TABLETS' IMPACT ON NORTH WEST TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING LEVEL 3 STUDENTS' PERFORMANCE AND ATTITUDE IN GEOMETRY

by

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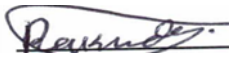
DECLARATION

I declare that the above dissertation, **Tablets' impact on North West Technical and Vocational Education and Training Level 3 students' performance and attitude in geometry**, is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the dissertation to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.



SIGNATURE

24 August 2025

DATE

DEDICATION

This study is dedicated to the memory of my late grandparents and parents, the Phales, Kgabis and Rakhudus.

I also dedicate this work to my loving husband, Gilbert Brashi Rakhudu, my four daughters, Linda Pertunia Rakhudu, Kelebogile Thuto Rakhudu, Sejabaledi Mehale and Kerata Remoratile Rakhudu, my two sons, Thusanang Tlhompho Rakhudu and Mduduzi Ndlovu and all my younger sisters and brothers.

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ABSTRACT

This study explored the impact of using tablets on Level 3 TVET students' performance and attitude in calculating geometrical objects. Focusing on a population of 120 Level 3 mathematics students at a TVET College through a mixed-methods approach, a convenient sample size of 60 students was employed. The Ellis's ABC model was utilised as a conceptual framework, providing a theoretical basis for understanding the relationship between cognition, emotion, and behaviour, and allowing for effective assessment tools and adaptable insights across contexts. By adopting this model, the researcher systematically explored how beliefs mediate the effects of activating events on emotional and behavioural outcomes, thus enabling both explanatory and intervention-focused studies. The null hypothesis posited no difference in performance and attitude between students using tablet devices versus traditional textbooks, while the directional hypothesis suggested improvements with tablet use. Data were collected using pre-test, post-test, semi-structured interviews, and ATMI, integrating both quantitative and qualitative findings. Data were analysed using regression analysis for quantitative responses and thematic coding for qualitative interviews and ATMI. Regression analysis was used to examine relationships and predictors within the numerical data, providing insight into trends and effect sizes for the quantitative responses. Regression analysis revealed no significant differences, supported by thematic coding that indicated consistent student experiences across groups. Results showed improved performance, attitude, and increased empowerment. The study proposes a model for enhancing mathematics performance in TVET colleges using mobile devices and suggests further research on lecturer engagement.

Keywords:

Mathematics, tablet devices, technology, attitude, pyramids, SAVOGOs, TVET colleges, geometrical objects, performance, students.

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ABBREVIATIONS

SAVOGOs – Surface Area and Volume of Geometrical Objects

TVET – Technical and Vocational Education and Training

L3 – Level 3

ANCOVA – Analysis of Covariance

CM – Campus Manager

DHET – Department of Higher Education and Training

SPSS – Statistical Package for the Social Sciences

RA – Regression Analysis

ANOVA – Analysis of Variance

ATMI – Attitudes towards Mathematics Inventory

TTBM – Traditional Textbook Method

HRDCSA – Human Resource Development Council of South Africa

HOD – Head of Department

4IR – Fourth Industrial Revolution

NATED – National Training Education

NW – North West

NCV – National Certificate Vocational

NQF – National Qualifications Framework

TD – Tablets Device

PS1 – Pilot Student No. 1

S1 – Student No. 1

R – Researcher

AST – Academic Support Tutor

ABC – Affect, Behaviour, and Cognition

CHAPTER ONE

OVERVIEW OF THE STUDY

This chapter provides an overview of the study. Firstly, a summary of the purpose of this study is given, as well as the context in which the study took place and why it is of significance to the reader. The problem is stated, along with the research questions and the delimitations of the study that define its scope. A summary of the literature, theoretical framework, aims, and objectives of the study, as well as a summary of the research questions, is provided. This chapter lastly summarises the layout of the whole study.

1.1 INTRODUCTION AND BACKGROUND OF THE STUDY

The introduction and background of this study referred extensively to what previous researchers have written on the topic. In this section, the global perspective, African perspective, South African perspective and North West Province perspective were explored.

1.1.1 Global perspective on mathematics teaching and learning

The challenges of learning mathematics traditionally by students in the United States, Kenya, Indonesia, South Africa, and European nations, according to Darling-Hammond (2025), include a range of challenges that affect students' engagement and understanding of Mathematics Level 3. These challenges are often interconnected and can be categorised into cognitive, pedagogical, socio-cultural, and emotional factors. (i) Cognitive factors include cases where some students may have difficulties with specific cognitive processes essential for mathematics, such as working memory or numerical reasoning (Darling-Hammond, 2025). (ii) Pedagogical approaches hint at traditional teaching and learning methods that often focus on rote learning and procedural skills, neglecting conceptual understanding and problem-solving abilities. (iii) Emotional factors refer to mathematics anxiety, fear and anxiety towards mathematics that can hinder learning and performance, creating a vicious cycle of avoidance and underperformance (Darling-Hammond, 2025), while (iv) socio-cultural

challenges in mathematics education include persistent inequities in access, a lack of culturally responsive pedagogy, and teacher shortages in high-minority schools. These challenges lead to a mathematics gap with profound implications for students and societies. The gap creates limitations in career opportunities, economic mobility, and informed decision-making in various aspects of life. To cap the gap globally, an intervention through the introduction of tablet devices was put in place. The low performance in mathematics is displayed in Table 1.1 below.

Table 1.1: Global comparative low performance of mathematics %, creating gap limitations

Country	**Performance**	**Traditional Method**	**Observed Challenges**
United States	Mean $< 40\%$	Teacher-centred lectures, isolated skill drills	Weak problem-solving, reasoning, conceptual understanding
Kenya	Mean $< 27\%$	Lecture, Q&A, minimal manipulatives	Low engagement, misconceptions, poor performance
Indonesia	Mean $< 45\%$	Teacher-centred, limited real-world context	Moderate procedural skills, low higher order thinking
South Africa	Mean $< 30\%$	Lecture-based, poorly resourced, English LOI	Conceptual gaps, Mathematical language barriers, and low numeracy skills

From the Table 1.1 above, the researcher concentrates only on Kenya and South Africa as the lowest performing countries to indicate the gap in mathematics globally. Mathematics education in Kenya, according to Ouma (2023), faces systemic challenges spanning primary, secondary, and early tertiary levels, with consistent reports of low student engagement, widespread misconceptions, and poor

performance. Integrating findings from studies, government reports, and education stakeholders, the challenges can be categorised as resulting from low student performance and conceptual misunderstanding. Evidence of low performance is reflected in Kenya National Examinations Council (KNEC) reports, which indicate that mean scores in KCSE Mathematics have consistently ranged between 18.36% and 27% in recent years. A substantial proportion of candidates perform below basic competency thresholds. These challenges are further evident at earlier stages of schooling, where many learners exhibit difficulties with foundational numeracy skills as early as Level 3. Such early learning deficits signal fundamental gaps that often remain unresolved and continue to manifest at the tertiary education level.

In addition, Jatileni et al. (2024) emphasise that misconceptions and terminology difficulties are also noted with students misinterpreting mathematical language, confusing terms with literal meanings, for example, interpreting “rectangle” as “crashed angle.” English as a second language exacerbates these linguistic challenges. Furthermore, the abstract nature of mathematics, with topics such as surface area and volume of geometrical objects or higher-level geometric concepts, is perceived as difficult, leading to persistent misconceptions. Darling-Hammond (2025) emphasises that most teachers rely on teacher-centred approaches, such as lecture and question-and-answer methods, emphasising rote learning rather than conceptual understanding or problem-solving. This limits critical thinking, inquiry, and application skills. Learner attitudes resulting in negative experiences with mathematics, difficulty grasping abstract concepts, and lack of early success contribute to mathematics anxiety.

1.1.2 Perspectives on mathematics teaching and learning in Africa

Students' performance and attitudes towards mathematics in Africa are significantly influenced by traditional teaching methods and students’ attitudes, leading to numerical gaps and an inability to progress academically. Dennis (2025) observes that in many African countries, students often struggle with mathematics, and this is attributed to several factors, including traditional teaching methods that may not engage students effectively. In addition, Gerber (2023) asserts that while students may perform well in other subjects, their performance in mathematics remains unsatisfactory. For instance, Gustafsson (2023) highlights that in South Africa, only a

small percentage of students achieved above 50% in mathematics examinations, reflecting a broader trend of underperformance and a serious gap in the subject.

Furthermore, Giri (2021) emphasises that the teaching approaches employed in mathematics education have a profound impact on student performance and attitude. A meta-analysis of African research over the past two decades revealed that teaching methods utilising concrete manipulatives significantly enhance student performance compared to traditional methods (Basedau, 2021). This suggests that innovative teaching strategies could be more effective in improving students' understanding and attitudes towards mathematics.

Higgins (2025) reveals that students' attitudes towards mathematics are shaped by their experiences in the lecture room. A mixed-methods study found that both teachers' and students' attitudes significantly influence performance. Positive attitudes can lead to better engagement and understanding, while negative attitudes often stem from a lack of confidence and perceived difficulty of the subject. Many students believe mathematics is challenging, which can lead to aversion and disengagement from the subject. This perception is often reinforced by traditional teaching methods that do not cater to diverse learning styles.

In a study conducted in Africa, Julaihi's (2022) recommendations for improvement were that to enhance students' performance and attitudes towards mathematics, several strategies can be implemented. The strategies are to adopt innovative teaching and learning methods where lecturers incorporate diverse teaching strategies that engage students actively, such as using manipulatives and technology in the classroom.

