimensions, as well as the relationship between these dimensions and the use of ICTs in teaching and learning mathematics in the classroom. RQ_{1b} and RQ_{1c} provided confirmatory analyses at the subscale level. For these two questions, the Kruskal-Wallis H test assessed variations across educational phases and school districts, finding no statistically significant differences. This indicated a uniform perception of motivation across the sample.

In demonstrating methodological rigour, the chapter elaborated on the validation process for subscale internal consistency, employing McDonald's coefficient omega, and Kendall's rank correlation coefficients to assess item-total correlations. This process confirmed internal consistency across the motivation dimensions, though it revealed an inconsistency within the behavioural engagement subscale. This particular result was noted for further in-depth examination in the qualitative phase of the research.

The chapter further explored subscale item analysis, presenting response frequencies, measures of central tendency (median, mode), and variability (IQR). It then proceeded to an integrated analysis that highlighted the interrelationships amongst the motivation dimensions (through Kendall's rank correlation coefficients), and the implied influence of ICT usage in mathematics teaching and learning on learner motivation. The adoption of the bootstrapping technique to estimate confidence intervals for various statistical measures added a layer of analytical rigour, providing a robust representation of the data.

The insights derived from the quantitative analysis detailed in this chapter were pivotal in refining the data generation instrument for the qualitative phase, marking a significant 'mixing' point of the quantitative and qualitative strands of this study's mixed methods design. Amongst these insights, the median score for individual interest ($Mdn = 2.75$, $95\% CI\,[2.25, 3.00]$, $bias = -.014$, $SE = .262$) specifically underscored the need for a more in-depth exploration of this dimension. This result, indicative of a tentative perception amongst participant teachers regarding their self-reported observations of learner individual interest, was one of several that warranted further qualitative investigation. This effort aimed to uncover the underlying factors at play, thereby contextualising the quantitative outcomes. Moreover, the quantitative results prompted a deeper investigation into the behavioural engagement dimension due to noted inconsistencies within its subscale. They also led to a more in-depth examination of the weak and statistically not significant correlations observed amongst certain motivation dimensions,

particularly within the engagement categories.

Indeed, while the results detailed in this chapter highlighted the positive influence of ICT use on learner motivation in mathematics education, they also served as a foundational springboard for the qualitative exploration into the complex dynamics of learner motivation that ensued. The next chapter presents findings from this qualitative phase, continuing the exploration of these intricate dynamics.

CHAPTER 6

QUALITATIVE FINDINGS

6.1 INTRODUCTION

6.1.1 Chapter Purpose

The preceding chapter detailed the results derived from the quantitative data analysis, addressing the primary purpose of this research study, as delineated by the quantitative research questions in Section 1.4.1. This quantitative exploration, while insightful, pointed to the need for a more in-depth examination of the relationship between ICT usage in mathematics education and learner motivation. This requirement formed the basis of the secondary purpose of this research study, which aimed to further explore learner motivation nuances and examine the varied discourse practices associated with the use of ICTs in teaching and learning mathematics.

Thus, this chapter focuses on presenting the findings from the qualitative data analysis, conducted as part of the study's second phase, as detailed in Section 4.3.2 and illustrated in Figure 4.1. This analysis adheres to the qualitative research questions introduced in Section 1.4.2, aiming to provide a comprehensive understanding of the complexities and subtleties that the quantitative data and their analysis alone could not fully capture.

6.1.2 Overview of Participants

For the qualitative phase of this study, eight individuals initially expressed interest during the quantitative phase. However, at the onset of this phase, only six were accessible and still willing to participate. Consequently, semi-structured interviews were arranged through a mix of online, telephonic, and in-person sessions. The subsequent subsections offer more details about these participants. It is important to note that the numerical order from one to six assigned to these participants does not reflect the sequence of the interviews, the transcription process, or the order of familiarisation and coding activities.

Semi-structured Interview Participant 1

Semi-structured interview participant 1 (SSI-P1), a mathematics teacher with six years of experience, had, at the time of the interview, taught nearly all high school grades except Grade 10. The interview was conducted in-person in SSI-P1's classroom, and recorded using two

handheld devices to ensure redundancy. The COVID-19 pandemic prompted SSI-P1's shift towards integrating technology tools in teaching. These tools included a laptop and projector for displaying educational content, a digital writing tablet for annotations, Microsoft OneNote for organisation and note-sharing, graphing tools like Desmos and GeoGebra for visualising mathematical concepts, YouTube for self-learning and sourcing educational content, and various Casio calculators for mathematical calculations in class.

Initially, SSI-P1 described integrating technology into teaching as challenging, likening it to being 'thrown into the deep end.' However, platforms like YouTube were instrumental in SSI-P1's self-learning journey, and in the discovery of supplementary teaching materials. SSI-P1 later became proficient enough to provide training to fellow teachers at their school on integrating technology into their teaching strategies.

Semi-structured Interview Participant 2

Semi-structured interview participant 2 (SSI-P2), who, at the time of the interview, had been teaching mathematics to Grades 9 and 10 for two years, shared insights into their and their learners' use of technology in both teaching and learning. The interview was conducted and recorded using Google Meet. SSI-P2 had always integrated technological tools into their teaching methodology, including a smart board for interactive content display and Microsoft PowerPoint as the primary tool for content presentation. In addition, they supplement their teaching with digital resources provided by the GDE and occasionally use YouTube to clarify and illustrate complex mathematical concepts.

During the interview, SSI-P2 conveyed that their training in the use of technology for mathematics education was mostly sufficient. In underlining their firm belief in a reciprocal approach to technology in the classroom, they emphasised the necessity of first equipping learners with the skills to effectively learn through technology. This, they argued, is crucial for enhancing the effectiveness of technology-based teaching methods.

Semi-structured Interview Participant 3

Semi-structured interview participant 3 (SSI-P3), who enthusiastically identifies as "full-blown on technology", has been teaching Grades 10 to 12 mathematics using technology since approximately 2011 or 2012. The COVID-19 pandemic in 2020 significantly intensified their use of technological tools in the classroom. SSI-P3 primarily uses a smart board and projector in the classroom, mainly for displaying content to learners. Other tools in their technological arsenal include a visualiser and a writing template, with the latter proving more functional for detailed demonstrations of mathematical problems. For lesson preparation, SSI-P3 prefers Microsoft Word for its versatility, in contrast to the more rigid PDF[1] files they used previously.

SSI-P3 revealed that they had not undergone any formal training in integrating technology into

[1]PDF, an acronym for Portable Document Format, describes a type of electronic document format developed in the early 1990s. It is commonly used for documents that appear the same across various devices and platforms. The primary characteristic of a PDF, which is both its advantage and limitation, is its non-editable nature, preserving the document's original layout and design. Additional information about this format is available at Adobe's official website: https://www.adobe.com/acrobat/about-adobe-pdf.html.

their teaching. Their proficiency is self-acquired, through reading manuals and hands-on experimentation. Despite the lack of formal training, SSI-P3 is optimistic about the role of technology in teaching and learning, particularly for mathematics. They consider it a crucial and forward-looking aspect of modern educational practices.

Semi-structured Interview Participant 4

Semi-structured interview participant 4 (SSI-P4) has predominantly used technology to teach mathematics to Grades 11 and 12 since the onset of the COVID-19 pandemic. The interview with SSI-P4 was conducted and recorded using Google Meet. The smart board stands out as SSI-P4's key technological tool in the classroom, utilised for a wide range of teaching activities. SSI-P4's enthusiastic discussion about the smart board highlighted its critical role in both their teaching methods and in supporting the learners' educational journeys. In addition to the smart board, SSI-P4 uses WhatsApp for communicating key syllabus information to learners and, though not a traditional technology tool, integrates gamification elements into their teaching approach.

SSI-P4 noted receiving basic training in operating the smart board, but the integration of this technology into their pedagogy was largely self-taught. While they teach mathematics across different grade levels, the emphasis on technology is more pronounced in senior grades. SSI-P4 attributes this to a belief that younger learners might be easily distracted by technology. Despite this, they recognise and appreciate the value that technology adds to the teaching and learning experience.

Semi-structured Interview Participant 5

Semi-structured interview participant 5 (SSI-P5), a mathematics teacher for Grades 11 and 12, distinguished themselves amongst other participants in the qualitative phase of this research study, with their enthusiastic shift towards creating and hosting their own educational content on digital platforms like YouTube. This approach underscores their fervent passion for education, and their commitment to youth development. The interview with SSI-P5 was conducted online and recorded using Microsoft Teams. Their preferred tools for teaching and content development are a tablet, selected for its versatility in both teaching and content creation—which was even utilised for the interview—and, at times, a smartphone.

Throughout the interview, SSI-P5 expressed strong opinions about the role of technology in teaching mathematics and other STEM[2] subjects. A recurring theme was the importance of collaboration amongst all parties involved in youth education, particularly at the high school level. SSI-P5 is resolute in their belief that technology is a crucial component in unlocking a more promising future for learners.

[2]STEM, the collective term for Science, Technology, Engineering, and Mathematics, represents four key academic disciplines considered foundational for equipping learners with the skills and perspectives necessary for success in contemporary and future careers. STEM education is about more than just conveying information; it is about fostering critical thinking, advancing scientific literacy, and developing innovative problem-solvers and pioneers for the next generation.

Semi-structured Interview Participant 6

Semi-structured interview participant 6 (SSI-P6) had been teaching mathematics, with the assistance of technology, to Grades 9 through 12 for about three years at the time of the interview. The interview was conducted telephonically and recorded using two audio-recording devices to ensure redundancy. For instructional purposes, SSI-P6 mainly uses a laptop and computer, along with a projector to display content clearly to the entire class. Additionally, learners in the classroom have access to laptops and computers. SSI-P6 also mentioned the availability of wireless internet, which both learners and teachers could access. In line with typical mathematics instruction, the use of calculators for solving equations was also mentioned.

During the interview, SSI-P6 expressed gratitude for having received sufficient training in integrating technology into mathematics teaching. They stressed the importance of teachers keeping up with technological developments, considering it crucial for addressing the diverse and dynamic needs of contemporary learners in today's classrooms.

6.1.3 Transcript Conventions and Nomenclature

Before presenting the findings from the qualitative phase of this research study, which is the primary focus of this chapter, it is essential to introduce the transcript conventions and nomenclature used. These will be encountered in the later sections of this chapter and are key for interpreting the findings.

The transcription process was a vital component of the qualitative phase of this research study. In order to preserve the integrity, and retain the essence and subtleties of the discussions, each interview was transcribed as soon as feasible after its completion. This approach was a vital part of the familiarisation phase in the reflexive thematic analysis method, as detailed in Section 4.4.3. The transcripts included all the relevant metadata, and were indexed with timestamps corresponding to the audio recordings, starting at 00:00:00. Below is an example illustrating how a standard transcript excerpt appears:

> **[00:01:30] SSI-P0:** This is a normal text transcription for semi-structured interview participant 0, recorded 1 minute and 30 seconds into the interview.
>
> **[00:01:50] RESEARCHER:** To which the researcher responded 20 seconds later.

In the interview transcripts, abandoned utterances were marked with an em dash (—). For direct quotations or assumed quotes, different colours, italics, and double quotation marks were employed. Specifically, a direct quote from a teacher was indicated in *"mulberry"* colour, while a quote purported to be from a learner, or learners as a collective, was shown in *"blue"*. These conventions are demonstrated in the following excerpt:

> **[00:02:10] SSI-P0:** When I teach mathematics, I usually—, [uhmmm], I sometimes say to my learners: *"Do you understand what we have just learned?"*
>
> **[00:02:15] RESEARCHER:** Hmmm... *(affirming)*

> **[00:02:15] SSI-P0:** They would then respond and say: *"Yes, we understand."*

Additional nuances from the interview sessions were captured in the transcripts as comprehensively as possible. This included filler words or phrases like [uhmmm] or Hmmm, which are indicative of pauses for thought, expressions of uncertainty, or verbal tics, as shown in the previous excerpt. Also highlighted in that excerpt, and the one to follow, are gestures such as affirmations or environmental details. These are conveyed in *(italics within round brackets)*. Subtle *≪ laughs ≫* or giggles are represented in red italics and enclosed in double angled brackets, all in an attempt to further enrich the transcription's portrayal of the interview atmosphere.

> **[00:03:05] SSI-P0:** *≪ laughs ≫* I know, right...? *(knock on the door)*

In instances where the emphasis in the text quoted from a transcript was not immediately evident, additional text [in a distinct colour and enclosed in square brackets] was inserted for clarity. Furthermore, any segments of the audio recording that were unclear have been clearly marked within the quoted text. These transcription techniques are demonstrated in the following excerpt:

> **[00:05:35] SSI-P0:** Yes, sometimes they [the learners] don't see the need to (. . . inaudible. . .) for their homework.

All interviews were conducted in English, although there were occasions when other languages were used by either the participant or the researcher. Instances of non-English language within the interview transcripts were indicated in italics (for example, *ngithi kubo* and *ukuthi*, as shown in the excerpt below). When non-English phrases appeared within quoted text, they were further highlighted using bold text (illustrated by the example ***Lalelani*** in the following excerpt):

> **[00:08:10] SSI-P0:** During the lessons, I would sometimes advise my learners, *ngithi kubo*: *"**Lalelani**, mathematics is your future!"*
>
> [...]
>
> **[00:10:15] SSI-P0:** ...and that is how I ensure *ukuthi* they really pay attention.

The previous excerpt also illustrates how large portions of text, when omitted from the quoted text from the transcript for various reasons, were indicated. This was achieved using an ellipsis (three consecutive dots) enclosed in square brackets. Within the same time index, the ellipsis served multiple purposes: (i) indicating a continuation from an interruption at a previous time index; (ii) signalling a lingering utterance; or (iii) denoting text that was omitted from the same time index.

The conventions and nomenclature outlined in this section are essential for a clear and accurate understanding of the interview data that will be presented later in this chapter. They provide the necessary framework and context needed to effectively interpret the qualitative data.

6.1.4 Chapter Outline and Organisation

The remainder of this chapter provides a detailed interpretive analysis of the themes derived from the reflexive thematic analysis. This represents a part of the fulfilment of the method's final phase, as detailed in Chapter 4. A total of 21 themes, including one with three subthemes, are presented. These themes were generated, developed, and refined through the third, fourth, and fifth phases of the reflexive thematic analysis method. The thematic findings are organised into five distinct sections, from 6.2 through 6.6.

According to Braun and Clarke (2021b), patterned meaning in reflexive thematic analysis can be reported at three distinct levels: (i) overarching themes; (ii) themes; and (iii) subthemes. However, this study's qualitative phase reports findings at only the second and third levels—themes and subthemes. Therefore, the organisation of these themes and subthemes into five sections is not indicative of overarching themes (the first level), but rather a logical grouping of related themes for clarity and coherence.

Section 6.7 offers an initial, concise contextualisation of the thematic findings, specifically focusing on their relation to, or answers to, the research questions posed in this qualitative phase of the study. This section, coupled with the summary provided in Section 6.8, lays the groundwork for a more comprehensive discussion and interpretation that follows in the subsequent chapter.

6.2 The Tapestry of Effective Learning: Exploring Motivation, Engagement, and Interest

6.2.1 Motivational Dynamics in Learning: The Spectrum of Learner Motivation

The theme *Motivational Dynamics in Learning: The Spectrum of Learner Motivation* refers to the varied ways learners exhibit their drive, interest, and proactivity (or lack thereof) within an educational context. This theme encapsulates a range, from learners who actively seek knowledge, demonstrate curiosity, persist in challenges, and show a strong sense of agency, to those who display more passive behaviours, expecting guidance without much initiative or showing signs of disinterest. It underscores the idea that motivation is not a fixed trait, but manifests on a continuum, influenced by various internal and external factors. This spectrum highlights the nuanced differences in how learners approach, interact with, and respond to the learning process.

The behaviours indicative of a highly motivated learner are situated at one end of the motivation spectrum. These behaviours are rooted in agency, exemplified by learners who not only actively participate in classroom discussions, but also consistently go above and beyond in their learning endeavours. Their actions range from seeking clarity during lessons to self-sourcing additional study materials. They not only actively engage with the teacher, but also collaborate with their peers. The motivation of these learners is not just determined by their grades or comprehension levels, but by their proactivity and commitment to the learning process. SSI-P2 encapsulates this sentiment, drawing from observations in the classroom:

> **[00:11:17] SSI-P2:** I'd say a learner who's interactive, despite their marks or their level of understanding is motivated. A learner who inquires the teacher, with the teacher to check their work while they're in class. A learner who goes an extra mile to download question papers for themselves, then practice, and then ask the teacher to assist. That would be a motivated learner for me.

Building on the characteristics of highly motivated learners, SSI-P1 introduces the elements of focus and attention as pivotal markers. For some learners, motivation is evident in their keen attention to the teacher, absorbing every word. Yet, for others, it materialises as meticulous note-taking, capturing every detail of the discourse. This diversity underscores the varied manifestations of motivation in a classroom setting. As SSI-P1 comments:

> **[00:16:56] SSI-P1:** Those ones would be looking at me and listening to what I'm saying. But obviously each learner is different. So some wanna write everything that you're saying.

Expanding the conversation about what characterises a motivated learner, SSI-P6 spotlights the significance of curiosity and inquisitiveness in learners. Such traits not only bolster resilience when faced with challenging tasks, but also propel learners to seek alternative approaches and collaborate with peers for solutions. Instead of passively waiting for answers, these motivated learners take the initiative to actively explore different avenues to enhance understanding. SSI-P6 portrays this scenario in the following excerpt:

> **[00:05:54] SSI-P6:** [Uhmm] Okay, being motivated—, okay, motivation means that you are always curious...
>
> **[00:06:03] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:06:04] SSI-P6:** And, [uhmm], you—, you try to understand even if you can't. And if—, if you don't understand a certain ma—, [uhmm], a certain math problem that you're doing in class, you—, you come up with ways to understand it, you know. You do—, you—, you just don't sit down and, you know, just wait for the teacher to show you, you know...
>
> **[00:06:26] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:06:27] SSI-P6:** ...and that's what I've been seeing, [uhmm], from my students. [Uhmm] They ask for help, they collaborate with other peers if they don't understand something. So that shows that they're motivated.

Highlighting another aspect of learner motivation, SSI-P3 emphasises the fundamental role of active listening in the learning process. Motivated learners, in SSI-P3's perspective, not only engage with the content, but also actively listen with the intent to genuinely understand. This proactive approach extends to their eagerness in undertaking and completing tasks assigned to them. SSI-P3 frames it in the following manner:

> **[00:10:28] SSI-P3:** [Errrhm] A motivated learner in my classroom is basically the ones that listen to basically understand and are keen to then carry out their own allocated piece of work...

Delineating the subtleties of motivation in the classroom, SSI-P4 places a strong emphasis on the power of attention as a primary indicator of a motivated learner. According to this perspective, heightened attention operates as a foundational element, paving the way for multiple outcomes, including the ability to actively listen, remain alert, immerse oneself in discussions, and initiate interactions. Furthermore, it underscores the importance of non-verbal cues as teachers, in their role akin to storytellers, constantly assess learners' reactions to gauge comprehension and engagement levels. The nuance of understanding these cues, as described by SSI-P4, goes beyond just recognising motivation; it offers teachers the dynamism to adapt their teaching approach accordingly. This detailed understanding is articulated in the excerpt below:

> **[00:10:56] SSI-P4:** Number one would be attention, because as a teacher, that's the first thing that you look for. Are they listening to what you're saying? Are they paying attention? And also, are they engaging...
>
> **[00:11:05] RESEARCHER:** Hmmm...
>
> **[00:11:05] SSI-P4:** ...with regards to asking questions? Are they looking? Are they watching? When you ask certain questions, are they thinking?
>
> **[00:11:12] RESEARCHER:** Hmmm...
>
> **[00:11:12] SSI-P4:** Are they confused? Because remember, as a teacher, you need to be a storyteller, right? When I ask a question, I really need to see, or really predict your facial reaction.
>
> **[00:11:19] RESEARCHER:** Hmmm...
>
> **[00:11:19] SSI-P4:** Are they surprised or even nod and say: *"Yes, we understand."*? So you look for those tell-tale signs as well. And also how they relate to other learners as well.

Exploring the ripple effects of motivation in learners, both SSI-P2 and SSI-P3 draw connections between motivation and other observable behaviours. SSI-P2 posits that a clear manifestation of motivation is the interest displayed by learners:

> **[00:16:44] SSI-P2:** ...if you're motivated, then you'll be more interested...

Complementing this view, SSI-P3 contends that a motivated learner naturally amplifies their engagement level:

> **[00:21:06] SSI-P3:** ...Because once, [errrhm], a learner is motivated, then they seem to engage more.

These observations by SSI-P2 and SSI-P3 are important and form the basis of understanding motivational dynamics in learning, and are explored in greater detail later in this section.

At the opposing end of the motivation spectrum are learners who are notably distinguished by a noticeable lack of agency. Their passive approach to learning is manifested in various ways: an unwillingness to take the lead, an expectation of spoon-feeding, a general aloofness from

class activities, and at times, exhibiting total disengagement from the learning process. SSI-P3 articulates this perspective with the following observation:

> **[00:10:28] SSI-P3:** ...Because the—, the ones without motivation would sit there and expect things to be done. They're not participating or in it. But the motivated ones are the ones that want to also carry out what's happening.

Even though this end of the motivation spectrum does not feature prominently in the dataset, its significance in understanding motivational dynamics cannot be understated. For teachers, identifying learners displaying these unmotivated behaviours is essential, as it enables them to step in and offer necessary support.

In summing up this theme, recognising that motivation is not a mere binary, but a vibrant spectrum, reinforces the idea that every learner has a unique motivational journey. From learners who radiate enthusiasm, initiative, and curiosity to those who may seem passive or disengaged, understanding these differences is paramount. This theme has illuminated not just the markers of motivation, but also the profound implications of such dynamics in the classroom.

For teachers, understanding this spectrum is not just beneficial—it is imperative. It empowers them to cater to each learner individually, ensuring no one is left behind. The journey of understanding learner motivation is one that requires both patience and adaptability. Ultimately, the goal is to harness these insights to foster a conducive learning environment where every learner, regardless of where they stand on the motivation spectrum, feels valued, understood, and inspired. This will serve to ignite the spark of learning in every learner, fostering a lifelong passion for knowledge and growth.

6.2.2 Igniting the Learning Flame: The Energising Role of Motivation in Education

The *Igniting the Learning Flame: The Energising Role of Motivation in Education* theme builds on the previous theme, and sheds light on the catalytic power of motivation within the educational journey. At its essence, this theme emphasises motivation as a force that stirs excitement, keenness, and a profound hunger for knowledge within learners. It is the spark that makes learners resonate with the subject matter, drawing them into a state of genuine interest and eagerness. Beyond merely capturing attention, effective motivation provides a stimulus—a drive that pushes learners to engage deeply and proactively with educational content. When this flame is kindled effectively, it manifests in learners who are not only academically inclined, but who also embody a spirited passion for discovery and understanding. In this light, motivation does not merely play a role—it sets the stage, turning the learning environment into a dynamic space of curiosity, challenge, and growth.

Reflecting on the essential elements of motivation, teachers recognise that it fundamentally stems from sparking excitement in learners. Such excitement, whether related to attending class or delving into the subject matter, lays a vital foundation by fostering keenness and eagerness amongst learners. This extends beyond merely creating a vibrant and engaging classroom environment; it permeates more deeply, potentially influencing learners' attention, retention, and educational outcomes. SSI-P1 strengthens this sentiment, underscoring the significance of ensuring learners are both excited and keen in the subject:

> **[00:16:19] SSI-P1:** I think it means getting the learners excited and keen in your—, your subject.
>
> **[00:16:23] RESEARCHER:** Right...
>
> **[00:16:24] SSI-P1:** And having them interested in what you are teaching...

SSI-P4 amplifies this perspective, underscoring that motivation fundamentally involves offering a stimulus to learners, seising their attention, and sparking excitement:

> **[00:10:32] SSI-P4:** [Uhmm] I think it's kind of like stimulus, how you generate interest in the—, in the learners, and how you get them excited about something.
>
> **[00:10:42] RESEARCHER:** Yeah.
>
> **[00:10:42] SSI-P4:** Yeah. About the lesson, about what you're going to teach, yeah. And grabbing their attention.

From a learner's perspective, motivation encompasses a clear and determined desire to learn, as articulated by SSI-P6. This viewpoint underscores motivation as not merely an external force, but an intrinsic will and hunger for knowledge and understanding:

> **[00:05:54] SSI-P6:** [Uhmm] Okay, being motivated—, okay, motivation means that you are ... willing to learn and you want to learn.

Building upon the concept of intrinsic will and hunger to learn, SSI-P1 sheds light on how learners, especially those with a strong academic bent, often display signs of being motivated through their behaviour and active involvement in the classroom. SSI-P1 draws attention to this notable dynamic by contrasting the expressions of academically inclined learners with those less academically oriented:

> **[00:27:29] SSI-P1:** You've got kids that are not very academically inclined, [uhmm], but we also got our—, our top kids who are very good in every class, you know...
>
> **[00:27:37] RESEARCHER:** Yes...
>
> **[00:27:37] SSI-P1:** ...and that then does obviously relay in—, in the way that they present themselves. [Uhmm] They are very motivated, they are very engaged, they are very, [uhmm], helpful, answer questions, etc., ask questions, etc., so...

This perspective underscores that there is a two-way relationship between a learner's motivation and their active, constructive participation in the classroom, spotlighting visible signs that often mark learners who are both academically inclined and deeply motivated. Furthermore, the distinction SSI-P1 makes highlights how these elements come together to create a supportive and interactive learning environment. Such behaviours do not only enhance their personal learning journey, but might also uplift the collective learning environment, showcasing a proactive, engaged, and mutually supportive classroom dynamic. Thus, motivation goes beyond internal factors, extending into observable behaviours that, in turn, may shape the overall educational

atmosphere of a classroom.

In wrapping up this theme, the vital essence of motivation in the educational journey has been spotlighted, revealing its multifaceted role in not only sparking, but sustaining the learning flame. The insights from teachers underscore that motivation is not solely about engendering initial interest, but is also intricately linked to learners' active engagement and the manifestation of an inherent desire to learn. Whether internally driven or externally stimulated, motivation acts as a pivotal force, subtly shaping learner behaviours and the overarching classroom dynamic, thus, entwining the individual and collective learning experiences.

6.2.3 Manifestations of Active Learning: Dimensions and Impact of Learner Engagement

The *Manifestations of Active Learning: Dimensions and Impact of Learner Engagement* theme delves into the multifaceted nature of how learners immerse themselves in the learning process. This theme captures the continuum of engagement, ranging from foundational attitudes such as willingness and focus, to overt classroom behaviours like participation, inquiry, and collaboration. At its core, engagement is not merely passive absorption; it is an active pursuit of understanding, marked by questions, clarifications, and palpable enthusiasm. The theme also underscores the ripple effect of individual engagement on the collective classroom environment, highlighting the shared benefits of an engaged learner body. Such manifestations, both subtle and explicit, are vital indicators of learners' investment in their learning journey and their proactive roles within the educational ecosystem.

Building upon insights from the previous theme, which highlighted the diversity in motivational markers amongst learners, it is evident that a similar complexity characterises learner engagement in classroom activities. For teachers, key signs of true engagement extend beyond a simple desire to learn, encompassing deep immersion in academic tasks and a collaborative spirit in the classroom. This perspective finds resonance in SSI-P6's observations:

> **[00:07:56] SSI-P6:** [Uhmm] Basically showing that you want to learn, the willingness to learn, collaboration, ... And always focusing...

Furthering the discussion, SSI-P3 identifies additional attitudes and dispositions indicative of an engaged learner, beyond mere participation or attentiveness. Central to this is the notion of learners assuming responsibility for their educational journey, and exhibiting a proactive response to the learning environment's stimuli. SSI-P3 elaborates on this by defining engagement as not just a passive reception of information, but an active response that reflects individual initiative:

> **[00:14:25] SSI-P3:** [Errrhm] A learner that I would call engaged, or if we say engagement, it's a learner that would respond to what they are hearing and learning. And then they will also have their—, take their own part to it...

This insight underscores the multifaceted nature of engagement, where personal investment in the learning process is as crucial as the ability to effectively respond to instructional stimuli.

Diving deeper into the characteristics of engaged learners, teachers frequently cite curiosity and enthusiasm as vital signs of a truly engaged mind. These are learners who are not just present in the classroom, but are actively absorbing information, questioning, and connecting with the material on a deeper level. This proactive approach to learning—marked by a constant search for more understanding and not just passive reception—is what teachers look for as a true measure of engagement. SSI-P4 articulates this observation succinctly, noting:

> **[00:13:02] SSI-P4:** They need to be inquisitive, enthusiastic, and they ask questions, a lot of questions.

This sentiment is echoed strongly by SSI-P6, who associates the learners' inquisitiveness directly with their level of engagement:

> **[00:07:56] SSI-P6:** ... [Uhmm] So most—, most of my students are very inquisitive and I'm—, I'm very happy about that.
>
> **[00:08:28] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:08:28] SSI-P6:** So that's how I know they are engaged in class.

These reflections suggest that for teachers, the ideal engaged learner is one who takes an active role in their learning journey. They are not just on the receiving end, but are pushing the boundaries of their understanding by asking questions and seeking more, a behaviour that not only enriches their own learning experience, but also creates a dynamic and interactive teaching and learning environment.

Ultimately, at the heart of classroom engagement lies the active participation of learners in the learning process. It is the difference between sitting in class and truly being present in the learning moment, and involves contributing to classroom discussions, interacting with peers, and immersing oneself in the tasks at hand. This concept of engagement as an active, participatory process is clearly and simply expressed by SSI-P4, noting:

> **[00:12:50] SSI-P4:** ...Engagement in class means taking part, participating in something.

This perspective reinforces the idea that engagement is not a passive experience, but a dynamic one, requiring learners' active and conscious effort to involve themselves in their educational journey. Expanding on this, SSI-P2 underscores the significance of clear communication between learners and teachers, particularly the importance of learners articulating both their comprehension and areas of confusion. This form of active engagement signifies not just the presence in class, but a deeper mental and emotional involvement in the learning material. In illustrating this point, SSI-P2 notes:

> **[00:12:33] SSI-P2:** A learner who is able to show what they understand, and then ask what they do not understand. I'm not sure if you understand. Like, if you are a learner, you're able to say: *"Ma'am, I understand this and this; however, I do not understand this part. Can you please explain this part?"* That would be an engaged learner, because they are grasping something out of the lesson, despite having things they still do not understand.

In the same vein, SSI-P3 emphasises the role of curiosity and initiative in solidifying understanding, suggesting that questions are not merely a tool for clarification, but also a means to confirm comprehension:

> **[00:14:25] SSI-P3:** ...Maybe if they don't understand, actually ask a question, or if they understand to demonstrate that (...inaudible...) the work the same way that is being demonstrated.

SSI-P2's insights, complemented by the sentiments of SSI-P3, draw attention to a critical facet of engaged learning: the learner's agency in acknowledging both their comprehension and areas of uncertainty. This active engagement goes beyond passive absorption of information; it is about learners taking charge, recognising their understanding, and seeking clarity where there are gaps. It reflects a form of agency where learners are co-navigators in their educational journey, advocating for their learning needs. This celebrates the idea that the classroom is not just a space for teaching, but for mutual discovery and growth.

Following the thread of learner agency and its importance in the educational journey, SSI-P4 adds another layer to this concept. In the ensuing excerpt, they point out that when learners voice their uncertainties or confusions, or when they affirm their understanding, these are not isolated actions. Rather, they often reflect questions that go unasked amongst their peers. SSI-P4's observation, grounded in their own anecdotal statistics, suggests that for every question raised, there are several other learners with the same question unasked. This implies that one learner's courage to seek clarification can benefit many, serving as a catalyst for the class's collective enlightenment. In this light, the engaged learner emerges not merely as a beneficiary of knowledge, but as a pivotal contributor within a larger network of shared understanding. This dynamic underscores the vital role of individual agency in creating a more interconnected learning environment, emphasising that classrooms are communities of shared knowledge. Here, each learner's engagement acts not just for personal understanding, but as a linchpin for the group's overall learning experience.

> **[00:13:08] SSI-P4:** Whether they're understanding or they're confused. So long as they're asking questions, then not only does it drive their own interest and their knowledge, but also all the others. Because remember that the statistics that says for every one learner that raises their hands, there's eight other learners that don't understand the very same question that the person's asked.
>
> **[00:13:24] RESEARCHER:** Hmmm...
>
> **[00:13:25] SSI-P4:** So it helps the whole class as well.

In the classroom, however, not all learners progress at the same pace; there are moments when individual learners or even the whole class might fall behind. Teachers face the challenge of

recognising these instances and, more importantly, have the responsibility of devising methods to re-engage these learners and help them catch up. SSI-P1 shares a personal tactic used when encountering such situations, emphasising a collective approach to learning:

> **[00:17:56] SSI-P1:** ...I pick on—, on the learners, you know, and if someone can't answer, then I take it as the whole class can't answer, and go back to the beginning and start again.

This theme has delved into the intricacies and multidimensional aspects of learner engagement, all through the lens of teachers' experiences. It underscores the role of learner engagement, not merely as a metric, but as an essential catalyst in the educational journey. From the unique characteristics of individual learners' engagement to the collective synergy within the classroom, each dimension contributes significantly to a vibrant learning ecosystem. These manifestations—whether they are questions asked, a demonstrated hunger for knowledge, inquisitiveness, or the courage to acknowledge one's own learning gaps—all highlight the profound impact of engagement on both personal and communal learning experiences. Here, learner agency emerges as a golden thread, intertwining these complexities. It enhances the tapestry of education while harnessing deeper levels of learner curiosity, signalling a dynamic, responsive, and deeply interconnected educational landscape.

6.2.4 The Nexus of Curiosity: How Genuine Interest Influences Learning Dynamics

The theme *The Nexus of Curiosity: How Genuine Interest Influences Learning Dynamics* explores the pivotal role of genuine curiosity and interest in shaping a learner's journey within the educational landscape. At its foundation, this theme underscores the intrinsic desire to learn, absorb, and remain attentive—a kind of magnetic pull that gravitates learners towards new information and understanding. Moving beyond just passive intrigue, this interest fuels proactive behaviours: from engagement and questioning to the drive for inter-topic connections and a forward-looking anticipation of future lessons. Yet, this curiosity is not confined within the walls of a classroom. It seeks applications, bridging the chasm between theoretical knowledge and the real world. Above all, this theme champions the idea that genuine interest is not just a passive state, but a powerful motivator. It propels learners to persist, integrate, and actively immerse themselves, reshaping the dynamics of both individual learning experiences and collective classroom atmospheres.

Teachers identify interest as the foundation upon which the desire to learn is built. Similar to engagement, it is a multifaceted concept that extends beyond the passive participation of learners; it involves both possessing and demonstrating an authentic desire to learn, assimilating the information provided, while sustaining focus throughout the educational activities. SSI-P4 elaborates on this, specifically underscoring a link between interest and engagement, with the latter serving as a central element in the previous theme:

> **[00:14:18] SSI-P4:** [Uhmm] Interest means, [uhmm], to absorb something...
>
> **[00:14:21] RESEARCHER:** Hmmm...
>
> **[00:14:21] SSI-P4:** ...[uhmm], to want to learn. It's related to engage, but it has to do with

> attention and learning.

In SSI-P2's view, the hallmark of a learner's interest within the classroom environment is interactivity. They assert:

> **[00:13:51] SSI-P2:** ...I think a learner that's interactive in class shows interest.

SSI-P2 further emphasises that interest is not a static element, but rather a catalyst, propelling learners towards active engagement. The progression is clear: once a learner finds something intriguing, their next instinctive move is to engage with it. As SSI-P2 puts it:

> **[00:16:44] SSI-P2:** ...And then if you're interested, you will for sure engage.

Expanding on this narrative, SSI-P3 points out an additional layer, emphasising the domino effect that a spark of interest can have on learners. This initial spark of curiosity, as SSI-P3 notes, acts as a gateway, activating a deep-seated drive to seek additional knowledge and discover more. SSI-P3 expresses it this way:

> **[00:15:54] SSI-P3:** [Errrhm] Interest I think, it's—, it's the—, the element when you have your learners that actually, [errrhm], want to know what's more. Or—, or what—, what else they can learn from what would be happening...