Julaihi (2022) suggests that in providing support and resources, colleges should ensure that adequate resources are available for both lecturers and students, including training for lecturers on effective mathematics instruction. Julaihi (2022) further suggests encouraging positive attitudes in mathematics by introducing programs aimed at building students' confidence in mathematics and shifting negative perceptions, as well as fostering a more positive attitude towards the subject. In conclusion, addressing the challenges faced by students in mathematics requires a multifaceted approach that considers teaching methods and attitudes towards

mathematics. By fostering a more supportive and engaging learning environment, it is possible to improve both performance and attitudes towards mathematics among African students.

1.1.3 Teaching and learning mathematics in South Africa

Mouton (2023) asserts that TVET colleges in South Africa are intended to prepare students for technical and vocational careers, incorporating both practical skills and foundational academic knowledge, such as mathematics. However, research consistently demonstrates challenges in student mathematics performance when traditional, teacher-centred pedagogy is employed. Recently, Mazana (2024) indicates alarmingly low completion rates for students in TVET colleges. In some cases, only 2% of students complete their programs within the minimum timeframe, with an overall average throughput rate as low as 0.6% in certain programs like Engineering and Related Design (ERD). Mathematics Level 3 is one of the subjects in the ERD programme, hence the low overall average throughput rate.

Limi (2025) notes that in South Africa, the traditional approach to teaching mathematics has been challenged by various factors affecting student performance and attitude. Research indicates that a strong correlation exists between students' attitudes towards mathematics and their performance levels. Factors such as self-confidence, sense of security, efficacy of mathematics, and motivation significantly influence these attitudes and performance outcomes. Ouma (2023) further asserts that the South African education system is lacking, particularly in addressing conceptual gaps, mathematical language barriers, and low numeracy skills. A recent study by the Department of Higher Education and Training revealed that 67% of Level 3 students require significant support with numeracy skills, and 53% need targeted assistance. By Level 2, 60% of students in the North West Province of South Africa are at a similar level of need, with 70% requiring focused interventions in numeracy skills. This is clearly reflected in Figure 1.1.

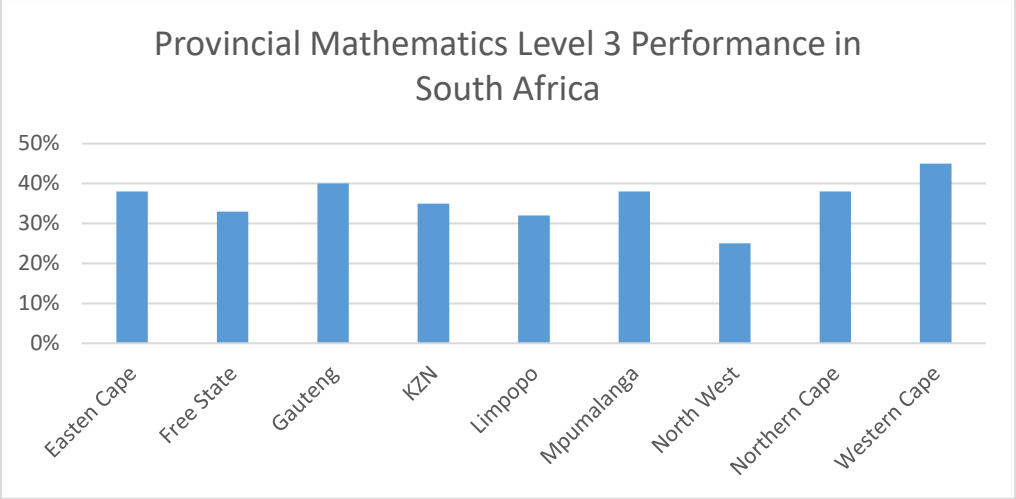


Figure 1.1: Provincial Mathematics Level 3 performance in South Africa

Saat et al. (2023) indicate a wide disparity in performance across different regions, with the Western Cape showing the strongest performance in numeracy, while North West's results were notably worse, with a mean percentage of <30% as indicated in Figure 1.1. Experts have called for urgent and effective interventions to address these gaps, particularly in lower-performing countries. The report also emphasises the need for educational reform, particularly in low-performing countries, and advocates for technological intervention and better resource availability. Stakeholders at all levels of the South African education system must come together and address these urgent issues thoroughly and effectively.

In the general National Senior Certificate (NSC) examinations of 2024, it is reflected that 69.1% of learners passed mathematics, up from 63.5% in 2023. Despite this improvement, participation is low. Only about 35.7% of the cohort wrote the mathematics examination, meaning roughly 24% of students succeeded in the subject. Quality passes of ≥ 60% remain limited to 17.7% of candidates, with distinctions achieved by only 1.4%, signalling persistent challenges in mastering mathematics at higher competency levels. While precise national averages for TVET mathematics scores were not explicitly provided in the sources, the academic context indicates significantly lower performance compared to NSC learners. Completion rates for TVET programmes are extremely low, with throughput rates in NCV courses including Mathematics Level 3, ranging from 0.6% in Engineering and Related Design to 5.9% in Mathematics Level 2. TVET students' mathematics performance lags behind NSC

learners in formal schooling. Even with some improvement at the NSC level, TVET throughput and pass rates remain far below national development targets. South African TVET Mathematics Level 3 performance remains significantly below national benchmarks, with mean pass rates and quality passes limited by the traditional approach and personal attitudes. With this gap in mind, it was concluded that TVET Mathematics Level 3 requires a targeted approach to reach even comparable levels of competence (Ouma, 2023).

1.1.4 Teaching and learning of mathematics in the North West Province of South Africa

From the North West Province perspective, Sundrani (2025) asserts that the performance of TVET students in traditionally taught mathematics is constrained by a combination of teaching and learning methods and institutional resource limitations. Traditional approaches, heavily leaning on rote memorisation and isolated theoretical engagement, fail to connect learning with practical applications demanded in vocational careers. Transitioning to a humanising, student-centred pedagogy that contextualises mathematics in real-life technical scenarios, alongside supportive institutional frameworks, is critical to enhancing student outcomes and workforce readiness.

In addition, Toyon (2021) asserts that based on a synthesis of the literature, research, and local reports, the performance of TVET students in mathematics, particularly within the North West Province of South Africa, is influenced by systemic, institutional, and pedagogical factors. Traditional mathematics instruction consisting primarily of rote learning, lecture-driven classes, and theoretical content delivery has been identified as a significant contributor to low student engagement and suboptimal learning outcomes.

Sundrani (2025) further indicates that TVET student completion rates remain low nationally, with only a small percentage completing NCV programmes within the minimum timeframe, as low as 0.6%–5.9% in some disciplines. This reflects broader systemic challenges affecting mathematics performance at TVET colleges. National Certificate Vocational (NCV) and National Accredited Technical Education Diploma (NATED) programmes require foundational mathematics competencies. Integrating

tablet-based methodology when learning mathematics topics such as SAVOGOs will bridge the theory-practice gap.

Higgins (2025) notes that students' self-concept and their attitudes towards learning invariably improve when technology is incorporated into instruction. Moreover, technological devices, according to Abalona et al. (2025), have assisted students in developing new relationships with mathematics content when they are able to learn and practice mathematical tasks using tablets. The implication is that students with positive attitudes towards learning mathematics may be inspired to understand mathematical skills and content when using technological devices. In addition, Kulik and Fletcher (2020) provide evidence that students enjoy their classes more and develop a more positive attitude when instruction is delivered in a technology-integrated mode (Eshetu & Wakuma, 2024).

As part of a strategy to improve performance, the Department of Higher Education and Training (DHET) gradually introduced the use of tablets and iPads into schools and institutions of higher learning. The introduction of tablets at the institution where this study was conducted occurred in 2021, with Level 3 students participating in a pilot study to explore whether learning using a tablet would improve performance in mathematics at the college. Since tablets and iPads allow students and lecturers to access the internet only when loaded with data or connected to Wi-Fi, practice typing skills, view and research educational materials, and produce lessons for teachers, special attention has been given to their management at the colleges to ensure efficient utilisation and storage.

The researcher chose Mathematics Level 3 students because they are at a critical stage that introduces them to the exciting Level 4, and it is therefore crucial for them to perform well in mathematics. Another important factor is that the mathematics topics covered in Level 3 overlap with those in Level 4. Thus, when students struggle with the mathematics content prescribed for Level 3, their poor performance in this subject has negative implications for both their overall performance in Level 4 and the college's throughput rate. It is also important to recall that, according to Badenhorst and Rammile (2023), in the Human Resource Development Council of South Africa (HRDCSA), TVET colleges are perceived as institutions admitting slow learners who

could not succeed in mainstream schools. Badenhorst and Rammile (2023) further caution that this often negatively impacts subjects like Mathematics, as most students who attend TVET colleges typically did not perform well in Matric mathematics. Moreover, Eshetu and Wakuma (2024) pointed out that some students attending TVET colleges are dropouts from higher institutions due to poor performance in mathematics. Mathematics Level 3 consists of two papers: Paper 1 and Paper 2. In my experience as a Level 3 mathematics lecturer at the college, I have noticed a trend where students usually perform well in Paper 1, while underperformance is observed in Paper 2. The percentage distribution for topics in Paper 2 is displayed in Table 1.2 below.

Table 1.2: A TVET NCV Mathematics Level 3 weighted values of topics (Paper 2) (DHET, 2014)

TOPICS/THEMES	WEIGHTED VALUE
Geometry and trigonometry	33.3%
Statistical analysis and data collection	33.3%
Financial mathematics	33.3%
TOTAL	100

From a weighted value of topics for Paper 2 in Table 1.2, Surface Area and Volume of Geometrical Objects (SAVOGOs) fall under the topic of geometry and trigonometry, weighing 33.3% in the final assessment. SAVOGOs always appear as Question 1 in the question paper, requiring responses based on the properties and applications of geometric figures such as square pyramids, triangular pyramids, right cones, hexagonal pyramids, hemispheres, and spheres. Such a question may sometimes be framed as a practical problem that requires the calculation of the surface area and volume of a gas storage tank in the form of a cylinder capped with a hemisphere at each end. From the researcher’s observations, students experience challenges in tackling such problems. It was further discovered that students often struggle to identify objects like squares, triangles, cones, circles, and hexagons, as well as to interpret net representations of 3-D objects. This is partly due to students' inability to identify relevant formulae to use in calculations related to these figures. Most of the time, students tend to use incorrect formulae, perform inaccurate calculations, and provide inappropriate responses. Consequently, it has also been observed that

students fail Mathematics Level 3, Paper 2, as they frequently cannot interpret given drawings or use relevant formulae in their calculations.

It was also discovered that some students tend to score better marks in statistical analysis and financial mathematics, each weighing 33.3%. Due to the extreme underperformance in SAVOGOs, students underperform in Mathematics Paper 2. As a result, the researcher wishes to assist students in realising their potential in the research and learning of different geometrical objects and formulae using their tablet devices. The underperformance in mathematics in the majority of TVET colleges is highlighted by some researchers (Simsek & Can, 2020). This often results in students being promoted to upper levels without achieving an acceptable standard in mathematics. Simdek and Can (2020) further note that this lack of mathematical achievement, in the worst-case scenario, often contributes to students dropping out of college. This, according to Chor and Toh (2021), reflects that only about 30% of students progress well with their studies in TVET colleges. The National Certificate Vocational (NCV) Level 3 comparative results for the years 2022 to 2024 are displayed in Table 1.3 below as evidence of students' underperformance in mathematics.

Table 1.3: A TVET NCV Mathematics Level 3 Comparative results for the year 2022 to 2024. (Oates et al., 2024)

	ENGINEERING AND RELATED DESIGN								
Year	**Subject**	**Level**	**Number Enrolled**	**Number wrote**	**Number Pass**	**Pass%**	**Through put Rate**	**Retention Rate**	**National Average**
2022	**Maths**	2	472	387	198	51.16	41.95	81.99	40.39
		3	409	350	118	**33.71**	28.85	85.58	41.45
		4	70	45	29	64.44	41.43	64.29	42.50
2023	**Maths**	2	318	249	148	59.44	46.54	78.30	41.74
		3	205	150	59	**39.33**	27.69	73.33	32.98
		4	109	96	54	56.25	49.54	88.07	44.70
2024	**Maths**	2	400	303	175	57.76	43.75	75.75	40.00
		3	199	160	52	**32.50**	26.13	80.40	37.70
		4	78	55	31	56.36	39.74	78.51	48.50

From the comparative results displayed in Table 1.3 above, it is evident that in 2022, out of 409 students who sat the final mathematics examination, only 33.71% passed. It can also be observed that in 2023, the number of students sitting the mathematics examination increased by 5.62%, but then dropped again in 2024 by 6.83%. This decline is presumably due to a reduction in the number of students enrolled in a TVET college and those who sat the examination in 2023 compared to the previous year (Oates et al., 2024). Consequently, the pass percentages of 33.71, 39.33, and 32.50 recorded in 2022, 2023, and 2024, respectively, clearly indicate that students are not performing well in mathematics and that an intervention is needed.

In the TVET college where the study was conducted, tablets were supplied to Level 3 students for pilot purposes in learning the different subjects displayed in Table 1.3. Although the piloting using tablet devices was intended to improve performance across all subjects, this study focused on performance in Level 3 mathematics, as it is the subject in which students underperform the most.

1.2 THE ORIGIN OF TVET COLLEGES IN SOUTH AFRICA (SA)

According to the TVET Act (Act 98 of 2021), all 50 public Further Education and Training (FET) Colleges were reclassified as TVET colleges, with about 300 campuses nationwide (TVET College Times, 2020). Of these 50 colleges, three are in the North West Province (McPherson & Foncha, 2022). In 2007, the Department of Higher Education and Training (DHET) began implementing the National Certificate (Vocational) NC(V) programmes in all TVET colleges. The NC(V) qualification was intended to replace the National Training Education (NATED) Report 191 programmes; however, these programmes were subsequently reintroduced. The NC(V) programme is awarded at three levels, namely Levels 2, 3, and 4 on the National Qualifications Framework (NQF).

This qualification is designed to provide both theoretical and practical experience in a specific vocational field. The practical component of the study may be offered in the workplace or in a simulated workplace. All activities in TVET colleges can be explained by the Career Counsellor to help students make informed choices through the development of (i) the structure and combination of subjects for NCV, (ii) National Certificate (Vocational) programmes, (iii) National Certificate (Engineering and

Related Design), (iv) the NCV Level 3 Mathematics curriculum at TVET colleges, and (v) the rationale for introducing tablet devices in the learning of Surface Area and Volume of Geometrical Objects (SAVOGOs).

1.2.1 The structure and combination of subjects for NC(V)

The TVET College First (second edition) of 2020, which was subsequently amended as *The TVET College First* (third edition), provides up-to-date information on the structure and combination of subjects for NC(V) programmes (News 24, July 2018). This edition provides the structure and combination of subjects applicable at every level of study for the qualification, i.e. Levels 2, 3, and 4. There are three compulsory fundamental subjects and four vocational subjects. The fundamental subjects, according to McPherson and Foncha (2022), are English First Additional Language, Mathematics or Mathematical Literacy, and Life Orientation. The four vocational subjects are drawn from the sub-field organisation of the NQF.

1.2.1.1 Sub-field programmes offered in the qualification

According to Gerber (2023), the subject combinations in each of the programmes offer a high degree of specialisation for an economic sector. Oates et al. (2024) further assert that it is important to note that from the vocational subjects, one subject may be chosen from any vocational programme to provide the student with either high levels of specialisation or the opportunity for broader training. Generally, Gerber (2023) emphasises that the first three vocational subjects listed for each programme are compulsory, while the others are from the pool of optional subjects.

1.2.2 The National Certificate (Vocational) Programme

According to McPherson and Foncha (2022), there are fourteen programmes that have been developed. They are Management, Marketing, Information Technology and Computer Science, Finance, Economics and Accounting, Office Administration, Electrical Infrastructure Construction, Civil Engineering and Building Construction, Engineering and Related Design, Primary Agriculture, Hospitality, Tourism, Safety in Society, Mechatronics, and Education and Development.

Table 1.4: The sub-field programmes offered in the Engineering and Related Design Qualification (TVET College First, 2020)

	Level 2	**Level 3**	**Level 4**
Fundamentals (The 3 fundamental subjects are included with the core and the optional subjects for all the programmes)	First Additional Language: English/ Afrikaans/IsiXhosa	First Additional Language: English/ Afrikaans/IsiXhosa	First Additional Language: English/ Afrikaans/IsiXhosa
	Life Orientation	Life Orientation	Life Orientation
	Mathematics	Mathematics	Mathematics
PROGRAMMES			
8. Engineering and Related Design	Engineering Fundamentals	Engineering Practice and Maintenance	Engineering Processes
	Engineering Technology	Material Technology	Professional Engineering Practice
	Engineering System	Engineering Graphics and Design (CAD)	Applied Engineering Technology
	Physical Science (o)	Physical Science (o)	Physical Science (o)
	OR	OR	OR
	Fitting and Turning (o)	Fitting and Tuning (o)	Fitting and Tuning (o)
	OR	OR	OR
	Automotive Repair and Maintenance (o)	Automotive Repair and Maintenance (o)	Automotive Repair and Maintenance (o)
	OR	OR	OR
	Engineering Fabrication (o)	Engineering Fabrication (o)	Engineering Fabrication (o)

	OR	OR	OR
	Welding (o)	Welding (o)	Welding (o)
	OR	OR	OR
	Refrigeration Principles (o)	Refrigeration Principles (o)	Refrigeration Principles (o)

The subject combination in each sub-field programme provides a high degree of specialisation. It is important to note that of the four compulsory vocational subjects, the fourth subject may be chosen from any sub-field, allowing the student to achieve high levels of specialisation (McPherson & Foncha, 2022).

1.2.3 NCV Mathematics Level 3 curriculum at TVET colleges

According to Colliot et al. (2024), a curriculum is the outline of concepts to be taught to students to help them meet the content standards and refers to what is taught in each course or subject. Thus, the outline of concepts for NCV Mathematics Level 3 includes Complex Numbers, Functions and Algebra, Space, Shape and Measurement, Data Handling, and Financial Mathematics. Complex numbers are usually very simple for most students, and they are performing moderately in Functions and Algebra. However, Functions and Algebra mostly challenge students, particularly when it comes to drawing graphs and their applications. Complex Numbers, Functions and Algebra, and part of Financial Mathematics make up Paper 1. Space, Shape, and Measurement is the most challenging topic and forms Paper 2, together with Data Handling and part of Financial Mathematics.