SSI-P4 further substantiates this perspective by discussing how learners begin to create their own internal puzzles, actively connecting various topics from different lessons and contemplating their implications for future lessons. This process indicates more than mere curiosity; it signifies an advanced level of cognitive assimilation and genuine curiosity. SSI-P4 details this, noting:

> **[00:14:36] SSI-P4:** When they ask questions, but not only questions based on what you're teaching, but how different topics relate to one another.
>
> **[00:14:43] RESEARCHER:** Hmmm...
>
> **[00:14:44] SSI-P4:** And also reiterating certain things they might've learned weeks back to say: *"Didn't we mean this when we meant that?"* It means that they're trying to make a puzzle, right? And it shows that way broader than what you're talking about. And then also asking about the lessons that are to come.
>
> **[00:15:00] RESEARCHER:** Hmmm...
>
> **[00:15:00] SSI-P4:** That okay, they're planning, they're interested and they want to prepare...

In SSI-P6's view, the expressions of curiosity and the desire to grasp concepts more fully often come through in simple, everyday interactions. For instance, when a learner seeks clarification or discusses alternative approaches to their homework, it signals more than just a plea for help. It is a clear indicator of their deep-rooted interest and a proactive attitude towards their learning

journey. These moments, though seemingly small, signify a deeper quest and an internal drive to not just participate, but to truly understand. This is captured in the following excerpt:

> **[00:09:43] SSI-P6:** So if you come to me and tell me that, [uhmm], you're not understanding homework and you want to do a certain way, or I know that, okay, you are interested...

Shifting focus to the wider applications and implications of nurturing interest within the classroom, this theme emphasises the potential of learners leveraging their in-class curiosity to not only interact more deeply with teachers and peers, but also to bridge the gap between academic theories and real-world practices. This process illustrates that the educational journey extends beyond the classroom walls, influencing how learners interpret and engage with their broader environments. SSI-P3 and SSI-P6 support this sentiment, suggesting a strong link between classroom learning and its practical applicability in the real world and various industries:

> **[00:15:54] SSI-P3:** ...Other—, [errrhm], so it's—, especially when it comes to applications of whether the mathematics or—, or where it could be used in actual industry.

> **[00:09:26] SSI-P6:** ...[Uhmm] So interest is—, interest in a learner is seeing that you want to integrate what you have learned in class also in the real world.

Tying it all together, SSI-P6 underscores that interest, motivation, and engagement in the classroom are deeply interconnected, forming a nexus that drives the learning process. SSI-P6 articulates this interconnectedness clearly, noting:

> **[00:14:27] SSI-P6:** ...So you have to be interested to be motivated in order to engage in class.

This intricate relationship suggests that a genuine interest is the bedrock upon which motivation to learn is built, subsequently leading to meaningful engagement in class activities. It is a chain reaction where curiosity fuels the desire to learn, which in turn encourages active participation. This perspective highlights the critical role of interest in the educational journey, acting not just as a passive trait, but as the catalyst initiating a domino effect of learning enthusiasm.

In sum, this theme has navigated the intricate landscape of how genuine interest influences learning dynamics, shedding light on its multifaceted nature and pivotal role in the educational journey. Through the insights shared by the participating teachers, it becomes clear that genuine interest is not just a passive bystander in the learning process; rather, it is a dynamic catalyst that fosters deeper involvement, stimulates critical connections between diverse ideas, and inspires the practical application of academic concepts beyond the classroom walls. It also emerges as a critical driver that shapes learners' engagement, motivation, and, ultimately, their academic success. SSI-P6's reflection underscores this interconnectedness, suggesting a holistic approach where interest forms the solid foundation for motivation and meaningful engagement. Thus, the nexus of curiosity is not merely a single point of convergence, but rather an extensive network of experiences, inquiries, and discoveries that continually mould the learners' pursuit of knowledge.

6.2.5 The Learning Triad: Dissecting the Interplay of Motivation, Engagement, and Interest

This theme, *The Learning Triad: Dissecting the Interplay of Motivation, Engagement, and Interest*, delves into the intricate relationships and distinctions between three fundamental pillars of the educational experience. At its core, this theme identifies the intertwined nature of motivation and engagement, where motivation often acts as a propelling force, leading individuals to actively engage with their learning environment. This engagement, in turn, can be seen as a manifestation or outcome of underlying motivations. On the other hand, interest emerges as a slightly distinct entity, representing a specific curiosity or focus towards a particular topic or subject. While interest can amplify both motivation and engagement, it possesses unique characteristics that set it apart from the other two. Together, these three elements—motivation, engagement, and interest—form a dynamic triad, each influencing and being influenced by the others, but each also retaining its own unique qualities. In a harmonious educational setting, the convergence of these three elements can pave the way for an enriching and productive learning journey.

The connection between motivation, engagement, and interest is pivotal in the learners' educational journey, as observed by teachers. SSI-P6 emphasises the tight-knit, triadic relationship amongst these concepts, asserting that the confluence of all three elements is indispensable for orchestrating a productive classroom session:

> **[00:14:27] SSI-P6:** Oh, definitely. They—, ... the concepts themselves are very similar. They are interrelated for sure. Because, [uhmm], when it comes to motivation, [uhmm], a learner first has to have interest in what they're learning for them to be motivated to keep forward, you know, and to engage in class...

SSI-P4 echoes the notion of the interconnectedness of motivation, engagement, and interest, underlining the collective necessity of all three components to ensure a productive educational session:

> **[00:20:54] SSI-P4:** [Uhmm] I think all—, all of them coexist and all need to be present to have a productive session...

These perspectives collectively suggest that not only does this triad stand as a requisite for effective learning sessions, but it also plays a pivotal role in steering learners towards a path of consistent self-development and continual academic pursuit. This triadic relationship lays the foundation upon which successful learning experiences are built. A deficiency or absence in one element could notably diminish the efficacy of the others, potentially hindering learners' progression towards acquiring and internalising knowledge. Without genuine interest, motivation may wane; lacking motivation, engagement is unlikely to be sustained; and without engagement, the initial interest may not be adequately nurtured. Hence, creating an ecosystem where all three—motivation, engagement, and interest—coalesce, becomes imperative for teachers striving to elevate their teaching efficacy and optimise learning outcomes.

Nevertheless, SSI-P3 offers a divergent perspective, suggesting that while motivation and engagement are closely linked, interest might stand somewhat apart. This viewpoint is intriguing

and introduces a compelling dimension, spotlighting instances in real-world settings where the absence or diminished prominence of one concept does not necessarily thwart the effectiveness of the others, at least in the short term:

> **[00:21:06] SSI-P3:** I think motivation, engagement, kind of go together, I think...
>
> **[00:21:19] RESEARCHER:** Okay...
>
> **[00:21:20] SSI-P3:** But then, [errrhm], interest is not—, is not necessarily—, I don't think it kind of—, because it's kind of detached from those two...

In sum, this theme has unveiled the multifaceted and sometimes divergent perspectives on the interplay between motivation, engagement, and interest in shaping the learning journey. The supporting narratives highlight a generally perceived inseparability of these concepts, projecting them as collective drivers that steer effective learning experiences and academic pursuits. However, the subtle deviation by SSI-P3 enriches this discussion, hinting at a potential for exploring varied configurations of these elements in different learning contexts, and for diverse learners. This highlights the need for teachers to discern and navigate the subtle dynamics of these elements in their classrooms, possibly crafting strategies that cater to diverse learner needs and contexts.

6.2.6 Mathematical Resonance: The Roles of Relevance and Value in Cultivating Learner Interest

Mathematical Resonance refers to the deep connection and alignment learners experience with the subject of mathematics when it reverberates with their own life contexts, previous knowledge, and aspirations. This theme delves into the factors that augment this resonance, with a particular focus on two pivotal elements: *Relevance* and *Value*.

Relevance, on the one hand, pertains to the learners' ability to relate mathematical concepts and processes to their lived experiences, personal interests, and prior knowledge. It emphasises the importance of context and real-world applications in making the subject matter relatable and thus, more captivating. When learners see the applicability of mathematics in their daily lives or can connect new information to what they already know, they are more inclined to take an active interest in the subject.

Value, on the other hand, underscores the perceived benefits and importance of the subject to the learner. This includes both intrinsic value, where learners find joy and satisfaction in mathematical exploration for its own sake, and extrinsic value, where learners recognise the utility of mathematics for future aspirations, career opportunities, or societal contributions.

Together, relevance and value serve as powerful catalysts in cultivating genuine interest in mathematics. They help transform the subject from a mere academic requirement into a meaningful journey of discovery and application, wherein learners are not just passive recipients, but active participants, eager to explore, question, and integrate mathematical knowledge.

To articulate the significance of relevance in mathematics education, teachers highlight the in-

tricate connection between learner interest and the subject's real-world applications. Learners often display increased interest when they can relate mathematical concepts to their lived experiences or see practical applications of their lessons. This interest intensifies when they can draw parallels between what they are learning and their prior knowledge. This interplay of familiarity and application plays a crucial role in maintaining learner interest, especially in complex topics. SSI-P1 encapsulates this observation, emphasising the teacher's role in making mathematics tangible and relatable. For instance, in teaching topics like calculus, which may initially appear abstract and disconnected from reality, the task involves linking these concepts to real-life phenomena, such as rate of change in physical objects. This approach not only enhances how learners engage with the subject matter, it also aids in solidifying their understanding by connecting new learning to familiar contexts. SSI-P1 describes this process in the following excerpt:

> **[00:22:33] SSI-P1:** [Uhmm] And these, you know, like learners, [uhmm], they struggle to obviously relate to a subject like math. So it's up to us then to relate it to them, because they always ask you: *"How does this help us in real life? This is not going to help..."*
>
> **[00:22:45] RESEARCHER:** Of course, of course...
>
> **[00:22:46] SSI-P1:** You know? [Uhmm] So learners that get interested is when they can relate what they're doing to what we're learning.
>
> **[00:22:55] RESEARCHER:** Alright, alright...
>
> **[00:22:55] SSI-P1:** And I mean that's like the basis of—, of what they teach you, you know, [uhmm], so relating it to something that they've known. So whether that—, what they've learnt in Grade 8, or whether that's something that they learnt yesterday, the relating part is gonna create the interest in what we're doing. And then to relate it into a real-life example, that's when it really gets, [uhmm], quite, you know, exciting for them.
>
> **[00:23:20] RESEARCHER:** Alright...
>
> **[00:23:21] SSI-P1:** So, for example, we're doing calculus now, very abstract, very unrelatable. How does a cubic function link into the real world? But then, obviously towards the end of calculus, we have, [uhmm], the rate of change. And then applying that to 2D and 3D problems, so that's very real life. Now something that they can literally see, [uhmm], in everyday, so literally having to take those examples and say: *"This is how we're going to start it off; know that that's where our end goal is; and where would you think you've seen those kinds of things before...?"*...
>
> **[00:23:54] RESEARCHER:** Alright...
>
> **[00:23:54] SSI-P1:** ...so linking it to what they see everywhere.

In exploring the role of value in mathematics education, teachers acknowledge that learners' engagement with mathematics is strongly influenced by their perception of the subject's value. Learners often demonstrate a heightened interest in mathematics when they perceive its direct benefits, such as relevance to their future goals and career paths. As SSI-P3 observes, learners

who recognise mathematics as essential for their chosen careers tend to exhibit greater enthusiasm and commitment. This is because they view mathematical knowledge as a critical step towards achieving their career objectives. SSI-P3 underscores that in the absence of this perceived value, learners are likely to approach mathematics with passive compliance, not active interest. Thus, highlighting the practical applications of mathematics and its relevance to everyday life and future careers is essential in cultivating a sustained and meaningful interest in the subject:

> **[00:17:15] SSI-P3:** [Errrhm] What I've noticed is sometimes, it's learners that know their own need for the subject, like of—, for—, it's in the careers that they want to—, to get into. So, they realise, okay, I need this, so they are interested because it applies to them.
>
> **[00:17:37] RESEARCHER:** Oh, it's—, it kind of paves the way to the career that they want to choose...
>
> **[00:17:40] SSI-P3:** Yah... Where they are—, where they really want to go. Otherwise it's—, it's very difficult generally to have interest in mathematics, that's what we have noticed. We've tried to actually help with that... Otherwise they just do it because it's required.

The role of the teacher in instructional delivery is a pivotal factor in cultivating learner interest in mathematics. This aspect is not just about imparting knowledge, but also about how the subject is presented and connected to the learners' interests and future aspirations. The method and manner in which content is presented can dramatically alter not only a learner's engagement and interest, but their perception of the relevance and value of the subject too. SSI-P1 highlights this, noting the role and approach of the teacher in presenting content:

> **[00:22:26] SSI-P1:** ...it's obviously up to the way that teacher is going to now present the content.

Once learners perceive value and relevance in mathematics, genuine interest in the subject begins to emerge from their own volition, rather than from extrinsic factors. SSI-P3 underscores this, indicating that the root of learners' interest often lies in their personal motivations, rather than external elements like technology usage:

> **[00:21:20] SSI-P3:** ...If—, because the lear—, the interest is kind of from some—, something else of their own, not necessarily because of the technology.

This observation is pivotal and will be further explored in subsequent sections. What is evident, however, is the essential nature of learner interest in the educational process. Without genuine interest in the classroom material, the effectiveness of teaching diminishes significantly. SSI-P1 encapsulates this notion in this excerpt:

> **[00:16:24] SSI-P1:** And having them interested in what you are teaching. Because if that is missing, then they're not really gonna learn.

This theme has underscored the significance of relevance and value in cultivating learner interest in the subject of mathematics. Relevance connects mathematical concepts to learners' lives, making abstract ideas tangible, while the perceived value of mathematics, for personal joy or

future aspirations, motivates deeper engagement. These elements, together with the pivotal role of teachers, form the cornerstone of cultivating a genuine interest in the subject. However, this theme also acknowledges that while relevance and value are key, the impact of extrinsic factors like technology usage in cultivating interest warrants further exploration. This interplay of internal drive, effective teaching, and external influences forms a dynamic environment where mathematics becomes not just a subject, but an integral part of learners' intellectual and practical lives.

6.3 Digital Dynamics in the Classroom: Harnessing Potential, Managing Pitfalls, and Sparking Interest

6.3.1 Digital Natives in the Classroom: Harnessing Technology Fluency and Constructive Exploration

This theme delves into the inherent synergy between the current generation of learners and the digital tools they have grown up with. Recognised as *digital natives*[3], these learners navigate technology with an ease and fluency unparalleled by previous generations. Their interaction with technology often leads to spontaneous exploration and constructive discovery, creating a dynamic where technology acts as an extension of their cognitive and academic journey. Whether it is their comfort with technological devices, their intuitive approach to new tools, or their capacity to use technology for meaningful academic ventures, this theme captures the positive interplay between modern learners and their technology tools, emphasising the constructive possibilities and organic explorations that can arise both in and outside the classroom.

Harnessing technology in the classroom is rooted in mutual expectations between teachers and learners. While learners anticipate the incorporation of technological tools during lessons, there exists a somewhat reciprocal expectation from teachers that learners utilise these tools to their fullest potential. SSI-P1 articulates this perspective in the subsequent excerpts:

> **[00:22:02] SSI-P1:** ...You know, so my learners have the expectation that technology must be used.

> **[00:15:13] SSI-P1:** ...I expect them to know what to do and how to use it...

In this respect, learners exhibit a natural aptitude and fluency for technology, evident in their ease with the technological tools integrated into the classroom setting. SSI-P1 offers further insight into this by noting:

> **[00:21:03] SSI-P1:** So they—, they're used to it...

SSI-P6 echoes a similar sentiment, emphasising that learners generally appear confident in their

[3]There is an ongoing debate surrounding the evolution of the term "digital native" since Prensky's (2001a, 2001b) seminal work. While there is a general consensus on the core definition of the term, the debate underscores the unique and intricate characteristics of individuals born in this dynamic technological era. It also explores how technology is integrated, or more precisely, how individuals choose to integrate technology into various facets of their lives (Bennett et al., 2008; Dingli & Seychell, 2015; Evans & Robertson, 2020).

understanding and use of technology for educational purposes. Moreover, SSI-P6 highlights that when learners encounter challenges with technological tools, their proactive approach takes precedence. They readily seek assistance with little concern for potential judgement from others. This perspective is further illustrated in the subsequent excerpt:

> **[00:05:13] SSI-P6:** ...they—, they seem like they do understand what they're doing. And if they don't, they just raise their hand and that's—, that's basically how they use it. And they—, I haven't, [uhmm], received any problems with them having, [uhmm], any issues using, [uhmm], the calculators or any other tools that we use, so yeah...

The 21st-century learner is distinctly attuned to technology. Leveraging this proficiency for teaching and learning not only resonates with their aptitude, but also heightens their motivation. Hence, embracing the pervasive nature of technology, the learners' inherent comfort with it, and their effortless use becomes a linchpin in contemporary classrooms. This perspective is detailed in the following excerpt:

> **[00:06:48] SSI-P6:** Okay, so I—, since we are in this, you know, 21st century, in this new era, as they say...
>
> **[00:06:55] RESEARCHER:** Hmmm... Hmmm *(affirming)*
>
> **[00:06:55] SSI-P6:** ...[uhmm], we are in a very fast-paced, [uhmm], we live in a very fast-paced, [uhmm], era or society. So we all have cell phones, we're all looking at our screens, so what better way to use that...
>
> **[00:07:11] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:07:12] SSI-P6:** ...[uhmm], to our advantage, you know. So I feel like as we have laptops and computers and such, we are giving learners more motivation to learn at school because they have those gadgets, you know.

Indeed, for the intrinsically motivated learner, technological interaction is not limited to the classroom walls. These learners often find additional value in harnessing technology to augment their educational experience. SSI-P3 underscores this perspective, noting:

> **[00:18:59] SSI-P3:** ...Because now you can get it thinking of the fact that you can carry the board with you. You could work elsewhere...
>
> **[00:19:10] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:19:10] SSI-P3:** ...without needing to be at school all the time. It's—, for those that will be actually motivated, they can—, yeah, who are internally motivated, then they can work at any other time.

More broadly, there is a marked difference in how learners utilise the technology available to them, both within and outside the classroom setting. This discrepancy arises mainly from two determinants: (i) the availability of technological tools to the learners; and (ii) their conscious

decision to employ technology beyond what is prescribed by the teacher. In this regard, SSI-P3 remarks:

> **[00:09:28] SSI-P3:** [Errrhm] There is—, I think that one would be—, it's a—, it's a 50/50. Some actually utilise everything I've seen. [Errrhm], Some actually have their workings on, let's say, on a tablet that can actually write on. So they keep their notes in terms of files on the computer instead of in terms of getting a book, which means they carry one little device, to classes, instead of carrying a bag full of books.
>
> **[00:09:54] RESEARCHER:** Ohhh...
>
> **[00:09:55] SSI-P3:** Which—, which is quite like excellent use. Then there's those that don't use it as much. So you have a whole spectrum of students. The ones that utilise it as much. Then you have the other ones that use minimum.

Such variances not only shape individual learning experiences, but also highlight the importance of understanding each learner's unique relationship with technology. By recognising these distinctions, more effective, responsive, and adaptive teaching strategies can be formulated to enhance classroom discourse.

While this theme provides a snapshot of digital natives in the modern classroom, there is a broader context to consider. Central to this understanding remains the recognition that the contemporary educational landscape presents certain expectations from both teachers and learners regarding technology's role, influencing its adoption and utilisation. Furthermore, living in the 21st century does not guarantee that all learners have access to, or even desire, technology in their educational pursuits. Thus, recognising these nuances, it becomes essential to devise strategies that effectively respond to this evolving landscape.

6.3.2 The Digital Distraction Dilemma: Navigating Technology's Challenges in Learning

While the integration of technology in classrooms has opened up a myriad of educational possibilities, it has also ushered in a set of challenges. This theme focuses on the other side of the technology coin: the potential pitfalls and distractions that digital tools can introduce. From wandering minds owing to unrelated online content to the lure of games and other non-academic applications, there is a balance to be struck in ensuring that technology enhances rather than detracts from the learning process. The role of teachers in managing and mitigating these distractions is paramount, as is the need for creating boundaries around technology use in the classroom. Moreover, this theme explores the multifaceted nature of technology's impact, highlighting the importance of discernment, guidance, and intentionality in leveraging technology for education while navigating its inherent challenges.

In classrooms, teachers have observed significant challenges in the way learners utilise technology, which often diverts them towards distractions. Notably, these learners demonstrate inappropriate use of technological tools at their disposal, frequently employ technology for unintended purposes, and even browse unrelated content on available devices. This perspective is encapsulated by SSI-P2 and SSI-P3 in the subsequent excerpts:

> **[00:10:08] SSI-P2:** They do not use it ≪ *laughs* ≫ in a proper way. That is why I was saying they do not have the proper skills, because they use it for the wrong reasons.

> **[00:18:03] SSI-P3:** ...Sometimes they don't do the exact same thing that is supposed to be done in the class...

Once on this trajectory, learners frequently find themselves caught in a dichotomy of distraction, as their minds drift away from the ongoing activities of the classroom. On the one hand, a constructive form of driftiness exists, which certain teachers even promote. It provides learners an opportunity to reflect on the lesson's content, immerse themselves, and formulate a comprehensive understanding of both the material and its broader implications. The key, however, is ensuring they return from their mental wanderings. The following conversation snippet with SSI-P4 exemplifies this perspective:

> **[00:19:51] SSI-P4:** [Uhmm] I would want them to wander.
>
> **[00:19:55] RESEARCHER:** Hmmm...
>
> **[00:19:55] SSI-P4:** I would want them to think.
>
> [**00:19:57] RESEARCHER:** Hmmm...
>
> **[00:19:57] SSI-P4:** But I would want them to come back as well.
>
> **[00:19:59] RESEARCHER:** Hmmm...
>
> **[00:20:00] SSI-P4:** Wandering not for them to get bored, but to apply themselves, think as to what problem are we solving. Because you must remember, math is a very demanding, mentally demanding exercise, right?
>
> **[00:20:09] RESEARCHER:** Hmmm... Hmmm...
>
> **[00:20:10] SSI-P4:** So, I wouldn't necessarily complain if they were wandering, but they're also coming back to understand why are we there...
>
> **[00:20:16] RESEARCHER:** Yeah...
>
> **[00:20:17] SSI-P4:** ...what are we trying to solve, and, yes—. Because I also wouldn't want to be teaching people who will be saying yes to everything, right?

On the other hand, there is a destructive (or potentially distracting) form of driftiness that arises from technology use within the classroom. Some teachers attribute this behaviour to the youthful tendencies of their learners, but the prevailing sentiment is that it persists largely because such habits are often perceived as typical classroom behaviours. SSI-P3 and SSI-P6 elaborate on this perception in the subsequent passages:

> **[00:20:12] SSI-P3:** ...because we are talking an age group that is not necessarily, you know, grown up, or manage to—, to—, to know how to balance themselves. So there is always that tendency to wander off.

> **[00:04:58] SSI-P6:** [Uhmm] Of course they're kids, you know, and sometimes they do, you know, wander and stuff like that...

> **[00:13:40] SSI-P6:** ...You know, they do wander at times... they relax a bit.

Turning attention from the learners to the technology itself, opinions arise regarding the intrinsic potential for distraction that technology offers. When learners are provided with resources such as the internet, as highlighted by SSI-P6 below, it introduces new avenues for distraction and potential misuse:

> **[00:08:40] SSI-P6:** ...[uhmm], since they do have access to Wi-Fi and such, it's—, it's—, it can be a bit too much because they tend to, [uhmm], take advantage of that.

> **[00:11:16] SSI-P6:** ...It goes back to what I've been saying, that since they have access to Wi-Fi and they get excited because they—, they're using computers or laptops, they get, [uhmm], distracted by online stuff, you know...

Certainly, the intrinsic curiosity and boundary-pushing nature of learners, driven by their child-like proclivity to explore and find opportunities for play, prevail even in scenarios demanding focus and seriousness. In the ensuing excerpt, SSI-P1 delineates how learners, with convincing fervour, argue that permitting games or comparable diversions—perceived distractions—could, contrarily, assist them in achieving and sustaining focus in the classroom:

> **[00:29:31] SSI-P1:** And if there's a game playing then maybe they'll focus. And I was like: *"What nonsense is that?"*
>
> **[00:29:36] RESEARCHER:** Yeah...
>
> **[00:29:36] SSI-P1:** *"I'm teaching you. Focus!"* You know? *"No, put my—, put sub—, subway surfers then we will focus..."*[a]
>
> [a] In this context, the learners are referencing a TikTok trend known as "sludge content", which is often criticised for promoting mindless time-wasting activities that erode an individual's attention span (D'Anastasio, 2023; Nolan, 2023).

Teachers again emphasise the substantial challenges related to the use of technology, particularly amongst younger learners in lower grades. The struggle to discern between appropriate and inappropriate technological use is apparent, with even technologically proficient 16-year-olds often lacking the mental discipline to separate academic use from socialising. This sentiment is encapsulated by SSI-P4, who articulates:

> **[00:02:07] SSI-P4**: ...And I don't think that as much as people are capacitated with technology, I don't—, I don't think when you're 16, you have that mental discipline to distinguish between now it's time to use technology for schoolwork and socialising. So it tends to be a little bit of a distraction for the younger grades. But it can still work...

Despite potential pitfalls, there exists a consensus amongst teachers that maintaining a strict control over technology use within the classroom prevents it from becoming a source of distraction. This highlights the role of oversight and control insofar as the use of technology in the classroom is concerned. SSI-P1 and SSI-P4 provide insight into this viewpoint, particularly emphasising scenarios where learner access to technological devices and tools is limited throughout the lesson:

> **[00:24:44] SSI-P1:** I think for the fact that it's just solely on my side with the technology, there's less room for distraction. If there was technology on their behalf and my behalf, I think then the distractions would open up, because they then, you know, start doing other things, so if they had a tablet or whatever they'd open up another book, or do someone else's homework, or whatever. So, there is that thing, but I think right now it's very controlled because it's only on my side.

> **[00:16:46] SSI-P4:** ...Because remember the technology on the context of my technology, where I'm only—, I'm the only person that has access to it. So I'm able to navigate and manage it very well. So I thi—, I think it works best in that—, in that way. I think so.

There is a prevailing belief amongst teachers that, with the right parameters in place, technology transitions from a potential distraction to an indispensable learning tool. As one teacher astutely observed, what might be initially perceived as a distraction can, under the right conditions, evolve into a vital instrument for education. This perspective is illuminated by SSI-P5's reflection:

> **[00:17:15] SSI-P5:** ...So I've found that—, I think sometimes, you know, we often think of learners and say they get distracted by technology. Right. But think about it, that the very same thing that was meant or rather that we deemed to be a distraction has now become a tool for learning...

Concluding the insights from this theme, the stance on technology's capacity to distract, appears multifaceted, originating from: (i) the challenges encountered in its classroom use; (ii) the dichotomy it presents between constructive and destructive driftiness; and (iii) its inherently distracting nature particularly for younger audiences. Nevertheless, a prevailing belief persists: when managed with appropriate constraints and guidelines, technology overcomes its distracting potentials and solidifies itself as an indispensable tool for learning.

6.3.3 **Digital Catalyst: Technology's Power to Spark Mathematical Curiosity**

This theme encapsulates the transformative role of digital tools and platforms in stimulating and sustaining a keen interest in the complex world of mathematics. It delves into how technology acts as an instigator, breaking traditional barriers of comprehension and making complex mathematical concepts more tangible, relatable, and engaging. SSI-P1 sheds light on how these complexities unfold in the classroom:

> **[00:23:21] SSI-P1:** So, for example, we're doing calculus now, very abstract, very unrelatable. How does a cubic function link into the real world? But then, obviously towards the end of calculus, we have, [uhmm], the rate of change. And then applying that to 2D and 3D problems, so that's very real life. Now something that they can literally see...

By serving as a bridge between abstract mathematical concepts and their real-world applications, digital tools ignite a sense of wonder, exploration, and deeper understanding. In the context of this theme, the term "catalyst" symbolises technology's distinct ability to accelerate learning processes, foster genuine curiosity, and cultivate a persistent mathematical inquiry. The insights from SSI-P2 and SSI-P5 capture this catalytic essence of technology, as they note of the learners:

> **[00:13:15] SSI-P2:** They are more interested when there's technology being used than when we are just having a traditional lesson without any use of technology. So I'd say they are more interested when we use technology.

> **[00:18:52] SSI-P5:** ... You know, and—, and—, and—, and honestly speaking, the more that I realised what has been stoked, the fire that has been—, had been stoked in learners, the more I realised that I think this is, you know, this tool should be exploited all the more...

In many scenarios, the teachers' decisions on how and when to introduce technology as a pedagogic supplement directly influence learners' reception of such initiatives. SSI-P4 elaborates on this dynamic in the following excerpt:

> **[00:13:37] SSI-P4:** [Uhmm] Because based on how I've introduced technology to be, [uhmm], they get excited and interested...

For learners, the specific type of technology used (whether it is streaming online content, hands-on work on laptops and other devices, or engaging with projected content) is secondary. The primary focus is on the catalytic power of any technology utilised in the classroom to enhance the processes of teaching and learning, thus making the subject matter more captivating for learners. This sentiment is further illustrated in the following excerpt:

> **[00:14:07] SSI-P2:** ...when we're watching videos, even if it's YouTube videos explaining math concepts. That is when they get interested, just watching something from the smart board...

In sum, this theme emphasises that in the modern educational landscape, technology is not merely an adjunct, but an essential element in kindling and nurturing a profound appreciation and enthusiasm for mathematics amongst learners.

6.4 LEARNER-CENTRIC DIGITAL INTERACTIONS: BEHAVIOUR, ATTITUDE, AND ENGAGEMENT IN THE TECHNOLOGY-INTEGRATED CLASSROOM

6.4.1 Digital-driven Dynamics: How Technology Shapes Learner Behaviour, Attitudes, and Interactions

This theme explores the nuanced influence of digital tools and platforms on learners within an educational context, highlighting technology as a dual force, acting as both a catalyst and mediator in shaping learner behaviours, attitudes towards subjects, and modes of interaction. It navigates through the various shades of learner engagement—from the enhanced anticipation and motivation sparked by technology introduction to subtle shifts in focus and interaction—encapsulating a delicate interplay between learners and digital tools. Moreover, it scrutinises both the positive and negative learner attitudes emerging in response to technological integration, revealing potential polarised perspectives. Furthermore, this theme elevates the collective dimensions of learning, accentuating the collaborative and interactive dynamics facilitated by digital platforms. It underscores the metamorphosis of the modern classroom where learners transition from mere passive recipients to active participants, dynamically influencing and being influenced by the technology they interact with.

Leveraging technology in teaching and learning intersects seamlessly with the technological adeptness of learners, thereby heightening their enthusiasm and drive for learning at school. As articulated by SSI-P6 in the following excerpt, the introduction of gadgets such as laptops into the learning environment potentially amplifies learners' enthusiasm and eagerness to learn, since it taps into their inherent familiarity and interest in such devices:

> **[00:07:12] SSI-P6:** ...So I feel like as we have laptops and computers and such, we are giving learners more motivation to learn at school because they have those gadgets, you know.

Moreover, technological tools, due to their contemporary and often stylish nature, wield an intrinsic allure and modern appeal, acting as a magnet that attracts learners to the classroom. SSI-P3 underscores this in the following snippet:

> **[00:19:39] SSI-P3:** ...It looks a little more fancy, and a bit nice.

Not only do technological tools themselves hold appeal, but also the manner in which teachers introduce technology into their classrooms fundamentally drives learners' motivation and anticipation, often manifesting as palpable excitement amongst the learners. SSI-P4 sheds light on this perspective, noting:

> **[00:13:37] SSI-P4:** [Uhmm] Because based on how I've introduced technology to be, [uhmm], they get excited and interested...

Technology emerges as a substantive anchor for learners' attention in the classroom environment. The integration of technology into lessons yields a discernibly positive shift, with learners frequently perceived to be more engaged and attentive compared to when more traditional

teaching methods are employed. SSI-P3 emphasises this perception, noting an increase in attentiveness with the incorporation of technological methods:

> **[00:19:39] SSI-P3:** It ki—, it kind of helps ... But it kind of helps, it really kind of helps. I think when it was just me and the board, I'm sure the attentiveness and them looking forward, it was a little less than now when—, you know, it's more on the technology side.

However, once the learners' attention has been captured, a subtle complexity unfolds in understanding the relationship between using technology for teaching and learning, and enhancing learner focus. While teachers predominantly affirm that technology generally bolsters focus amongst learners, they also acknowledge the variability and potential subjectivity of this connection. A brief dialogue with SSI-P2 illustrates this nuanced relationship:

> **[00:16:10] SSI-P2:** I think that one is subjective. However, they—, I'd say they are more focused.
>
> **[00:16:19] RESEARCHER:** You feel like they're more focused?
>
> **[00:16:20] SSI-P2:** Yeah.

Similarly, SSI-P4 subtly underscores a belief in technology's capacity to amplify focus:

> **[00:13:37] SSI-P4:** ...but I also know that we're going to be focusing a lot harder than we were before...

Integrating technology into the classroom facilitates interactive dynamics, serving as a catalyst for interactivity and collaboration amongst learners. An interactive and collaborative classroom environment is pivotal, fostering not only enhanced understanding and retention of material, but also promoting social skills and cooperative learning amongst learners. SSI-P3 encapsulates this by sharing their strategy of leaning on technology to enhance the interactive nature of lessons, explaining how it mimics—and even improves upon—traditional teaching and learning methods:

> **[00:05:18] SSI-P3:** ...So we'll be putting in work and as we go. So the plan is, okay, this is our topic, this is what we're doing. But what the kind of setup that I use is it's interactive ... So I actually work out maths just like I would do it on the board, just with the slides on technology.

Learners, too, acknowledge the emergent collaborative culture within the classroom, becoming active participants in their own educational experiences. This sense of cooperative learning, where learners also have a say in shaping the trajectory of their lessons, is echoed by SSI-P4 through a recounting of a learner's perspective:

> **[00:19:10] SSI-P4:** ...this other one learner mentioned that our learners—, [uhmm], our lessons are not necessarily like lessons. It's kind of like a collaborative, like, instrument because...
>
> **[00:19:24] RESEARCHER:** Hmmm...

> **[00:19:24] SSI-P4:** ...they also contribute to how the lesson becomes because they can prepare for them, right?
>
> **[00:19:28] RESEARCHER:** Hmmm...
>
> **[00:19:28] SSI-P4:** ...In that way, they have contributed to the whole environment and the tone of the lesson...

The sentiment of collaborative learning through technology is also reflected in the experiences shared by other teachers. Technology not only serves as a tool for information dissemination, but also fosters a sense of unity and joint endeavour in the learning environment. SSI-P6 highlights this dynamic, illustrating how the use of computers becomes a collective, participatory activity in the classroom, wherein tasks are disseminated digitally and worked upon in a united manner:

> **[00:04:08] SSI-P6:** Okay, so basically when, [uhmm], they're using the computers, I just send the work that they need to do on the computers and we just work together.

This reveals an educational setting where both the teacher and the learners navigate the learning journey cohesively, using technology as a medium to bind their collaborative efforts.

Teachers leverage technology to bring vitality to lessons on typically dull mathematical topics like geometry, transforming them into engaging and interactive learning experiences. Technology provides a dynamic platform that allows even intricate and often less appealing concepts to become more digestible and interactive. SSI-P5 illustrates this capacity, emphasising the importance of utilising technology to enhance interaction, particularly in complex areas like geometry:

> **[00:10:10] SSI-P5:** ...You know, obviously, you can try to superimpose and try to annotate, you know, onto, you know, whatever it is that you exported, especially when you're dealing with things like geometry, you know, it needs to be something that is as interactive as possible...

SSI-P6 echoes this perspective, highlighting the transformation of the classroom into an interactive hub of learning through the adept use of technological tools by learners:

> **[00:05:13] SSI-P6:** ...[uhmm], but I would like to say they are using it at the best of their ability because, [uhmm], there's a lot of interaction, you know, they—,...

This underscores the notion that the utilisation of technology is not merely a one-sided affair led by the teacher; learners actively engage with available tools, co-creating an environment that buzzes with interaction and collaborative learning.

Shifting focus to attitudinal changes, learners in technology-enabled environments showcase a spectrum of behaviours, ranging from displaying negative attitudes to taking increased agency in their tasks due to technology adoption. Despite the implementation of technology in teaching and learning environments, some learners, as SSI-P1 notes, still exhibit hesitancy and a negative disposition towards their mathematics lessons:

> **[00:27:11] SSI-P1:** They don't look forward to mat—, the—, to my class...