1.3 Space, Shape, and Measurement

The curriculum for Mathematics Level 3, according to Colliot et al. (2024), consists of five chapters. "Space, Shape, and Measurement" is the third chapter and is the most challenging for students. This chapter consists of three sections: (i) Calculation of the surface area and volume of two- and three-dimensional shapes, (ii) Use of the Cartesian coordinate system to derive and apply equations, and (iii) Solution of problems by constructing and interpreting trigonometric models. The first section on the calculation of the surface area and volume of two- and three-dimensional shapes

has been particularly challenging for students to understand and consistently appears as Question1 in their Level 3 Mathematics Paper 2. The question usually appears in a diagrammatic form, featuring either a square pyramid, triangular pyramid, right cone, or sphere in the Mathematics Level 3 question paper. Below is an example of a square pyramid question.

Example 1.1: Calculate the total surface area and volume of the object in Figure 1.1.

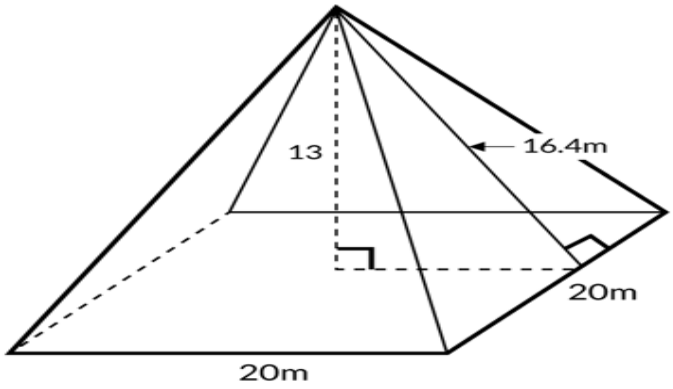


Figure 1.2: An example of a square pyramid question

To attempt the question in Figure 1.2 above, firstly, the students need to know and understand that the surface area formulae for pyramids and cones are defined as the sum of the base area and the area of the lateral faces.

That is, Surface area = Base area + Lateral area of the pyramid

$$SA = B + L$$

$$S A = B + \frac{1}{2}ph_s$$

P stand for the perimeter of the base and h_s is the slant height, which is equal to 16.4m. Now, for the base area, students need to notice that the base of the pyramid is a square, so that they can calculate the area of a square. Then $B = lw$

$$= 20m \times 20m$$

$$= 400m^2$$

P stands for the perimeter of a base. Also, students need to know what a perimeter is and how to calculate it. According to Ross (2020), a perimeter is either a path that surrounds a shape (in two dimensions) or its length (one-dimensional). The perimeter of a circle or an ellipse is called its circumference. A calculated perimeter is the length of fence required to surround a yard or garden. The students need to realise that the figure below is a square, and they also need to know how to calculate the perimeter

of a square. Perimeter of square = $l + l + w + w$. Because a square has equal sides, it will be P = $l + l + l + l$. P= $2l + 2l. P = 4l. P = 4(20) = 80m$. Now $L = \frac{1}{2}ph_s$

= $\frac{1}{2}80(16.4)$

= $656m^2$

Now SA= $B + L$

= $400m^2$+$656m^2$

=$1056m^2$

Now, the Volume of a pyramid is equal to one-third of the base area times the perpendicular height. That is, Volume of Pyramid: V = $\frac{1}{3}Bh$ $_{\perp}$

= $\frac{1}{3}(400)(13)$

= $1733.33m^3$

The researcher has observed that students tend to avoid this section, with most leaving the question unattempted. Even if performance can be better in Mathematics Paper 1, the fear of Paper 2 has resulted in incompetence in the whole Mathematics Level 3. It should be noted that the pass percentage of Mathematics Level 3 is about the combination of percentages from the two papers. That is, if a student scored 42% in Paper 1 and later scored 15% in Paper 2, the student will end up with a total mark of 28.5%, which is incompetent in Mathematics as a whole.

Recently, students at TVET colleges were supplied with tablets by college management as a motivation to learn and improve performance in different offerings. The researcher wishes to explore whether the use of tablet devices in learning Mathematics Level 3 improved performance and attitude in tackling problems related to volume. These tablets have enabled students to explore and learn through websites, videos, apps, and games. Furthermore, students appeared to be fascinated by learning and having fun at the same time, which helps them stay engaged with the mathematics resources. This concurs with Ross (2020), who notes that today's students work well with technology devices and find the drawing of square pyramids fascinating when using tablet devices. In addition, Brooke et al. (2022) further assert that: i) students can learn quickly with tablets as they use them to solve square sums, write, and draw; ii) tablets have direct communication in the sense that they connect all major stakeholders: students, parents, and lecturers.

It is important to mention that, with tablet devices, students can be assisted even when classes are not in session. In addition, with tablets, there is no way a student will fall behind, as it gives instant access to individual research. During research, students have access to thousands of websites and videos that can show examples of lessons. It should also be noted that a lecturer can address a multitude of learning styles since not all students are equal. To the researcher, this implies that tablets are a smart investment since they can easily be updated with the newest version of information, unlike in the past, when colleges had to buy new books, which ended up costing tens of thousands of Rands to supply hundreds of students when changing the curriculum.

One of the advantages that students could take advantage of is that the tablets have a voice recording function, which students can use to record lessons or ideas they have. Students can go back and listen to the recording later and remember exactly what information was shared. In addition, one can easily observe that tablets give timely and effective constructive feedback and lesson options, which are essential in the case of a student who is underperforming. They also give the students a chance to rectify the situation. If a student is doing an online quiz but does not do well, they can watch a video on the side and redo it immediately. As mentioned before, a tablet is a system where students turn in work in a strictly digital format in cases where paper is no longer an option. Tablets also provide learning simulations, which give the students the right feeling about improved knowledge, perceptions of the learning environment, and the required skills. To emphasise this point, tablets can also bring experiences to the classroom that would not have been possible. In conclusion, tablets can open doors to fascinating topics and get students excited about learning.

1.4 The global perspective of students' performance after learning mathematics with tablet devices

The global performance of students after learning mathematics with tablet devices, according to Wang et al. (2024), has shown positive effects on various aspects of learning. Studies indicate that mobile learning, including the use of tablets, enhances students' essential and higher-order thinking skills, establishes interactivity, and facilitates learning through inquiry. This has been particularly beneficial for students in Namibia, where the use of PMDs in mathematics classrooms has been associated

with increased motivation, enjoyment, and enhanced performance. Wang et al. (2024) further assert that learning with tablet devices offers new approaches to enhancing students' activities and interest in mathematics. They allow access to educational resources and participation in learning activities from any place at any time, providing flexible, personal, and interactive learning not confined to a classroom learning environment.

Jatileni et al. (2024) emphasise that the integration of tablets in teaching and learning has been found to support students' development of mathematics learning skills and to positively impact teaching mathematics concepts at the secondary school level. However, there are also challenges such as the unequal distribution of resources and technology, which need to be addressed in future policies and practices. Overall, the use of tablets in mathematics education, according to Tang et al. (2021), has led to a significant shift in instructional practices, with a medium-level positive effect on students' mathematics performance. This shift is driven by the ability of tablet devices to provide learning opportunities that include new and engaging learning methods, both beyond and inside the classroom.

According to Aspiranti and Larwin (2021), tablet devices have become increasingly integrated into mathematics education worldwide. This integration is facilitated by Bring Your Own Device (BYOD) programs and institutional provision of devices. The global trend reflects steady adoption in K-12 and higher education, particularly in countries such as the United States, Indonesia, and European nations, where both teachers and students have access to web-enabled tablets and software environments designed for mathematics instruction.

Jatileni et al. (2024) further assert that tablet use in mathematics supports multiple learning modalities: visual (graphs, charts, geometric constructions), auditory (interactive tutorials), and kinesthetic (touch interaction for manipulating objects). Typical tools include GeoGebra, Desmos, NumWorks, and other interactive applets, while gamified approaches such as Kahoot or DragonBox engage students in problem-solving and algebraic exercises.

1.5 Pedagogical and cognitive impacts of learning with tablet devices

1.5.1 Learning gains

Evidence from systematic reviews and meta-analyses, according to Saat et al. (2023), indicates that tablet-mediated learning in mathematics yields moderate positive gains in student performance, particularly when interventions are designed with clear instructional purposes. Observed benefits include i) improved problem- solving and critical thinking skills of students using apps like GeoGebra or interactive worksheets solve more complex tasks correctly, ii) Higher engagement and motivation where studies consistently report increased time-on-task and intrinsic interest, iii) Enhanced conceptual understanding where visual and dynamic representations help students grasp abstract algebra, geometry, and trigonometry concepts, and iv) Multi-level accessibility referring to tablets support diverse learners, including students with disabilities, due to touch input, multimedia resources, and customised interfaces.

1.5.2 Cognitive and Affective Dimensions

Tablet- mediated learning supports cognitive scaffolding through immediate feedback, hints, and stepwise problem-solving guidance (Tang et al., 2021). Students demonstrate higher self-regulation, persistence in problem-solving, and collaborative learning tendencies when tablets are used in facilitated group activities. Affective benefits include reduced math anxiety, increased enjoyment, and a preference for digital learning over traditional textbooks.

1.5.3 Rationale for introducing tablet devices in the learning of SAVOGOs

The rationale for any study, as noted by Gerber (2023), is the reason for conducting the research. The rationale for research is also defined by Mouton (2023) as an important part of the researchers' publication, as it justifies the study's novelty and significance. Thus, the main reason for this study was to determine the impact of the use of tablets on Level 3 NW TVET College students' performance and attitude in learning to calculate SAVOGOs. This study should contribute to the development of improved educational policies that recommend the use of tablets in educational institutions.

The improved educational policy emphasised that students and lecturers should obtain optimal access to technological tools, advance mathematical sense-making, and support communication, reasoning, and problem-solving (Brooke et al., 2022). The policy also recommends that effective lecturers optimise the potential of technology to develop students' understanding, stimulate their interest, increase their proficiency in learning SAVOGOs, and provide greater access to mathematics for every student globally, nationally and provincially (Mouton, 2023).

The research on students studying mathematics with tablet devices is crucial on various levels globally, nationally, and provincially for several reasons. At the global level, according to Gerber (2023), it helps in understanding the effectiveness of tablet technology in enhancing mathematics education and the impact of tablet-mediated learning on students' performance. It also informs global governments and educational institutions about the best practices and challenges in deploying tablet technology in mathematics education. Jatileni et al. (2024) provide insights into the integration of tablet technology in mathematics teaching and learning at the national level, helping to identify the most effective ways to implement tablet technology in schools and colleges. It also aids in the development of procurement programs for colleges to enable the purchase and supply of tablets to their faculty and student bodies.

The integration of technology also offers a detailed analysis of the role of tablets in teaching and learning mathematics in specific provinces, such as Gauteng Province in South Africa, where it is used to access various forms of media for meaningful teaching of mathematics concepts. It also highlights the need for adequate technological support infrastructure and ongoing training for teachers and students to optimise the use of tablet technology in their teaching and learning (Wang et al., 2024).

The research on students studying mathematics with tablet devices, according to Ross (2020), is crucial on various levels in South Africa for several reasons. The first reason, according to Gerber (2023), is educational equity; ensuring equal access to education is a central theme in South Africa's education policies. Tablets play a pivotal role in achieving equity by providing access to the internet, e-textbooks, and educational applications, which can create equal educational opportunities. The second, according to Mouton (2023), is an enhanced learning experience, positing that ablets offer an interactive and engaging learning environment, which can enhance students'

enjoyment and understanding of mathematics. This is particularly important for students who may find traditional methods less appealing. Wang et al. (2024) emphasise the third as teacher engagement and pedagogical knowledge, positing that tablets can support learners in their learning practices by providing access to various forms of media and educational applications that promote meaningful engagement in instructional mathematics conversations. The fourth is student motivation and performance, which emphasises that the use of tablets in mathematics classrooms has been associated with increased motivation, enjoyment, and enhanced performance among students. This can lead to better academic performance. Finally, cultural acceptance and integration, which is about the integration of tablets into the learning environment, is essential for cultural acceptance and can help bridge the gap between traditional and modern educational practices.

Overall, the research on students studying mathematics with tablet devices is vital for improving the quality of education in South Africa, ensuring that all students have access to quality learning opportunities, and fostering a culture of digital literacy and engagement in mathematics (Aspiranti & Larwin, 2021). Furthermore, Alex (2021) posits that the research on tablet technology in mathematics education is vital for improving the quality of mathematics education and ensuring that students have access to effective learning tools that can enhance their engagement and performance in the subject. Furthermore, educational technology specialists, also known as instructional technology specialists or EdTech specialists, according to Gerber (2023), collaborate with lecturers and school administration to facilitate the use of technology in classrooms and the school. Mouton (2023) asserts that an educational technology specialist should be well-organised, with proficiency in technology and an aptitude for teaching. Brooke et al. (2022) further assert that, with the increasing use of various technologies in schools, instructional technology specialists are rapidly becoming key participants in reshaping the learning process globally, nationally, and provincially.

1.6 LITERATURE REVIEW

In this chapter, I present only a summary of the literature reviewed; the comprehensive review is provided in Chapter 2. According to McMillan and Jones (2022), the main aim of conducting a literature review is to enhance the understanding of a topic to build

on previous knowledge, thereby placing its findings in a historical context. While a substantial and impressive number of studies exist on the integration of technological devices in the learning of mathematics across different colleges, the literature review indicates that additional research is needed to enhance the impact of tablet devices on Level 3 NW TVET College students' performance and attitudes in learning SAVOGOs. Therefore, in this study, the literature was reviewed firstly to include the use of technology in the lecture room; secondly, the review continued to encompass the integration of tablets in the lecture room. The third section of this review explored creativity and hands-on learning with tablets, and fourthly, the use of tablets for anytime, anywhere education. Finally, literature on studies that used tablets in mathematics learning is discussed in Chapter 2.

1.6.1 Use of technology in the lecture room

Brooke et al. (2022) define technology as any device that can be used to promote students' learning, including tablets, calculators, iPads, Smart Boards, digital cameras, video cameras, Portable Digital Assistants (PDAs), MP3 players, and computers. In another study, Coughlan et al. (2025) emphasise that technology has been shown to improve attitudes and performance in mathematics. To reinforce this point, Salazar and Wild (2022) reveal that, with the introduction of computers in TVET colleges over 10 years ago, there is considerable research supporting the notion that technology can help transform learning. Furthermore, the researchers' experience at TVET colleges indicates that the field of mathematics education has changed significantly due to technology. The researcher also discovered that educational technology facilitates simple computation and the visualisation of mathematical situations and relationships, allowing students to better comprehend mathematical concepts in practice.

1.6.2 Integration of tablets in a lecture room

Alex (2021) asserts that, as digital technologies have been shown to enhance learning, handheld tablet devices have started to become more prevalent in colleges. A tablet, according to Buzzard (2020), has been described as a small and portable media player that can be loaded with audio or video files from a computer. Moreover, the tablet, according to Alex (2021), has helped to provide engaging lessons using multimedia

capabilities for students and lecturers. In addition, Coughlan et al. (2025) support the notion that the quick and easy access to the internet with the tablet allows students to take notes on material and to better consolidate countless pieces of information. More specifically, a tablet has provided several opportunities to practise computational problems (Buzzard, 2020). In that way, it is expected that the use of the device allows lecturers to customise the learning to the needs of individual students to help them become more proficient in a mathematics lecture room.

1.6.3 Creativity and hands-on learning with tablets

Literature reveals that tablets inspire creativity and hands-on learning with features that cannot be found in any other educational tool. For example, powerful apps from the App Store, such as iTunes U and iBooks, allow students to engage with content in interactive ways, find information instantly, and access an entire library wherever they go. The researcher also discovered that tablets could transform traditional classrooms by utilising Academic Support Tutor (AST) resources effectively. AST is a mathematical programme that lecturers and students can use to assist with the challenges students may face while learning mathematics. Tablets have the potential to revolutionise the way learning is conducted in the classroom.

1.6.4 Tablet for anytime, anywhere education

Bara (2023) states that for students who have been absent from a lecture, missed a lesson, or need a reteach, the tablet facilitates learning anytime and anywhere. This is due to the tablet's sleek, user-friendly design, which can motivate all types of learners to succeed (Dias & Deodalo, 2025). Additionally, a tablet enables a variety of lessons to always unfold within one classroom (Buzzard, 2020). Furthermore, the device can provide remediation, independent work, group activities, and enrichment. For example, students who may require further explanation of certain concepts can easily navigate to a tutorial video stored in an application on the device.

1.6.5 Literature on studies that used tablets in mathematics learning

While the implementation and use of tablets in teaching and learning is relatively new, many institutions have been trying to maximise their efficiency in the classroom. Globally, literature on studies that utilised tablets for mathematics learning includes

the development at (i) Abilene Christian University (ACU) in Texas, USA, (ii) a study conducted by Audi (2023) on the learning of Euclidean geometry using tablet devices, (iii) a study conducted by Arvanitaki and Zaranis (2020) on students' intensive satisfaction and the relationships created when learning through the use of tablets, (iv) a study by Aldossry (2023) comparing the effects of a worksheet condition and a tablet condition on academic engagement in a college setting, (v) a study by Novita and Herman (2021) on how the use of mobile technology in the classroom can help to deepen and enhance the learning process, and (vi) a study conducted by Sacristán and Enriquez (2023) on the utilisation of tablet devices in a higher education setting. This chapter presents only a summary of these studies; a more detailed discussion is provided in Chapter 2.

1.7 THEORETICAL FRAMEWORK THAT UNDERPINNED THE STUDY

The theoretical framework, according to Mouton (2023), is the structure that can hold or support a theory of a research study. To achieve the goals of this study in examining the academic achievement and attitudes of students learning Level 3 SAVOGOs, the concepts of "learning," "use of tablets," and "attitude" played a major role in the investigation and were later measured, as these are essential concepts to define within the framework. Webster (2022) defines learning as the activity or process of gaining knowledge or skill by studying, practising, being taught, or experiencing something. Bara (2023) builds on this definition, stating that learning is the process of acquiring new understanding, knowledge, behaviours, skills, values, attitudes, and preferences. We can better understand learning by studying and knowing Ellis's ABC model of attitude and learning.

This chapter, therefore, introduces the conceptual framework that underpins this study, with a particular emphasis on Ellis's Affect (A), Behaviour (B), and Cognition (C) (ABC) model of attitude and learning, which is a fundamental framework in cognitive learning. Developed by psychologist Albert Ellis, the ABC model assists individuals in analysing situations by recognising the Activating Affect (A), Behaviour (B), and Cognition (C). This ABC model, illustrated in Figure 1.3 below, is employed in cognitive learning to confront irrational thoughts and cognitive distortions. In this study, the ABC model will assist in recognising the irrational thoughts and cognitive

distortions underlying underperformance and negative attitudes in learning SAVOGOs.