Similarly, SSI-P3 sheds light on a different issue, articulating that learners sometimes exploit the convenience offered by technology to the point of fostering laziness and eschewing note-taking in class:

> **[00:15:01] SSI-P3:** [Errrhm] They—, there's a number of—, of behaviours that seem to be affected by technology. The fact that the board, you could still see it tomorrow, on your own device, kind of makes some learners lazy. They don't want to take notes anymore.

In contrast, the integration of technology in learning can also catalyse a positive shift in learner attitudes and behaviours. SSI-P5, who employs online platforms like YouTube to disseminate educational content, highlights a notable change. Once acclimated to this digital modality, learners not only find enjoyment in engaging with digital learning content, but also experience a positivity ripple effect that cascades across their overall academic performance:

> **[00:18:52] SSI-P5:** ...What you will find, you'll find a lot of comments of people who are saying, you know, I started listening to your videos and I started developing interest... And once they start realising *ukuthi*: *"No man, this thing* ***ebengilokhu ngi-complainer ngayo****, is actually something that is—, I can actually enjoy."* Right. They start doing well. That's one. Alright. So they improve. And secondly, it starts kind of triggering them to do well even in other subjects...

As a consequence of this burgeoning positivity, SSI-P5 observes a keen and intentional adoption of, and enjoyment in, mathematics by the learners, attributed to the utilisation of technology in this manner:

> **[00:05:57] SSI-P5:** ...And I mean, looking at the results, I mean, you know, ... it seems to be something that, you know, that is, learners have taken up and they are really, really enjoying it...

Encouragingly, the integration of technology into learning extends its influence to the social dynamics within the classroom, fostering a lively, competitive spirit amongst learners. Earning '*bragging rights*' becomes a spirited pursuit amongst learners who excel in utilising technology, sparking an intriguing aspect of peer interaction and engagement. A scenario depicted by SSI-P6 unveils how proficiency in using technology becomes a badge of honour amongst peers, as they gleefully showcase their adept skills:

> **[00:10:43] SSI-P6:** ...So I think it's the whole thing of them being able to show each other: *"Hey, I can use my laptop..."*...
>
> **[00:10:52] RESEARCHER:** Yeah...
>
> **[00:10:52] SSI-P6:** ...you know, and they—, they find it quite interesting to do that. So, yeah, they find it quite interesting...

Indeed, the multifaceted social dynamics within the classroom sometimes become notably salient. Particularly amongst teenagers, who notably lean into social proofing and peer critique, these interactions serve as potent drivers for engagement and participative learning. Immersed

in an environment where the actions of peers substantially shape individual behaviours, learners, as observed by SSI-P4, are propelled towards active participation and investment in their tasks by a collective consciousness and a shared sense of accountability amongst their peers:

> **[00:15:35] SSI-P4:** ...Because you must remember that as these learners are teenagers, they—, they rely a lot on social proofing, right?
>
> **[00:15:56] RESEARCHER:** Hmmm...
>
> **[00:15:56] SSI-P4:** They see a whole class starting and doing their homework. You can't be a slacker, right?
>
> **[00:16:01] RESEARCHER:** Hmmm...
>
> **[00:16:01] SSI-P4:** You don't want to disappoint the whole class. You don't want to disappoint me, exactly...
>
> **[00:16:04] RESEARCHER:** ≪ *laughs* ≫
>
> **[00:16:05] SSI-P4:** So... ≪ *laughs* ≫ So they want to put in the effort.

Pivoting to explore another facet of this theme, technology also emerges as a key player in forging an environment that promotes empowerment and facilitates self-driven learning. In this vein, it serves not only as a motivational tool, but also as a catalyst for enhanced work engagement amongst learners. SSI-P3 notes a palpable increase in learner diligence and involvement when technology is integrated into the learning experience, implicitly contrasting it with a previous lack of engagement:

> **[00:15:15] SSI-P3:** ...So it kind of—, kind of motivates them a bit more to actually work...
>
> **[00:15:36] RESEARCHER:** To work...?
>
> **[00:15:36] SSI-P3:** ...they wouldn't work as much when they didn't have...

Moreover, technology not only incentivises learners to work, but also facilitates self-paced learning and revision, particularly benefiting those with access to more advanced devices. The access to digital learning content becomes pivotal, providing essential utility for both learners and teachers alike. In this regard, teachers discover a valuable ally in technology, as it eliminates the need for repetitive coverage of old material. Instead, learners can independently revisit recorded lessons whenever required. SSI-P5 elucidates this convenience, presenting a scenario where the teacher, metaphorically positioned '*in the learner's back pocket*' via their mobile device, is accessible anytime:

> **[00:17:15] SSI-P5:** Right. So you've got your teacher in your back pocket if you put your phone there. Right. And you can access that resource any time...

Further, SSI-P5 highlights the mitigation of the repetitive burden on teachers during revision

periods, as they can simply direct learners to relevant recorded lessons, seamlessly integrating technology into the revision process:

> **[00:29:16] SSI-P5:** ...let's say, at some point, they wanna, you know, do revision, they don't need to repeat themselves [the teachers], right? And they can say: *"Right, watch this lesson, tomorrow* ***sizoyenza*** *something, you know, in line with, you know, what the revision that I've asked you to go through..."*...

With digital tools readily available, learners are afforded the autonomy to extend their studies beyond the conventional classroom, exploring a spectrum of out-of-class engagement and practice that balances both self-directed and collaborative learning approaches. This view is corroborated by SSI-P1, who shares how access to supplementary video resources, linked through their prescribed textbooks, proves advantageous especially for learners inherently driven towards self-study. These additional video resources have not only been instrumental in practising mathematics, but also in facilitating homework completion outside of school hours:

> **[00:26:02] SSI-P1:** So, what happens is on their own, the learners can then go ahead and watch videos based on the work that they're doing. So...
>
> **[00:26:08] RESEARCHER:** Alright...
>
> **[00:26:09] SSI-P1:** ...this textbook then opened up, [uhmm], videos on examples, videos on how to do those sums, etc. So, then, [uhmm], we said that they could, [uhmm], go ahead and do the homework to the best of their ability and study using those—, those resources.

Moreover, the digital environment opens up avenues for collaborative learning experiences, offering learners a platform where they can come together in virtual spaces to discuss, debate, and co-construct knowledge. This can transpire even through straightforward platforms such as WhatsApp, exemplifying that technological interaction in learning does not always require advanced or specialised tools, as highlighted by SSI-P4:

> **[00:17:35] SSI-P4:** I think the—, I think a big yes, because if—, if we look at this is where WhatsApp would come in.

Technology has been instrumental in crafting virtual learning spaces, which are crucial in reshaping learner attitudes towards mathematics homework. SSI-P4 highlights the significance of these digital platforms, offering insights into how they provide learners, especially those reluctant to engage with homework due to a lack of available assistance, with an accessible environment to navigate through their confusions and challenges:

> **[00:18:23] SSI-P4:** Because certain learners don't necessarily do their homeworks, they don't want to. They don't have the—, the—, the platform to ask questions, to say: *"Hey, I'm so confused, I don't know who to ask. And since you were there, I asked you about how to do the homework."*
>
> **[00:18:36] RESEARCHER:** Hmmm...

> **[00:18:36] SSI-P4:** So I thi—, I think outside the classroom, it's even more important as well.

In summary, the exploration of *Digital-driven Dynamics* underscores the significant influence of technology on learner behaviours and interactions. While technology opens doors for self-guided and collaborative learning experiences, enhancing engagement and providing alternative platforms for study and interaction, it also unveils challenges, such as occasional procrastination and disparities amongst learners. Furthermore, it is compelling how technology, while serving as an educational tool, also metamorphoses into a social and motivational instrument, influencing peer interactions, social dynamics, and ultimately, academic engagement. The multifaceted narratives supporting this theme reveal a nuanced view of how digital tools shape, and sometimes reshape, educational and social dynamics, presenting both opportunities and hurdles in modern learning environments.

6.5 Teaching in the Digital Era: The Multifaceted Dynamics of Technology in Teaching

6.5.1 Teacher Evolution: Navigating the Digital Landscape in Teaching Practice

The *Teacher Evolution: Navigating the Digital Landscape in Teaching Practice* theme delves into the multifaceted journey of teachers as they embrace, adapt to, and integrate technology within their teaching environments. It highlights the dynamic relationship between a teacher's evolving digital skill set, their teaching methods, and the tools at their disposal. From the initial stages of self-taught technological exploration to becoming adept content creators, teachers traverse a spectrum of comfort, proficiency, and innovative application. This theme acknowledges the challenges teachers face, such as balancing traditional methods with new digital tools, catering to varied learner capabilities, and the periodic need for self-assessment in terms of technological proficiency. Furthermore, it underscores the teachers' pivotal role in leveraging technology's potential for enriching the learning experience while ensuring inclusivity, thoughtfulness, and purpose in its application. As the digital landscape continuously shifts, teachers remain agile, continually reassessing and refining their approach to best serve their learners in an ever-evolving classroom setting.

A crucial starting point for teachers in effectively navigating the digital landscape in their teaching practice lies in their proficiency and comfort with technology. This proficiency is not merely about mastering advanced tools, but encompasses the basics of technological application in the classroom. The competence of teachers in this area significantly influences learner behaviour and attitudes, influencing not just technology-enabled learning, but also shaping their engagement and receptiveness in a broader educational context. Acknowledging the rapid evolution of technology, teachers face the continuous challenge of updating their skills. As SSI-P1 puts it:

> **[00:10:15] SSI-P1:** ...I think that—, that—, [uhmm], where technology and teaching is concerned, there definitely—, there's—, there's so much going on all the time. So, I think that there's a lot more that I could be doing.

Echoing a similar perspective, SSI-P2 underscores the idea that there is still untapped poten-

tial in the use of technology in teaching. This viewpoint highlights a common challenge for teachers: fully capitalising on the capabilities of technological tools in the classroom. SSI-P2 indicates the need for more thorough groundwork and understanding to enhance technology implementation:

> **[00:09:03] SSI-P2:** ...because I believe that there's still more things, like, that have to be considered before the implementation of the technology...

SSI-P3 brings to light a different facet of technology integration in teaching: the largely self-taught nature of digital skills. While some technological tools come equipped with basic instructions, effectively integrating these tools into classroom settings demands extra effort and initiative from teachers. This often involves learning and adapting on the job, which is a significant part of their professional growth. SSI-P3 describes this reality:

> **[00:03:52] SSI-P3:** ...Some of the things come with, you know, [uhmm], enough information, but the other things we're going to learn on the job, you know, like find a way.

The path of continual learning and discovery in technology-enabled teaching eventually culminates in a stage where the integration of technology becomes an almost instinctive process, constantly improving through persistent practice. At this juncture, teachers find themselves adept and comfortable with the use of technology in their classrooms. SSI-P4 reflects on this stage of ongoing proficiency and learning, acknowledging the dynamic nature of this journey:

> **[00:08:18] SSI-P4:** ...I wouldn't be presumptuous to think, [uhmm], I am 100%, but I think I'm doing a decent job.
>
> **[00:08:24] RESEARCHER:** Hmmm...
>
> **[00:08:24] SSI-P4:** Because you always find something new...

The success of technology-integrated teaching hinges on the teacher's ability to plan methodically and select appropriate digital tools for their instructional strategies. This approach entails recognising the best technological fit for various teaching scenarios and preparing lessons with these tools in mind. SSI-P3's experience exemplifies the agility required in this process. The journey from a more static, inflexible method to one that allows for adaptability and fluidity in lesson delivery illustrates the importance of continually refining the choice and use of technological resources to enhance the teaching and learning experience:

> **[00:05:18] SSI-P3:** [Errrhm] Back—, what I used to do at the beginning was basically put in what looked like notes and whatnot on a PDF file and then work on that one when it's in the class. But I realised it kind of makes me like cramped up. I can't change, because a PDF file, you can't change it. So now I use Microsoft Word...

Further echoing this sentiment, SSI-P6 emphasises the continuous effort to refine teaching practices and lesson planning by utilising the technological resources available. This perspective highlights a proactive approach to continually refine and evolve instructional methods. SSI-P6 articulates this dedication:

> **[00:02:55] SSI-P6:** Okay, so as, [uhmm], an educator I always strive, you know, to improve my teaching practices and my learn—, my lessons. So I make sure that I sit down and plan accordingly and make sure I use the technological tools that I have at my disposal...

The teacher's role in navigating the digital classroom also involves addressing the varying levels of technological access and proficiency amongst learners. In a classroom where some learners have full access to technology while others do not, it is vital for teachers to employ strategies that are inclusive and equitable. SSI-P3 exemplifies how this disparity can be managed by creating a learning environment that is supportive and effective for every learner, irrespective of their access to or proficiency with technology:

> **[00:08:44] SSI-P3:** But then we have from the basic learner without any...
>
> [...]
>
> **[00:09:07] SSI-P3:** So they just work on their own book. (...inaudible...) So it caters for everyone naturally. The one with technology and the one without.

Recognising the diverse technological access and proficiency amongst learners, SSI-P6 provides another perspective on balancing technological and traditional teaching methods. They illustrate a strategy that incorporates both modern and conventional educational tools. This balanced approach is crafted to accommodate all learners, ensuring that those with limited or no access to technology are not disadvantaged. SSI-P6 elaborates on their strategy:

> **[00:12:13] SSI-P6:** ...So I do try to keep a balance. So we do use your traditional pen and papers, your reading textbooks and such...
>
> **[00:12:21] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:12:22] SSI-P6:** And I keep the homework at a minimum when it comes to working with technology.
>
> **[00:12:28] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:12:28] SSI-P6:** So we know that, okay, even if you don't have access to technology, we can still do it in the classroom.

The array of technological tools and methods used by teachers is diverse, as highlighted in the various teacher profiles in Section 6.1.2. Amongst these innovative practices, some teachers take it a step further by designing their own digital content, thereby enriching the educational experience. This ingenuity is not limited to content creation; it extends to adopting novel teaching strategies like gamification to enliven the classroom environment. SSI-P4 shares their unique approach, explaining how they incorporate elements of healthy competition and recognition in their teaching:

> **[00:15:21] SSI-P4:** We also have this construct of a leaderboard where we have, [uhmm], the top performing learner for that week, the most improved learner for that week, and, [uhmm], the favourite learner from all—, every—, every person in the classroom, right?

The integration of technology in education also brings to light the nuanced challenges of aligning teaching methods with the digital prowess of learners. As captured by the *Digital Natives in the Classroom* theme (under Section 6.3), today's learners demonstrate a natural affinity for technology. This evolution calls for teachers to elevate their technological skills to match their learners' capabilities. SSI-P1 articulates this aspect, emphasising the need for teachers to match the technological fluency of their learners:

> **[00:28:40] SSI-P1:** So, we—, as much as we expect them to be with it, we also need to be with it. You know, they're very technologically based on their own, you know, they can do lots of things over all the different various social media platforms. So, if we expect them to be so high level, we also need to be high level.

Perhaps in response to this challenge, or others like it discussed in certain themes under Sections 6.3 and 6.6, some teachers have adopted a more restrained approach to technology in the classroom. This includes teachers like SSI-P2, who have decided against using technology tools daily, underscoring a nuanced approach to integrating digital resources in educational settings. This decision reflects an understanding of the complexities involved in balancing technology use with other pedagogical methods:

> **[00:08:24] SSI-P2:** I do not use them on a daily basis, number one...

A mitigating approach, like SSI-P4 suggests, is to instead adopt a targeted use of technology, particularly in higher grades where learners are more mature and likely better equipped to benefit from digital tools:

> **[00:02:07] SSI-P4:** ...But I think it's very well and mature in Grade 11 and Grade 12.

Irrespective of learner grade, some teachers, particularly those adept at integrating technology in their teaching, are able to use digital tools to captivate and educate. They leverage the inherent appeal of technology to engage learners, steering their attention towards educational objectives. SSI-P6 elaborates on this approach, emphasising how appealing yet educational digital tools can be instrumental in enhancing learning experiences:

> **[00:10:07] SSI-P6:** ...you know, so I feel like that's the best way to—, to—, to, you know, I don't know, to—, to get them to see something that—, that's nice to look at, but also very educational, you know, so that has helped a lot...

In navigating the digital landscape of education, teachers encounter a diverse array of challenges and opportunities. This theme has woven together varied experiences, strategies, challenges, and insights, shedding light on the intricate balance teachers maintain while integrating technology in the classroom. Their journey, from the initial steps of integrating technology into teaching practices to the advanced stages of skilful and adaptive use, illustrates a landscape rich

with continuous learning and discovery.

The narratives highlight a spectrum of approaches: some teachers plan and adapt their teaching methods to leverage technological tools, while others adopt a more cautious or selective approach, choosing to use technology sparingly or in specific contexts. The agility to balance traditional and modern teaching methods, especially in consideration of varying learner access to technology, emerges as a key skill.

Ultimately, this theme reinforces the necessity of a thoughtful, dynamic approach to technology in education. It reaffirms that while technology offers vast potential for enhancing learning, its integration into education requires thoughtful planning, adaptability, and an acute awareness of the diverse needs and capabilities of learners.

6.5.2 **Responsive Pedagogy: Tailoring Teaching to Grade Levels and Learner Needs**

Building on the previous theme, *Responsive Pedagogy* encompasses the deliberate and adaptive teaching strategies employed by teachers to address the varying needs and capabilities of learners. This approach recognises the distinct requirements of different grade levels, with more mature grades often demanding intricate and extensive preparation. Beyond just grade-level considerations, responsive pedagogy emphasises the importance of reading and reacting to in-the-moment learner cues, such as visual signs of motivation or distraction. By blending careful preparation with on-the-spot adaptability, teachers practising responsive pedagogy demonstrate a commitment to fostering optimal learning environments that cater to each learner's unique needs.

In the following excerpt, SSI-P6 highlights the essence of responsive pedagogy by detailing their process of curriculum review and individual adaptation for each grade level's needs. This approach underscores a commitment to differentiated instruction, where teaching strategies are thoughtfully tailored to meet the distinctive abilities and developmental stages of learners. Through SSI-P6's methodical preparation, the educational experience is personalised, reflecting the teacher's dedication to cultivating an inclusive and effective learning environment. Such practice not only embodies the principles of pedagogical differentiation, but also reinforces the role of teachers as dynamic and responsive facilitators of the learning journey.

> **[00:01:13] SSI-P6:** Okay, so basically I start by reviewing the curriculum and identifying the specific topic in which we have to, [uhmm], look at during the time. Then I make sure that I cater for each grade, [uhmm], adequately. [Uhmm] So I make sure that I—, I make sure that I cater for, [uhmm], each student at every grade level, yeah, based on their capabilities basically.

Adding to this narrative, SSI-P1 points out that the complexity of teaching content scales with the grade level, necessitating more thorough preparation. Emphasising the importance of this groundwork, SSI-P1 notes that learners' gains from classroom sessions are contingent on the teacher's focused and extensive preparatory efforts. SSI-P1 explains:

> **[00:07:32] SSI-P1:** So, I find that the content is very high-level... So, prepping has to be done on another level where the Grade 12s are concerned... But where the Grade 12s are concerned, and the prep that's required for them, you have to do extensive research in prepping and consulting, you know, to make sure that you are at that level where they can understand what you're doing. So, if I am not prepared and I teach them something, obviously that's going to be very impacting.

Teachers' keen awareness of their learners' engagement is a crucial aspect of responsive pedagogy. They become adept at interpreting signs of waning attention or understanding through learners' subtle non-verbal cues in the classroom. Recognising these cues signals to the teacher the need to adjust their teaching methods or redirect the lesson's trajectory to recapture the learners' attention. This awareness and adaptability are fundamental to maintaining an effective learning environment. SSI-P1 shares their experience with this process:

> **[00:17:12] SSI-P1:** ...you know, if a child isn't focused, then for me, it's—, they're looking somewhere else, so, distracted by something, or you know, you have to interpret their facial expressions also quite a lot, because a lot of them have, you know, either blank faces or worried faces, so you have to really interpret body language quite a bit as well.

To recalibrate the classroom dynamic and refocus learners, teachers may employ a variety of strategies. SSI-P1 shares a proactive technique that involves gently challenging the learner who appears to have drifted away from the lesson. This method not only prompts the learner to refocus, but also serves as a cue for the rest of the class to reorient their attention to the lesson. Describing this interactive method, SSI-P1 explains:

> **[00:20:31] SSI-P1:** And when there's a learner that is—, I feel isn't engaged, I pick on that learner.
>
> **[00:20:34] RESEARCHER:** Yes.
>
> **[00:20:34] SSI-P1:** I'm saying: *"Where are you? What have we been talking about? What did I just say?"*
>
> **[00:20:38] RESEARCHER:** Yes...
>
> **[00:20:38] SSI-P1:** *"Tell me how we go about that..."* So asking them questions and redirecting what we're doing. To fo—, refocus them in—, engage them or reengage them into the lesson.

To conclude, this theme underscores the intricate art and science of teaching that is attuned to the diverse needs of learners across different grade levels and their varied capabilities. The insights provided by teachers demonstrate that effective teaching is not a one-size-fits-all endeavour, but rather a dynamic interplay between careful preparation and in-the-moment adaptability. Teachers must remain vigilant, adept at interpreting the often silent, but expressive language of their learners' engagement, and ready to pivot their strategies to ensure that every learner stays connected to the educational journey. Such a commitment requires a profound level of pedagogical sensitivity and a dedication to professional growth—qualities that are indispensable for fostering an inclusive, supportive, and effective learning environment. Ultimately, this theme celebrates the dedication of teachers who continuously evolve their practices to recognise, meet, and nurture the unique potential within each learner.

6.5.3 Pedagogical Technology Integration: The Journey of Teacher Training and Self-learning in Classroom Technology

This theme explores the evolution and progress of teachers as they seek to seamlessly integrate technology into their teaching methodologies. It delves into the avenues and resources—both formal and informal—that teachers employ in their journey towards technological proficiency. Recognising that the landscape of education is ever-evolving, especially with rapid technological advancements, this theme underscores the importance of continual learning and adaptation. Teachers often find themselves at the intersection of traditional pedagogical methods and the demands of a digital age. Thus, they navigate a spectrum of experiences, from formal training sessions to self-initiated research on platforms like YouTube, to collaborations with peers. While some teachers may have embarked on this journey without formal training, their drive to enhance learning outcomes through technology pushes them to innovate and learn. This theme also acknowledges the gaps and challenges, emphasising that there's always room for growth and improvement. Through all these layers, the central narrative remains the same: teachers' relentless pursuit of skills and knowledge to provide the best technology-enhanced education to their learners.

The journey of integrating technology into pedagogy often begins with a notable absence of formal instruction, compelling teachers into a self-guided exploration of educational technology. This scenario underscores a gap in the pedagogical training that teachers receive, necessitating them to independently seek out and develop the necessary skills to leverage technology effectively in the classroom. Reflecting on this, SSI-P1 and SSI-P3 shared:

> **[00:03:58] SSI-P1:** There was no training, I taught myself...

> **[00:04:09] SSI-P3:** Yeah, there is no formal training.

These remarks bring to light the resourcefulness and initiative required of teachers to fill the training void in this critical aspect of contemporary education. In this regard, it becomes evident that in the absence of structured training, teachers like SSI-P1 have had to seek out their own methods for developing technological proficiency. The reliance on self-help resources such as YouTube highlights the initiative and independence necessary to self-educate. Beyond individual effort, there is also an element of communal development, as these self-taught skills are then disseminated amongst colleagues. SSI-P1 narrates this experience:

> **[00:04:36] SSI-P1:** ...And, [uhmm], YouTube then became, you know, our best friend and stuff... So, I had to start that. So, I learned on my own. And then I shared with my colleagues here.

This illustrates the proactive stance that teachers like SSI-P1 take in order to enhance their pedagogical practices with technology, as well as the collaborative spirit that pervades their professional community, contributing to a collective elevation of skills and teaching quality. This collaborative journey is marked by continuous learning and professional development, as emphasised by SSI-P1's experience:

> **[00:07:32] SSI-P1:** ...I find that I'm learning a lot more...

SSI-P6 offers a contrasting viewpoint to the commonly cited gap in formal technology training for teachers. In a reflective account, SSI-P6 emphasises a more positive experience with the integration of technology into their teaching practice, facilitated by adequate training during their practical experience:

> **[00:00:40] SSI-P6:** Oh yes, I've definitely received proper, [uhmm], training when it comes to integrating technology into, [uhmm], mathematics lessons. And that's because I received my training through my practicals. So I was fortunate enough to do my practicals at the school which I am currently working at right now. So I can definitely say they were adequate, yeah.

SSI-P6's experience draws attention to the disparities in technology training amongst teachers, emphasising that where effective training protocols are in place, teachers can significantly benefit. Furthermore, it illustrates that while there are systemic gaps in providing comprehensive technology training for teachers, there are instances where the educational system successfully bridges these gaps.

In highlighting the complexities of technological integration in education, SSI-P4 differentiates between the ability to operate a piece of technology and the skill required to incorporate it into effective teaching. They reflect:

> **[00:02:49] SSI-P4:** [Uhmm] I would suppose. I'm in the fence with regards to that because no one necessarily teaches you how to fully use a smart board, for example. That's one of the technologies we use.
>
> **[00:02:59] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:02:59] SSI-P4:** We're taught how to operate it. Because I've seen people who are excellent at it and people who are just average, you can just do what it needs to do...

Through SSI-P4's observations, the dialogue shifts towards recognising the spectrum of proficiency amongst teachers, and underscores the importance of comprehensive training programmes that not only focus on the technical know-how to use technology, but also empower them to apply it creatively and effectively in their teaching.

On the topic of empowerment, SSI-P5 contributes to the dialogue by advocating for training programmes that empower teachers with the capability to create and curate their own digital learning materials. This skill would not only enhance their teaching toolkit, but also provide a repository of content for sustained use. Furthermore, this approach would provide the potential for teachers to become more autonomous and resourceful, crafting their own digital learning experiences tailored to their learners' needs and their own pedagogical style. SSI-P5 elaborates on this point:

> **[00:27:39] SSI-P5:** ...If a teacher can be able to curate content, you know, if they feel: *"Hhayi, angifuni ukubukela eka..."*

> [...]
>
> **[00:29:14] RESEARCHER:** ...they should be empowered to do so, yes.
>
> **[00:29:16] SSI-P5:** Yeah, they should be empowered to do so, create content so that let's say, at some point, they wanna, you know, do revision, they don't need to repeat themselves, right? And they can say: *"Right, watch this lesson, tomorrow* ***sizoyenza*** *something, you know, in line with, you know, what the revision that I've asked you to go through..."*

At its core, this theme has illuminated how technology integration in the classroom is a journey marked by teacher ingenuity and self-directed growth, occurring often without formal guidance. The collaborative spirit amongst teachers has been vital in developing the skills to effectively incorporate technology into their teaching. While some, like SSI-P6, have had the advantage of direct training, others underscore the need for professional development that empowers teachers as both users and creators of digital content, as suggested by SSI-P5. This highlights a pathway to a more personalised and effective use of educational technology. Ultimately, this theme captures the teaching profession's resilience in adapting to technological demands, advocating for a balanced approach where systemic support complements teachers' initiatives, ensuring technology enhances the learning journey for all.

6.5.4 Technology-induced Hiccups: Navigating Disruptions in Teaching due to Technology

This theme encompasses the varied challenges teachers face when integrating technology into their pedagogical methods. While technology offers a vast array of teaching and learning benefits, it is not without its disruptions. From its potential to divert attention away from core teaching objectives, to the occasional glitches and unexpected technical issues, technology can sometimes serve as a double-edged sword in the educational space. The theme highlights the need for teachers to be equipped not only with the skills to use technology, but also the strategies to mitigate potential distractions and disruptions that can arise in its wake.

The integration of multiple technological devices into the classroom aims to enrich learning, but can sometimes lead to an overwhelming mix of distractions. For teachers, the simultaneous management of these devices can create an overcomplicated and challenging teaching environment. Such complexities may subtract from precious lesson time, with teachers' attention divided between delivering educational content and managing technological interactions. SSI-P3 shares their experience in this regard:

> **[00:18:15] SSI-P3:** ...So there is—, there's a lot of destruction that's there... that just—, for—, it can distract me... (...inaudible...) ...are kind of distracting.

Teachers also contend with the unpredictable nature of technology, where occasional malfunctions demand immediate technical support and disrupt the educational process. Such interruptions can significantly derail the flow of a lesson and undermine its effectiveness. SSI-P6 reflects on the impact of such incidents:

> **[00:11:16] SSI-P6:** ...And, [uhmm], sometimes we do have techno—, technical issues that do, [uhmm], distract the whole class...

In sum, the adoption of technology in teaching is a double-edged sword; it offers innovative ways to engage learners, but also introduces potential disruptions. As teachers contend with distractions from multiple devices and unexpected technical issues, it becomes clear that effective integration of technology demands both adept management and prompt support. The crux of this theme is finding equilibrium: ensuring that technology acts as a bridge to enhanced learning rather than an obstacle, thereby preserving the integrity and fluidity of teaching.

6.6 Navigating the Digital Turn in Education: Tools, Impacts, and Imperatives

6.6.1 Visual Empowerment through Technology: Harnessing Digital Tools for Enhanced Perception in Mathematics

This theme focuses on the transformative role of technology in advancing visual learning methods within the teaching and learning of mathematics. Leveraging the innate human preference for visual information, digital tools are spotlighted as powerful enablers that simplify complex concepts, making them more digestible and engaging. Whether it is through dynamic graphs, interactive simulations, or vivid diagrams, technology not only enhances comprehension, but also amplifies interest, making mathematics lessons more appealing and accessible. From the perspectives shared, it is evident that the digital visual stimuli resonate deeply with learners, often becoming a source of enthusiasm and anticipation for mathematics classes.

SSI-P5 brings to the forefront the pivotal role of technology in enhancing the visual aspects of learning. This highlights how technology's capability to present information visually plays a crucial role in engaging learners, particularly in subjects like mathematics where visual aids can significantly enhance understanding. Here is how SSI-P5 articulates this aspect:

> **[00:05:57] SSI-P5:** ...And, you know, when you talk about the use of technology, ... it's punctuated by so many different aspects, you know, one, the visual effect, you know, ...

Building on this perspective about visual learning, SSI-P6 discusses how incorporating computers and other technology in the classroom enhances the learning experience by providing rich visual representations. This method of teaching is particularly appealing to learners, as it caters to their preference for visual learning and helps maintain their interest in the subject. Additionally, it underscores the notion that '*seeing is believing*' in the context of learning, while also illustrating how such approaches can serve as a gauge for teachers to measure learner interest and engagement in the subject matter in real-time. SSI-P6 articulates their observations:

> **[00:09:53] SSI-P6:** ...you are, [uhmm], trying to understand this. And basically, as—, as—, as we use computers and such, [uhmm], there's a lot of visual representation, you know, and kids love that. They—, they love seeing to learn...

> **[00:10:07] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:10:07] SSI-P6:** ...you know, so I feel like that's the best way to—, to—, to, you know, I don't know, to—, to get them to see something that—, that's nice to look at, but also very educational, you know, so that has helped a lot. So that's how I can see that they're interested.

SSI-P4 adds depth to the conversation by contrasting the traditional, text-heavy approach to learning with the vibrant, visually-rich experience provided by technology in mathematics education. They emphasise how digital tools introduce a vivid, colourful dimension to educational materials, creating a sense of wonder and opening new pathways for understanding complex subjects like mathematics. This fresh perspective not only captivates learners, but also encourages them to apply similar techniques in their studies. SSI-P4 reflects on this transformative effect:

> **[00:11:42] SSI-P4:** I—, I think, it—, ... , anything that has to do with the visuals, right, it changes everything. Because you must remember, these learners have been learning things from a textbook that's black and white, right? They're lucky if they had something that had colour. But when they can visualise this in a very new technological way, it's like, it's marvelling. *"I've never seen a graph drawn this way. I've never seen a diagram drawn in different colours. It means when I study as well, I can apply what sir is applying in the board. Instead of using a pencil, I can use different markers in my diagrams or my question papers."*

By highlighting the visual appeal of technology in education and its positive influence on learners, SSI-P1 notes that learners not only enjoy the visual elements of technology, but also benefit significantly in their learning process. This observation is concisely expressed in the following excerpt:

> **[00:19:40] SSI-P1:** ...So they get a lot more out of technology, visually, and they—...

Shifting focus to the role technology plays as a visual stimulus, SSI-P1 then brings to the fore the essential role that visual elements in technology play in enhancing learning. They assert the necessity of such visual stimuli for learners, particularly in subjects like mathematics, where conceptualisation can be greatly aided by visual representation. Technology, in this context, becomes a scaffold that is not just beneficial, but also essential, supporting and enriching learners' understanding. SSI-P1 elaborates on the importance of this aspect:

> **[00:18:49] SSI-P1:** ...[Uhmm] And for them, they do need visual...
>
> **[00:19:06] RESEARCHER:** Alright...
>
> **[00:19:07] SSI-P1:** [Uhmm] So for them being so visual, [uhmm], it is important for them to continuously see.

Continuing the focus on technology as a key visual stimulus in learning, SSI-P4 comments on the stimulating nature of digital visuals compared to conventional print materials. They highlight how digital visuals can capture and retain learners' attention more effectively than traditional methods, such as printed materials. By incorporating vibrant and interactive technology

into lessons, learners are offered a more stimulating and captivating educational experience. SSI-P4 explains:

> **[00:07:35] SSI-P4:** And what that does, it's like a visual, and it stimulates the learners so that they can look at something instead of, for example, printing that on paper...

SSI-P2 adds to the narrative by emphasising the dynamic role of the smart board as a multifunctional technological tool in the classroom. They point out the smart board's ability to present diverse visual multimedia representations, effectively capturing learners' interest across various content areas. SSI-P2 articulates the importance of interactive visual technology in enhancing learner interest:

> **[00:14:07] SSI-P2:** My learners would be interested when we are using smart boards, when we're watching videos, even if it's YouTube videos explaining math concepts. That is when they get interested, just watching something from the smart board.

This perspective from SSI-P2 showcases the smart board as a key instrument in facilitating an interactive and visually stimulating learning environment. It exemplifies how incorporating diverse visual stimuli through technology can make even complex subjects like mathematics more accessible and engaging for learners.

Overall, the visual empowerment facilitated by technology, as captured by this theme, stands as a testament to the evolution of modern pedagogy, where abstract concepts are transformed into tangible visual narratives, bridging the gap between theoretical mathematics and its real-world visual applications. This approach is not just effective in mathematics, but may also extend to other subject areas, serving as a pivotal aspect of contemporary digital pedagogy. It significantly enhances the educational journey, reinvigorating learner enthusiasm, interest, and engagement across various disciplines. Furthermore, it highlights the evolving skill set required of teachers, as already alluded to in earlier themes in this chapter. As they adapt to these innovative tools, teachers play a crucial role in effectively integrating technology, ensuring it enhances rather than hinders the learning experience. This dual focus on learning and teacher development underscores the comprehensive influence of visual technology in the educational landscape.

6.6.2 Digital Renaissance in Education: Redefining Flexibility, Engagement, and Boundaries

The *Digital Renaissance in Education* theme addresses a transformative epoch in teaching and learning, powered by technological advancements. Just as the historical Renaissance marked a rebirth of art, culture, and intellectual pursuits, this digital revival denotes a profound shift in educational methodologies and learner experiences. Technology, in this context, is not just a tool, but a catalyst, driving profound changes in how teachers prepare and deliver content, how learners engage with this content, and how the very boundaries of the educational space are perceived. This theme captures three essential dimensions of this transformation: *Flexibility*, *Engagement*, and *Boundaries*. These form the basis of the three subthemes which are further expounded in the following subsections.

Technological Advantages and Flexibility

Technological Advantages and Flexibility explores the integration of technology in the classroom and its influence on instructional design and delivery. This subtheme highlights how technology infuses agility and adaptability into teaching methods, allowing teachers to swiftly tailor content, methodologies, and even pacing to meet the diverse needs of learners. It emphasises the transformative nature of digital tools, which inject a fresh dynamic into traditional teaching approaches, creating a more responsive and engaging educational environment. A central aspect of this subtheme is striking a balance between innovative technological practices and the established effectiveness of traditional methods. This equilibrium is crucial in fully leveraging technology's potential in education, ensuring it acts as a catalyst for progress while honouring the essential principles of conventional teaching.