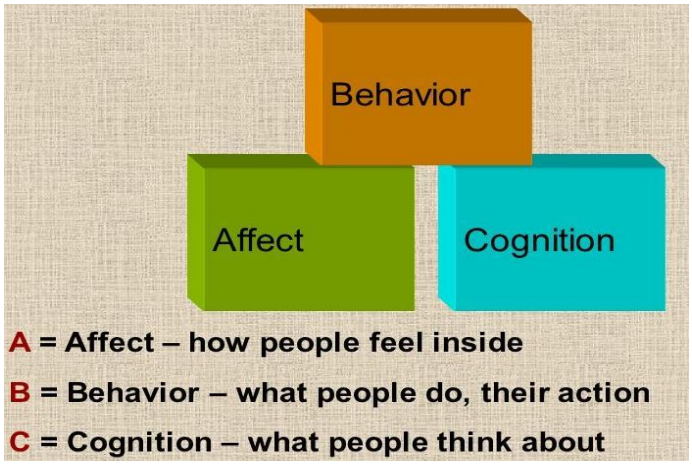


Figure 1.3: Albert Ellis *(1955)*, the ABC model

According to the ABC Attitude Model, Affect refers to the emotional aspect that encompasses the feelings and emotions linked to an attitude object, which, in this research, pertains to the calculation of surface area and volume of geometric figures in mathematics. The Behaviour component represents the actions that reflect a tendency to respond in a specific manner towards the mathematical object of study. Cognition, on the other hand, is the mental aspect that includes the beliefs and perceptions students hold regarding their attitude towards mathematics. In this research, all three components are evident prior to the researcher determining the existence of an attitude towards the subject.

However, the cognitive learning component, which the researcher deemed essential for this study, was not clearly and thoroughly defined within the model. The researcher identified the emphasis on the cognitive learning component as her contribution to the existing body of knowledge. According to Adams (2025), cognitive learning is characterised as an active learning style that aims to assist learners in optimising their cognitive abilities. These were highlighted to emphasise that at the collegiate level, cognitive teaching strategies prioritise significant mathematical learning. Moreover, this study does not emphasise rote memorisation or the repetitive learning of mathematical content. Rather, mathematics instructors aimed to impart the essential principles of mathematics for lifelong learning. Ultimately, the participants in this research acquired mathematical skills and strategies that enhanced their performance

in college, including the ability to think critically and establish enduring connections among mathematical concepts.

This research indicates that students found it simpler to relate new mathematical concepts to their prior knowledge, thereby enhancing their mathematical memory, retention, and cognitive abilities. Additionally, the elements of cognitive learning, its advantages, and various cognitive learning strategies are examined in detail in Chapter 3, which outlines the theoretical framework of the study.

1.8 PROBLEM STATEMENT

An ongoing debate about the efficiency of using technology to enhance mathematics learning practices is observed in TVET colleges. While the Fourth Industrial Revolution (4IR) questions what it means to be efficient in the twenty-first century, a firm response lies in how students learn mathematics and how teachers teach it. Traditional methods of instruction that focus on paper-and-pencil practice, according to Bara (2023), are still predominant in most mathematics classrooms across the country, including TVET colleges. In these lecture classrooms, the main resources used are textbooks and worksheets, while instruction is one-directional, from the lecturer to students. As a result, Engelbrecht and Borba (2024) assert that students have no ownership of their learning. This resulted in the information gap that lies in the performance and attitudes of TVET college students who are now using tablets. Prior research (Adeyemi et al., 2025; Tabassum, 2025) focuses on the evolution of technology use, perceptions of its advantages and disadvantages, and effects on foundational school learners, and should also be supported by references.

Recently, Level 3 students in North West TVET colleges have been equipped with tablets to enhance their learning. Some of the research conducted on tablets in mathematics education has primarily focused on: (i) the evolution of teaching and learning through technology, (ii) the experiences and perceptions of students and lecturers regarding the advantages and disadvantages of technology, and (iii) the impact of tablet devices on foundational school learners' mathematics performance and attitudes. This study intends to explore the impact of tablet use on Level 3 NW TVET college students' performance and attitudes in learning to calculate SAVOGOs.

1.9 AIMS AND OBJECTIVES

1.9.1 The aim of the study

This study aims to determine the impact of using tablets on TVET Level 3 students' performance and attitude in calculating SAVOGOs.

1.9.2 Objectives

The following objectives were formulated to achieve the above aim. The study intends to:

- Establish how Level 3 students' performance compares with using tablet devices as opposed to the traditional textbook method of learning.
- Investigate how Level 3 students' attitudes compare with using tablet devices as opposed to the old traditional textbook method of learning.
- Determine challenges experienced by Level 3 students when learning SAVOGOs using tablet devices.
- Determine the benefits of learning SAVOGOs with tablet devices.
- Suggest a model maximising improvement performance in mathematics at TVET Colleges using mobile devices.

1.10 RESEARCH QUESTIONS AND HYPOTHESIS

In this study, the main research question was:
What is the impact of using tablets on TVET Level 3 students' performance and attitude in calculating SAVOGOs?
To unpack the main question, the following were sub-questions.

(i) How do Level 3 students' performance differ when using tablet devices as opposed to the traditional textbook method of learning?
(ii) How do Level 3 students' attitudes vary when using tablet devices as opposed to the old textbook method of learning?
(iii) What challenges do Level 3 students experience when learning SAVOGOs using tablet devices?

(iv) What benefit do Level 3 students experience when learning SAVOGOs using tablet devices?
(v) Which model can maximise performance in mathematics at TVET College using mobile devices?

- The null hypothesis of the study was:

There is no variation in performance and attitude when a cohort of Level 3 students calculate SAVOGOs using tablet devices as opposed to the traditional textbook method.

- The directional hypothesis was:

Groups of TVET Level 3 students calculating SAVOGOs using tablet devices improved performance and attitude as opposed to the traditional textbook method.

1.11 RESEARCH METHODOLOGY

1.11.1 Research Paradigm

According to Creswell and Clark (2023), a paradigm incorporates the accepted theories and beliefs associated with individual researchers, leading to the adoption of a qualitative, quantitative, or mixed methods approach in their study. Four of the beliefs that are usually reviewed in research are constructivism, pragmatism, transformative, and post-positivism. To achieve the goals of this study, it was framed by the pragmatic worldview.

1.11.2 Research Design

To address the questions, in this research, a quasi-experimental research design was used. Quasi-experimental design, according to Kaya and Kutluca (2024), is identical to experimental research in the sense that there is manipulation of the independent variable. Creswell and Clark (2023) assert that one-group designs composed of post-

test only and pre-test–post-test are one of the four categories of quasi-experimental research design. Finally, Creswell and Clark (2023) further emphasise that the one-group designs (post-test only and pre-test–post-test) are further divided into two categories, which are: one-group post-test-only design and one-group pre-test–post-test design. Between the two categories of the one-group designs, this study was guided by a one-group pre-test–post-test design because it minimises problems related to having no comparison or control group.

1.11.3 Research Methodology/Approach

Research methodology, according to Vos et al. (2024), is the path through which researchers conduct their research. Furthermore, Creswell and Clark (2023) note that there are three approaches to research for answering research questions and hypotheses: qualitative, quantitative, and mixed methods. This study employed a mixed-methods sequential explanatory design to statistically determine the relationship among the variables and to make sense of the experience using both qualitative and quantitative approaches (Creswell & Clark, 2023).

1.11.4 Population and Sampling

Although "Population" and "Sample," according to Vos et al. (2024), are two different terms, they are both related to each other. The population is used to draw samples. Making statistical inferences about the population is the primary purpose of the sample. Without the population, samples cannot exist (Creswell & Clark, 2023).

1.11.5 Population

MacMillan and Schumacher (2018) refer to population as an aggregate or totality of all the objects or events, subjects, or members that conform to a set of specifications and to which we tend to generalise the results of the research. The population in this study consisted of Mathematics Level 3 students at TVET colleges. Even though the total population of the college was about 1,020 NCV students, the population targeted was 120 Mathematics Level 3 students.

1.11.6 Sampling strategy

According to Cohen and Kelly (2020), a sample refers to a subset of elements drawn from a larger population and selected for inclusion in a study; it represents a smaller section of the population under investigation. To select participants for this study, a quasi-experimental one-group pre-test-post-test design sampling method was employed. In this study, the students within the lecture room were not randomly selected. Thus, students were grouped at the beginning of their Level 3 academic college years to create a heterogeneous group of 20 students in a lecture room. Because of this, 20 students in a lecture room comprised the study's sample. Three groups consisting of twenty (20) students each were taught by the same lecturer, and this constituted a sample frame of 60 students for this study.

1.12 INSTRUMENTATION AND DATA COLLECTION TECHNIQUES

1.12.1 Data collection instruments

The study employed a pre-test, a post-test, and semi-structured interviews as data collection instruments, allowing the interviewer flexibility rather than strict adherence to a formalised question framework. Instead, more open-ended questions were asked, allowing for conversation with the interviewee, rather than a direct question-and-answer pattern. The Attitudes Toward Mathematics Inventory (ATMI), created by Tapia and Marsh (2004), was also administered to the participating students.