Modern technology, particularly the use of wireless devices like Bluetooth tablets, has significantly altered the classroom landscape. Gone are the days of teachers being confined to the front of the classroom, a position that often implied a strict, authoritative role. Now, equipped with these modern tools, teachers can move amongst their learners, breaking down barriers and cultivating a more interactive and accessible educational environment. This shift in teaching dynamics, as SSI-P1 illustrates, fosters a more inclusive and interactive educational environment:

> **[00:06:49] SSI-P1:** ...And then have my writing tablet (. . . inaudible. . .) with the pen. It used to be, [uhmm], a wired lap—, [uhmm], writing tablet, but now it's a Bluetooth tablet.
>
> **[00:07:12] RESEARCHER:** Alright...
>
> **[00:07:12] SSI-P1:** So, I can walk around...

SSI-P1 further elucidates the transformative effect of adopting wireless technology in educational settings. The shift from a wired to a Bluetooth tablet is not just a technological upgrade, but a gateway to a new chapter in educational engagement. With the newfound mobility and flexibility offered by wireless devices, teachers can interact more effectively with their learners, gaining insights into their learning processes, and providing more tailored guidance. SSI-P1 articulates:

> **[00:21:03] SSI-P1:** ...Even when I transitioned from having my wired, [uhmm], tablet to a Bluetooth tablet, it opened a different chapter, you know...
>
> **[00:21:23] RESEARCHER:** Alright...
>
> **[00:21:24] SSI-P1:** ...in that I could now engage more with them.
>
> **[00:21:27] RESEARCHER:** Alright...
>
> **[00:21:27] SSI-P1:** Because I can now walk around more, I can see more what they're doing, etc.

SSI-P4 highlights how technology significantly streamlines the lesson preparation process, en-

hancing flexibility and communication in teaching and learning. By using technological tools, teachers can create more dynamic and visually engaging lessons. For example, SSI-P4 uses various colours and shapes to illustrate complex diagrams, aiding in the clarity and comprehension of challenging concepts. This technological approach allows for a more organised and visually distinct presentation of concepts, enabling learners to understand and differentiate between various elements of the lesson. Moreover, this method not only simplifies the teaching process, but also primes learners for the lesson ahead. SSI-P4's use of technology goes beyond mere presentation; it facilitates proactive planning, addressing potential learner queries and focusing on critical areas, thereby ensuring a smooth, well-prepared, and engaging learning experience. This method contrasts sharply with traditional teaching methods, where the structure and content of lessons are often unpredictable and less interactive. SSI-P4 captures this in the following excerpt:

> **[00:03:59] SSI-P4:** ...And then while I'm preparing my lesson, I use different colour notations to draw different shapes and sizes of the diagrams that I'm going to be teaching. And also on a side note, I mentioned possible questions that the learners might ask and possible ideas that I will probably need to spend more time in. And in that way, it makes the lesson very, very smooth and very prepared.
>
> **[00:04:39] RESEARCHER:** So you draw these shapes on the smart board?
>
> **[00:04:41] SSI-P4:** Yes, I do. Using different—, different colour notation because the trick in—, in—, in Euclidian geometry, it's five diagrams drawn in one, right?
>
> **[00:04:49] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:04:50] SSI-P4:** So to separate them, you need to use different colour notation to see which shape is saying what and what story is it telling in relation to all the other shapes as well. So it's very, very useful. I think the more important one, I think it's the pre-suggestion and the notifying of the learners because in the heyday, many years back, you never knew what lesson you were going to do, which topic you were going to cover, and what are you expected. You just go to class and then you're surprised as the teacher goes through the session.
>
> **[00:05:19] RESEARCHER:** Hmmm, that's true.
>
> **[00:05:20] SSI-P4:** Yeah, so while your mind is primed for the classroom, I think it's—, although you don't know fully what the context is, but your mind is ready for it and receives it very well.

Resonating with SSI-P4's perspective, SSI-P1 underscores the significant role of technology in enhancing educational presentations, particularly in mathematics. The use of technology in the classroom allows for more vibrant, colourful, and accurate visual representations, greatly enriching the learning experience for learners. This technological capability introduces a higher degree of flexibility in teaching methods. SSI-P1 highlights the distinct advantages of using digital platforms over traditional methods (which may fall short due to time constraints and potential inaccuracies), such as the ability to use a broader range of colours and create more accurate diagrams with ease, which is especially beneficial in subjects requiring detailed visual aids like mathematics. SSI-P1 notes:

> **[00:19:13] SSI-P1:** You know, so that technology aspect also, you know, on the computer, I can use five more different colours than I can with just the normal...
>
> **[00:19:20] RESEARCHER:** Yes...
>
> **[00:19:21] SSI-P1:** ...[uhmm], whiteboard marker. You know, if that makes sense. So I can go and highlight, I can go and underline, I can, [uhmm], draw acc—, more accurate images using OneNote, etc., you know, show a Cartesian Plane, whatever, whereas here, it takes time and the inaccuracies are a lot more, you know, for example, just drawing a trig function, or...
>
> **[00:19:39] RESEARCHER:** Yes...
>
> **[00:19:40] SSI-P1:** ...whatever the case may be.

In further elaborating on the flexibility provided by technology in the classroom, SSI-P4 delves into the versatile nature of the smart board in the classroom. This tool is lauded for its adaptability and multifunctionality. Beyond being a simple writing surface, the smart board acts as a large-scale computer, where teachers can not only write, but also upload and interact with documents. It allows for a seamless integration of various teaching aids, such as displaying diagrams while simultaneously drawing or annotating them, enhancing the clarity and engagement of the lesson. SSI-P4 aptly describes it as akin to a tablet, but on the scale of a liquid-crystal display (LCD) screen, thus significantly enriching the educational experience with its expansive and interactive features:

> **[00:06:16] SSI-P4:** Yeah, but you can write on it, you can open it like a computer, you can put documents on it and you can stick documents, like for example, a diagram on the screen while you answer that question or draw on the diagram. So it's literally having a tablet the size of an LCD screen in the classroom.

Building on the insights shared by SSI-P4 about the smart board, SSI-P5 emphasises the significant time-saving benefits and flexibility afforded by using a tablet in the teaching process. Like the smart board, the tablet is a tool that significantly enhances the flexibility and efficiency of the teaching process. SSI-P5's reliance on the tablet for tasks such as annotating, exporting resources, and overlaying content echoes the versatility that SSI-P4 highlighted with the smart board. In geometry, for instance, where interactive teaching is essential, the tablet streamlines the process by reducing the time needed for drawing and redrawing diagrams. SSI-P5 observes that this reduction in time-consuming activities allows for a more focused and in-depth teaching experience, thereby improving the overall efficiency and effectiveness of the educational process:

> **[00:10:10] SSI-P5:** [Uhmm] Okay, so I rely a lot on using a tablet. Yeah, and for the sole reason that you can annotate stuff, you can, you know, export, you know, resources onto it. You know, obviously, you can try to superimpose and try to annotate, you know, onto, you know, whatever it is that you exported, especially when you're dealing with things like geometry, you know, it needs to be something that is as interactive as possible. What it also does, *mfowethu*, is that it also cuts down a lot of time. You know, you'd imagine if you have to try and redraw, you know, let's say a

> sketch, you know, *ye*-geometry, right?
>
> **[00:11:06] RESEARCHER:** Hmmm...
>
> **[00:11:06] SSI-P5:** That's time taken away from the actual lesson, right?
>
> **[00:11:11] RESEARCHER:** Hmmm...
>
> **[00:11:12] SSI-P5:** And to be quite honest with you, you know, for me, I think it just helps with efficiency...

This parallel in the use of different technological tools underscores a broader theme: the transformative role of digital devices in reshaping educational methodologies, making them more dynamic, time-efficient, and conducive to interactive learning. SSI-P3 brings a unique perspective to the discussion, focusing on the impact of software solutions. This shift from physical devices to software underscores the breadth of the digital transformation in the classroom. SSI-P3 points out how even a simple, software-based writing template, originally designed for drawing, can be repurposed to enhance writing exercises with its detailed capabilities. This simple yet innovative application of software tools demonstrates their critical role in augmenting classroom flexibility, enabling teachers to adapt various digital solutions to meet specific educational needs. It reveals another layer of the digital renaissance in education: the fusion of both hardware and software innovations to create a more dynamic, efficient, and versatile learning environment. Encapsulating this, SSI-P3 notes:

> **[00:06:37] SSI-P3:** Basically, I have a—, a writing template.
>
> **[00:06:41] RESEARCHER:** Okay...
>
> **[00:06:41] SSI-P3:** [Errrhm] It's a work-on template, which is meant for drawing, but I use it for writing because now it allows all the detail.

The integration of technology in education not only enhances learning, but also establishes a new norm for speed and efficiency in the classroom. As SSI-P1 observes, this becomes evident when technology is absent or limited. In a setting where teachers and learners are habituated to the use of digital tools, the lack of these resources noticeably slows the classroom rhythm. Without the aid of digital resources, teachers are compelled to revert to more traditional methods, such as writing on the board, which is time-consuming and less efficient. Erasing and rewriting on the board, a process once standard, now seems cumbersome in contrast to the streamlined efficiency technology offers. SSI-P1's experience highlights how integral technology has become to maintaining a swift and effective classroom discourse, with its absence markedly impacting the speed and fluidity of lessons:

> **[00:18:36] SSI-P1:** ...if I don't have my technology, we are a lot slower...
>
> **[00:18:42] RESEARCHER:** Alright...

> **[00:18:42] SSI-P1:** ...because everything has to be now written out in the board, then you must erase the board, and you must start again. So the—, the speed factor...

While the advantages of technology in the classroom are clear, SSI-P4's insights serve as a cautionary reminder about the reliance on these tools. They emphasise that technology should be viewed primarily as a supplement to the teaching and learning processes, rather than the sole focus. This perspective is crucial to maintain a balanced educational approach, where technology enhances rather than completely replaces traditional methods. SSI-P4's experience also reflects a broader trend: teachers who skilfully integrate technology into their teaching can gain a special reputation amongst learners as innovators and champions of modern educational practices. However, the fundamental goal remains to use technology to support and enrich, not to overshadow, the core principles of teaching and learning. In SSI-P4's words:

> **[00:13:58] SSI-P4:** [Uhmm] I've—, I've gained a reputation for it being something that supplements and helps them.

Aligning with SSI-P4's insights, SSI-P5 also stresses the supplementary nature of technology in educational settings. They articulate that while technology plays a significant role in the classroom, especially during the packed schedule of a typical school hour, its purpose is to enhance and support the existing teaching and learning processes, not to overshadow them. This reinforcement of technology as a supplementary tool highlights its limitations in replicating certain aspects of traditional teaching, such as the irreplaceable value of live, interactive communication between teachers and learners. SSI-P5 articulates:

> **[00:16:03] SSI-P5:** ...Right. But what it's actually as you indicated earlier on, that what it's supposed to do is supplement. Right. So you can imagine what happens within a one hour period in a school. Right. You know, *uthole ukuthi* you can't rewind what the teacher has said.

SSI-P5, an enthusiast in content creation, brings to light another significant benefit of technology in the classroom: the value of secondary or recorded content. This aspect of digital technology is a powerful supplement to conventional teaching techniques, as it allows for the replication and distribution of lesson content at any time. Through the use of recordings, technology extends the reach of educational material, allowing learners to access and review lessons at their convenience. This is an important aspect, as it enables continuous learning while also accommodating various learning paces and styles. Additionally, this capability of making educational content universally accessible not only reinforces the lessons taught in class, but also democratises education, catering to the diverse needs of the modern learner. SSI-P5 captures this sentiment in the following excerpt:

> **[00:16:48] SSI-P5:** ...So what it simply does is that it just takes the content that you see in class and it makes it accessible to you at any given point in time.

Elaborating further on the practical applications of secondary or recorded content in the classroom, SSI-P5 presents a specific use-case that demonstrates its effectiveness. By strategically integrating this type of content into regular lessons and for revisiting past topics, SSI-P5 illustrates how technology can be actively used to enrich both teaching and learning. This ap-

proach goes beyond mere supplementation; it actively engages learners and revitalises the learning atmosphere. The excitement and enthusiasm elicited amongst learners when incorporating recorded content into lessons, as observed by SSI-P5, again highlight the transformative effect such practical teaching methods can have:

> **[00:18:52] SSI-P5:** ...So what—, what I've actually done in my class is that, you know, now and then I would say: *"Hey, **wozani**! Come, let's watch..."*. And then, you know, use that to supplement for—, for—, for teaching and learning. So I really have been encouraged by the sense of excitement that I get...

In summing up this subtheme, the insights from the participant teachers offer a compelling overview of how technology serves as a pivotal enhancement in education. Through the adept use of digital tools like tablets, smart boards, and secondary or recorded content, this theme highlights a significant evolution in the teaching and learning processes. These technologies enrich the educational experience by introducing greater interactivity, efficiency, and flexibility, effectively meeting the diverse needs and learning styles of learners. Yet, as highlighted by the participant teachers, the integration of technology must be thoughtfully balanced with traditional teaching practices. It is a tool to augment, not overshadow, the fundamental principles of education. The true essence of this digital renaissance lies in its ability to meld the best of both worlds—traditional and digital—creating a more inclusive, dynamic, and engaging learning environment for all learners.

Learner Engagement and Enriched Experience

In this subtheme, the focus is on technology's dual effect in modern education—both enhancing learner engagement and enriching the educational experience. Building upon the insights from the previous subtheme, this subtheme delves deeper into the role of digital tools, going beyond their supplementary function in teaching and learning processes. This narrative showcases how technology serves as a bridge to more accessible, relatable, and captivating learning experiences, transforming education from a routine necessity into an engaging and dynamic journey for learners. It illustrates how technology supports diverse learning styles, promotes active participation, and facilitates interaction, thereby creating an environment that inspires learners to explore and discover. Central to this narrative is the recognition that technology is not just an ancillary tool, but a fundamental element in crafting a learner-centric and enriched educational landscape.

Continuing from the insights of the previous subtheme, SSI-P2 acknowledges the supportive role of technology in the teaching and learning process. Emphasising a strategic and balanced use of technology, they clarify that it should not overshadow the essence of the lesson, but rather serve as an enhancement. This approach aligns with the previously emphasised need for a balance between traditional teaching methods and technological tools, ultimately serving to reinforce and enrich the learning experience. By doing so, SSI-P2 maintains a blend of traditional and modern educational practices, ensuring that technology acts as a facilitator rather than the core of the lesson. Elaborating on this balanced integration, SSI-P2 notes:

> **[00:08:24] SSI-P2:** ...And then I use them as support for what I have taught the learners. So I just don't depend on them for the whole lesson. I—, I would teach first, and then I use them as support.

For subjects traditionally perceived as difficult, like mathematics, SSI-P2 further highlights how the incorporation of technology in the classroom can significantly change the way learners view and engage with these subjects. Through the use of digital tools, mathematics becomes a more enjoyable and less intimidating subject for learners. This change in perception is crucial, as it not only makes mathematics more engaging, but also helps to alleviate the anxiety often associated with it. SSI-P2 captures this sentiment with the following remark:

> **[00:12:00] SSI-P2:** It makes—, I would say, it makes maths more fun and less—, yeah, it makes less intimidating, if I may say.

Echoing SSI-P2's observations, SSI-P6 adds to the conversation about the role of technology in revitalising subjects like mathematics. They underscore how incorporating technological tools into mathematics classes significantly boosts their fun and interactive elements. The utilisation of technology in this way shifts the educational experience from merely informative to actively engaging. Capturing this effect, SSI-P6 remarks:

> **[00:10:52] SSI-P6:** ...It makes, [uhmm], math class very fun and very interactive, even if it's not.

SSI-P1 highlights another crucial aspect of technology's influence in education: its ability to expedite the learning process. This facet of digital integration into the classroom goes beyond enhancing learner engagement; it directly impacts the speed at which learners can assimilate and understand new information. This increased pace is not just about covering more material in less time, but also about fostering a more efficient and effective learning environment. SSI-P1 succinctly captures this with their statement:

> **[00:19:40] SSI-P1:** ...they move at a faster pace with the technology.

Furthering the discussion, SSI-P1 underscores the significance of even the most basic technological tools in stimulating learner interest and excitement in the classroom. Highlighting the example of a scientific calculator, they illustrate how such a fundamental device can play a pivotal role in engaging learners. SSI-P1 points out that the excitement generated amongst learners when they discover new functionalities and applications of these basic tools is a key aspect of how technology can enrich the learning experience. Consistent with patterns identified in earlier themes, it fosters a sense of enjoyment and curiosity, which are crucial for effective learning. This aspect of technology, as SSI-P1 notes, not only makes learning more interesting, but also deepens the learners' appreciation for the subject matter. SSI-P1 captures this sentiment with the following remarks:

> **[00:15:47] SSI-P1:** But they get very excited to see that their calculator can do much more than just add two plus two, you know...
>
> **[00:15:53] RESEARCHER:** Okay...
>
> **[00:15:53] SSI-P1:** So just the—, the basics moving on into more—, something more. It's very interesting to them. They quite enjoy it.

SSI-P6 reinforces the idea, as noted by SSI-P1, that technology's introduction to the classroom often sparks excitement amongst learners. This excitement is more than just a fleeting response; it represents a significant shift in the learners' engagement and interest levels. The laughter in SSI-P6's voice as they share this observation conveys the palpable enthusiasm that technology can inspire in an educational setting. SSI-P6 aptly expresses this sentiment:

> **[00:08:40] SSI-P6:** ≪ *laughs* ≫ As I said, [uhmm], it—, it's a bit exciting for them at times...

SSI-P4 adds a new dimension to the ongoing discussion on technological integration in education, tying back to the first subtheme. They highlight the cost-effectiveness of using technology as a significant advantage in adopting a technological approach in the classroom. More than just a cost-saving measure, technology, according to SSI-P4, also serves to enhance the learning experience by drawing learners' attention, stimulating their minds, and ensuring their active engagement in lessons. They further point out that with technology, the need for traditional and often costly educational resources like textbooks and photocopies can be significantly reduced. SSI-P4 encapsulates these benefits of technology in the classroom with the following insights:

> **[00:07:46] SSI-P4:** ...So it draws attention to the whole lesson, to what you're talking about, and it's very stimulating. And I think it's also cost effective as well.
>
> **[00:07:56] RESEARCHER:** Hmmm...
>
> **[00:07:56] SSI-P4:** You don't have to buy many textbooks. You don't have to do photocopies that learners lose anyways, and it's engaging. So yeah, that's the summary of it.

For SSI-P6, emphasis is on the importance for teachers to stay current with technological advancements, especially those that can enrich the learning experience in classrooms. They point out that using technology in teaching is particularly appealing to learners, many of whom are already familiar with various aspects of digital tools in their daily lives. This familiarity makes technology a powerful medium for connecting with learners, effectively meeting them halfway in their learning journey. The use of technology, according to SSI-P6, not only resonates with the youth, but also fosters a reciprocal learning environment where learners are more receptive and engaged. SSI-P6 articulates this perspective, stating:

> **[00:15:14] SSI-P6:** ...But I feel like as time moves, we also have to move with it, you know. So I feel like this is a great opportunity just to, [uhmm], show how technological tools do enhance learning for learners. And yeah, it's—, it's—, yeah... I—, I feel like if you meet learners or the youth halfway, it really does work. And using technology tools meets them halfway.

Aligning with SSI-P6's insights on keeping in step with technological progress, SSI-P1 takes a pragmatic approach by incorporating social media platforms like WhatsApp into their teaching strategy. This approach creates a virtual space for direct communication with learners and enables them to interact amongst themselves, sharing notes and educational content. While this method may only be accessible to those learners who have the necessary devices, it represents a progressive step towards meeting youth in their digital comfort zone. This approach not only aligns with modern communication methods, but also enhances learner engagement with lesson content. SSI-P1 describes their experience with using WhatsApp as an educational tool:

> **[00:26:24] SSI-P1:** ...In addition to that, I've created WhatsApp groups for them to communicate with me, but I don't know if that's technologically based. You know, it's just then sharing information, sharing documents, [uhmm]...

Staying within the discussion on the use of social media tools like WhatsApp for communication, SSI-P1 broadens the discussion to the wider role of technology in cultivating diverse interactions within the educational environment. Similar to how WhatsApp creates a platform for interaction, they recognise that technology in a wider sense supports multiple forms of interaction within the classroom: between teachers and learners, amongst learners themselves, and between learners and the content. Amongst these, SSI-P1 places special emphasis on the teacher-to-learner interaction, considering it a key indicator of the classroom's overall climate and the learners' understanding. The prevalence of technology in the classroom simplifies and enhances these interactions, making them more dynamic and effective. It allows for a more nuanced understanding of where each learner stands in their educational journey. SSI-P1 elaborates on this point, stating:

> **[00:20:14] SSI-P1:** So, there's obviously different levels of the way that you engage. I can engage with the learner, the learner can engage with another learner, and then engage with me... and then engage in a group.
>
> **[00:20:24] RESEARCHER:** Alright...
>
> **[00:20:14] SSI-P1:** [Uhmm] But I feel that the teacher-to-learner, is obviously very, very important because it tells me where they are at.

In addition to facilitating and cultivating classroom interactions, technology is also crucial for bringing abstract mathematical concepts into a context that learners can relate to and understand. SSI-P5 elaborates on the use of technology to weave storytelling into the teaching of mathematics, thereby transforming the subject from a series of abstract constructs into relatable, everyday concepts. This method, which integrates technology with narrative techniques, effectively brings mathematical ideas into the context of learners' daily lives, making them more concrete and understandable. This practical application helps learners see the relevance of mathematics in their own experiences. SSI-P5 shares their perspective on this approach:

> **[00:11:41] SSI-P5:** ...You know, I've used the concept of storytelling, if I can just show you something that I did, the concept of storytelling to make the subject accessible within the context of daily living, right? To show that these are not just, you know, abstract constructs, you know, or figures of someone's imagination, but it's something that lends itself practically every single day, right? You experience these things, but it's just that we don't often, you know, bring them into the light, you know, and into the user, I mean, into the students' experience on a daily basis...

Revisiting the importance of secondary or recorded content as a supplemental tool, as discussed in the previous subtheme, SSI-P1 emphasises the effectiveness of video resources that accompany their mathematics textbook. These resources, beyond just being convenient supplements, actively encourage learners to take the initiative in their respective educational journeys. Technology, in this context, acts as an effective partner in homework and study, allowing learners to engage with the content through videos that explain and demonstrate mathematical concepts and problem-solving techniques. This self-directed approach to learning, facilitated by technology, not only supports learner engagement, but also enriches the learning experience. SSI-P1 describes how these technological tools complement traditional learning methods:

> **[00:26:02] SSI-P1:** So, what happens is on their own, the learners can then go ahead and watch videos based on the work that they're doing. So...
>
> **[00:26:08] RESEARCHER:** Alright...
>
> **[00:26:09] SSI-P1:** ...this textbook then opened up, [uhmm], videos on examples, videos on how to do those sums, etc. So, then, [uhmm], we said that they could, [uhmm], go ahead and do the homework to the best of their ability and study using those—, those resources.

Expanding upon the idea of a self-directed approach to learning, SSI-P5 delves into the advanced capabilities of technology in education, particularly focusing on the valuable insights gained from data analytics. As someone involved in content creation, SSI-P5 values the analytics generated by the platforms hosting their educational content, as these data offer insights into how learners interact with the material. Such analytics can reveal which aspects of the content are most engaging or challenging for learners, providing a level of insight beyond traditional teaching methods. This level of insight, grounded in empirical data, is invaluable for assessing learner engagement and tailoring the educational experience. Moreover, these platforms often allow for learner feedback through comments, offering teachers actionable insights to improve the educational experience based on direct learner input. SSI-P5 points out that technology's greatest benefit lies in its ability to provide empirical evidence of engagement, transforming subjective observations into data-driven conclusions. SSI-P5 elaborates on this advantage of technology in education:

> **[00:22:50] SSI-P5:** You know, so herein lies the advantage of using technology, right? Because you are not only—, this thing is not just a concept and a figment of your own imagination, but you've got data *mfowethu*, you know, you've got data to actually corroborate, you know, your claim. So what happens is that there is the analytics, you know, that are given on, you know, by these platforms. So you're able to see exactly how they engage with the stuff, right? You're able to see, you know, from the comments section, you know, by you're able to see from their comments

> that they actually have watched and they are now engaging back there. ... So the beautiful thing about having technologies is exactly that. We've got an added benefit, right? Of now being able to extract data and say: *"Look, so here it is..."*

In sum, this subtheme has revealed that technology's greatest strength lies in its ability to resonate with learners, meet them at their level of familiarity, and provide teachers with the tools to tailor the learning experience effectively. Furthermore, it has demonstrated its potential capability to facilitate interactive classroom dynamics, integrate social media platforms, leverage video resources, and personalise learning experiences through data analytics. Each aspect underscores technology's role as a vital catalyst in enriching and diversifying educational approaches. The insights from this exploration reflect a broader trend towards a digital-first approach in education, where technology is harnessed to create more immersive, responsive, and learner-centred learning environments.

Pedagogic Enablers and Extended Boundaries

Pedagogic Enablers and Extended Boundaries reflects on the role of technology as a fundamental enabler in the evolution of modern education. This subtheme considers the broad ways in which digital tools and platforms are transforming traditional teaching and learning spaces. Emphasising the idea of education transcending physical and conventional boundaries, it explores how technology facilitates a more connected, global, and accessible learning experience. Furthermore, it explores technology's capacity to tailor learning experiences to individual needs, and prepare learners for a digitally integrated future. Central to this narrative is the concept of technology not just as a tool, but as a catalyst that opens up new avenues for inclusive, diverse, and interactive educational practices.

The versatility of technology is key in its role as a pedagogic enabler, as observed and articulated by SSI-P5. They highlight how technology enriches the learning environment by providing a multi-sensory experience, particularly enhancing auditory learning. This approach to education, supported by various technological tools and techniques, diversifies and deepens the sensory engagement of learners. By integrating various auditory and sensory elements into teaching methodologies, technology facilitates a richer, more engaging learning process. SSI-P5 elaborates on the potential of technology to amplify and diversify the sensory aspects of learning:

> **[00:05:57] SSI-P5:** ...And, you know, when you talk about the use of technology, ... it's punctuated by so many different aspects, ... you know, obviously, the auditory effects, and you can also incorporate many other things within your pedagogical style of teaching, *uyabona*, so that you engage as much, you know, of the sensory experience as possible...

SSI-P4 further elaborates on the concept of technology as a pedagogic enabler, underscoring its effectiveness in accommodating the diverse spectrum of learners within a typical classroom. Recognising that each learner has unique learning needs and approaches, SSI-P4 points out the adaptability of technology in addressing this diversity. It provides a platform that is equally beneficial for learners who excel academically, those who are consistently hard-working, and even those who may not display conventional talent, but show commitment and effort. This inclu-

sive approach enabled by technology is crucial in acknowledging and supporting the individual learning paths of each learner. SSI-P4 articulates this inclusive capacity of technology:

> **[00:15:35] SSI-P4:** ...So it engages learners in a very different way because it accommodates the learners that are very super bright and the learners that are working hard and they're getting recognition. And the learners that are not necessarily talented, but they're putting in what's the effort...

SSI-P4 focuses on the smart board as a standout technological advancement in the educational landscape. They regard it as a tool that has profoundly changed the nature of classroom teaching. The smart board, with its ability to facilitate interactive learning experiences, represents a significant departure from conventional instructional methods. It has become a quintessential example of how technology can drastically enhance classroom discourse and learner engagement. SSI-P4 expresses this transformative impact:

> **[00:05:56] SSI-P4:** Oh, so specifically the smart board. I don't think there's anything that has revolutionised teaching in the classroom like smart board and stuff like that...

SSI-P2 reinforces the importance of the smart board in enhancing classroom experiences, detailing its specific applications. They point out how smart boards enable access to Supplementary Digital Learning Resources (SDLRs) from the GDE, which are instrumental in providing structured learning materials. These resources include a rich repository of questions and various templates for different subjects, including mathematics. This integration of technology simplifies both the preparation and teaching processes, allowing teachers to devote more time and attention to learners rather than to extensive preparatory tasks. This efficiency gain allows for a greater emphasis on interactive and learner-focused teaching methods. SSI-P2 describes their experience on this approach:

> **[00:07:43] SSI-P2:** Okay, so we use smart boards, and they have, [uhmm], SDLR[a], which is like a site that has activities for all the subjects, math—, maths included. And then the presentations are also found on the SDLR, as well as some questions.

[a] The GDE offers a variety of SDLRs, including digital lessons, study guides, e-books, 2D/3D animation videos, and examination guidelines, accessible through the online GDE Content Portal via this URL: https://gdecontent.co.za/login/index.php. These resources are intended to support both learners and teachers.

Building on the notion of interactive and learner-focused teaching, SSI-P4 reinforces the value of technology as an essential tool in the classroom. Specifically, they highlight its ability to simplify complex tasks and concepts. For SSI-P4, the adoption of technology in teaching is a deliberate and strategic choice, aimed at making difficult concepts more accessible and comprehensible to learners. This approach echoes the balanced use of technology highlighted in the first subtheme. It is through this lens that technology becomes a critical tool in enhancing understanding and facilitating learning, especially in areas that learners might find challenging. SSI-P4 articulates the value of technology in facilitating this aspect of teaching:

> **[00:13:37] SSI-P4:** ...Because when I—, when I make a transition to use that technology, it means I'm using something. I'm trying to explain something that's very complex and trying to simplify it.

SSI-P6 takes a holistic view of the role of technology in education, seeing it as a gateway to a world of possibilities that extend far beyond the classroom walls. They perceive technology not just as a tool for immediate educational purposes, but as a preparation for future real-life settings. This forward-thinking approach, as articulated by SSI-P6, fosters anticipation and excitement amongst learners about their future prospects. By incorporating technology into the learning process, teachers are not just teaching curriculum content, but are also equipping learners with skills and experiences that are valuable in real life. SSI-P6 encapsulates this vision of technology as a preparatory tool for the future:

> **[00:13:17] SSI-P6:** So when it comes to technology, obviously also using the gadgets, [uhmm], it also helps in the real life setting. So I feel like we're setting them up for the future. So I feel like they're quite excited about that. So, yes.

Expanding the discussion, SSI-P6 specifically addresses the dynamic role of online educational platforms in reshaping the educational landscape. They emphasise that these platforms extend far beyond the confines of traditional classroom learning, offering learners a gateway to a wider array of mathematical challenges and concepts. This expansion is pivotal for broadening learners' academic horizons, exposing them to diverse topics and challenges that extend beyond the typical classroom curriculum. This expansion of knowledge and perspective is a crucial benefit of incorporating technology into education, instilling key skills in learners that will become invaluable in their future endeavours. SSI-P6 discusses the broadening influence of these platforms:

> **[00:04:17] SSI-P6:** ...Then, [uhmm], when it comes to, [uhmm], the online educational platforms, that's, [uhmm], a great way of, [uhmm], finding out more about math problems that we don't necessarily do in traditional, [uhmm], classrooms. So that just broadens, [uhmm], the—, the students' horizons, if I can say so, yeah.

In agreement with SSI-P6's view, SSI-P5 acknowledges the significant shift in education brought about by online platforms. SSI-P5 articulates this change by likening it to a "classroom without walls", a metaphor that vividly captures the essence of modern education's departure from conventional confines. This description by SSI-P5 illustrates effectively how technology has expanded the boundaries of learning, creating an open and limitless educational landscape. Such an approach signifies a departure from the traditional, walled classroom setting, embracing a more accessible and far-reaching educational model. SSI-P5 succinctly encapsulates this idea:

> **[00:05:57] SSI-P5:** ...I often look at it as having a classroom without walls...

SSI-P5 highlights the unique characteristics of virtual learning spaces, where learners can engage more freely due to the anonymity these platforms provide. This aspect significantly reduces the fear of judgement, encouraging more open and honest communication. In addition, as highlighted in the previous subtheme, these digital spaces are invaluable for gathering au-

thentic feedback, a process greatly facilitated by the anonymity they provide. The blend of anonymity and direct feedback mechanisms results in reliable data that teachers can use to improve their teaching methods and better understand learner needs. SSI-P5 points out that one of the true advantages of decentralising the classroom through the use of technology is the ability to gauge genuine learner interest and engagement. They note the contrast between the unrestricted expression in virtual spaces and the more reserved, face-to-face interactions, emphasising the value of unfiltered feedback in these digital environments. SSI-P5 elaborates on this perspective:

> **[00:24:21] SSI-P5:** But, are learners interested? And we can only—, you—, you—, you can rely on the technology to check how they are engaging with it and what their comments are. And remember, you know, the advent of social media is such that, you know, people feel like they can express themselves unreservedly, you know, because it's not person-to-person interactions, you know, whereas, *mina nawe besizoba* a little bit modest-*inyana* in how I, you know, convey something to you, because I want to sort of preserve how your feelings and all of that.
>
> **[00:25:00] RESEARCHER:** Hmmm... Yeah...
>
> **[00:25:01] SSI-P5:** ...But at the same time—, so they can leave any comment that they want.

In conclusion, this subtheme has highlighted how technology, as a pedagogic enabler, is pivotal in driving an educational evolution, making learning more relevant, accessible, and aligned with the demands of the modern world. From the revolutionary impact of smart boards to the expansive reach of online platforms, technology has proven to be a powerful catalyst in broadening learners' horizons and preparing them for future challenges. In the process, it has opened up new avenues for learner exploration and expression. As technological advancements continue to be embraced, a new educational paradigm emerges, transforming the metaphorical "classroom without walls" into a tangible reality. This paradigm shift offers limitless possibilities for teachers and learners, creating a landscape rich in opportunities for exploration, growth, and innovation.

6.6.3 Driving Digital Transformation in Education: The Need, Collaboration, and Empowerment

The theme *Driving Digital Transformation in Education: The Need, Collaboration, and Empowerment* refers to the collective momentum, urgency, and actions required to embed technology as a foundational pillar within educational settings. This theme underscores the pressing necessity for educational systems to evolve with the technological age. At its core, it underlines a multifaceted approach where the integration of digital tools is not just seen as an optional accessory, but as a vital component for modern pedagogy. Collaboration here emphasises the concerted effort from various stakeholders, including academia, industry, and government, highlighting the importance of unity in bringing about transformative change. Lastly, empowerment addresses the resources, training, and support provided to teachers, ensuring that they are not just passive recipients, but active participants in the technological metamorphosis of their classrooms. Together, these elements articulate a vision where technology and education intertwine seamlessly, driven by necessity, facilitated by cooperative efforts, and sustained by empowering the primary custodians of education—the teachers.

In addressing the imperative for collaboration and partnerships, SSI-P5 brings to light several crucial aspects that underscore the necessity of these elements in educational transformation. Foremost, they emphasise that integrating technology into education is not just beneficial, but essential, highlighting the opportunity it presents for enhancing mathematics education in South Africa. SSI-P5 underlines the importance of partnerships, both with government entities and the private sector, as vital for successfully integrating technology in educational initiatives. They stress that maintaining the status quo in education risks stagnating progress, advocating instead for an approach marked by agility and adaptability to change. Support from various sectors is deemed crucial for nurturing the seeds of educational advancement already planted. SSI-P5 encapsulates this perspective, emphasising the need for agility and cooperative efforts to foster educational evolution:

> **[00:27:39] SSI-P5:** ...Definitely we need partnerships, we need partnerships. For us to try and maintain the status quo in terms of, you know, education, you know, would only be killing the seeds that have already been sown, you know, and, you know, times change, right? Times change. And so I think for me, we need to approach education with a sense of agility. And if there is in any way, shape or form that, you know, government can be able to assist, and even the private sector, you know, to help initiatives...

In line with the emphasis on collaboration for driving educational transformation, SSI-P1 highlights the critical role of inter-school collaboration. They stress the importance of schools coming together to share ideas and experiences, viewing these exchanges as vital for enhancing educational practices in the digital age. This perspective rests on the belief that collective efforts and shared knowledge amongst educational institutions can lead to more effective integration of technology and overall improvement in teaching methodologies. SSI-P1 succinctly captures this need:

> **[00:10:26] SSI-P1:** ...there needs to be more schools that collaborate...

For SSI-P6, the urgency is for teachers to adapt and embrace technological advancements in education. Recognising that some teachers may be resistant to abandoning traditional teaching methods in favour of technological integration, SSI-P6 stresses that adapting to technology is becoming increasingly essential. They point out that teachers who cling to old methods risk being left behind as the educational environment rapidly transforms. The transition to technology in education is not just an option, but is becoming a necessity. SSI-P6 emphasises the need for teachers to keep pace with these changes, highlighting the importance of moving forward alongside technological progress:

> **[00:15:14] SSI-P6:** ...I feel like maybe some teachers don't really want to branch out into using technology and whatever because they're so, [uhmm], stuck on using the old way of things. But I feel like as time moves, we also have to move with it, you know...