1.12.2 Data collection techniques

Classes of Level 3 students at a TVET college were given a pre-test to establish baseline scores for SAVOGOs' performance. Proceeding with the collection of data, a post-test was used after analysing the pre-test to collect quantitative data to weigh the interconnection of learning performance towards SAVOGOs of Level 3 students when learned using a tablet and when the traditional method of learning was used. Students' results obtained through the traditional teaching method were compared with those of students instructed using tablet devices in the learning of SAVOGOs. To gather qualitative data, interviews with the participating students were conducted at the end of the collection of quantitative data. For the researcher to yield validity to this study,

a disposed ATMI survey was used to determine students' attitudes in the learning of SAVOGOs. The Attitudes Toward Mathematics Inventory (ATMI), according to Tapia and Marsh (2004), is a validated survey instrument designed to measure high school and college students' attitudes toward mathematics across four main dimensions: self-confidence, enjoyment, value, and motivation. The ATMI is intended to assess affective factors in mathematics education, recognising that students' attitudes can strongly influence participation, engagement, and achievement. It included questions about: Self-confidence (SC): Measures students' confidence in learning and performing mathematics. Enjoyment (ENJ): Assesses the pleasure students experience while working with mathematics. Value (VAL): Evaluates the perceived usefulness and relevance of mathematics in life, and Motivation (MOT): Captures students' willingness to engage in mathematical activities and to pursue further studies. Responses are typically recorded on a five-point Likert scale ranging from strongly disagree to strongly agree, with both positively and negatively worded items included to reduce response bias. Regarding the reliability and validity of ATMI, Tapia and Marsh (2004) assert that ATMI is a reliable and valid instrument across various populations.

1.13 DATA ANALYSIS AND INTERPRETATION

The focus of this study is on the notion of mixing or combining qualitative and quantitative methods by following the inferential quasi-experimental data analysis and interpretation. Inferential analysis, according to Williams et al. (2022), involves making predictions or inferences about the population based on the sample data. It requires statistical methods to estimate parameters (e.g., means, variances) and to test hypotheses. Inferential analysis is crucial for drawing conclusions about the population and can be used to evaluate the effectiveness of interventions. Inferential analysis is essential for understanding the impact of interventions. The researcher carefully designed this study to minimise biases and enhance validity, ensuring that the results are generalisable to the broader population. The interpretation and data analysis were conducted in two stages. Part 1, which was about the questionnaire results, dealt with a quantitative analysis of data. Part 2 was a qualitative interpretation of the results of the interview and ATMI survey.

1.13.1 Analysing quantitative data

The study design compared the outcomes for the dependent variable of students' mathematics academic performance and student attitudes within one group using the traditional method, and when using the tablet device in the learning of SAVOGOs. A group of students participated in a lecturing classroom using the traditional instruction of mathematics, and the same group was later taught using tablet devices. The researcher sequentially followed the following procedures when analysing data quantitatively:

- Preparation of the data file using SPSS
- Data transformation
- Regression analysis
- ANCOVA

1.13.2 Qualitative data analysis

To complement the results and add value to the questionnaire, a qualitative approach was employed. The researcher prepared raw data transcriptions, duplicated the data, and formulated basic codes for recognised themes. The researcher further read the text closely to gain insight into the themes present in the content and generated categories and codes. The overlap of coding was minimised, leading to the formulation of ideas about the experiences highlighted in the text. In this study, thematic analysis served as the method for analysing qualitative data. The researcher subsequently examined the data to identify common topics, themes, ideas, and meanings that emerged frequently.

1.14 METHODOLOGICAL NORMS

Reliability and validity, as described by Limi (2025), are the two main aspects of credibility and trustworthiness that the researcher can employ to validate the correctness of the study. Now that this study has applied a mixed-method approach, the researcher has a section to address reliability and validity for the quantitative part to measure the quality and rigour of the data collection instrument. For the qualitative

approach, the researcher needs a section about credibility to measure the quality and rigour of this study. Further details on validity and reliability are outlined in Chapter 4.

1.15 RESEARCH ETHICS

This part contains permission, privacy, confidentiality, possible harm, voluntary participation, etc. According to Creswell and Clark (2023), ethical considerations in mixed methods research encompass issues that arise across both quantitative and qualitative approaches, spanning three key phases: the initial framing of the study, the data collection process, and the data analysis stage. In this study, permission was requested from the UNISA Ethics Committee, the Department of North West Education, the Principal of the TVET college where the study was conducted, and consent from participants.

1.16 LIMITATIONS AND DELIMITATIONS OF THE STUDY

Limitations, according to Simon et al. (2025), are the shortcomings, conditions, or influences that cannot be controlled by the researcher and that place restrictions on the methodology and conclusions. In this study, schools and private TVET colleges were not included; furthermore, this study was limited to Mathematics Level 3 students only in TVET colleges in the North West Province.

1.17 RESEARCHERS' CONTRIBUTIONS TO THE STUDY

The researcher developed the following model after observing improvements in mathematics results due to the use of tablet devices. This initiative aims to amalgamate technology into the learning process, with a fundamental focus on the development and support of both students and teachers. Providing teachers with ample time to familiarise themselves with the technology and design appropriate lessons allows for the best chance of a successful programme. The researcher also recommends that TVET College sectors consider providing students with training on the use of tablet devices in an educational setting.

1.18 DEFINITION OF KEY CONCEPTS

- A tablet device, sometimes known as an iPad, according to Simon et al. (2025) and Limi (2025), is regarded as a portable mobile learning and operating device or system with a touchscreen interface and a wireless personal technological device. Tablets are generally larger than smartphones, with screens 7 inches (18 cm) or larger, and smaller and more portable than laptops. Unlike traditional laptops, tablets rely primarily on touch input, though many can connect to external keyboards or styluses for additional functionality.
- **The surface area and volume of geometrical objects** can be calculated for any three-dimensional (3D) geometrical shape. The Total Surface Area can be defined as the total area covered by an object, including its base as well as the curved part. If an object has both the base and curved area, then the total surface area will be equal to the sum of the base and curved area and is measured in square units.
- **TVET colleges**: Technical Vocational Education and Training (TVET) colleges in South Africa play a crucial role in the post-school education system by providing vocational and technical education. They aim to address skill shortages, improve employment prospects, and contribute to economic growth. TVET colleges offer a variety of qualifications, including National Certificates and Diplomas, equipping students with practical skills for specific occupations. Their primary purpose is to transform education and training to improve the livelihoods of individuals and contribute to the broader economy.
- The traditional textbook method in South African education is characterised by its focus on memorisation of facts and traditional values. It emphasises memorisation and the transmission of knowledge, often lacking in contextualisation and historical inquiry.
- The National Certificate Vocational (NCV), according to Williams et al. (2022), is a vocational qualification in South Africa designed to provide practical skills and knowledge for specific careers, equivalent to a matric certificate.
- The National Qualifications Framework (NQF), according to Cohen and Kelly (2020), is a comprehensive system designed to classify, organis and develop qualifications across various educational sectors, enhancing the quality and recognition of qualifications.

- Computer Applications (Apps): Computer applications, according to Aldossry (2023), are programs designed to perform specific tasks or functions for users, ranging from productivity and communication to entertainment and specialised professional tools.

1.19 ASSUMPTIONS

Assumptions, according to McMillan and Jones (2022), are somewhat out of one's control, but if they are not presented, the study will become irrelevant. The target population are from a TVET college in the rural area of North West Province with three campuses where data was collected. Calculation of geometrical objects is the aspect covered in this study. Sixty Level 3 mathematics students from rural areas participated in this study. As assumed before the study commenced, the rural setting introduced certain logistical constraints, most notably limited access to reliable transport and inadequate network connectivity. These factors presented potential challenges during the data collection process, as they could affect participant availability and communication. Accordingly, transportation difficulties and network limitations are acknowledged as limitations of this study. According to Mazana (2024), research limitations are inherent constraints in a study that affect the scope, validity, reliability, or generalisability of findings. These can arise from methodological choices, researcher-related factors, or practical considerations such as time, budget, or access to participants. Hassan and Sani (2025) further assert that recognising limitations is not a weakness but demonstrates integrity, scientific rigour, and transparency.
In this study, practical constraints are the lack of transport and network issues in rural areas. The strategies used to identify and mitigate limitations were to acknowledge and transparently describe them clearly by specifying their origin and potential impact on the findings. If transport can prevent students from attending or writing tests, this will result in methodological enhancements, which was achieved through expanding the sample size. For the network issues, this would mean rescheduling until the network is available, and this would affect the duration and quality of the study.

This study further assumed that the participants would answer the pre-test and post-test to the best of their ability and respond to the interview questions honestly, truthfully, and to the best of their knowledge. The study also assumed that all students

participating in this study were ready for Mathematics Level 3 and had passed the Mathematics Level 2 examination. The study further assumed that the participating lecturer was well-educated, knowledgeable, and experienced.

1.20 CHAPTER OUTLINE

Chapter 1: Introduction and background to the study

This chapter consists of the introduction, background of the study, and a brief literature review. It also includes the statement of the problem, the aim and objectives of the study, and the research questions and hypotheses. A brief explanation of the research methodology, methodological norms, and design used in this study is also included.

Chapter 2: Literature/scholarship review

In this study, the literature was reviewed first to include (1) the use of technology in the lecture room. Secondly, the review continued to examine the integration of tablets in the lecture room. The third section of this review explored creativity and hands-on learning with tablets, and finally, the use of tablets for anytime, anywhere education.

Chapter 3: Theoretical framework

This chapter begins by outlining the Affective, Behavioural, and Cognitive (ABC) Model used to frame this study. The ABC Model of Attitude, according to Mazana (2024), also known as the Tripartite Model, serves as a valuable theoretical framework for developing measures of attitudes toward mathematics, specifically through the Attitudes Toward Mathematics Inventory (ATMI).

Chapter 4: Research methodology and design

This chapter describes the research design and methodology chosen for this study. It also discusses the research approach, population and sampling techniques employed, instrumentation and data collection techniques, and how the data were analysed. Finally, it refers to research ethics, ensuring the reliability, validity, credibility, and trustworthiness of results.