Contrary to the challenges and reluctance highlighted by SSI-P6 regarding technology integration in education, SSI-P1 presents an encouraging viewpoint. They found that embracing technological tools in teaching is not as daunting as it may initially appear. SSI-P1 reflects on their personal experience, noting that the process of understanding and effectively using new

technology can be surprisingly quick. The primary challenge, as they recall, was initially learning to write on a tablet and ensuring the display was accurate on the screen. However, they found that with just about a day of experimentation and familiarisation, the process became remarkably simple. This experience provides a counter-narrative to concerns about the difficulty of embracing technological tools in the classroom. It suggests that while the initial step towards using technology in education may appear daunting, it quickly becomes manageable and, as they put it, "incredibly easy" once the teacher recognises their own capabilities with the tools:

> **[00:08:58] SSI-P1:** I think it takes, less than a day in order to understand the type of technology that you're using.
>
> **[00:09:04] RESEARCHER:** Alright.
>
> **[00:09:04] SSI-P1:** ...I think the—, the most difficult part was probably learning how to write on the tablet and making sure that it comes out right on the screen.
>
> **[00:09:14] RESEARCHER:** Okay.
>
> **[00:09:14] SSI-P1:** That was it. And that takes about 24 hours, you know, playing around with it, but once you realise what your capabilities are, then it's very easy, you know...
>
> **[00:09:21] RESEARCHER:** Alright.
>
> **[00:09:21] SSI-P1:** ...like, incredibly easy.

SSI-P5 reinforces the fundamental principle underpinning the use of technology in education: the learner's interest must always be at the core of teaching and learning practices. They stress the importance of a collaborative, "all hands on deck" approach, where the collective efforts of teachers and various other stakeholders are aligned with the primary goal of catering to the needs and interests of learners. This perspective underscores the notion that while technology is a critical tool for educational advancement, its effective utilisation hinges on how well it serves the learner's needs. SSI-P5 succinctly captures this ethos, emphasising that the ultimate focus of educational endeavours, particularly those involving technology, should always revolve around the learner:

> **[00:29:52] SSI-P5:** It's all hands on deck, *mfowethu*.
>
> **[00:29:54] RESEARCHER:** Hmmm...
>
> **[00:29:54] SSI-P5:** Ultimately, it's the interest of the learner that we put central to what we do.

The need to integrate technology into the teaching and learning processes has already been underscored in other themes of this chapter, as has the imperative to empower teachers to effectively integrate technology in their teaching endeavours. This theme has extended the narrative by highlighting the need for collaboration and partnerships amongst all relevant stakeholders. It underscores that the digital transformation in education is not merely a technological shift, but a collective journey that requires the active involvement of teachers, administrators, government

bodies, and the private sector. Furthermore, it stresses that modernising educational practices through technology goes hand in hand with ensuring these practices are inclusive, adaptive, and attuned to the evolving needs of learners. By weaving together the strengths and resources of varied contributors, this theme articulates a vision of an education system that is not just technologically advanced, but also deeply collaborative and empowering for all involved.

6.6.4 The Unintended Barriers: Economic and Relational Impediments in Technology-integrated Learning

This theme encapsulates the inadvertent hurdles introduced by the integration of technology into the learning environment. While many of the other themes developed from the dataset have celebrated the potential and advantages of technology in education, this theme crucially highlights the challenges and possible pitfalls. Such a perspective ensures a comprehensive understanding of participants' views.

At the forefront are economic barriers—where the cost of technology might exclude some learners from partaking fully in the digital learning experience. This is not limited to advanced devices; even foundational tools like calculators can pose financial challenges. Some learners find the cost of preferred calculator models exorbitant, leading them to settle for basic versions. As articulated by SSI-P1, while the white calculator is often recommended, many learners opt for the more affordable black, blue, or pink models due to cost constraints:

> **[00:14:43] SSI-P1:** Definitely. It is more recommended. But the black, [uhmm], blue and pink one is more budget friendly.

Equally significant is the unintended impact that technology can have on the quality and nature of interactions between teachers and learners. While technological tools pave the way for inventive engagement methods for those learners privileged with access to advanced devices like tablets or computers, they can also unintentionally obscure the fundamental human connection that is vital for effective teaching and learning. SSI-P6 expresses this sentiment in the following excerpt:

> **[00:04:58] SSI-P6:** ...And most of the time, since we are working with laptops and computers, I don't necessarily see all the time what they are doing...

This theme underscores the importance of devising strategies to reduce these barriers. There is a pressing need to ensure equitable access to technology and its effective integration into the learning environment.

6.6.5 Navigational Challenges in the Digital Classroom: The Impact of Power Outages on Technology-driven Learning

Delving into the vulnerabilities of an over-reliance on technology, this theme highlights the disruptions caused by power outages in technology-dependent classrooms. In regions where regular power outages or "loadshedding" are common, technology-driven learning can be severely hampered. Such outages not only disrupt classroom discourse, but also the continuity and flow of lessons, underscoring the necessity for contingency planning in the digital age.

Teachers have noted the significantly disruptive impact of power outages on integrating technology in the classroom. When the electricity supply is consistent, they leverage a full array of technological tools to enhance teaching and learning, creating a dynamic, technology-enabled environment. However, faced with power outages, they must pivot back to more traditional teaching methods, such as using whiteboards and markers. This dichotomy is aptly captured by SSI-P1's observation:

> **[00:03:05] SSI-P1:** ...And I use the technology, obviously, as far as possible. [Uhmm] Loadshedding permitted, you know. So, when it's not loadshedding, I can use my projector and all my tools. [Uhmm] If it is loadshedding, it should be back to basics with, [uhmm], whiteboard and—, and markers.

SSI-P1 elaborates on the debilitating effects of power outages, highlighting how they not only disrupt the use of technology, but also fundamentally compromise classroom discourse and the learning process. They articulate:

> **[00:11:23] SSI-P1:** ...you know, [uhmm], when there is like a power outage, [uhmm], that affects the entire process, and you know, [uhmm], learning is like, in a way, compromised and hindered.

Indeed, the debilitating effects of power outages are not lost on learners. They perceive a noticeable difference in the pace and agility of lessons contingent on the availability of electricity. This dynamic is again articulated by SSI-P1, who observes:

> **[00:18:36] SSI-P1:** I think they can definitely see, particularly now with the loadshedding, that if I don't have my technology, we are a lot slower...

For learners, the frequent interruptions due to power outages are more than mere inconveniences; they significantly detract from their educational experience. SSI-P6 captures this concern, pointing out the distracting nature of such disruptions:

> **[00:11:38] SSI-P6:** ...which is just unfortunate because of the whole loadshedding thing.
>
> **[00:11:41] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:11:41] SSI-P6:** But, [uhmm], those are a few things that do get them distracted time to time.

In conclusion, this theme brings to light a critical yet often overlooked aspect of technology-dependent education systems. Insights from teachers clearly demonstrate that power outages are significant disruptors, not mere inconveniences, in the teaching and learning processes. Such outages necessitate an abrupt reversion to traditional teaching methods, markedly slowing lesson pace and diminishing the quality of the learning experience. These interruptions not only impede teachers' ability to deliver content effectively, but also disrupt learners' engagement and focus, significantly affecting the overall educational journey. This discussion underscores the need for resilient educational strategies that can adapt to such infrastructural challenges, ensuring a seamless and effective learning experience under varying conditions.

6.6.6 Glitches in the Matrix: Navigating Technical Inconsistencies and Contemporary Classroom Excuses in the Digital Era

With the myriad of technological tools introduced into the classroom comes a new set of challenges related to their consistent and efficient operation. This theme addresses minor technical issues—like colour inconsistencies in projections—that can detract from the learning experience. As pointed out by SSI-P1 in the subsequent excerpt, these are not merely aesthetic nuisances; they can also disrupt the flow of classroom discourse:

> **[00:09:40] SSI-P1:** And the colours that's on the laptop is not necessarily the colours that are projected.
>
> **[00:09:44] RESEARCHER:** Alright...
>
> **[00:09:44] SSI-P1:** So, sometimes it might be dark on your laptop, but then when it comes here *(pointing at the projector board)* and say the light hits or something, and the learners can't see those brighter colours...

Moreover, the evolution of age-old excuses, where '*the dog ate my homework*' transforms into technology-related alibis, accentuates the unintended by-products of a digital classroom. Such side effects of a digital classroom are illuminated by SSI-P3, who emphasises how some learners exploit common technological glitches, such as network connectivity issues, as convenient excuses for unfinished tasks:

> **[00:08:08] SSI-P3:** Now learners can literally tell you that, you know, my network this and that, it was fine when we were teaching, but—...

This theme highlights the imperative for both teachers and learners to navigate these emerging challenges with resilience, adaptability, and genuine sincerity.

6.6.7 Digital Disparities: The Landscape of Learner Access to Technology Tools in Education

This theme rounds off the current section by delving into the disparities in resources available to different learners. It is intent on highlighting the distinct reality of an unequal landscape of technology access amongst learners. On the one hand, there is a distinction between the minority with personal technology devices who can use them in the classroom, and the majority who rely solely on classroom-provided tools, as demonstrated by the subsequent excerpts:

> **[00:11:54] SSI-P1:** The only form of technology, [uhmm], you know, for me, I don't feel that they need to have things like a graphing app or whatever, on their calc—, on their phone. [Uhmm] Because a lot of them don't have access to phones that can process those types of apps.

> **[00:09:56] SSI-P2:** They only rely on smart boards.

> **[00:09:14] SSI-P4:** ...the only technology that we both have is the smart board...

> **[00:03:45] SSI-P6:** Okay, so I've already mentioned computers and laptops as well as calculators.

On the other hand, this theme also underscores the disparities in home access to digital resources. It sheds light on how teachers sometimes step in to navigate these challenges:

> **[00:12:22] SSI-P6:** And I keep the homework at a minimum when it comes to working with technology.
>
> **[00:12:28] RESEARCHER:** Hmmm... *(affirming)*
>
> **[00:12:28] SSI-P6:** So we know that, okay, even if you don't have access to technology, we can still do it in the classroom.

Importantly, this theme emphasises the importance of equity in the digital education landscape. It pushes the dialogue towards ensuring that the advantages of technology are not just limited to those with resources, but are accessible to all.

6.7 Findings in Context

This chapter was dedicated to presenting the qualitative findings derived from the reflexive thematic analysis of data generated in the qualitative phase of this research study. Guided by the qualitative research questions listed in Section 1.4.2, the foremost question (RQ_{2a}) aimed to uncover, from the teachers' perspectives, the relationship between the use of ICTs in teaching and learning mathematics and the motivation of learners to learn mathematics, as indicated by the quantitative results.

To better understand this relationship, it was vital to first explore how teachers conceptualise a motivated learner (RQ_{2b}), and how they perceive the interplay between motivation and its observable manifestations of interest and engagement. The themes presented in Section 6.2 vividly capture teachers' perspectives on motivation, highlighting its multifaceted nature, and its energising role in educational settings. These themes delve into how interest affects learning dynamics, and the ways in which different facets of engagement manifest in active learning. Notably, this section reveals the interconnectedness of motivation, interest, and engagement, and their collective effect on shaping learners' educational experiences. These themes, along with others in Sections 6.3.3 and 6.4.1, also shed light on the correlations identified in the quantitative results across different motivation dimensions.

Section 6.5 addresses RQ_{2c} by depicting the teachers' adaptive journey with the increasing integration of technology in classrooms. It showcases the intentional, adaptive teaching strategies that teachers employ to cater to the diverse needs of digital-era learners, along with the challenges they face in integrating technology into their teaching practices.

The exploration of the perceived use of ICTs in learning mathematics from the teachers' perspective (RQ_{2d}) is primarily addressed in Sections 6.3 and 6.4. These sections detail the characteristics of modern learners in technology-enriched classrooms, the challenges of digital distractions, and the role of teachers in managing these challenges. Importantly, they emphasise the capacity of technology to stimulate mathematical curiosity, enhance learner engagement,

and reshape learner behaviours, attitudes, and interactions. Collectively, the themes in these sections offer a holistic perspective on teachers' perceptions of learners' use and interaction with ICTs in their educational journeys.

Lastly, Section 6.6, although not directly tied to any particular qualitative research question, captures broader aspects of technology integration in education as perceived by teachers. This section adds valuable context that augments the overall purpose of the study, and establishes a foundation for the integrative discussion and interpretation to be presented in Chapter 7.

6.8 SUMMARY

This chapter presented the findings from the qualitative phase of the research study, which was dedicated to exploring the intricate dynamics of learner motivation, and the discourse practices associated with the use of ICTs in teaching and learning mathematics. Partially guided by the results from the quantitative phase, the chapter began with an overview of the six teacher participants who contributed through semi-structured interviews. It established a clear set of conventions and nomenclature to aid in the clear presentation of findings.

The core of the chapter was dedicated to the outcomes of a reflexive thematic analysis, which identified 21 themes and an additional three subthemes. These were presented in a logically clustered manner to form a cohesive argument. Interwoven with the thematic presentation were initial insights into aspects of the quantitative phase that required further in-depth exploration, effectively bridging the two research phases.

The chapter then contextualised these qualitative themes in relation to the qualitative research questions, underscoring the study's methodological rigour. This approach not only reinforced the significance of the findings, but also set the stage for a comprehensive integrative discussion and interpretation of both the quantitative results and qualitative findings undertaken in the next chapter.

CHAPTER 7

DISCUSSION AND INTERPRETATION

7.1 INTRODUCTION

7.1.1 Chapter Purpose

The preceding chapters of this thesis have laid the groundwork with the presentation of quantitative results in Chapter 5 and qualitative findings in Chapter 6, each addressing the primary and secondary purposes of this research study in line with the respective quantitative (Section 1.4.1) and qualitative (Section 1.4.2) research questions. These chapters align with the distinct phases of the research design, specifically the explanatory sequential mixed methods approach detailed in Section 4.3.2 and Figure 4.1.

This chapter takes a crucial step forward by making the connection between the quantitative evidence and the qualitative insights, as guided by the mixed methods research questions in Section 1.4.3. Dedicated to synthesising these outcomes, it represents the final and integral step of the adopted mixed methods research design. This synthesis actualises the 'mixing' element, integral to this design, by systematically intertwining these diverse outcomes into a unified narrative.

The primary objective of this chapter is to deliver a holistic set of insights. It systematically explores both the quantitative results and qualitative findings, with a focus on how the latter help explain the quantitative evidence regarding the use of ICTs in mathematics education. The chapter aims to elucidate the influence of ICT use on learner motivation, responding to the specific research questions that have directed this critical phase of the study. Consequently, it offers a comprehensive perspective on the role and implications of ICTs in the educational context, highlighting their influence on teaching and learning dynamics.

7.1.2 Approach to the Integrative Discussion and Interpretation

In mixed methods research designs, the integration or 'mixing' of datasets is a quintessential and fundamental component, as highlighted by Creswell and Plano Clark (2017). Plano Clark (2019) defines integration in mixed methods research as an "explicit conversation between (or interrelating of) the quantitative and qualitative components of a mixed methods study" (p. 108), distinguishing it from research that merely includes both quantitative and qualitative informa-

tion without meaningful interaction.

Recent scholarly work, including that by Hands (2022) and McCrudden et al. (2021), has emphasised the importance of clear and explicit integration techniques in mixed methods studies to enhance the transparency and integrity of the overall research process. This has led to the development of systematic approaches to articulate the purpose of mixing and to demonstrate it effectively. Hands (2022), for instance, explores various techniques appearing in literature for integrating datasets, and illustrates integrating qualitative and quantitative datasets using a convergence table. Similarly, McCrudden et al. (2021) discuss different purposes for mixing, such as "triangulation, complementarity, development, initiation, and expansion" (p. 2), highlighting how joint displays can integrate quantitative and qualitative data for each purpose. Guetterman (2023) builds on this by outlining the intentions behind using joint displays in mixed methods research, which are typically aligned with the study's problem statement, purpose statement, and research questions. McCrudden (2023) provides a comprehensive view of visual displays, including joint displays, and guidelines for their application in mixed methods research. Joint displays, defined as "visual displays that are used to integrate quantitative and qualitative data during data collection, analysis, and interpretation", have become flexible and effective tools for integration (McCrudden et al., 2021, p. 1).

In this study, the integration strategy was primarily driven by complementarity, with qualitative findings employed to elaborate on the results from the quantitative strand. There was also a developmental aspect, where insights from the quantitative data analysis informed the refinement of the qualitative research instrument used for data generation. The *integrated results matrix*, as suggested by McCrudden et al. (2021), was employed for its ability to present quantitative results and qualitative findings side-by-side, facilitating the comparison of these outcomes and the generation of meta-inferences. This type of joint display, effective for visually presenting summative results, was adopted in this research study to clearly demonstrate the connection between quantitative evidence and qualitative themes, thus fulfilling its objective of providing a holistic understanding of the role of ICT use in mathematics education and its influence on learner motivation.

7.1.3 Chapter Outline and Organisation

The remaining sections of this chapter are dedicated to an integrative discussion and interpretation of the outcomes of this research study. Organised into two main parts, each section addresses key aspects of the study's outcomes.

Section 7.2, the first part, focuses on the integration and discussion of both the quantitative results and qualitative findings. This section pays particular attention to the interrelationships amongst motivation, interest, and engagement, as investigated in the two phases of the study. Here, joint displays are utilised as integration tools, enabling a visual linkage between the quantitative and qualitative strands, and facilitating the generation of overarching meta-inferences.

In Section 7.3, the second part, the narrative delves deeper into the discussion and interpretation of key insights. This section examines the influence of ICT use in teaching and learning mathematics on learner motivation from the perspective of teachers. It also explores broader dynamics that have emerged from the analysis of both quantitative and qualitative data.

The chapter concludes with Section 7.4, which summarises the key takeaways and reflects on their overall contribution to the thesis. This final section ties the insights gained in this chapter back to the larger narrative of the study.

7.2 Integration of Quantitative Results and Qualitative Findings

7.2.1 Motivation

The concept of learner motivation, as observed by teachers in the context of ICT use for mathematics education, echoes the multifaceted theoretical perspectives on motivation, as discussed in Section 3.2.2. Particularly, these observations resonate with the taxonomy of human motivation under self-determination theory (Deci & Ryan, 2008; Ryan & Deci, 2000a, 2000b). The theme *Motivational Dynamics in Learning: The Spectrum of Learner Motivation* (Section 6.2.1) effectively captures this resonance, portraying motivation as a dynamic spectrum that transcends the simplistic intrinsic–extrinsic duality (Lepper et al., 1973; Ryan & Deci, 2000a). This perspective emphasises learner agency and autonomy, manifesting in various behaviours indicative of high motivation. Such behaviours include proactive information-seeking, active engagement in classroom discussions with peers and teachers, and the display of focused attention and curiosity.

In contrast, the opposite end of this motivation spectrum, as distinctly captured by this theme, is marked by learners exhibiting a noticeable lack of agency. This is characterised by a lack of engagement, passive attitudes, and a reluctance to participate actively in the learning process. Such behaviours reflect a disconnection from the educational experience, where learners show little initiative or motivation to engage with the material or in classroom activities.

The subsequent theme, *Igniting the Learning Flame: The Energising Role of Motivation in Education* (Section 6.2.2), further elucidates the catalytic role of motivation in stimulating learner excitement and keenness. This theme reflects the view that motivation acts as a spark, igniting a deep-seated desire for learning, particularly evident in learners who display a strong appetite for knowledge and understanding.

Together, these themes align with Sivan's (1986) constructivist perspective on motivation, illuminating four key elements: (i) the inextricable link between learning and motivation; (ii) the developmental aspect of motivation where learners, especially those with higher motivation levels, seek continual growth in their educational journey; (iii) the significance of social and contextual factors in shaping learner motivation; and (iv) the recognition of motivation as a critical catalyst for competent classroom functioning.

This refined understanding of motivation, drawing from practical observations and theoretical foundations, sets the stage for an in-depth exploration and understanding of how the use of ICTs can foster motivation, and by extension, interest and engagement in mathematics education, as elaborated in the following sections.

7.2.2 **Interest**

In the context of this study, interest is conceptualised as a multifaceted construct, stratified into situational interest—sparked by external stimuli, and individual interest—reflecting a person's enduring engagement with specific content or activities, and the psychological state that ensues from this engagement (Hidi & Renninger, 2006; Krapp, 1999; Schiefele, 1991). Through a joint display, Table 7.1 integrates the quantitative results and qualitative findings for both types of interest, offering a comprehensive view of their manifestation in educational contexts.

The qualitative findings, particularly through the *The Nexus of Curiosity* theme (Section 6.2.4), highlight the crucial role of interest in shaping the learning dynamics of the classroom. This theme reveals how genuine interest motivates learners to persist and immerse themselves in their learning, reshaping both individual experiences and the collective classroom atmosphere. Additionally, the *Mathematical Resonance* theme (Section 6.2.6) emphasises the importance of relevance and value in cultivating learner interest in mathematics. It illustrates how making mathematical concepts relevant to learners' lives, and highlighting the subject's value for personal and future aspirations, can transform mathematics from a mere academic requirement into a meaningful journey of discovery. This process encourages learners to transition from passive recipients to active participants and integrators of mathematical knowledge.

For situational interest, quantitative analysis revealed interesting results. The median for the sample ($Mdn = 2.00$) and the 95% CI of the median ($CI\,[2.00, 2.50]$) suggest that teachers generally agree that the use of ICTs in mathematics education positively influences learners' situational interest. This aligns with the fundamental nature of situational interest as being externally stimulated, in this case by the integration of technology in teaching and learning.

The median for individual interest ($Mdn = 2.75$, 95% $CI\,[2.25, 3.00]$), falling between the '*Agree*' and '*Neither Agree nor Disagree*' response anchors, indicates a more nuanced perception amongst teachers. They appear somewhat tentative in affirming that technology use in mathematics education consistently influences learners' individual interest. This is understandable given that individual interest is inherently a more internal, personal trait, which may not be as readily observable or influenced by external factors, such as the use of ICTs, as situational interest is.

Notwithstanding these distinctions, the quantitative analysis further revealed a moderate positive and statistically significant relationship between situational and individual interest. This finding suggests a notable interdependence between these two types of interest, indicating that the presence of one often coincides with the presence of the other. Such an observation hints at the layered complexity of interest in educational contexts, where situational triggers may reinforce or echo deeper, enduring individual interests.

Revisiting the qualitative findings, the *Digital Catalyst: Technology's Power to Spark Mathematical Curiosity* theme (Section 6.3.3) draws a connection between the use of digital tools and the stimulation of interest in mathematics. It suggests that technology acts as a catalyst for situational interest, corroborating the quantitative results. Additionally, it hints at the potential of technology to nurture individual interest over time, thereby supporting the corresponding quantitative findings, albeit in a more subtle manner.

Table 7.1: Integrated results matrix: Joint display representing quantitative results and qualitative findings for the interest dimensions of motivation.

Construct	Quantitative Results			Qualitative Findings (Themes)	Meta-inferences and Implications
		95% Confidence Interval			
	Median	Lower	Upper		
Situational Interest (SI)	2.00	2.00	2.50	The Nexus of Curiosity: How Genuine Interest Influences Learning Dynamics Mathematical Resonance: The Roles of Relevance and Value in Cultivating Learner Interest Digital Catalyst: Technology's Power to Spark Mathematical Curiosity	**Meta-inference:** The qualitative findings underscore the critical role of interest in educational contexts and corroborate the quantitative results regarding learner situational interest. This concurrence affirms the significant positive influence of ICTs on enhancing situational interest amongst learners in mathematics education. The corroborative nature of these results and findings suggests that ICTs are effective in stimulating learners' context-specific interest, thereby enriching their overall learning experience. **Implication:** Given the positive influence of ICTs on situational interest, educational strategies should be designed to leverage technology in ways that specifically cater to and spark situational interest in learners. This could involve the integration of contextually relevant digital content, interactive learning tools, and technology-driven activities that resonate with learners' immediate learning environment and experiences.

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Table 7.1: Integrated results matrix: Joint display representing quantitative results and qualitative findings for the interest dimensions of motivation. *(Continued)*

Construct	Quantitative Results			Qualitative Findings (Themes)	Meta-inferences and Implications
		95% Confidence Interval			
	Median	Lower	Upper		
Individual Interest (II)	2.75	2.25	3.00	The Nexus of Curiosity: How Genuine Interest Influences Learning Dynamics Mathematical Resonance: The Roles of Relevance and Value in Cultivating Learner Interest Digital Catalyst: Technology's Power to Spark Mathematical Curiosity	**Meta-inference:** Although individual interest, being an intrinsic and enduring trait, presents challenges in observational assessment, the qualitative findings offer a deeper understanding that complements the quantitative results. These findings suggest that ICTs, though their influence on individual interest is more subtle, nonetheless play a role in nurturing a sustained interest in mathematics learning. The qualitative findings, therefore, bolster and deepen the understanding provided by the quantitative results, indicating that ICTs can be instrumental in nurturing a long-term, individual interest in mathematics amongst learners. **Implication:** The subtlety with which ICTs influence individual interest underscores the need for teachers to thoughtfully integrate technology in ways that resonate personally with learners. This might involve tailoring digital content to individual learning styles and interests, or using technology to provide personalised learning experiences that cultivate each learner's enduring interest in mathematics. Such an approach can help in maintaining and enhancing individual interest over time, reinforcing the value of mathematics in learners' personal and educational growth.

Source: Author.

This intricate interplay between the two types of interest and the potential role of ICT in their development highlights the importance of understanding the different ways in which technology can be strategically used in mathematics education to not only capture, but also sustain learner interest.

7.2.3 Engagement

In this research study, engagement in learning contexts is broadly conceptualised as encompassing a learner's effort, interest, willingness, agency, and enthusiasm in tasks, activities, or interactions related to learning (Christenson et al., 2012; Oncu & Cakir, 2011). This overarching definition captures the essence of engagement in its most general form. Research has progressively refined this concept into a multidimensional construct, comprising behavioural, affective, cognitive, and agentic dimensions, as detailed in Section 3.2.4. The behavioural dimension involves learners' actions in both social and academic aspects of school life (Archambault et al., 2009; Rumberger & Rotermund, 2012). The affective dimension pertains to learners' emotional states, including their "feelings, interests, perceptions, and attitudes toward school" (Archambault et al., 2009, p. 654). The cognitive dimension encompasses learners' engagement in academic tasks, requiring "thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills" (Mahatmya et al., 2012, p. 47). Lastly, the agentic dimension is about learners' active and constructive contributions to the instructional process (Reeve & Tseng, 2011). Each of these dimensions plays a vital role in creating a comprehensive picture of engagement within educational contexts. Table 7.2 presents a joint display that integrates the quantitative results with qualitative findings across all dimensions of engagement, offering an in-depth understanding of how each dimension manifests and interacts in various educational settings.

The qualitative findings, particularly highlighted in the *Manifestations of Active Learning: Dimensions and Impact of Learner Engagement* theme (Section 6.2.3), provide a vivid illustration of learner engagement as perceived by teachers in their classrooms. These observations bring to life the multidimensional nature of engagement: behavioural engagement is observed through learners' collaborative spirit in class activities; affective engagement is seen in their curiosity and enthusiasm; cognitive engagement is evident from their deep immersion in academic tasks; and agentic engagement manifests in their proactive responses to learning stimuli. Clear communication between learners and teachers, as this theme articulates, further underscores active engagement, reflecting a deeper mental and emotional connection with the learning material. A key thread in these observations is the role of learner agency, which enhances the educational experience by harnessing deeper levels of curiosity.

By encompassing all dimensions of engagement, this theme offers a comprehensive view that aligns with both the broad definition of engagement and its specific facets. The decision to present the theme in its entirety, rather than segregating it into distinct dimensions, was made to preserve the holistic nature of engagement as observed in the study. This approach emphasises that the collective impact of behavioural, affective, cognitive, and agentic dimensions is greater than their individual contributions, echoing the concept that '*the whole is greater than the sum of its parts*.' This integrated perspective allows for a more nuanced understanding of how these dimensions interplay and complement each other in real-world educational settings. The clear

Table 7.2: Integrated results matrix: Joint display representing quantitative results and qualitative findings for the engagement dimensions of motivation.

Construct	**Quantitative Results**			**Qualitative Findings (Themes)**	**Meta-inferences and Implications**
		95% Confidence Interval			
	Median	Lower	Upper		
Behavioural Engagement (BE)	2.00	2.00	2.00	Manifestations of Active Learning: Dimensions and Impact of Learner Engagement Digital-driven Dynamics: How Technology Shapes Learner Behaviour, Attitudes, and Interactions	**Meta-inference:** The integration of ICTs in the teaching and learning of mathematics markedly enhances learners' participation and collaboration. This enhancement is evident in the increased collaborative efforts and dynamic participation seen in technology-integrated classrooms, a finding consistently reflected in the qualitative themes. Furthermore, quantitative data reveal a strong consensus amongst teachers regarding the positive influence of ICTs. These converging insights from both qualitative observations and quantitative evidence underscore the significant role of ICTs in promoting more active and cooperative learning environments, thereby enriching the behavioural aspects of learners' educational experiences. **Implication:** ICTs effectively promote active involvement in the learning process, suggesting that teachers should leverage technology to encourage group work and interactive activities.

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Table 7.2: Integrated results matrix: Joint display representing quantitative results and qualitative findings for the engagement dimensions of motivation. *(Continued)*

Construct	Quantitative Results			Qualitative Findings (Themes)	Meta-inferences and Implications
		95% Confidence Interval			
	Median	Lower	Upper		
Affective Engagement (AE)	2.00	2.00	2.00	Manifestations of Active Learning: Dimensions and Impact of Learner Engagement Digital-driven Dynamics: How Technology Shapes Learner Behaviour, Attitudes, and Interactions	**Meta-inference:** ICTs ignite curiosity and enthusiasm, as seen in the qualitative observations. However, they also present challenges like hesitancy in some learners, indicating a diverse range of emotional responses to the incorporation of technology. **Implication:** While ICTs can be powerful tools to engage learners emotionally, teachers should be mindful of varying responses, and work to create inclusive, technology-integrated environments that cater to diverse emotional needs.
Cognitive Engagement (CE)	2.00	2.00	2.00	Manifestations of Active Learning: Dimensions and Impact of Learner Engagement Digital-driven Dynamics: How Technology Shapes Learner Behaviour, Attitudes, and Interactions	**Meta-inference:** The shift towards self-guided explorations and deeper intellectual involvement, facilitated by ICTs, points to a significant enhancement in cognitive engagement. This aligns with the quantitative results, where teachers recognised the role of ICTs in promoting thoughtful and critical engagement with learning materials. This concurrence of qualitative insights and quantitative evidence underscores the pivotal role of ICTs in enriching the cognitive aspects of learners' educational experiences. **Implication:** The use of ICTs should be strategically designed to enhance critical thinking and independent learning, thereby deepening learners' cognitive engagement with the subject matter.

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Table 7.2: Integrated results matrix: Joint display representing quantitative results and qualitative findings for the engagement dimensions of motivation. *(Continued)*

Construct	**Quantitative Results**			**Qualitative Findings (Themes)**	**Meta-inferences and Implications**
		95% Confidence Interval			
	Median	Lower	Upper		
Agentic Engagement (AgE)	2.00	2.00	2.00	Manifestations of Active Learning: Dimensions and Impact of Learner Engagement Digital-driven Dynamics: How Technology Shapes Learner Behaviour, Attitudes, and Interactions	**Meta-inference:** Learners are taking more proactive roles in their education due to the availability and use of digital tools, as evidenced in both qualitative and quantitative data. This indicates a strong influence of ICTs in enabling learners to actively shape their learning paths and influence classroom dynamics. This evidence points to the strong role of ICTs in fostering agentic engagement, where learners are not just passive recipients, but active contributors to their educational experiences. **Implication:** Educational strategies should focus on harnessing ICTs to enhance learner agency, providing opportunities for learners to contribute to and shape their educational experiences. The emphasis on learner agency is particularly crucial, as it emerged as a prominent and powerful dimension of engagement throughout the qualitative themes. Recognising and nurturing this aspect of a learner's journey is key to unlocking more meaningful and effective educational experiences.

Source: Author.

parallels drawn between the theoretical aspects and teachers' perceptions of learner engagement in their environments not only validate the multidimensional view, but also highlight its practical applicability in educational research and practice.

The quantitative analysis revealed that the median scores for all four dimensions of engagement (behavioural, affective, cognitive, and agentic) were identical ($Mdn = 2.00$), each with a remarkably narrow 95% CI of $[2.00, 2.00]$. This uniformity across the dimensions strongly suggests that the use of ICTs in teaching and learning mathematics has a very positive influence on enhancing various aspects of learner engagement. Further exploration into the relationships between these dimensions revealed an interesting aspect: the correlations were statistically not significant, and exhibited relatively weak relationships (see Tables 5.15 and E.21). This evidence indicates that while ICTs uniformly enhance each dimension of engagement, these enhancements operate more independently than synergistically. The influence of ICTs on each dimension appears distinct, rather than interlinked, suggesting diverse ways in which technology interplays with different facets of engagement in educational contexts.

The unusual precision of the 95% CI of $[2.00, 2.00]$ for the median scores is an expected characteristic when dealing with medians, as opposed to means or other measures of central tendency, due to the discrete nature of median statistics (Hesterberg, 2015). Such a narrow CI, often uncommon in other statistical measures, prompted a detailed examination of the bootstrap estimates to uncover deeper insights. This examination revealed slight variations, especially for the cognitive ($bias = .001$, $SE = .032$) and agentic ($bias = -.001$, $SE = .024$) dimensions. Although these minor biases do not significantly alter the overall alignment, they bring to light a level of inherent bias within the data. This nuanced variability within the data highlights that while the overall impact of ICTs on engagement appears consistent at face value, closer inspection reveals subtle differences in how these effects manifest across different engagement dimensions. Table E.20 in the Appendix provides a detailed breakdown of these results.

Within the *Digital-driven Dynamics* theme (Section 6.4.1), the nuanced interplay between the use of ICTs and learner engagement is highlighted, mirroring the quantitative results that suggest a strong influence of technology across all engagement dimensions. This theme brings into focus how the use of technology enhances behavioural engagement, as evidenced by collaborative and interactive learning activities, where teachers observe a heightened sense of unity and joint endeavour amongst learners. Affective engagement is also vividly captured by this theme, as technology ignites curiosity and enthusiasm, although some learners still exhibit hesitancy and a negative disposition towards their lessons.

On the cognitive front, the facilitation of self-paced learning and revision by ICTs contributes to deeper intellectual involvement, allowing learners to extend their studies beyond the conventional classroom and explore self-directed learning avenues. This empowerment is also a key aspect of agentic engagement, where learners, equipped with digital tools, take proactive roles in their education. The autonomy afforded by technology also fosters a balance between self-directed and collaborative learning approaches, dynamically influencing both academic content assimilation and peer interactions.

However, these positive aspects come with inherent challenges. Disparities in technological accessibility can lead to inconsistent engagement levels amongst learners, highlighting the need

for equitable access to digital resources. Furthermore, technology's role as both an educational enhancer and a social mediator is evident, influencing not just academic engagement, but also the social dynamics within the classroom. This dual functionality of ICTs, as vividly captured in the qualitative theme, not only strengthens, but also corroborates the quantitative results. It illustrates a comprehensive influence on all dimensions of engagement: behavioural, affective, cognitive, and agentic. This alignment between the qualitative insights and quantitative results underscores how ICTs serve both as a catalyst for and a mediator of learner engagement, impacting the spectrum of engagement dimensions in a multifaceted and profound manner. Such outcomes provide teachers with valuable insights into effectively integrating ICTs in teaching, recognising the transformative potential, and addressing the challenges to maximise positive influence on learner engagement.

7.2.4 Synergising Motivation, Interest, and Engagement: A Holistic View of the Learning Experience

This section has delved into the concepts of motivation, interest, and engagement, examining their multidimensional foundations and manifestations in both quantitative and qualitative data. Each of these components, significant in its own right, collectively form an essential foundation for understanding the learning process. The current subsection aims to explore the synergy amongst these three critical elements, presenting a holistic view of their collective contribution to the learning experience. Together, motivation, interest, and engagement constitute the cornerstone of learning, owing to their interconnected nature and combined dynamics within the educational process. The interplay amongst these elements is essential in supporting and enhancing the overall learning journey.

The qualitative insights gleaned from the theme *The Learning Triad: Dissecting the Interplay of Motivation, Engagement, and Interest* (Section 6.2.5) bring into focus the intricate and, at times, divergent relationships amongst these fundamental pillars of the learning process. This theme highlights how motivation, engagement, and interest are interconnected yet retain distinct characteristics within the educational context. Motivation propels active engagement, and engagement manifests as a direct outcome of motivational drives. Interest, while closely related, maintains its distinct characteristics, focusing curiosity and preference towards specific topics or subjects. This nuanced understanding of their distinct yet intertwined roles is key to comprehending how they collectively shape and enhance the learners' educational journey.

These qualitative insights bolster and enrich the quantitative results (see Tables 5.15 and E.21), providing a deeper understanding of the relationships amongst motivation, interest, and engagement. Notably, a moderate positive and statistically significant relationship between situational and individual interest ($\tau_b = .418$, $95\% \, CI \, [.098, .688]$, $p = .022$) highlights how context-specific interest can align with and enhance long-term, intrinsic interest. Situational interest also demonstrates a moderate positive and statistically significant relationship with affective ($\tau_b = .531$, $95\% \, CI \, [.232, .763]$, $p = .006$) and agentic ($\tau_b = .483$, $95\% \, CI \, [.089, .776]$, $p = .011$) engagement, and a weak positive, but statistically significant relationship with cognitive engagement ($\tau_b = .399$, $95\% \, CI \, [.110, .673]$, $p = .041$). These results underscore situational interest's potential role in triggering emotional involvement, deepening intellectual engagement, and motivating learners to take an active role in their education. Furthermore, the

moderate positive and statistically significant relationship between individual interest and cognitive engagement ($\tau_b = .573$, $95\% CI\,[.336, .721]$, $p = .003$) illustrates the potential influence of sustained interest in fostering deep and thoughtful engagement with learning materials.

These results and findings collectively suggest that while motivation, interest, and engagement are conceptually interlinked, their interactions are complex and varied. The distinct yet overlapping influences of situational and individual interest on different dimensions of engagement underline the need for educational strategies that are as varied and nuanced as the learners themselves. Such an approach necessitates teachers to recognise and cultivate these various facets, leveraging ICTs to create learning experiences that are not only contextually engaging, but also personally resonant and intellectually stimulating. By doing so, teachers can create an educational environment that resonates with each learner's unique interests and motivations, thereby enhancing the overall efficacy and richness of the learning experience.

Ultimately, the convergence of motivation, interest, and engagement forms a dynamic and influential framework that can significantly enhance the learning journey. Understanding and balancing these elements, while acknowledging their unique contributions and interrelations, are key to crafting effective and fulfilling educational experiences. This holistic approach, informed by both qualitative themes and quantitative evidence, offers a comprehensive view of how learners can be best engaged and motivated, fostering a rich and dynamic educational environment.

7.3 Interpretation of Key Insights

7.3.1 Interpreting the Influence of ICT Use in Teaching Mathematics on Learner Motivation: Teacher Observations

This subsection focuses on the influence of ICTs on learner motivation in the context of teaching mathematics, drawing upon insights from teacher observations. It aims to dissect and interpret the multifaceted effects of ICTs from a pedagogical standpoint, reflecting on how teaching practices evolve in response to technological advancements. Teaching in the digital era represents a dynamic journey of discovery and adaptation for teachers. They face the challenge of keeping pace with the rapid evolution of technology, while also catering to 21st-century learners for whom technology is an integral part of their lives. The reflexive thematic analysis approach yielded a rich array of themes, out of which four directly address the nuances of technology's influence on teaching mathematics and its consequent effect on learner motivation. These themes collectively capture the essence of this evolving digital teaching environment, and form the focal point of this subsection.

Insights from the *Teacher Evolution: Navigating the Digital Landscape in Teaching Practice* theme (Section 6.5.1) offer a compelling look at how teachers' proficiency with digital tools fundamentally influences the learning environment. This theme illustrates the complex journey of how teachers progressively adapt to and integrate technology into their teaching practices, confronting various challenges along the way. The success of technology integration is largely dependent on the teacher's ability to thoughtfully select and methodically plan the use of digital tools that complement their instructional strategies.

Key to this process is the teacher's skill in identifying the most effective technological tools for diverse teaching scenarios, and tailoring their lesson plans accordingly. This approach is crucial, particularly in classrooms where learners have varying levels of access to, and proficiency with, technology. By adopting strategies that cater to all learners, teachers ensure an equitable educational experience.

As the digital landscape continually evolves, it calls for teachers to enhance their technological skills to match and support their learners' growing technological adeptness. Teachers who are particularly skilled in integrating technology demonstrate the ability to captivate and educate using digital tools. They harness technology's inherent appeal to engage learners, redirecting their attention towards educational goals. Such adept integration enhances learner engagement across various educational contexts, irrespective of learner grade.

Ultimately, the *Teacher Evolution* theme underscores the pivotal role of teachers in leveraging technology's potential for enriching the learning experience. It highlights the need for inclusivity, thoughtfulness, and purpose in technology's application, ensuring that teaching methods remain agile and responsive to the ever-evolving classroom setting and learner needs.

These insights align seamlessly with the core aspects of the *Responsive Pedagogy: Tailoring Teaching to Grade Levels and Learner Needs* theme (Section 6.5.2), which encapsulates the essence of adaptive teaching strategies vital for addressing diverse learner needs. This theme underscores the importance of differentiated instruction, a cornerstone in responsive pedagogy, where teaching methods are carefully adapted to align with the distinct abilities and developmental stages of learners across different grade levels.

A key aspect highlighted in this theme is the necessity for teachers to be both prepared and flexible, adept at adjusting their teaching methods in response to the immediate cues and responses of learners, particularly in technology-enhanced learning environments. This level of responsiveness and in-the-moment adaptability is crucial in ensuring that every learner remains engaged and connected to the learning process.

Moreover, the theme stresses that the effectiveness of classroom sessions is heavily reliant on the teacher's focused and extensive preparatory efforts, demonstrating that successful teaching in the digital era is a blend of careful planning and the ability to pivot strategies based on learner feedback. Thus, by practising responsive pedagogy, teachers demonstrate not only a deep understanding of their learners' unique needs, but also a commitment to continual professional development.

In essence, the *Responsive Pedagogy* theme celebrates the dedication of teachers who continuously evolve their practices to recognise, meet, and nurture the unique potential within each learner, ensuring that their educational experiences are as enriching and effective as possible.

Building upon the notion of continual professional development and the evolution of teaching practices, the *Pedagogical Technology Integration: The Journey of Teacher Training and Self-learning in Classroom Technology* theme (Section 6.5.3) delves into how teachers adapt and grow amidst the rapid advancements of the digital age. This theme extends the narrative of teachers' commitment to pedagogical enhancement, particularly their journey towards tech-

nological proficiency in the classroom. It highlights the innovative ways that teachers initiate professional development, even in the absence of extensive formal training, showcasing their deep commitment to enhancing technological capabilities for their learners' benefit.

The journey of integrating technology into teaching methods is portrayed as a path marked by resilience, innovation, and self-directed growth. Here, teachers actively seek digital skills through various means, be it through informal channels, self-driven research, or collaborative learning with peers, demonstrating adaptability and resourcefulness. While some benefit from structured training, others highlight the need for more comprehensive professional development programmes that foster a deeper understanding and creative application of educational technology.

This commitment to self-improvement and innovation in technology integration is vividly portrayed in this theme, illustrating teachers' efforts to bridge the gap between traditional pedagogical methods and the emerging demands of the digital era. From embracing new digital tools to adapting their pedagogical approaches, this theme captures the essence of teachers' proactive efforts to stay abreast of technological changes and enrich their classrooms with engaging, effective, technology-enhanced learning experiences. Ultimately, this theme reaffirms the pivotal role of teachers in creating dynamic, technology-enriched learning environments, significantly influencing learner motivation and engagement.

Advancing from the emphasis on proactive efforts and technological adaptability in the *Pedagogical Technology Integration* theme, the *Technology-induced Hiccups: Navigating Disruptions in Teaching due to Technology* theme (Section 6.5.4) presents the flip side of technology integration in education. While the former theme emphasises teachers' innovative approaches to embracing and adapting digital tools, this theme delves into the challenges and disruptions that accompany the use of such technology in the classroom. It brings into focus the fine line between technology as a facilitator of enriched learning and its potential to introduce complications and distractions in the educational process.

This theme addresses the complexities arising from integrating multiple technological devices, which, while intended to enhance learning, can lead to an overwhelming array of distractions. Teachers face the dual challenge of managing these devices and maintaining the focus of their lessons, often resulting in overcomplicated teaching environments and reduced instructional time.

Furthermore, teachers often grapple with the unpredictable nature of technology. Occasional malfunctions and technical issues demand immediate attention and support, leading to interruptions that can significantly disrupt the educational process. Such technological hiccups can derail the flow of a lesson, undermining its effectiveness and continuity.

In this context, the theme underscores the need for teachers to possess not only technological skills, but also strategies to mitigate these disruptions. It highlights the importance of preparedness in handling the unpredictable aspects of technology and maintaining the continuity of the educational experience. Ultimately, this theme complements the previous one by showing that the journey to creating dynamic, technology-enriched learning environments involves navigating both the opportunities and challenges presented by technology, reinforcing the critical role

of teachers in ensuring that technology serves as an enabler rather than a barrier to effective learning.

To wrap up this subsection, the overarching insights from the explored themes converge to highlight the complex yet important role of ICTs in reshaping the landscape of teaching mathematics and its consequential influence on learner motivation. These themes collectively sketch a dual narrative: on one side, ICTs emerge as a powerful tool that revolutionises teaching methods and significantly enhances learner interest and engagement; on the other, they present teachers with a set of unique challenges that demand a delicate balance of skill, innovation, and adaptability. The ability of teachers to navigate this dual nature of ICTs—enhancing learning experiences while managing potential disruptions—is crucial. It is through this careful balancing act that technology truly becomes an enabler of enriched, engaging, and motivating learning experiences in mathematics. Ultimately, the effective use of ICTs in teaching mathematics emerges as a critical factor in motivating learners, enriching their educational experience through interest and engagement, and paving the way for a more dynamic and interactive learning environment.

7.3.2 Interpreting the Influence of ICT Use in Learning Mathematics on Learner Motivation: Teacher Perspectives

This subsection explores the influence of ICT use in the context of learning mathematics, with a specific emphasis on its influence on learner motivation as perceived by teachers. The aim is to dissect how learners' interactions with ICTs within mathematics classrooms shape their motivational dynamics, while considering the distinct attributes of today's modern learner in educational environments. A comprehensive interpretation of this influence is undertaken through the synthesis of two distinct themes derived from the reflexive thematic analysis. Together, these themes offer insights into the dynamic relationship between learners' engagement with ICTs in their mathematical learning journeys and the resulting effects on their motivational states. This exploration, observed and interpreted through the lens of teachers, offers a nuanced perspective on the role of ICT in enhancing or influencing the motivational aspects of mathematics learning.

In the *Digital Natives in the Classroom: Harnessing Technology Fluency and Constructive Exploration* theme (Section 6.3.1), the focus is on the distinct characteristics of modern learners who have grown up in an era saturated with technology. These learners exhibit an inherent aptitude and ease with technology, making it a seamless part of their learning process. This natural proficiency is apparent in their confident use of various technological tools within the classroom. Unlike previous generations, their interaction with technology is characterised by an intuitive understanding and a confident approach to using these tools for educational purposes.

This theme further reveals that for these digital natives, the interaction with technology transcends classroom boundaries. Especially evident in learners who are intrinsically motivated, technology becomes a powerful extension of their learning environment. They actively harness digital tools to enhance and expand their educational experiences, engaging in exploratory and self-guided learning beyond the traditional classroom setting. This effortless integration of technology into their learning signifies a shift in the educational paradigm, where digital tools are not merely supplementary, but essential elements of the learning process.

However, this technological fluency amongst modern learners presents a unique challenge to

teachers, particularly those who may not be as versed in the use of technology in pedagogical settings. The disparity between learners' digital fluency and some teachers' technological proficiency can lead to a disconnect in the educational experience. As emphasised in the previous subsection, this theme reiterates the critical need for teachers to understand and adapt to this evolving dynamic. Teachers are encouraged to not only match their learners' technological skills, but to also effectively integrate these tools to foster a more dynamic and engaging learning process. Therefore, this theme highlights the necessity of adapting educational strategies to align with learners' technological familiarity, ensuring that technology serves as an enabler of enriched learning, rather than as a barrier in the modern classroom.

In the theme *The Digital Distraction Dilemma: Navigating Technology's Challenges in Learning* (Section 6.3.2), the focus shifts to the challenges and complexities that arise when this familiarity becomes a double-edged sword in educational settings. This theme explores how technology, while offering vast educational possibilities, can also lead to significant distractions. Teachers observe learners frequently employing technological tools for unintended purposes, such as browsing unrelated content, which often leads to a dichotomy of distraction.

This dichotomy encompasses both constructive and destructive forms of distraction. On one side, there is 'constructive driftiness' where learners wander mentally, engaging in reflective thinking that can enhance their grasp of the subject matter. However, the challenge lies in ensuring learners return from these mental wanderings. Conversely, there exists 'destructive driftiness,' a form of distraction stemming from the misuse of technology, often seen as typical behaviour amongst younger learners.

Further, the theme highlights the intrinsic potential for distraction inherent in technology. Resources like the internet open new avenues for misuse, especially amongst younger learners, who often struggle to discern between appropriate and inappropriate use of technology. Even technologically proficient learners sometimes lack the mental discipline to separate academic use from socialising.

Despite these challenges, teachers believe that with well-defined boundaries and control, technology can shift from being a distraction to an essential educational tool. Strict oversight of technology use within the classroom is considered vital in preventing it from becoming a hindrance to learning. Under proper guidance, what initially appears as a distraction can transform into a critical resource for education, highlighting the importance of structured and intentional technology use in the learning process.

To sum up the discussion in this subsection, insights from *Digital Natives in the Classroom* and *The Digital Distraction Dilemma* themes present a nuanced picture of ICT use in mathematics learning. Digital natives show inherent proficiency with technology, leveraging it for exploratory and self-directed learning that enhances their engagement in mathematics. However, the potential distractions posed by technology necessitate careful management and strategic oversight by teachers to maintain focus and effectiveness in the classroom.

These themes emphasise the need for a critical balance in using ICT for educational purposes. While ICTs can enrich learning experiences and meet the intrinsic motivations of modern learners, their success hinges on the teachers' ability to navigate their challenges. Teachers are

pivotal in ensuring that technology acts as an enabler, not a barrier, in fostering interest and engagement in mathematics.

Ultimately, effectively using ICT in mathematics learning requires understanding both the learner's digital fluency and the necessary pedagogical strategies to maximise technology's educational potential. Teachers are key to this process, guiding the use of technology to enrich education and achieve the fundamental goals of sparking interest, promoting engagement, and boosting motivation in mathematics.

7.3.3 Interpreting Broader Dynamics: The Digital Evolution in Education and its Multifaceted Impacts

This subsection focuses on the broader implications of the digital transition within educational settings, particularly on the evolutionary impact of digital technology on education. It examines the multifaceted effects and implications of this evolution through seven key themes identified from the reflexive thematic analysis. These themes collectively highlight the technological transformation as well as external and environmental influences shaping the digital educational landscape. Together, they provide valuable insights into the diverse dynamics of technology adoption in the teaching and learning of mathematics, guiding teachers and policymakers on how to effectively navigate and harness the potential of digital advances.

The theme *Visual Empowerment through Technology: Harnessing Digital Tools for Enhanced Perception in Mathematics* (Section 6.6.1) recognises the transformative power of digital tools in demystifying complex mathematical concepts. These tools leverage the human preference for visual learning, providing an enriched educational experience that shifts from dense textual presentations to engaging, interactive visualisations. This change in approach aligns with the learners' natural inclinations, as alluded to in earlier parts of this chapter, fostering a deeper engagement with the material and sustaining interest in mathematics.

Technology's capacity to visually represent information is a game-changer in education, especially in disciplines such as mathematics where visual aids are crucial for understanding abstract concepts. The incorporation of technology in this visual capacity offers a dynamic alternative to traditional print media, capturing learners' attention more effectively, and aiding in their conceptualisation of the material.

Through this theme, the educational value of technology as a visual enhancer is brought to the forefront. Interactive and animated digital tools not only maintain learner interest, but also act as crucial scaffolds that build upon and expand their comprehension. This adoption of technology provides a stark contrast to conventional learning methods, and represents a significant shift towards a more visually stimulating and engaging educational landscape.

The *Digital Renaissance in Education* theme (Section 6.6.2) marks a transformative era in educational practices, driven by technological advancements. Mirroring the revival of art and intellect during the historical Renaissance, this digital era signifies a profound metamorphosis in educational approaches. It is characterised by technology's role as a transformative agent, reshaping how teachers deliver content, how learners engage with it, and redefining the conceptual boundaries of education. This theme is explored through three distinct subthemes, each

highlighting an aspect of this evolution: *Flexibility*, *Engagement*, and *Boundaries*.

The first subtheme, focusing on technological advantages and flexibility, explores how digital tools inject agility and adaptability into education. It highlights the versatility of technology in tailoring content and methodologies to diverse learner needs, blending innovative practices with traditional teaching effectiveness. This balanced approach ensures technology augments, rather than overshadows, the foundational principles of education, leading to a more responsive and dynamic learning environment.

The second subtheme delves into technology's dual role in enhancing learner engagement and enriching educational experiences. Here, digital tools are seen not merely as adjuncts, but as key elements that make learning more relatable, engaging, and suited to diverse learning styles. This narrative illustrates technology's integral role in fostering a learner-centric environment, pivoting education towards interactive and personalised approaches.

In the third subtheme, technology is framed as a fundamental pedagogic enabler, extending the boundaries of traditional education. It explores how digital tools facilitate global connections and personalised learning experiences, emphasising the idea of education without physical or traditional boundaries. This subtheme showcases technology's role in fostering inclusive, varied, and interactive educational practices, thereby enabling a more connected and relevant learning experience for learners.

Together, these subthemes weave a comprehensive narrative of the digital renaissance in education, illustrating a paradigm shift towards more flexible, engaging, and expansive educational practices. This shift sees technology as a cornerstone in modern education, enhancing traditional teaching methods and redefining the educational experience. It signifies a blending of old and new pedagogical approaches, leading to an enriched, dynamic, and inclusive educational environment that is well-suited to the demands of a rapidly evolving digital world.

The *Digital Renaissance in Education* theme illuminates a pivotal shift towards a digitally enriched educational paradigm, a shift that is not self-acting, but demands a concerted, cross-sectoral effort, as underscored in the *Driving Digital Transformation in Education: The Need, Collaboration, and Empowerment* theme (Section 6.6.3). This theme amplifies the call for a steadfast commitment and unified support for a foundational integration of technology in educational settings. It accentuates the urgency for educational systems, particularly in South Africa's mathematics education, to progress from traditional pedagogies to a digital-centric approach, underlining technology's role as a crucial enhancer rather than an optional add-on. The theme delineates the collaboration required amongst stakeholders—academia, industry, and government—stressing that the journey towards digital integration is a shared venture, replete with mutual challenges and triumphs.

This collaborative ethos is not just about pooling resources, but also about the interexchange of innovative ideas and pedagogical strategies, which is vital for refining educational practices in the digital age. The narrative acknowledges the apprehensions and resistance encountered by teachers as they navigate away from traditional methodologies. Yet, it also presents a counterpoint with experiences from teachers who have embraced technology, discovering that the anticipated hurdles can be transformed into pathways of empowerment with adequate training

and support.

Central to this theme is the principle that learners' interests should anchor teaching and learning practices, ensuring that technological adoption serves the educational needs of learners foremost.

In weaving these threads together, the theme presents a vision of an educational system that is not only technologically equipped, but also deeply interconnected and learner-focused. It calls for a unified approach towards embracing technological change, where education is continuously adapted and enriched to meet the evolving needs of learners, and where teachers are empowered to be at the forefront of this transformation, ensuring that the digital leap in education is both progressive and inclusive.

In the theme *The Unintended Barriers: Economic and Relational Impediments in Technology-integrated Learning* (Section 6.6.4), the focus shifts to the unforeseen challenges that accompany the journey of integrating technology into learning environments. This theme centres on two predominant issues: economic barriers and relational dynamics between teachers and learners.

The economic aspect stresses the need for equitable access to digital tools, recognising that the cost of technology, even basic tools like calculators, can create disparities in educational experiences. Meanwhile, the theme also brings attention to how technology, while fostering innovative teaching methods, can inadvertently affect the teacher-learner relationship, a crucial aspect of effective teaching and learning.

Overall, the insights from this theme underscore the importance of addressing these barriers thoughtfully. This calls for strategies that not only facilitate technological access, but also preserve the quality of interpersonal interactions in the classroom. The need for this balanced approach has consistently been prevalent throughout the discussion and interpretation presented in this chapter, highlighting the complexity of integrating technology in education—a journey that requires navigating both its transformative potential and its unintended consequences.

Further addressing the practical challenges of technology integration in education, the theme *Navigational Challenges in the Digital Classroom: The Impact of Power Outages on Technology-driven Learning* (Section 6.6.5) brings into focus the significant and often disruptive effects of power outages, particularly in contexts like South Africa where power instability is a common issue. This theme reveals the extent to which power instability, or 'loadshedding,' can impede technology-driven teaching and learning. Teachers, who ordinarily employ a variety of technological tools to enrich the educational experience, find themselves constrained to switch back to more traditional methods during outages. This abrupt shift hampers the dynamism of a technology-enabled classroom, and also affects the continuity of the learning process.

This theme underscores not only the logistical challenges posed by power outages, but also their substantial impact on the pace and agility of lessons. Learners perceive a noticeable difference when electricity is unavailable, affecting the rhythm and efficiency of their educational experience. These frequent interruptions go beyond minor inconveniences, deeply affecting learners' engagement and the overall quality of education.

The insights gleaned from this theme emphasise the imperative for educational strategies that are both resilient and adaptable to infrastructural challenges like power outages. They highlight the crucial need for contingency plans and versatile teaching approaches that ensure continuous, effective learning, irrespective of technological constraints. Ultimately, these insights underscore the importance of developing an education system that can fluidly navigate between different teaching modalities, thereby maintaining a consistent, high-quality educational experience in the face of technological uncertainties.

Continuing the exploration of practical challenges in technology-integrated education, the theme *Glitches in the Matrix: Navigating Technical Inconsistencies and Contemporary Classroom Excuses in the Digital Era* (Section 6.6.6) focuses on the minor yet significant challenges, and often overlooked, that emerge in digital learning environments. This theme brings to the forefront issues like colour inconsistencies in projections, illustrating how such technical challenges, though seemingly minor, can disrupt the flow of teaching and detract from learners' educational journeys. These issues, while seemingly trivial, contribute to disruptions in the learning environment.

Moreover, this theme captures the modern evolution of classroom excuses, showcasing how the digital era has transformed traditional excuses into technology-related ones, such as blaming network connectivity or related issues for unfinished tasks. This intriguing side effect of digital classrooms signifies a new dimension of classroom challenges in the digital era.

The overarching insight from this theme underscores the importance of resilience and adaptability for both teachers and learners in navigating these challenges. It points to the need for sincerity in handling these new dynamics, suggesting that successful navigation through these technological inconsistencies is crucial for maintaining the integrity and effectiveness of the learning process. This theme complements the broader discussion on technology integration in education, illustrating the need for a holistic approach that not only embraces the benefits of digital tools, but also adeptly navigates their minor yet significant pitfalls.

The *Digital Disparities: The Landscape of Learner Access to Technology Tools in Education* theme (Section 6.6.7) concludes this subsection by addressing the crucial issue of equitable access in technology-integrated education, shedding light on the significant disparities in access to digital resources amongst learners. This theme draws a clear distinction between a minority of learners who have personal technological devices for classroom use and the majority who rely on the technology available only at school.

This theme also highlights the disparity in digital access beyond the classroom walls, revealing another layer of inequality that teachers must navigate to provide equitable education. Such disparities underscore the challenge of ensuring that the digital revolution in education does not become exclusive to those with personal devices, but remains inclusive and accessible to all learners.

The insights drawn from this theme suggest the need for equity in digital education. They call for a movement towards levelling the technological playing field, ensuring that all learners, regardless of their personal resources, have equal access to the educational opportunities afforded by technology. This again ties back to the overarching narrative, stressing the broader educa-

tional challenge of creating an inclusive environment. In this landscape, technology should act as a bridge, not a barrier, ensuring equal opportunities for all in the digital learning journey.

This subsection has explored a range of themes, each highlighting a critical facet of the digital evolution in education. From the empowering capabilities of digital tools in elucidating complex mathematical concepts through visual learning to the vast advantages, opportunities, and challenges ushered in by the digital renaissance, it has highlighted the multifaceted nature of this educational evolution. Central to this narrative are the teachers, who stand as the primary stewards of educational processes within classrooms. The themes discussed throughout this subsection articulate a vital need for balance: the effective integration of technology in education must carefully weigh its transformative potential against possible pitfalls. If certain aspects fall out of balance, the entire educational journey for learners may be compromised, thereby significantly diminishing the potential value of ICTs in education. This discussion not only ties into the central thesis of this research, but also contributes significantly to the wider discourse on digital education, emphasising the imperative for a holistic, thoughtful approach that recognises both the opportunities and the pitfalls of digital integration in learning environments.

7.4 SUMMARY

This chapter marked the culmination of the study's mixed methods approach, where quantitative results and qualitative findings were seamlessly integrated to reveal insights aligned with the study's foundational statements and research questions. The integration was facilitated by an integrated results matrix, a type of joint display underscored by literature for its effectiveness in mixed methods research. This strategic and systematic approach proved pivotal in addressing the mixed methods research questions outlined in Section 1.4.3, especially the first, effectively drawing on the strengths of both quantitative and qualitative data to enrich the insights obtained.

Focusing on RQ_{3a}, which investigated how qualitative findings elucidate the relationship between the use of ICTs in mathematics education and learner motivation, as observed by teachers, the chapter utilised joint displays as an essential analytical tool. These displays juxtaposed quantitative evidence with qualitative themes, facilitating the drawing of meta-inferences and implications regarding the intricate interplay amongst motivational dimensions within the ICT teaching and learning context. Through this analysis, a comprehensive portrayal emerged, detailing the diverse ways that digital tools influence learning environments, and in turn, learner motivation.

In addressing RQ_{3b}, the chapter provided a comprehensive account of the relationship between the use of ICTs in teaching mathematics and learner motivation, drawing from teachers' observations. It delved into the practical realities of ICT integration, highlighting the benefits and outlining the challenges encountered. This part of the discussion vividly illustrated the pedagogical landscape, underscoring the complex relationship between technology use in teaching and motivational dynamics in the classroom.

Similarly, in addressing RQ_{3c}, the chapter refocused the discussion to the connection between the use of ICTs in learning mathematics and learner motivation, once more from the teachers' perspective. It underscored the dynamic interplay between technology use in learning mathematics and the motivation to learn, revealing both the opportunities presented by and the chal-

lenges posed by ICTs within learning environments.

Beyond addressing these specific questions, the chapter presented broader interpretations of the dynamics of the digital transition within educational settings. It reflected on the evolutionary role of ICTs in education, considering their widespread implications for both teachers and learners. This perspective situates the study's outcomes within the ongoing technological evolution, recognising its implications for decision-making amongst educational stakeholders, and forecasting its potential influence on the future landscape of education, particularly in teaching and learning practices. These are further expounded in the next chapter.

CHAPTER 8

CONCLUSION

8.1 INTRODUCTION

This is the final chapter of this thesis. It begins with a concise summary of the study, highlighting its rationale, key design and methodological elements, and reiterating the principal outcomes. The chapter then progresses to delineate the study's main contributions across methodological, practical, and scholarly domains. This is followed by a reflective assessment of the study's strengths and limitations, offering an introspective view of its merits and scope. The chapter then transitions to present the key recommendations drawn from the integrative interpretation of the results and findings. It concludes with a final reflection that encapsulates the research journey and situates the study within its broader context, underscoring its wider implications.

8.2 SUMMARY OF THE STUDY

The current state of mathematics education within the NCS Grades R–12 South African schooling system presents notable performance challenges, highlighted by results from ILSAs in the GET phase, and the NCS final examinations in the FET phase. These challenges cast a shadow over South Africa's aspirations as delineated in the NDP, which ambitiously aims for improved performance in ILSAs like the TIMSS, and seeks to prepare at least $450,000$ learners to pursue bachelor's degree programmes requiring mathematics and science by 2030. The dissonance between these goals and the current educational outcomes poses significant concerns for the nation's socio-economic progress and its standing in the global community.

This study was initiated against the backdrop of these educational challenges. It specifically investigated teachers' perceptions of ICT use in the mathematics classroom, and its relationship with learner motivation. The investigation was grounded in Sivan's (1986) conceptualisation of motivation within a social constructivist setting. Here, Sivan describes motivation as manifesting through observable interest and engagement, both of which are inherently multidimensional. Interest is divided into situational and individual types, reflecting the diverse ways learners become curious about mathematical concepts and applications. Engagement, meanwhile, is characterised by behavioural, affective, cognitive, and agentic dimensions, each contributing to a comprehensive understanding of how learners interact with, and assimilate, mathematical con-

cepts. Collectively, these dimensions offer a comprehensive view of how learners interact with mathematics, particularly in environments enriched by ICTs.

This study, grounded in the philosophical underpinnings of the Pragmatic paradigm, was shaped by its epistemological, ontological, axiological, and methodological assumptions. The Pragmatic paradigm stood out as the most suitable amongst the dominant paradigms in educational research due to its reflexive nature, and emphasis on methodological flexibility. A key tenet of this paradigm is its focus on methodology, advocating for the selection of the most appropriate research methods to ensure optimal outcomes. Aligned with this philosophy, a mixed methods approach was chosen. This approach, amongst the three common methodological approaches, best aligned with the philosophical tenets of the Pragmatic paradigm. Within this methodological approach, the explanatory sequential design was selected for its comprehensive ability to address the research phenomenon. Consistent with this design, the study was conducted in two sequential phases. Initially, a quantitative phase involved surveying teachers to understand their perceptions of ICT use in teaching and learning mathematics, focusing on its influence on learner motivation. This was followed by a qualitative phase, featuring semi-structured interviews aimed at gaining deeper insights into the relationship between ICT use in teaching and learning mathematics, and learner motivation, elaborating on the results from the quantitative data analysis. A combination of multilevel and sequential mixed methods sampling procedures was employed as the study's integrated sampling strategy to select potential participants.

The survey collected data from 55 teachers, resulting in 23 valid responses. These were analysed using appropriate descriptive and inferential statistical techniques to uncover trends and patterns. The analysis revealed a generally positive perception of the use of ICTs in enhancing learner motivation, yet it also pointed to underlying complexities that warranted further qualitative investigation. Consequently, follow-up semi-structured interviews were conducted with six teachers, enriching the study with a diverse thematic landscape. Through the reflexive thematic analysis approach, the qualitative phase derived 21 themes, along with three subthemes, offering nuanced insights into teachers' experiences with ICTs in educational settings. Notably, it revealed an intricate relationship between motivation, interest, and engagement as perceived by teachers. Furthermore, these findings revealed how teachers and learners navigate the use of ICTs in their educational journeys, the influence of using ICTs on various aspects of learner motivation, and the ways in which the constantly evolving landscape of technology-enriched education is reshaping classroom dynamics and discourse.

The integration of quantitative and qualitative strands, a cornerstone of the mixed methods approach, was a crucial aspect of this research. This 'mixing' occurred at two pivotal points. Initially, the results from the quantitative phase were used to refine the data generation protocol for the qualitative phase. Subsequently, an integrated interpretation of both the quantitative results and qualitative findings was conducted, providing a holistic understanding of the role of ICTs in fostering learner motivation within the mathematics classroom. Distilling from these integrated outcomes, the subsequent section highlights the key contributions of this research study.

8.3 CONTRIBUTIONS

8.3.1 Methodological Contribution

This research study makes two significant methodological contributions to the field of mixed methods research. Firstly, it offers a disciplinary contribution by extending mixed methods approaches to explore the use of ICTs in classroom environments, particularly within the distinct cultural and developmental context of South Africa. This application not only broadens the scope of mixed methods research, but also demonstrates its adaptability and reflexivity in diverse settings.

Secondly, the study makes a methodological contribution through its explicit emphasis on, and transparency in, the integration of quantitative and qualitative strands, particularly during the interpretation phase of the research design. This was accomplished through the use of an integrated results matrix, a type of joint display that effectively bridges quantitative evidence with qualitative themes, thereby enriching the interpretive depth. This approach enhances the existing literature by demonstrating a systematic method for integrating data strands in mixed methods research, responding to the growing demand for such techniques amongst scholars in the field.

8.3.2 Practical Contribution

This research study brings to light the role of technology in teaching and learning mathematics, particularly focusing on how it influences learner motivation. It uncovers the intricate ways in which learners interact with technology in their educational pursuits, identifying both the opportunities and challenges this interactivity presents. Central to this interactivity is the teacher's role in effectively mediating and guiding technology use in the classroom. Moreover, the study unveils the complex journey teachers undertake in embracing technology within their teaching practices, navigating its pedagogical affordances, amidst the backdrop of technology-savvy 21st-century learners. What emerges in this confluence of learners' interactions with ICTs and teachers' journey through technological integration is a nuanced understanding of technology's potential to influence learner motivation. This potential, however, is contingent upon the teachers' ability and proficiency to adeptly navigate a technology-rich educational landscape.

On a more detailed level, the meta-inferences and practical implications drawn for each dimension of motivation, as detailed in Tables 7.1 and 7.2, provide valuable contributions towards realising the educational goals of South Africa's 2030 NDP through the strategic use of ICTs. These insights offer pragmatic strategies for integrating ICTs in educational settings, thereby aligning with, and potentially accelerating the achievement of the nation's broader educational aims. Highlighting the need for strategic ICT integration, they stress the importance of empowering teachers with the skills and knowledge necessary for effective technology use. By addressing these areas, the study supports the advancement of South Africa's educational objectives, demonstrating how ICT can be a key enabler in meeting the ambitious targets set by the NDP. For these practical strategies to be effective, they must be rooted in robust scholarly and theoretical underpinnings. The next subsection delves into this aspect, highlighting the key scholarly contributions of this study.

8.3.3 Scholarly Contribution

This study makes several key contributions to the scholarly community. Firstly, it enriches the global dialogue on the utility of ICTs in educational settings. By exploring the intricacies of technology integration in classrooms, this research deepens the understanding of how various theoretical and psychological components interact in educational environments. Particularly, it sheds light on the mechanisms through which strategic ICT use can develop and nurture motivation to learn mathematics.

The study's second scholarly contribution arises from the adoption and expansion of Sivan's (1986) conceptualisation of motivation within a social constructivist setting. This research not only adopts this theoretical lens, but also expands it by incorporating elements that reflect recent disciplinary progress. Specifically, it refines the conceptualisations of both interest and engagement as multidimensional constructs. In this sense, it provides a more sophisticated understanding of interest, and deepens the concept of engagement by adding the agentic dimension, which emerged prominently in the qualitative findings. In addition to these theoretical enhancements, the study contributes by developing a quantitative measure, derived from existing ones, to specifically assess motivation in its complex, multidimensional form from the distinctive perspective of teachers.

Lastly, but importantly, this research demonstrates the inherent complexity of motivation as a multidimensional construct. It highlights the intricate interplay between its dimensions of interest and engagement, as conceptualised in this study. This suggests the need for careful consideration when investigating motivation, particularly its manifestations in diverse educational contexts, even extending beyond technology-enhanced learning environments.

8.4 Strengths and Limitations

8.4.1 Strengths

The strength of this research study lies in its well-structured design and methodological rigour. As elaborated in Section 4.3.2, the explanatory sequential mixed methods research design brings inherent advantages. Notably, the integration of quantitative and qualitative data facilitated richer and more nuanced outcomes than would have been possible using either approach in isolation, thereby enhancing the breadth and depth of the research outcomes. In this study, the quantitative results were pivotal in shaping the direction of the qualitative phase, identifying areas that needed more in-depth qualitative exploration. Conversely, the qualitative findings provided profound explanations for the relationships between various dimensions of motivation, as initially observed in the quantitative phase. The ultimate integrative interpretation of both datasets painted a comprehensive picture of how the use of ICTs, together with other contextual factors within and outside the classroom, influences learners' motivation to learn mathematics.

The strength of this study was further augmented by the careful application of robust statistical techniques for the quantitative data analysis, complemented by the meticulous use of reflexive thematic analysis for the qualitative data. This latter approach was instrumental in generating authentic, contextually grounded insights, offering a profound exploration of teachers' perceptions of ICT use in classroom settings. The choice and application of these well-established

analytical methods are in line with the Pragmatic paradigm's emphasis on methodological appropriateness and adaptability, further reinforcing the study's methodological soundness.

8.4.2 Limitations

The research design, while a major strength in many respects, also entailed inherent limitations, as detailed in Section 4.3.2. The implementation of the explanatory sequential mixed methods design, known for its time-intensive nature, affected several aspects including sample selection and management, the collection and generation of data, as well as the subsequent analysis of these data. This challenge was amplified by the COVID-19 pandemic, which coincided with the critical periods of data collection and generation. The pandemic imposed severe restrictions on access to participants and research sites, necessitating a shift to remote and virtual interactions. A tangible consequence of the pandemic's restrictions was the loss of contact with some participants from the quantitative phase who had initially expressed interest in the qualitative phase. This situation potentially compromised the depth and richness of the qualitative data.

Furthermore, the geographic delimitation of the study, as detailed in Section 1.6.1, combined with the disruptive impact of the COVID-19 pandemic, significantly influenced the sampling strategies and sizes. The geographic scope, while necessary for the study's focus, coupled with pandemic-related constraints, resulted in smaller sample sizes than ideally desired, particularly for the quantitative phase. This dual limitation introduced potential judgement errors and selection bias, subsequently affecting the generalisability of the results and the transferability of the findings. The constrained sample size also limited the range of statistical techniques applicable in the quantitative analysis. Despite this limitation, careful consideration was given to selecting the most appropriate methods to mitigate these constraints and ensure the robustness of the analysis.

Another limitation of this study was its reliance on self-reported data from participating teachers during both the quantitative and qualitative phases. Although depending solely on self-reports can potentially introduce elements of subjectivity and recall bias, the significant value of teachers' first-hand accounts must be acknowledged. Their insights were instrumental in gaining a comprehensive understanding of the dynamics of ICT use within classroom settings. Despite the inherent limitations of self-reported data, the perspectives of teachers provided an indispensable and holistic view of the educational environment. They offered rich and context-specific information that was essential to the outcomes of this study.

8.5 Recommendations

8.5.1 Opportunities for Professional Development

A key insight from the integrative interpretation of the quantitative evidence and qualitative themes in this study is the pivotal role of teachers as stewards of educational processes within classrooms. While this study primarily captures the perspectives of teachers, a limitation previously acknowledged, the value of their experiences and insights is substantial, and resonates with broader research trends. A significant aspect of their professional journey involves self-initiated learning and informal training to effectively integrate ICTs into their teaching practices. The outcomes of this research underscore the importance of teachers' proficiency with

digital tools in shaping the learning environment. Thus, it is recommended that opportunities for professional development be continuously provided, enabling teachers to stay current with the rapidly evolving landscape of technology-enhanced education.

A specific suggestion in this regard is the establishment of collaborative teacher networks or platforms. These forums would offer invaluable opportunities for teachers to share their experiences and learn from one another. Such platforms could serve as valuable supplements to formal training programmes, providing a space where practical strategies and best practices can be exchanged. This approach would not only strengthen the merits of informal learning communities, but also enhance the overall professional development landscape. With sufficient training and support, teachers will be better prepared to navigate the challenges of a future rich with technology, and cater to the needs of technology-savvy learners in their classrooms.

8.5.2 **Areas for Future Research**

The integrated interpretation detailed in Chapter 7 serves as a springboard for several promising areas for future research, particularly focusing on the intersection of ICT use in mathematics education and learner motivation. This subsection outlines three key research directions that could be pursued:

First, an important area for future research involves the investigation, development, and assessment of pedagogical strategies that thoughtfully integrate technology, aimed explicitly at stimulating and sustaining learner interest, as well as fostering learner engagement. Exploring this domain could be instrumental in identifying methods that effectively harness technology to boost motivation during the learning process. Such a line of inquiry holds significant potential for shaping educational approaches that not only effectively leverage digital tools, but also adequately prepare learners for a future that is increasingly shaped by technological advancements.

Second, the complex and intricately linked learning triad of motivation, interest, and engagement, as observed particularly in technology-rich educational environments, presents considerable scope for further detailed exploration. Future studies should aim to elucidate the dynamics amongst these concepts. By building upon the mixed methods approach used in this research, subsequent studies could explore alternative designs within this methodological framework, or employ a variety of data collection and generation techniques. Methods such as in-depth classroom observations or the inclusion of learners' perspectives could be particularly beneficial. The adoption of such varied research strategies is likely to yield more comprehensive insights into how these critical educational constructs interact and manifest within technology-enhanced learning environments.

Third, this study's focus on situational and individual interest paves the way for more granular research in the domain of interest development. Future research could delve into the nuances of the Four-Phase Model of Interest Development as proposed by Hidi and Renninger (2006). By examining how ICTs influence each specific phase of this model, from the initial triggering of situational interest to the cultivation of well-developed individual interest, researchers could gain valuable insights. Such an investigation would be instrumental in understanding how technology can either facilitate or hinder the evolution of interest within educational environments.

8.6 FINAL REFLECTION

Embarking on this research journey has been an enlightening experience that has enriched my understanding of how technology intersects with education. Delving into the complexities of how ICTs influence learner motivation has not only broadened my academic perspective, but also deepened my appreciation for the intricate dynamics of modern educational environments. This journey of discovery has been a blend of challenges and discoveries, each contributing to a greater appreciation of the multifaceted nature of education in a digital era.

Throughout this research study, I have gained a renewed appreciation for the power of education and the critical role of technology in shaping future learning paradigms. This journey has been more than a pursuit of academic knowledge; it has fostered a deeper commitment to contributing to an educational landscape that is adaptive, inclusive, and forward-thinking.

Improving the quality of education and educational outcomes remains a top priority on the national agenda. As ICTs increasingly permeate the educational landscape, they present a spectrum of challenges and opportunities. Consequently, the task at hand is to embrace and harness these technologies, drawing on strong theoretical and empirical underpinnings, with the aim of enriching the learning experience while also maximising educational benefits for learners.

In the context of South Africa, technology has long been regarded as a catalyst for socio-economic growth and empowerment. The outcomes of this research provide evidence supporting this view, suggesting that ICTs indeed hold the potential to revolutionise education. Realising this potential, however, demands a unified and concerted effort from all educational stakeholders. This effort must include a focus on significant socio-psychological and cultural aspects, such as learner motivation, which play a crucial role in shaping learners' educational journeys. This entails not only understanding, but also strategically responding to the diverse needs of learners in technology-rich learning environments. By adopting a collaborative and strategic approach, it becomes possible to fully leverage the capabilities of technology, thus not only advancing the field of education, but also contributing to the broader socio-economic progress of the nation.

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APPENDIX A

RESEARCH APPROVAL CERTIFICATES

A.1 GAUTENG DEPARTMENT OF EDUCATION

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**12 August 2019**
Validity of Research Approval:	**04 February 2020 – 30 September 2020** **2019/192**
Name of Researcher:	**Mhlongo S.T**
Address of Researcher:	[redacted]
Telephone Number:	
Email address:	
Research Topic:	**An exploratory mixed methods study of the use of technology in Grade 9 mathematics classrooms and how it relates to learner motivation.**
Type of qualification	**PhD**
Number and type of schools:	**Five Secondary Schools**
District/s/HO	**Ekurhuleni North, Gauteng East, Johannesburg East and Ekurhuleni South**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

12/08/2019

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

.....

Mrs Faith Tshabalala
Acting Director: Education Research and Knowledge Management

DATE: 12/08/2019

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

A.2 GAUTENG DEPARTMENT OF EDUCATION (EXTENSION)

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**12 May 2021**
Validity of Research Approval:	**08 February 2021– 30 September 2021** **2019/192A**
Name of Researcher:	**Mhlongo ST**
Address of Researcher:	[redacted]
Telephone Number:	
Email address:	
Research Topic:	**An exploratory mixed methods study of the use of technology in Grade 9 mathematics classrooms and how it relates to learner motivation**
Type of qualification	**Phd**
Number and type of schools:	**5 Secondary Schools**
District/s/HO	**Ekurhuleni North, Gauteng East, Johannesburg East and Ekurhuleni South**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

12/05/2021

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. ***Because of COVID 19 pandemic researchers can ONLY collect data online, telephonically or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate. The approval letter will then indicate the type of arrangements that have been made with the school.***
4. ***The Researchers are advised to make arrangements with the schools via Fax, email or telephonically with the Principal.***
5. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
6. *A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
7. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
8. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
9. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
10. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
11. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
12. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
13. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
14. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
15. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
16. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

.....

Mr Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: ....12/05/2021.....

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

A.3 WITS HUMAN RESEARCH ETHICS COMMITTEE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Mhlongo

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H19/08/22**
PROJECT TITLE	An exploratory mixed methods study of the use of technology in grade 9 mathematics classrooms and how it relates to learner motivation
INVESTIGATOR(S)	Mr S Mhlongo
SCHOOL/DEPARTMENT	Education/
DATE CONSIDERED	16 August 2019
DECISION OF THE COMMITTEE	Approved Permission letters from schools required before data collection can commence
EXPIRY DATE	16 January 2023

DATE 17 January 2020 **CHAIRPERSON** _____
(Professor J Knight)

cc: Supervisor : Dr R Dlamini and Dr S Khoza

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

_____ 17 / 01 / 2020
Signature **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

APPENDIX B

RESEARCH PERMISSION LETTERS AND FORMS

B.1 Gauteng Department of Education Permission Letter

University of the Witwatersrand
School of Education

Educational Information & Engineering Technology
Wits School of Education
27 St Andrews Road
Parktown
2193

26 July 2019

The Director: Education Research and Knowledge Management
Gauteng Department of Education
7th Floor Talis Building
6 Hollard Street
Masharlltown
2107

Dear Ms Faith Tshabalala,

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT GAUTENG GOVERNMENT SECONDARY SCHOOLS

My name is Siyabonga Mhlongo, a PhD candidate at the Wits School of Education in the Faculty of Humanities at the University of the Witwatersrand. I hereby wish to request your permission to carry out research at 5 Gauteng government secondary schools. My research study is entitled: An exploratory mixed methods study of the use of technology in Grade 9 mathematics classrooms and how it relates to learner motivation.

The purpose of this study is twofold: first, it seeks to explore and analyse the different discourse practices in the use of technology in Grade 9 mathematics classrooms for both teaching and learning, and second, it seeks to uncover the extent to which this use of technology relates to the motivation of the learners to learn mathematics. Its basis is on (a) the significance of Grade 9, which marks the transition from the General Education and Training (GET) phase of learning to the Further Education and Training (FET) phase learning in the South African schooling system, and (b) the importance of mathematics in the economic progress and growth of our country.

If permission is granted, I will seek voluntary participation and permission from the principals of the schools, the teachers who use technology to teach Grade 9 mathematics, as well as the Grade 9 learners (and their parents or guardians) who use technology to learn mathematics. To collect the data that will assist this research study, I intend following a three-step process. The first step will involve conducting *individual semi-structured interviews* with the teachers in order to establish their perceptions of using technology to teach mathematics in their classrooms. Each individual interview will be audio-recorded, will last between 30 and 45 minutes and will be conducted outside of the teachers' classroom time. In the second step, I will *unobtrusively observe* classroom sessions wherein the teacher and the learners use technology during the teaching and learning processes. It will be necessary to video-record each session in order to fully capture the various classroom interactions and to revisit the sessions at a later stage of the research study. The information collected during the first two steps will be analysed, leading to the third and final step, where learners (with the assistance and co-operation of the teacher) will be requested to complete a *survey questionnaire* which will assist in gaining insight into their interest and engagement (both of which are elements of motivation) levels relative to (a) how they have been taught mathematics using technology, and (b) how they have used technology to learn mathematics. This will take between 15 and 20 minutes to complete.

My intention is to carry out this research during the first and second terms of 2020. The reason I have chosen these schools is because they amongst the few Gauteng public secondary schools that make full use of technology to teach and learn mathematics in Grade 9 classrooms. The data collection will begin only once permission has been obtained from the school principals and consent has been granted by the

teachers, learners and learners' parents or guardians. The data collected will be used exclusively for this research study, will be stored in a password-protected repository (in the case of digital data) or in a locked office (in the case of paper-based data) where no one other than the research team will have any access, will not be disclosed to anyone else, and will be securely discarded 5 years after the completion of this research study.

In order to ensure that the schools, teachers and learners are all protected, privacy, anonymity and confidentiality will be maintained at all times. To guarantee this, the research participants will not be advantaged or disadvantaged in any way; they will be reassured that their participation is voluntary and that they can withdraw their permission at any time during this research study without any penalty or prejudice; and at all times, pseudonyms and/or numbers will be used whenever any of the schools, teachers or learners are referred to in any documents, manuscripts, or similar that will emanate from this research study. Furthermore, there are no foreseeable risks for the schools or participants in participating in this research study and the schools and participants will not be compensated in any way.

You may ask any questions or request any further information or clarity concerning this research study if necessary by contacting me at any time using the contact details provided at the bottom of this letter. I look forward to your response as soon as it is convenient.

Yours sincerely,

_____

Mr Siyabonga Mhlongo
PhD Candidate
Wits School of Education

Mobile: [redacted]
e-Mail: [redacted]

B.2 PRINCIPAL PERMISSION LETTER

UNIVERSITY OF THE WITWATERSRAND
SCHOOL OF EDUCATION

Educational Information & Engineering Technology
Wits School of Education
27 St Andrews Road
Parktown
2193

14 May 2021

The Principal
Name of the School
Address Line #1
Address Line #2
Address Line #3
Address Line #4

Dear [Name of Principal],

RE: INVITATION TO PARTICIPATE AND REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT YOUR SCHOOL

My name is Siyabonga Mhlongo, a PhD candidate at the Wits School of Education in the Faculty of Humanities at the University of the Witwatersrand. I hereby wish to request your permission to carry out research at your school. My research study is entitled: AN EXPLORATORY MIXED METHODS STUDY OF THE USE OF TECHNOLOGY IN GRADE 9 MATHEMATICS CLASSROOMS AND HOW IT RELATES TO LEARNER MOTIVATION.

The purpose of this study is twofold: first, it seeks to explore and analyse the different discourse practices in the use of technology in Grade 9 mathematics classrooms for both teaching and learning, and second, it seeks to uncover the extent to which this use of technology relates to the motivation of the learners to learn mathematics. Its basis is on (a) the significance of Grade 9, which marks the transition from the General Education and Training (GET) phase of learning to the Further Education and Training (FET) phase learning in the South African schooling system, and (b) the importance of mathematics in the economic progress and growth of our country.

If permission is granted, I will seek voluntary participation from the teacher(s) who use technology to teach Grade 9 mathematics. To collect the data that will assist this research study, I intend following a two-step process. In the first step, I will request the teacher(s) to complete an **online** *survey questionnaire*. The aim of this questionnaire is to illuminate the teacher(s)' perceptions of the learners' interest and engagement (both of which are elements of motivation) levels relative to (a) how they have been taught mathematics using technology, and (b) how they have used technology to learn mathematics. This will take between 10 and 15 minutes to complete. The information collected during the first step will be analysed, leading to the second and final step. In this step, I will conduct **online** *individual semi-structured interviews* with the teacher(s) who would have given his/her (their) permission to be interviewed. The purpose of the interview will be twofold: first, it will be to clarify some of the findings from the first step, and second, it will be to establish his/her (their) perceptions of using technology to teach mathematics in his/her (their) classroom(s). Each individual interview will be audio recorded, will last between 30 and 45 minutes and will be conducted outside of the teacher's classroom time.

My intention is to carry out this research during the second and third terms of 2021 and once consent has been granted by the teacher(s). The reason I have chosen your school is because it is one of the few Gauteng public secondary schools that **make full use of technology to teach and learn mathematics in Grade 9 classrooms**. The data collected will be used exclusively for this research study, will be stored in a password-protected repository (in the case of digital data) or in a locked office (in the case of paper-based data) where no one other than the research team will have any access, will not be disclosed to anyone else, and will be securely discarded five (5) years after the completion of this research study.

In order to ensure that your school and the teacher(s) are all protected, privacy, anonymity and confidentiality will be maintained at all times. To guarantee this, the research participants will not be advantaged or disadvantaged in any way; they will be reassured that their participation is voluntary and that they can withdraw their permission at any time during this research study without any penalty or prejudice; and at all times, pseudonyms and/or numbers will be used whenever the school or the teacher(s) are referred to in any documents, manuscripts, or similar that will emanate from this research study. Furthermore, there are no foreseeable risks in participating in this research study and the participants will not be compensated in any way.

In light of the above background and details, I am inviting your school to participate in this research study.

You may ask any questions or request any further information or clarity concerning this research study if necessary by contacting me at any time using the contact details provided at the bottom of this letter. I look forward to your response as soon as it is convenient.

Yours sincerely,

Mr Siyabonga Mhlongo
PhD Candidate
Wits School of Education

Mobile: [redacted]
e-Mail: [redacted]

B.3 Principal Consent Form

PRINCIPAL CONSENT FORM

Please fill in and return the reply slip below indicating your willingness for your school to participate in this voluntary research study

---

Dear Siyabonga Mhlongo,

I hereby accept your invitation and further give my permission for you to undertake your research study entitled: An exploratory mixed methods study of the use of technology in Grade 9 mathematics classrooms and how it relates to learner motivation at my school. I further acknowledge that I have been adequately informed of the nature of the research study, together with all its requirements.

Principal's Name: _____

Principal's Signature: _____

Date: _____

School Stamp

Appendix C

Participants Information Sheets and Forms

C.1 TEACHER INFORMATION SHEET



UNIVERSITY OF THE WITWATERSRAND
SCHOOL OF EDUCATION

TEACHER INFORMATION SHEET 14 May 2021

Dear Grade 9 Mathematics Teacher,

My name is Siyabonga Mhlongo, a PhD candidate at the Wits School of Education in the Faculty of Humanities at the University of the Witwatersrand. I am currently conducting a research study entitled: AN EXPLORATORY MIXED METHODS STUDY OF THE USE OF TECHNOLOGY IN GRADE 9 MATHEMATICS CLASSROOMS AND HOW IT RELATES TO LEARNER MOTIVATION.

The purpose of this study is twofold: first, it seeks to explore and analyse the different discourse practices in the use of technology in Grade 9 mathematics classrooms for both teaching and learning, and second, it seeks to uncover the extent to which this use of technology relates to the motivation of the learners to learn mathematics. Its basis is on (a) the significance of Grade 9, which marks the transition from the General Education and Training (GET) phase of learning to the Further Education and Training (FET) phase learning in the South African schooling system, and (b) the importance of mathematics in the economic progress and growth of our country.

As part of this research study, I would like to invite you to (a) complete an **online** *survey questionnaire*, and with your further permission (b) take part in an **online** *individual semi-structured interview*. The purpose of the questionnaire is to illuminate your perceptions of the learners' interest and engagement (both of which are elements of motivation) levels relative to (a) how they have been taught mathematics using technology, and (b) how they have used technology to learn mathematics. This will take between 10 and 15 minutes to complete. The purpose of the interview will be twofold: first, it will be to clarify some of the findings from the analysis of the survey questionnaire data, and second, it will be to establish your perceptions of using technology to teach mathematics in your classroom. With your permission and in order to supplement the interview notes that I will be taking, I would like to audio-record our interview session. The interview will last between 30 and 45 minutes and will be conducted outside of your classroom time.

The reason I have chosen you is because you teach Grade 9 mathematics in one of only few public secondary schools in Gauteng that make full use of technology to teach and learn mathematics in Grade 9 classrooms. The data collected will be used exclusively for this research study, will be stored in a password-protected repository (in the case of digital data) or in a locked office (in the case of paper-based data) where no one other than the research team will have any access, will not be disclosed to anyone else, and will be securely discarded five (5) years after the completion of this research study.

I will strive to ensure that any information obtained during this research study that could potentially identify you will be kept strictly confidential. Pseudonyms (fictitious names) and/or numbers will be used whenever you or the school are referred to in any documents, manuscripts, or similar that will emanate from this research study. You will not be advantaged or disadvantaged in any way. Furthermore, I'd like to reassure you that your participation is completely voluntary and that if you experience any distress or discomfort in completing the survey questionnaire or during our interview session, we will stop immediately and/or resume at another time without any penalty or prejudice. You can also withdraw your permission to participate at any time during this research study.

There are no other foreseeable risks in participating in this research study. You will not receive any direct benefits, including compensation, from participating in this study.

If you have any questions afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research thesis which will be available online through the university library website. It may also be published through reputable journals and conference proceedings. If you wish to receive a summary of this report, I will be happy to send it to you upon request. If you have any queries, concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (non-medical) via telephone on +27 (0) 11 717 1408 or via email at Shaun.Schoeman@wits.ac.za

Yours sincerely,

Mr Siyabonga Mhlongo
PhD Candidate, Wits School of Education

RESEARCH TEAM

Researcher: Siyabonga Mhlongo [redacted]
Supervisor: Reuben Dlamini [redacted]
Supervisor: Samuel Khoza [redacted]

C.2 Teacher Consent Form

TEACHER CONSENT FORM

Please fill in and return the reply slip below indicating your willingness to be a participant in this voluntary research study

---

Dear Siyabonga Mhlongo,

I, the undersigned, hereby give my consent for you to undertake your research study entitled: An exploratory mixed methods study of the use of technology in Grade 9 mathematics classrooms and how it relates to learner motivation with me. I further give my consent for the following:

	Tick One	
Permission to fill in a questionnaire	Yes	No
I agree to fill in a survey questionnaire for this study.	☐	☐
Permission to be interviewed	Yes	No
I would like to be interviewed for this study.	☐	☐
I know that I can stop the interview at any time and don't have to answer all the questions asked.	☐	☐
Permission to be audio-recorded	Yes	No
I agree to be audio-recorded during the interview session.	☐	☐
I know that the recorded audio will be used for this project only.	☐	☐

Informed consent

I understand that:

- I am voluntarily offering to participate in this research study, and that my name and information will be kept confidential and safe, and that my name and the name of my school will not be revealed.
- I do not have to answer every question and that if I experience any distress or discomfort in completing the survey questionnaire or during the interview session, I can ask you to stop immediately and/or resume at another time without any penalty or prejudice.
- I can ask not to be audio-recorded, and that I can withdraw my permission to participate at any time during this research study.
- the data collected will be used exclusively for this research study.
- all digital data collected will be stored in a password-protected repository.
- all paper-based data collected will be stored in a locked office.
- only the research team, and no one else, will have access to any of the data collected.
- all the data collected will be securely discarded five (5) years after the completion of this research study.

Teacher's Name: _____

Teacher's Signature: _____

Date: _____

APPENDIX D

RESEARCH INSTRUMENTS

D.1 SURVEY QUESTIONNAIRE



TEACHER INFORMATION SHEET

Dear Mathematics Teacher,

My name is Siyabonga Mhlongo, a PhD candidate at the Wits School of Education in the Faculty of Humanities at the University of the Witwatersrand. I am currently conducting a research study which aims to **explore the use of technology in mathematics classrooms**.

I would be delighted if your could participate in my research study by (a) completing this **online** *survey questionnaire*, and with your further permission (b) take part in an **online** *individual semi-structured interview*.

If you have any questions afterwards about this research, feel free to contact me on the details listed below. If you have any queries, concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (non-medical) via telephone on +27 (0) 11 717 1408 or via email at Shaun.Schoeman@wits.ac.za

Yours sincerely,

Mr Siyabonga Mhlongo
PhD Candidate, Wits School of Education

RESEARCH TEAM

Main Researcher:

Siyabonga Mhongo
[redacted]

Supervisor:

Reuben Dlamini
[redacted]

Supervisor:

Samuel Khoza
[redacted]

○ I have read and understood the information above



TEACHER CONSENT FORM

Dear Siyabonga Mhlongo,

I hereby give my consent for you to undertake your research study with me, which aims to explore **the use of technology in mathematics classrooms**. I further give my consent for the following:

Permission to fill in a questionnaire

	Yes	No
I agree to fill in this survey questionnaire for this research study.	◯	◯

Informed consent

I understand that:

- I am voluntarily offering to participate in this research study, and that my name and information will be kept confidential and safe, and that my name and the name of my school will not be revealed.
- if I experience any distress or discomfort in completing this survey questionnaire, I can stop immediately and/or resume at another time without any penalty or prejudice.
- I can withdraw my permission to participate at any time during this research study.
- the data collected will be used exclusively for this research study.
- all digital data collected will be stored in a password-protected repository.
- all paper-based data collected will be stored in a locked office.
- only the research team, and no one else, will have access to any of the data collected.
- all the data collected will be securely discarded five (5) years after the completion of this research study.

◯ I consent to taking part in this research study
◯ I DO NOT consent to taking part in this study



DEMOGRAPHIC INFORMATION

I teach mathematics using technology at my school.
*(selecting **No** will end this online survey as it is intended only for those teachers who use technology in their mathematics classrooms)*

◯ Yes
◯ No

I teach mathematics using technology in the following schooling phase:

◯ Foundation Phase - Grades 0 to 3
◯ Intermediate Phase - Grades 4 to 6
◯ Senior Phase - Grades 7 to 9
◯ FET Phase - Grades 10 to 12

My school is in the following Gauteng Department of Education (GDE) district:

◯ Ekurhuleni North
◯ Ekurhuleni South
◯ Gauteng East
◯ Gauteng North
◯ Gauteng West
◯ Johannesburg Central
◯ Johannesburg East
◯ Johannesburg North
◯ Johannesburg South
◯ Johannesburg West
◯ Sedibeng East
◯ Sedibeng West
◯ Tshwane North
◯ Tshwane South
◯ Tshwane West



INSTRUCTIONS FOR SURVEY QUESTIONS

Thank you for filling out the preamble sections of this online survey questionnaire. The questions that follow are the gist of this survey questionnaire and seek to gather insights based on your perceptions during the teaching and learning processes in your mathematics classroom.

For each of the questions that follow, the question stem is presented in **bold font**, followed by a number of statements for which you must state the extent to which you agree or disagree with each statement using five (5) scale points, namely:

- Strongly Agree
- Agree
- Neither Agree nor Disagree
- Disagree
- Strongly Disagree



BEHAVIOURAL ENGAGEMENT

Because of the use of technology in teaching and learning in my classroom...

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
In class, my learners work as hard as they can	○	○	○	○	○
When my learners are in class, they actively participate in class activities	○	○	○	○	○
My learners pay attention in class	○	○	○	○	○
When my learners are in class, they just act like they are working	○	○	○	○	○
When my learners are in class, their minds often wander	○	○	○	○	○
If my learners have trouble understanding a problem, they go over it again until they understand it	○	○	○	○	○
My class attendance is good	○	○	○	○	○



AFFECTIVE ENGAGEMENT

Because of the use of technology in teaching and learning in my classroom...

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
My learners are very interested in learning	○	○	○	○	○
My learners think what they are learning in class is interesting	○	○	○	○	○
My learners like what they are learning in class	○	○	○	○	○
My learners enjoy learning new things in class	○	○	○	○	○
My learners think learning is boring	○	○	○	○	○



COGNITIVE ENGAGEMENT

Because of the use of technology in teaching and learning in my classroom...

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
When my learners learn new information, they try to put the ideas in their own words	○	○	○	○	○
My learners make up their own examples to help them understand the important concepts they learn from my class	○	○	○	○	○
My learners persist on more challenging tasks	○	○	○	○	○
My learners demonstrate appropriate effort to task	○	○	○	○	○
My learners are self-motivated	○	○	○	○	○



AGENTIC ENGAGEMENT

Answer the following with respect to what you have observed in your classroom.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
My learners let me know what they need and want	○	○	○	○	○
During the lesson, my learners express their preferences and opinions	○	○	○	○	○
When my learners need something in class, they ask me for it	○	○	○	○	○
During the lesson, my learners ask questions to assist them to learn	○	○	○	○	○
My learners let me know what they are interested in	○	○	○	○	○

Answer the following based on your responses you have given above.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
The use of technology in teaching and learning mathematics in my classroom contributes to the observations I have noted above	○	○	○	○	○



SITUATIONAL INTEREST

Because of the use of technology in teaching and learning in my classroom...

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
My learners enjoy working on mathematics topics	○	○	○	○	○
My learners want to know more about mathematics	○	○	○	○	○
My learners think that mathematics is interesting	○	○	○	○	○
My learners expect to master mathematics well	○	○	○	○	○
My learners are often fully focused on mathematics; they are not distracted by other things	○	○	○	○	○
My learners are often bored	○	○	○	○	○



INDIVIDUAL INTEREST

Because of the use of technology in teaching and learning in my classroom...

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
My learners are very interested in learning mathematics	○	○	○	○	○
My learners practice a lot of mathematics outside of school	○	○	○	○	○
My learners always look forward to their mathematics lessons because they enjoy them a lot	○	○	○	○	○
My learners watch a lot of mathematics-related TV programs	○	○	○	○	○
My learners want to pursue careers in mathematics or mathematics-related disciplines later in life	○	○	○	○	○
When my learners read or watch something mathematics-related, they are fully focused, and they forget everything else around them	○	○	○	○	○



INTERVIEW INVITATION AND CONSENT

Permission to be interviewed
(interviews will be conducted using an online tool for convenience)

	Yes	No
I would like to be interviewed for this research study.	○	○

For interview purposes, I can be reached on the following mobile number:

D.2 TEACHER INTERVIEW SCHEDULE

INTERVIEW SCHEDULE

THE USE OF TECHNOLOGY IN MATHEMATICS CLASSROOMS AND HOW IT RELATES TO LEARNER MOTIVATION: AN EXPLANATORY SEQUENTIAL MIXED METHODS STUDY

The primary focus of the in-depth semi-structured interview with the teacher who teaches mathematics is to establish what the technology tools are that enable the teacher to deliver content and engage with learners during a classroom session. Furthermore, the interview seeks to also explore how the teacher uses these technology tools (the teacher's *perception* of the use of technology tools) and what the teacher thinks the overall benefit is to the learners. Lastly, the interview seeks to understand what teachers think a motivated (engaged / interested) learner looks like. All of this inquiry will help with the explanation and understanding of some of the relationships uncovered in the quantitative phase of the study.

Examples of questions to be asked follow below. Additional questions and probing may occur in response to the interviewee's comments, but all questions will remain within the primary focus of the interview as briefly outlined above.

Interview ID: _____

Date: _____

Time: _____

Interviewer: _____

SECTION A: Introductory and Background Questions

1. How long have you been teaching mathematics using technology?
2. Which grades to you teach mathematics using technology?
3. Have you had adequate training that enables you to take full advantage of technology for the purposes of teaching mathematics?
4. Please briefly talk me through how you prepare for a typical mathematics lesson in the context of using technology.

NOTES: _____

SECTION B: Technology Tools and their Use (Teacher)

5. What technology tools do you have access to and use when teaching in your mathematics classroom?
6. How do you use these technology tools?
7. Do you think you are using these technology tools the best way you can?

NOTES: _____

SECTION C: Technology Tools and their Use (Learner)

8. What technology tools do your learners have access to and use when learning in your mathematics classroom?
9. How do they use these technology tools?
10. Do you think they are using these technology tools the best way they can?

NOTES: _____

SECTION D: Learner Motivation

11. What do you understand *motivation* to mean? Or put differently, what do you think are the characteristics of *a motivated learner* in your classroom?
12. What role, if any, does the use of technology (whether by you or the learners) play in the motivation of learners to learn mathematics?

NOTES: _____

SECTION E: Engagement Questions

13. What do you understand *engagement* to mean? Or put differently, what do you think are the characteristics of *an engaged learner* in your classroom?
14. Tell me more about how your learners behave in class, especially when technology is being used?

NOTES: _____

SECTION F: Interest Questions

15. What do you understand *interest* to mean? Or put differently, what do you think are the characteristics of *an interested learner* in your classroom?
16. What gets your learners interested?

NOTES: _____

SECTION G: PHASE I Clarification Questions

17. Does the use of technology in teaching and learning distract learners?
18. What can you comment about learners practicing mathematics outside of school? In other words, does the use of technology compel learners to practice mathematics outside of school?
19. What can you comment about learners looking forward to their mathematics lessons? In other words, is the use of technology so enjoyable that learners look forward to their mathematics lessons?
20. Do learners' minds wonder when being taught (or when they are learning) mathematics using technology?

NOTES: _____

SECTION H: Conclusion

21. We have spoken about three concepts, *motivation*, *engagement*, and *interest*, in so far as the use of technology in your classroom is concerned. Would you say that there is any relationship between these three concepts?

22. Is there anything else you would like to add or clarify before we conclude our interview?

NOTES: _____

Thank you very much for participating in this research study. Your time and insights are greatly appreciated.

■ ENDS ■

APPENDIX E

QUANTITATIVE RESULTS SUPPLEMENTS

E.1 Item-total Correlations for Motivation Dimensions Subscale Items

Table E.1: Full results of Kendall's rank item-total correlation coefficient (τ_b) calculations between all the items of the situational interest subscale and their corresponding total.

Variable	Statistical Measures			Correlation Statistics						
				SI1	SI2	SI3	SI4	SI5	SI6 (R)	SI Total
Situational Interest (SI)	Correlation Coefficient (τ_b)			.717**	.808**	.641**	.709**	.554**	.421*	1.000
	Sig. (2-tailed)			.000	.000	.000	.000	.001	.014	
	N			23	23	23	23	23	23	23
	Bootstrap[a]	Bias		−.006[b]	−.001	−.003	−.005	−.003	−.003	.000
		Std. Error		.086[b]	.052	.107	.114	.159	.139	.000
		95% Confidence Interval	Lower	.511[b]	.687	.399	.431	.199	.135	1.000
			Upper	.846[b]	.892	.817	.867	.803	.679	1.000

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.
[b] Based on 4997 samples.

Table E.2: Full results of Kendall's rank item-total correlation coefficient (τ_b) calculations between all the items of the individual interest subscale and their corresponding total.

Variable	Statistical Measures			Correlation Statistics						
				II1	II2	II3	II4	II5	II6	II Total
Individual Interest (II)	Correlation Coefficient (τ_b)			.375*	.626**	.621**	.596**	.546**	.765**	1.000
	Sig. (2-tailed)			.041	.001	.001	.001	.003	.000	
	N			22	22	22	22	22	22	22
	Bootstrap[a]	Bias		.003	−0.004	.002	−.003	−.002	−.001	.000
		Std. Error		.165	.147	.119	.117	.145	.073	.000
		95% Confidence Interval	Lower	.019	.295	.355	.333	.214	.593	1.000
			Upper	.673	.860	.815	.785	.783	.877	1.000

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.

Table E.3: Full results of Kendall's rank item-total correlation coefficient (τ_b) calculations between all the items of the behavioural engagement subscale and their corresponding total.

Variable	Statistical Measures			Correlation Statistics							
				BE1	BE2	BE3	BE4 (R)	BE5 (R)	BE6	BE7	BE Total
Behavioural Engagement (BE)	Correlation Coefficient (τ_b)			.406*	.698**	.272	.577**	.527**	.366*	.409*	1.000
	Sig. (2-tailed)			.017	.000	.126	.001	.002	.038	.026	
	N			23	23	23	23	23	23	23	23
	Bootstrap[a]	Bias		−.006	−.005[b]	−.003	.000	.002	.000	−.001	.000
		Std. Error		.150	.090[b]	.146	.117	.120	.139	.158	.000
		95% Confidence Interval	Lower	.073	.482[b]	−.051	.317	.272	.071	.059	1.000
			Upper	.663	.836[b]	.528	.779	.741	.614	.682	1.000

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.
[b] Based on 4999 samples.

Table E.4: Full results of Kendall's rank item-total correlation coefficient (τ_b) calculations between all the items of the behavioural engagement subscale and their corresponding total (excluding item BE3).

Variable	Statistical Measures			Correlation Statistics						
				BE1	BE2	BE4 (R)	BE5 (R)	BE6	BE7	BE Total
Behavioural Engagement (BE)	Correlation Coefficient (τ_b)			.380*	.697**	.672**	.496**	.358*	.469*	1.000
	Sig. (2-tailed)			.027	.000	.000	.004	.043	.011	
	N			23	23	23	23	23	23	23
	Bootstrap[a]	Bias		−.003	−.003	−.001	.002	−.003	−.003	.000
		Std. Error		.149	.084	.106	.128	.158	.135	.000
		95% Confidence Interval	Lower	.046	.508	.435	.232	.017	.160	1.000
			Upper	.631	.831	.844	.721	.633	.690	1.000

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.

Table E.5: Full results of Kendall's rank item-total correlation coefficient (τ_b) calculations between all the items of the affective engagement subscale and their corresponding total.

Variable	Statistical Measures			Correlation Statistics					
				AE1	AE2	AE3	AE4	AE5 (R)	AE Total
Affective Engagement (AE)	Correlation Coefficient (τ_b)			.604**	.666**	.706**	.456*	.584**	1.000
	Sig. (2-tailed)			.001	.000	.000	.012	.001	
	N			23	23	23	23	23	23
	Bootstrap[a]	Bias		−.004	−.006[b]	−.003[c]	−.002	−.001	.000
		Std. Error		.119	.101[b]	.089[c]	.130	.139	.000
		95% Confidence Interval	Lower	.320	.454[b]	.496[c]	.176	.283	1.000
			Upper	.787	.814[b]	.849[c]	.684	.818	1.000

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.
[b] Based on 4983 samples.
[c] Based on 4999 samples.

Table E.6: Full results of Kendall's rank item-total correlation coefficient (τ_b) calculations between all the items of the cognitive engagement subscale and their corresponding total.

Variable	Statistical Measures			Correlation Statistics					
				CE1	CE2	CE3	CE4	CE5	CE Total
Cognitive Engagement (CE)	Correlation Coefficient (τ_b)			.403*	.492**	.723**	.387*	.395*	1.000
	Sig. (2-tailed)			.029	.005	.000	.036	.032	
	N			23	23	23	23	23	23
	Bootstrap[a]	Bias		−.004[b]	−.004	−.002	−.006[c]	.001	.000
		Std. Error		.137[b]	.147	.081	.175[c]	.152	.000
		95% Confidence Interval	Lower	.106[b]	.151	.553	−.050[c]	.055	1.000
			Upper	.644[b]	.728	.869	.664[c]	.663	1.000

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.
[b] Based on 4984 samples.
[c] Based on 4944 samples.

Table E.7: Full results of Kendall's rank item-total correlation coefficient (τ_b) calculations between all the items of the agentic engagement subscale and their corresponding total.

Variable	**Statistical Measures**			**Correlation Statistics**					
				AgE1	AgE2	AgE3	AgE4	AgE5	AgE Total
Agentic Engagement (AgE)	Correlation Coefficient (τ_b)			.679**	.695**	.656**	.525**	.724**	1.000
	Sig. (2-tailed)			.000	.000	.000	.003	.000	
	N			23	23	23	23	23	23
	Bootstrap[a]	Bias		−.004	−.004	−.001	−.002[b]	−.005[c]	.000
		Std. Error		.103	.099	.108	.190[b]	.088[c]	.000
		95% Confidence Interval	Lower	.452	.466	.404	.059[b]	.520[c]	1.000
			Upper	.849	.846	.834	.801[b]	.862[c]	1.000

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.
[b] Based on 4998 samples.
[c] Based on 4999 samples.

E.2 Independent Samples Kruskal-Wallis Test Results

E.2.1 Schooling Phases

Table E.8: Results of the independent samples Kruskal-Wallis H test for the situational interest dimension across categories of schooling phase.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of situational interest is the same across categories of schooling phase.	
Test Summary	
Total N	23
Degrees of Freedom	3
Test Statistic	.407[a]
Asymtotic Sig.[b] (2-sided test)	.939
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.9: Results of the independent samples Kruskal-Wallis H test for the individual interest dimension across categories of schooling phase.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of individual interest is the same across categories of schooling phase.	
Test Summary	
Total N	22
Degrees of Freedom	3
Test Statistic	1.255[a]
Asymtotic Sig.[b] (2-sided test)	.740
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.10: Results of the independent samples Kruskal-Wallis H test for the behavioural engagement dimension across categories of schooling phase.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of behavioural engagement is the same across categories of schooling phase.	
Test Summary	
Total N	23
Degrees of Freedom	3
Test Statistic	2.319[a]
Asymtotic Sig.[b] (2-sided test)	.509
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.11: Results of the independent samples Kruskal-Wallis H test for the affective engagement dimension across categories of schooling phase.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of affective engagement is the same across categories of schooling phase.	
Test Summary	
Total N	23
Degrees of Freedom	3
Test Statistic	.533[a]
Asymtotic Sig.[b] (2-sided test)	.912
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.12: Results of the independent samples Kruskal-Wallis H test for the cognitive engagement dimension across categories of schooling phase.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of cognitive engagement is the same across categories of schooling phase.	
Test Summary	
Total N	23
Degrees of Freedom	3
Test Statistic	3.740[a]
Asymtotic Sig.[b] (2-sided test)	.291
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.13: Results of the independent samples Kruskal-Wallis H test for the agentic engagement dimension across categories of schooling phase.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of agentic engagement is the same across categories of schooling phase.	
Test Summary	
Total N	23
Degrees of Freedom	3
Test Statistic	3.618[a]
Asymtotic Sig.[b] (2-sided test)	.306
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

E.2.2 Schooling Districts

Table E.14: Results of the independent samples Kruskal-Wallis H test for the situational interest dimension across categories of schooling district.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of situational interest is the same across categories of schooling district.	
Test Summary	
Total N	23
Degrees of Freedom	5
Test Statistic	4.831[a]
Asymtotic Sig.[b] (2-sided test)	.437
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.15: Results of the independent samples Kruskal-Wallis H test for the individual interest dimension across categories of schooling district.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of individual interest is the same across categories of schooling district.	
Test Summary	
Total N	22
Degrees of Freedom	5
Test Statistic	5.661[a]
Asymtotic Sig.[b] (2-sided test)	.341
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.16: Results of the independent samples Kruskal-Wallis H test for the behavioural engagement dimension across categories of schooling district.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of behavioural engagement is the same across categories of schooling district.	
Test Summary	
Total N	23
Degrees of Freedom	5
Test Statistic	4.438[a]
Asymtotic Sig.[b] (2-sided test)	.488
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.17: Results of the independent samples Kruskal-Wallis H test for the affective engagement dimension across categories of schooling district.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of affective engagement is the same across categories of schooling district.	
Test Summary	
Total N	23
Degrees of Freedom	5
Test Statistic	8.748[a]
Asymtotic Sig.[b] (2-sided test)	.120
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.18: Results of the independent samples Kruskal-Wallis H test for the cognitive engagement dimension across categories of schooling district.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of cognitive engagement is the same across categories of schooling district.	
Test Summary	
Total N	23
Degrees of Freedom	5
Test Statistic	1.520[a]
Asymtotic Sig.[b] (2-sided test)	.911
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

Table E.19: Results of the independent samples Kruskal-Wallis H test for the agentic engagement dimension across categories of schooling district.

Independent-Samples Kruskal-Wallis Test Summary	
Null Hypothesis	
The distribution of agentic engagement is the same across categories of schooling district.	
Test Summary	
Total N	23
Degrees of Freedom	5
Test Statistic	6.878[a]
Asymtotic Sig.[b] (2-sided test)	.230
Decision	
Retain the null hypothesis.	

[a] The test statistic is adjusted for ties.
[b] The significance level is .050.

E.3 CONFIDENCE INTERVAL FOR THE MEDIAN

Table E.20: Full results of the calculation of the 95% confidence interval for the median, including the interquartile range of the median and the 95% confidence interval for the interquartile range for all dimensions of motivation.

Dimension	N	Measure	Statistic	Bootstrap[a]			
						95% Confidence Interval	
				Bias	Std. Error	Lower	Upper
Situational Interest	23	Median	2.000	.034	.129	2.000	2.500
		Interquartile Range	.500	.234	.367	.000	1.500
Individual Interest	22	Median	2.750	−.014	.262	2.250	3.000
		Interquartile Range	1.000	−.108	.209	.500	1.125
Behavioural Engagement	23	Median	2.000	.000	.000	2.000	2.000
		Interquartile Range	.000	.263	.455	.000	1.000
Affective Engagement	23	Median	2.000	.000	.000	2.000	2.000
		Interquartile Range	.000	.080	.273	.000	1.000
Cognitive Engagement	23	Median	2.000	.001	.032	2.000	2.000
		Interquartile Range	.000	.387	.487	.000	1.000
Agentic Engagement	23	Median	2.000	−.001	.024	2.000	2.000
		Interquartile Range	.000	.441	.526	.000	1.000

[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.

E.4 Correlation Matrix for Motivation Dimensions

Table E.21: Full results of Kendall's rank correlation coefficient (τ_b) calculations between all the dimensions of the interest and engagement scales.

Variable	Statistical Measures			Correlation Statistics					
				SI	II	BE	AE	CE	AgE
Situational Interest (SI)	Correlation Coefficient (τ_b)			1.000	.418*	.091	.531**	.399*	.483*
	Sig. (2-tailed)				.022	.635	.006	.041	.011
	N			22	22	22	22	22	22
	Bootstrap[a]	Bias		.000	−.003	.002	−.006[b]	−.003[c]	−.005
		Std. Error		.000	.152	.157	.137[b]	.144[c]	.176
		95% Confidence Interval	Lower	1.000	.098	−.221	.232[b]	.110[c]	.089
			Upper	1.000	.688	.395	.763[b]	.673[c]	.776
Individual Interest (II)	Correlation Coefficient (τ_b)			.418*	1.000	−.007	.254	.573**	.067
	Sig. (2-tailed)			.022		.971	.192	.003	.727
	N			22	22	22	22	22	22
	Bootstrap[a]	Bias		−.003	.000	.003	−.002[b]	−.007[c]	−.012
		Std. Error		.152	.000	.227	.138[b]	.097[c]	.229
		95% Confidence Interval	Lower	.098	1.000	−.446	−.025[b]	.336[c]	−.412
			Upper	.688	1.000	.438	.515[b]	.721[c]	.482
Behavioural Engagement (BE)	Correlation Coefficient (τ_b)			.091	−.007	1.000	−.010	.331	−.131
	Sig. (2-tailed)			.635	.971		.962	.109	.517
	N			22	22	22	22	22	22
	Bootstrap[a]	Bias		.002	.003	.000	−.001[b]	.002[c]	.006
		Std. Error		.157	.227	.000	.066[b]	.263[c]	.215
		95% Confidence Interval	Lower	−.221	−.446	1.000	−.170[b]	−.248[c]	−.532
			Upper	.395	.438	1.000	.114[b]	.774[c]	.311
Affective Engagement (AE)	Correlation Coefficient (τ_b)			.531**	.254	−.010	1.000	.229	.279
	Sig. (2-tailed)			.006	.192	.962		.272	.172
	N			22	22	22	22	22	22
	Bootstrap[a]	Bias		−.006[b]	−.002[b]	−.001[b]	.000[b]	−.006[d]	−.006[b]
		Std. Error		.137[b]	.138[b]	.066[b]	.000[b]	.153[d]	.183[b]
		95% Confidence Interval	Lower	.232[b]	−.025[b]	−.170[b]	1.000[b]	−.048[d]	−.092[b]
			Upper	.763[b]	.515[b]	.114[b]	1.000[b]	.519[d]	.617[b]

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Table E.21: Full results of Kendall's rank correlation coefficient (τ_b) calculations between all the dimensions of the interest and engagement scales. (*Continued*)

Variable	Statistical Measures			Correlation Statistics					
				SI	II	BE	AE	CE	AgE
Cognitive Engagement (CE)	Correlation Coefficient (τ_b)			.399*	.573**	.331	.229	1.000	.053
	Sig. (2-tailed)			.041	.003	.109	.272		.797
	N			22	22	22	22	22	22
	Bootstrap[a]	Bias		−.003[c]	−.007[c]	.002[c]	−.006[d]	.000[c]	−.002[c]
		Std. Error		.144[c]	.097[c]	.263[c]	.153[d]	.000[c]	.196[c]
		95% Confidence Interval	Lower	.110[c]	.336[c]	−.248[c]	−.048[d]	1.000[c]	−.329[c]
			Upper	.673[c]	.721[c]	.774[c]	.519[d]	1.000[c]	.432[c]
Agentic Engagement (AgE)	Correlation Coefficient (τ_b)			.483*	.067	−.131	.279	.053	1.000
	Sig. (2-tailed)			.011	.727	.517	.172	.797	
	N			22	22	22	22	22	22
	Bootstrap[a]	Bias		−.005	−.012	.006	−.006[b]	−.002[c]	.000
		Std. Error		.176	.229	.215	.183[b]	.196[c]	.000
		95% Confidence Interval	Lower	.089	−.412	−.532	−.092[b]	−.329[c]	1.000
			Upper	.776	.482	.311	.617[b]	.432[c]	1.000

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
[a] Unless otherwise noted, bootstrap results are based on 5000 bootstrap samples.
[b] Based on 4980 samples.
[c] Based on 4997 samples.
[d] Based on 4977 samples.

Appendix F

Qualitative Findings Supplements

F.1 Reflexive Thematic Analysis: Codes and Code Labels



Figure F.1: Initial codes (represented as code labels) resulting from coding the first semi-structured interview transcript ($n = 84$).



Figure F.2: Initial codes (represented as code labels) resulting from coding the second semi-structured interview transcript ($n = 44$).



Figure F.3: Initial codes (represented as code labels) resulting from coding the third semi-structured interview transcript ($n = 54$).



Figure F.4: Initial codes (represented as code labels) resulting from coding the fourth semi-structured interview transcript ($n = 68$).

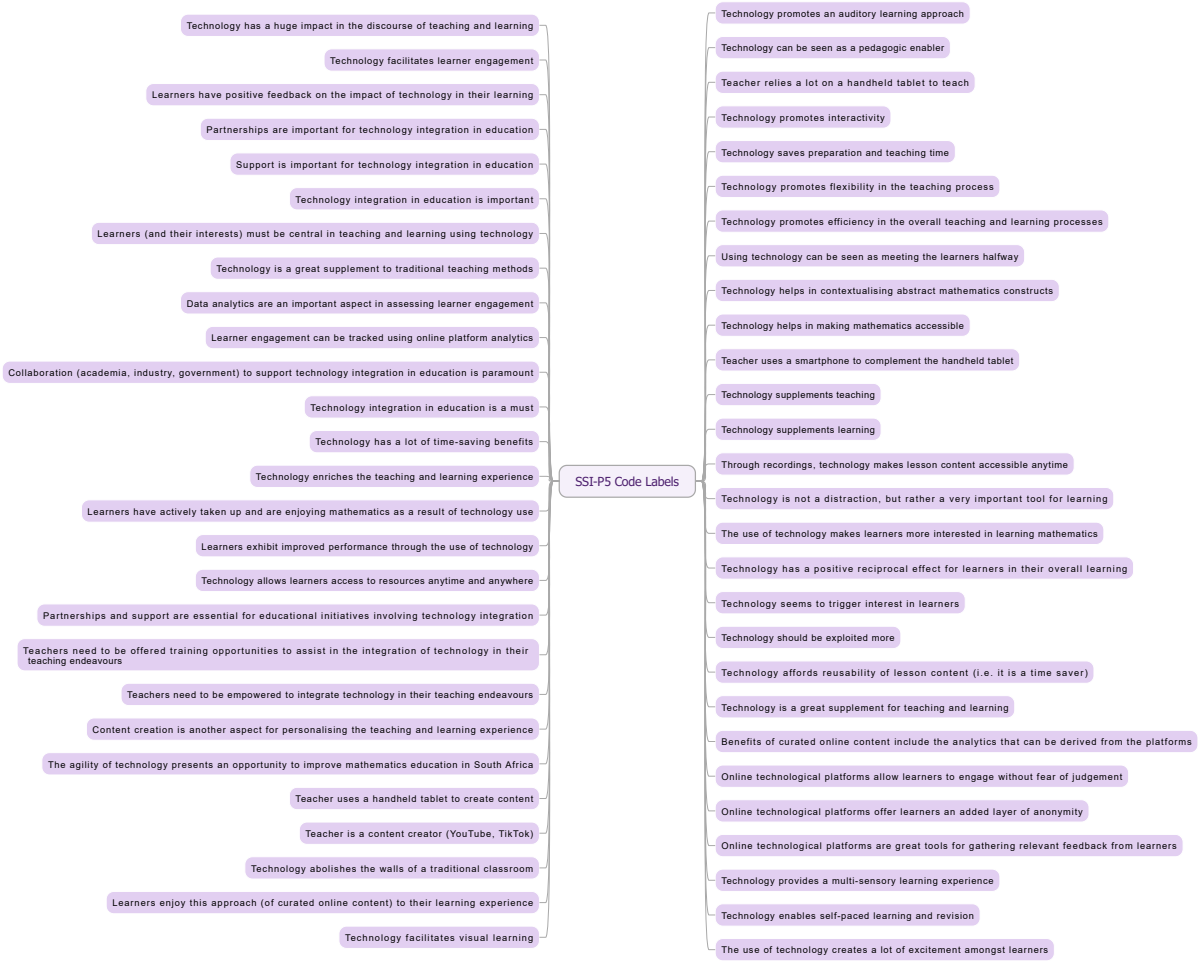


Figure F.5: Initial codes (represented as code labels) resulting from coding the fifth semi-structured interview transcript ($n = 55$).



Figure F.6: Initial codes (represented as code labels) resulting from coding the sixth semi-structured interview transcript ($n = 62$).

F.2 REFLEXIVE THEMATIC ANALYSIS: INITIAL THEMES

Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process.

Initial Themes and Collated Constituent Code Labels
1. Characteristics of a motivated learner (28)
A motivated learner is focused in what is being taught and learned in the classroom
A motivated learner is attentive
A motivated learner demonstrates interactivity
A motivated learner inquires with the teacher
A motivated learner engages with the teacher
A motivated learner goes the extra mile
A motivated learner demonstrates agency
A motivated learner is seen by the interest they demonstrate
A motivated learner self-practices
A motivated learner seeks assistance when they require it
A motivated learner listens to understand
A motivated learner demonstrates keenness to carry out allocated work
A non-motivated learner expects things to be done for them
Unmotivated learners lack initiative
A non-motivated learner does not participate
A non-motivated learner exhibits signs of not being “in it”
A motivated learner engages more
A motivated learner is an attentive learner that listens
A motivated learner is an attentive learner that pays attention
A motivated learner is an attentive learner that engages
A motivated learner is an attentive learner that is alert
A motivated learner is an attentive learner that is immersed
A motivated learner is an attentive learner that interacts with other learners
A motivated learner demonstrates curiosity
A motivated learner shows willingness to learn
A motivated learner is inquisitive
A motivated learner persists when undertaking (often difficult) tasks
A motivated learner works collaboratively and constructively with peers
2. Characteristics of an engaged learner (21)
Engaged learners participate in classroom discourse
Learners’ engagement can vary depending on their academic inclination
An engaged learner shows understanding
An engaged learner asks for clarification
An engaged learner demonstrably grasps something out of the lesson
An engaged learner asks questions when necessary
An engaged learner is responsive
An engaged learner asks questions if they don’t understand
An engaged learner demonstrates their understanding
An engaged learner takes ownership of their learning process
An engaged learner participates in class
An engaged learner is inquisitive
An engaged learner is enthusiastic
An engaged learner asks questions

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Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process. *(Continued)*

Initial Themes and Collated Constituent Code Labels
Engaged learners benefit the whole class
Engagement entails demonstrating the hunger to learn
Engagement entails collaboration
Engagement entails focusing and immersing oneself in school work
Engagement means showing willingness to learn
An engaged learner is one that is always focused
An engaged learner is very inquisitive
3. Characteristics of an interested learner (14)
An interested learner demonstrates interactivity
An Interested learner latches on (engages) on tasks of interest
An interested learner is driven to want to know or learn more
An interested learner wants to relate what they are learning to the real world
Interest entails absorbing something
Interest entails having the desire to learn
Interest entails demonstrating attention when learning
An interested learner asks questions
An interested learner seeks to know how different topics relate
An interested learner wants to know what to expect in future lessons
An interested learner demonstrates the need to want to integrate what they are learning in class into the real world
An interested learner takes initiative
An interested learner engages the teacher
An interested learner will be motivated to persist in tasks and really engage in class
4. Conceptual relationship between motivation, engagement, and interest (4)
Motivation and engagement are intricately linked
Interest is a separate concept (from motivation and engagement)
Motivation, interest, and engagement all need to be present for a productive lesson
Motivation, engagement, and interest are very similar concepts and are interrelated
5. General aspects of motivation (8)
Motivation means getting learners excited
Motivation entails getting learners keen
Motivation is having learners interested in what is being taught
Motivation entails generating interest in the learners
Academically inclined learners exhibit all the signs of a motivated learner
Motivation entails providing a stimulus of sorts
Motivation entails generating excitement about something
Motivation entails wanting to learn (having a hunger to learn)
6. Learner training on the use of technology to learn (3)
Learners lack the necessary skills to use technology tools
Learners need training to use technology better
Learners need training on how to receive teaching using technology
7. Perceptions on the uses of technology (learner point of view) (14)
Teacher expects that learners use technology as best they can
Learners are used to the technology tools used in the classroom

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Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process. *(Continued)*

Initial Themes and Collated Constituent Code Labels
Learners expect that technology be used in the classroom
Learners are technologically fluent
Learners exhibit improper use of technology tools
Learners sometimes use technology for the wrong reasons
Learners sometimes check unrelated things on devices
Internally motivated learners take full advantage of technology outside the classroom
There is a huge variance in how learners use the technology they have access to
Younger learners struggle to discern between the right and wrong use of technology
Learners have no issues using (or learning via) the smart board
Using technology has become intuitive to the learners
Learners are comfortable with using technology
Learners are familiar with technology gadgets
8. Perceptions on the uses of technology (teacher point of view) (18)
Teacher admits there is still a lot of room for growth when using technology to teach
There is a need for teachers to match learner capabilities and abilities in using technology
Technology is not used daily to teach
Teacher not using technology to its full potential
Teacher plans and prepares lessons with the use of technology in mind
Teacher makes use of a writing template
Teacher uses technology to cater for those with and those without technology tools
Using technology is a predominantly self-taught skill
Teacher has the ability to choose the best tool for purpose
Technology is more suitable for mature grades
Using technology to teach is an intuitive process that improves with practice
Teacher is very comfortable using technology in the classroom
Teacher uses elements of gamification in the classroom
Teacher is a content creator (YouTube, TikTok)
Teacher uses these technology tools the best way possible according to ability
Teacher plans lessons with an understanding of available technologies
Teacher is able to leverage technology affordances for the benefit of learners
Teacher carefully and thoughtfully balances traditional and technological approaches
9. Preparation and teaching practices (5)
Teacher calibrates the preparation and teaching according to learner capabilities and grade level
Teacher has multiple approaches for getting learners to (re)focus in the classroom
Preparation for teaching senior grades (i.e. Gr. 12) requires extensive research and consulting
Teacher prepares according to the grade being taught (Gr. 12 requires most thorough preparation)
Teacher relies on reading visual cues to ascertain levels of learner motivation
10. Reasons why learners get interested (9)
Learners find mathematics interesting if they can relate it to their lived experiences
Learners find mathematics interesting if they can link concepts to prior knowledge
If learners are not interested in what is being taught, no learning will take place
Learners get interested if they see real-world uses / applications of what they are learning
Learner interest is closely related to how the teacher presents the lesson
Learners are only interested in mathematics if they perceive value in it
Learners are only interested if there's something in it for them

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Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process. *(Continued)*

Initial Themes and Collated Constituent Code Labels
Learners exhibit interest if they perceive value in the task or subject
Interest comes from the learner's own volition (and not necessarily from using technology)
11. Teacher training on the pedagogic integration of technology (12)
Teacher has had no formal training in integrating technology in teaching
Teacher's pedagogic integration of technology skills are self-taught
Collaboration with other teachers helps in developing technology integration know-how
Teacher has relied on platforms like YouTube to learn how to integrate technology in teaching
Continual learning is important when it comes to integrating technology in teaching
Teacher has adequate training to use technology
Teacher lacks formal training to use technology for teaching
Teacher has no formal training to use technology in the classroom
Teacher has some training to operate the smart board in the classroom
Teachers acknowledges that there's always room for continual development
Teachers need to be offered training opportunities to assist in the integration of technology in their teaching endeavours
Teacher has received adequate training to integrate technology in the teaching process
12. Technology applications used by learners (4)
Through their textbook, all learners have access to additional video resources to supplement their learning
Learners have video access to practice mathematics outside of school
Teacher encourages consumption of secondary content (i.e. YouTube videos)
Learners enjoy this approach (of curated online content) to their learning experience
13. Technology applications used by teachers (6)
Teacher sometimes uses online technological platforms (Google Classroom, Google Meet, Zoom) to teach
Teacher uses software packages (Microsoft OneNote, calculator application) to support teaching
Teacher occasionally uses mathematics packages (Desmos, GeoGebra) to demonstrate some concepts
Teacher uses PowerPoint presentations in the classroom
Teacher uses SDLRs in preparation and for teaching in the classroom
Teacher uses common software platforms in the classroom (i.e. MS Word, MS PowerPoint, Adobe Acrobat)
14. Technology as a distraction to learners (causing driftiness) (5)
Learners minds sometimes wander with the use of technology in the classroom
Technology causes learners' minds to wander off (especially younger learners)
Technology makes learners' minds wander (but in a positive and constructive way)
The use of technology does cause learners' minds to wander
With the use of technology, learners' minds tend to wander at times
15. Technology as a distraction to learners (in and of itself) (11)
Technology can be distracting to learners, especially when they have access to other applications or games
When within the teacher's control, technology is not a distraction in the classroom
Learners believe that "distractions" help them gain and maintain focus in the classroom
Technology is not distracting
Technology sometimes distracts learners
The use of technology can be very distracting for learners in lower grades
Technology does not distract learners (because the teacher maintains control)
Technology is not a distraction, but rather a very important tool for learning
Online stuff is very distracting

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Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process. *(Continued)*

Initial Themes and Collated Constituent Code Labels
When learners have access to the internet, it can cause a lot of distraction
Technology is not distracting (unless learners have access to other enablers such as the internet)
16. Technology as a distraction to teachers (3)
Teacher sometimes finds technology as a distraction
Technology can distract the teacher
Technical issues (requiring technical support) tend to distract lesson flow
17. Technology as a driver of behaviour (34)
Using technology for teaching and learning taps into the learners' technology savviness and therefore motivates learners
Technology creates anticipation amongst learners
Offline video resources are useful for practicing mathematics outside of school
Despite the use of technology, learners have a negative attitude towards their mathematics lessons
Learners are more focused when technology is being used
Technology encourages some learners to practice mathematics outside of school
Technology plays a role in learners looking forward to their mathematics lessons
Technology causes learners to focus (i.e. their minds don't really wander)
Technology promotes an interactive classroom setup
Technology attracts learners into class
Technology focuses learners attention in class
Learners are more attentive with the use of technology than without
Technology makes learners lazy
Technology encourages learners to work
The use of technology has a positive reciprocal effect on learners' learning behaviours
The use of technology in the classroom makes learners excited
The use of technology improves learner focus
Technology encourages learners to participate
Technology plays a marked role in learners doing mathematics outside of the classroom
Technology improves learner attitudes towards mathematics homework
Learners look forward to their lessons because of the use of technology
The use of technology fosters collaboration
The use of technology encourages learners to contribute during classroom discourse
Technology facilitates learner engagement
Learners have positive feedback on the impact of technology in their learning
Learners have actively taken up and are enjoying mathematics as a result of technology use
Learners exhibit improved performance through the use of technology
Technology promotes interactivity
Technology has a positive reciprocal effect for learners in their overall learning
Technology enables self-paced learning and revision
The use of technology fosters a culture of collaboration
Technology fosters interactivity
Learners (when using technology) are comfortable letting the teacher know what they need and want
The best technology users earn the "bragging rights" in the classroom
18. Technology benefits (82)
Wireless tools (i.e. Bluetooth tablet) allow for mobility within the classroom
Technology helps learners learn at a faster pace
The use of technology allows for colourful presentations

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Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process. *(Continued)*

Initial Themes and Collated Constituent Code Labels
The use of technology allows for more accurate presentations
Access to video resources can be a good homework companion for learners
Access to video resources can be a good studying companion for learners
Teacher uses different colours and visuals to enhance the learning experience
Learners get excited by the use of (even basic) technology in the classroom
Learners get excited by learning new things they can do with (even the basic) technology in the classroom
The use of technology speeds “things” up in the classroom
Technology allows for flexibility in how mathematics is taught in the classroom
Technology promotes and supports multiple interactions (teacher-learner, learner-learner, learner-content) in the classroom
Wireless technology tools allows the teacher the ability to move around in the classroom
Wireless technology tools facilitate teacher-learner engagement
The use of online / offline textbook companion resources (i.e. videos) supplements teaching
Teacher uses social media tools (WhatsApp) to communicate with learners
Technology promotes relatability in learning mathematics
Technology is used to support teaching and learning
Technology makes mathematics more fun
Technology makes mathematics less intimidating
Teacher sometimes uses already existing templates
Teacher sometimes uses already existing questions (question banks)
Technology facilitates access to content
Technology allows learners to “carry the board with them”
Technology affords mobility
Technology affords learners the possibility to work anywhere
Templates offer speed and expediency
Technology offers flexibility in the classroom
Technology is fancy and nice
Technology eases lesson preparation
Technology affords flexibility in the teaching process
Technology affords flexibility in the learning process
Technology facilitates the ease of communication with learners
The smart board has revolutionised classroom discourse
The smart board is a very flexible and versatile classroom tool
Technology draws attention to the lesson
Technology draws attention to the teacher
Technology is very stimulating
Technology is cost effective
Technology is engaging
Technology serves as a teaching supplement
Technology serves as a learning supplement
Teacher uses technology to communicate future topics
Technology accommodates all types of learners in different ways
Technology is useful in simplifying complex tasks and concepts
Technology has a huge impact in the discourse of teaching and learning
Technology is a great supplement to traditional teaching methods
Data analytics are an important aspect in assessing learner engagement
Learner engagement can be tracked using online platform analytics
Technology has a lot of time-saving benefits
Technology enriches the teaching and learning experience
Technology allows learners access to resources anytime and anywhere

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Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process. *(Continued)*

Initial Themes and Collated Constituent Code Labels
Technology abolishes the walls of a traditional classroom
Technology promotes an auditory learning approach
Technology can be seen as a pedagogic enabler
Technology saves preparation and teaching time
Technology promotes flexibility in the teaching process
Technology promotes efficiency in the overall teaching and learning processes
Using technology can be seen as meeting the learners halfway
Technology helps in contextualising abstract mathematics constructs
Technology helps in making mathematics accessible
Technology supplements teaching
Technology supplements learning
Through recordings, technology makes lesson content accessible anytime
Technology affords reusability of lesson content (i.e. it is a time saver)
Technology is a great supplement for teaching and learning
Benefits of curated online content include the analytics that can be derived from the platforms
Online technological platforms allow learners to engage without fear of judgement
Online technological platforms offer learners an added layer of anonymity
Online technological platforms are great tools for gathering relevant feedback from learners
Technology provides a multi-sensory learning experience
The use of technology creates a lot of excitement amongst learners
The use of online educational platforms enriches classroom discourse
Technology eases the dissemination of lesson content
Technology expands classroom reach (beyond the traditional classroom)
Technology helps broaden learners' horizons
The use of technology excites learners
Technology is very "nice to look at"
The use of technology makes mathematics lessons fun and interactive (even if the subject itself may not be fun)
The use of technology goes beyond teaching—it's preparing learners for the future
Using technology resonates with the youth
Using technology appeals to most learners as they may already be familiar with certain aspects of it
19. Technology creates barriers in the classroom (3)
The cost of technology may create a barrier for learners
Technology can create a barrier between the teacher and learner(s)
Technology sometimes creates a barrier between the learners and the teacher
20. Technology disadvantages (2)
Inconsistencies (especially colour) sometimes exist between what is projected and the original content
Technology deficiencies are the modern-day version of "the dog ate my homework"
21. Technology integration in education (17)
Content creation is another aspect for personalising the teaching and learning experience
The adoption of technology for teaching and learning is driven by management
Teacher believes integrating technology in teaching is not that difficult
Teacher emphasises the importance of inter-school collaboration to share ideas and experiences
Partnerships are important for technology integration in education
Support is important for technology integration in education
Technology integration in education is important

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Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process. *(Continued)*

Initial Themes and Collated Constituent Code Labels
Learners (and their interests) must be central in teaching and learning using technology
Collaboration (academia, industry, government) to support technology integration in education is paramount
Technology integration in education is a must
Partnerships and support are essential for educational initiatives involving technology integration
Teachers need to be empowered to integrate technology in their teaching endeavours
The agility of technology presents an opportunity to improve mathematics education in South Africa
Technology should be exploited more
The ubiquity of technology tools in the classroom is characteristic of a fast-paced society
There is an urgent need to adapt to technological advancements
There is a need for teachers to embrace technology
22. Technology tools (gadgets) used by teachers (10)
Teacher uses various tools (laptop, projector, calculator, and sometimes a writing tablet) when teaching mathematics in the classroom
Teacher uses a smart board in the classroom
Teacher uses a smart board in the classroom
Teacher uses a visualiser in the classroom
Teacher uses a projector in the classroom
Teacher uses a smart board in the classroom
Teacher uses a handheld tablet to create content
Teacher relies a lot on a handheld tablet to teach
Teacher uses a smartphone to complement the handheld tablet
Teacher uses various technology tools (laptop, computer, projector, calculator) in the classroom
23. Technology tools used by learners (9)
Learners have access to some technology tools (calculator, projector) when learning mathematics
Learners have limited access to technology tools (like laptops, smartphones, tablets)
Learners prefer to use their phones whenever they can
Learners rely only on the smart board
Some learners have technology tools to use in class (i.e. cellphones, tablets)
Some learners don't have technology tools to use in class
Learners only have access to the smart board in the classroom
Learners have access to various technology tools (computers, laptops, calculators, online educational platforms) in the classroom
Learners have limited access to technology resources at home (or outside of the classroom or school environment)
24. The disruptive nature of power outages (loadshedding) (3)
Regular power outages (loadshedding) limit the use of technology in the classroom
Power outages hinder classroom discourse
Power outages hinder the effective use of technology in the classroom
25. The general nature of mathematics (4)
Mathematics is a challenging subject
Teacher expects learners to be focused and attentive in class (because of the nature of mathematics)
The nature of mathematics requires that learners be fully engaged in the classroom
Mathematics is generally uninteresting to most learners
26. The intersection of interest and technology (9)
The use of technology can assist to make mathematics content more relatable and interesting for learners
Learners are more interested when technology is being used

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Table F.1: Initial themes and constituent code labels (with code label count per theme) listed in alphabetical order of themes after the third phase of the reflexive thematic analysis process. *(Continued)*

Initial Themes and Collated Constituent Code Labels
Technology use fosters interest in learners
Watching videos (i.e. on YouTube) sparks learner interest
The use of secondary content (i.e. YouTube videos) interests learners
The use of technology in the classroom makes learners interested
The use of technology makes learners more interested in learning mathematics
Technology seems to trigger interest in learners
Hands-on work (on laptops and computers) spurs interest in learners
27. Theoretical aspects (9)
Teacher-to-learner interaction is important for engaging learners in the classroom
Learners' motivation can vary depending on their academic inclination
The use of technology is a classroom norm
Learners are very self-aware of their learning in the classroom
Elements of gamification facilitate learner engagement
In general, learners rely on social proofing
Gamification elements are motivation-inducing
Learner agency in class is important
Interested learners are important in driving the whole culture of the classroom
28. Theoretical aspects: Constructivist approach to learning (6)
Interest in mathematics is created by relating it to real-life examples
Linking mathematics to patterns and real-life applications makes it more interesting
Learners enjoy seeing how mathematics can be applied in everyday situations
Learners get excited when they are able to "connect the dots"
The traditional approach to teaching and learning is boring
Reading to learn is boring
29. Visual aspects of technology (12)
Technology helps learners visualise complex concepts
Learners enjoy the visual aspect of technology and its impact on their learning experience
Technology affords a visual learning environment
Visual learning interests learners
Technology offers a visual dimension to learning
Technology promotes visual learning
Technology is a visual stimulus for learners
Technology facilitates visual learning
Learners love seeing to learn
Technology affords a visual learning experience
The visual aspects of technology get learners interested
The visual aspect of technology makes learners look forward to their mathematics classes