Chapter 5: Findings of the study

This chapter focuses on the findings of data collected from tests, interviews, and documents. This was done through statistical equipment and the identification of patterns, trends, and themes.

Chapter 6: Discussion of the Research findings

This chapter focuses on the discussion of findings from questions and hypotheses. The discussion of findings in relation to literature, the theoretical framework, and students' performance and attitudes was also addressed in this chapter. It further touches on limitations and delimitations, as well as implications and recommendations for further research.

Chapter 7: Conclusions and recommendations

This is the last chapter of this study. In this chapter, I present a summary of the chapters, a summary of the literature reviewed, the findings, the limitations of this study, recommendations for further research, and final reflections, as well as the conclusion.

1.21 CONCLUSION

The overview and the introduction, as well as the background of this study, referred extensively to what previous researchers have written on the topic. The global perspective, African perspective, South African perspective and North West province perspective were explored in this chapter. The literature review covering various aspects of the use of technology, integration of tablets in the lecture room, as well as literature on studies using tablets was explored in this chapter. In addition, the theoretical framework underpinning the study was thoroughly interrogated. Furthermore, the origin of TVET colleges in South Africa, the global perspective of students' performance after learning mathematics with tablet devices, the informed gap, studies' aims and objectives, as well as research questions and hypotheses were also covered in this chapter. The chapter continues to explore the research methodology and design, instrumentation and data collection techniques as well. Data

analysis and interpretation, methodological norms, research ethics, limitations and delimitations of the study were also looked at. The chapter finally explored the researcher's contributions to the study, definitions of key concepts, assumptions and chapter outlines. Chapter 2, which follows, provides a comprehensive review of the literature informing this study.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

McMillan and Jones (2022) assert that the purpose of the literature review is to summarise and evaluate the existing knowledge on a research topic. More specifically, it serves to drive the arguments for discovery and promotion of the study (Dias & Deodalo, 2025). The purpose of this study was to determine the impact of tablet use on Level 3 NW TVET college students' performance and attitude in learning to calculate SAVOGOs. While a substantial amount of research exists on the integration of technology in the learning of mathematics, the researcher contends that additional research is needed to examine how tablet devices specifically affect Level 3 NW TVET college students' performance and attitude in learning to calculate SAVOGOs.

This chapter establishes a framework by including relevant literature that reviews prior research to help understand the topic of study. The review is organised into several sections to create an outline that supports the research purpose of this study. The review adds to the discussion of (i) the global, African and provincial perspective of tablet use, (ii)the use of technology in the mathematics classroom, (iii) the implications for policy and practice (iv) integration of tablets in the mathematics classroom, (v) the use of tablets in mathematics learning, followed by a discussion on creativity and hands-on learning, (vi) tablets for anytime, anywhere education, (vii) utilised tablets in mathematics learning, and (viii) examines the effectiveness of tablets in learning mathematics, followed by a discussion on the benefits of tablet use. The review then addresses factors that negatively influence tablet integration. The chapter continues to explore the importance of tablets globally, nationally, in SA, as well as provincially. Then the chapter concludes by exploring students' attitudes towards learning mathematics and the general overview of tablet devices in learning Mathematics L3.

2.2 USE OF TECHNOLOGY IN THE LECTURE ROOM

Brooke et al. (2022) assert that the use of technology in the lecture room provides students with educational technology (EdTech) that has significantly evolved and

changed the world in which we live today. EdTech has been defined by Kaya and Kutluca (2024) as the use of hardware, software, and other digital technologies to advance learning, teaching, and administration in colleges. Brooke et al. (2022) further define EdTech as a technology that usually helps facilitate collaboration in an active learning environment. Usually, technology affects the way individuals communicate, learn, and think. In addition, Audi (2023) notes that technology helps to play an important role in society today and determines how people interact with each other daily. Technology, according to Brooke et al. (2022), also added value in EdTech in learning during the COVID era.

EdTech is a wider concept that literally indicates the importance of technology in any educational setting, including schools, colleges, universities, institutes of business training, and residences. Kaya and Kutluca (2024) further state that EdTech is also the joint use of tablets in colleges to promote online learning, along with educational theory and experience. Considering the researchers' experience, many kinds of technological devices can be used in a mathematics lecture room. With the introduction of technologies at TVET colleges, there is much belief that they can help to transform the learning of mathematics and can also improve performance in the subject of mathematics. To consider the significance and impact that technology has on learning, a review of the historical connection between technological innovations and education is essential at TVET colleges. As innovations prevail, legislators and college officials search for techniques to adapt and integrate new tools, like tablets, in support of learning mathematics and to adequately prepare students.

2.2.1 Importance of tablets in students' learning mathematics during the COVID-19 era

The COVID-19 pandemic, according to Alex (2021), has created the largest disruption of education systems in history, affecting nearly 1.6 billion learners in more than 190 countries and all continents. Closures of schools and other learning spaces have impacted 94% of the world's student population, and up to 99% in low and lower-middle-income countries. It has become the researcher's observation that tablets are an easy means for students to receive mathematics lessons from lecturers. Due to the COVID-19 era, a range of resources for online mathematics learning, such as videos, PDFs, and interviews, were used by students as part of their learning materials at the

college. Students were willing to become more effective learners by expanding the mathematics lessons received beyond conventional textbooks to incorporate educational content. Online curricula using tablets encourage students to set their own rate of learning mathematics, and there is the extra versatility of setting a timetable that suits the agendas of all. As a result, there was no reason to give up on EdTech, as it creates a greater balance between jobs and studies by having an online education tool, such as tablets. Studying online, according to Coughlan et al. (2025), teaches flexibility and vital skills in time management, which makes it easier to find a good work-study balance and allows for a customised mathematics learning experience. There are a few reasons why students are drawn to an online education course as opposed to taking courses in a traditional mathematics classroom setting. First, some students have full-time jobs, which limit their opportunities to attend mathematics classes scheduled during normal college hours. Also, online mathematics classes allow students to work independently and move at their own pace. Finally, these classes offer more of a one-on-one lecturer-student relationship rather than a lecturer having to spread their focus amongst thirty other mathematics students.

Kaya and Kutluca (2024) assert that flexibility assists students in setting their own tempo for studying mathematics. But for each student's individual requirements and level of competence, online mathematics learning is also flexible. Due to the pandemic, in most institutions, the researcher observed that online classes are used more than the normal traditional mathematics classes, and most of the time allow the interaction of more than one student at a time. This online mathematics learning allows greater interaction and more feedback between students and the lecturer in almost all cases. With new technology such as tablets, it is easier for all to create an improved mathematics learning environment. Online mathematics classes became a popular concept in schools when the pandemic struck the world. The researcher also noticed that the existence of online mathematics classes was reinstated in colleges to avoid missing the essential months of college life. Thus, schools, colleges, and universities had to enforce online classes during COVID-19 due to strict lockdowns. Every institution started using various online tools, such as tablets, to keep the classes as effective as physical classes. While the use of tablets has been growing at a rapid rate for quite a few years now, their real importance was discovered when their use during

COVID-19 came into existence. The ‘study online’ part of college life was unexpected, but slowly everybody adapted to it.

Like there are two sides to the same coin, online learning also has many advantages and disadvantages. While online classes started without a choice, their impact gradually began to creep in. Students had difficulty focusing, but various techniques helped in solving that issue. Today, the utility of tablets is recognised by all age groups and not just the technical or business industry. Additionally, students should note that learning is a lifelong process of attaining success. Also, students should realise that taking online classes was always for additional classes and courses. Moreover, online classes were flexible and were often taken alongside a primary source of education. Furthermore, it is now the ‘new normal’ in every phase of education.

In this COVID-era, tablets have been changing the way lecturers and students work and live. Both lecturers and students are seeking to embrace tablet methods and applications with the rising use of EdTech. No one can deny the fact that online mathematics classes are much more convenient than physical classes. Students can dress the way they want, can access the class from any part of the world, and can also record the class for future reference. Physical classes were usually uncomfortable for many students, although they were more impactful.

McMillan and Jones (2022) assert that tablets have a positive impact on students’ learning of mathematics. Kaya and Kutluca (2024) further emphasise that tablets cause students to be more engaged; thus, students often retain more information about what they have learned. Globally, tablets, according to Gerber (2023), have become relevant to students and provide meaningful learning experiences. Currently, the researcher is a contract lecturer for the University of South Africa (UNISA) Midlands academic literacy programme, offering quantitative numeracy skills topics. During the lecturing process of this module, students learn remotely. Buzzard (2020) posits that remote learning, referred to as distance learning or online learning, involves students and lecturers interacting outside the traditional classroom setting. According to Alex (2021), this approach allows students to access instructional content from anywhere with an internet connection, offering flexibility and accessibility that traditional in-person education may not provide. Unlike virtual schools or fully online programs, remote learning, according to Brooke et al. (2022), is often temporary or

situational, such as during school closures due to emergencies or pandemics. The researcher discovered that tablets provide hands-on learning opportunities that are integrated into the scheduled areas, including mathematics, reading, science, and social studies, as well as other academic subjects. Furthermore, tablets give students opportunities to collaborate with their peers, resulting in learning from each other.

During the process of remote learning, students state that tablets are becoming such an integral part of their everyday learning, as most education today requires some type of technology use. Also, students and the researcher, as the lecturer, are using tablets daily to communicate and get information on SAVOGOs in multiple ways. The prevalent daily use of tablets in students' lives overall makes the use of tablets very relevant to the students and provides a connection that greatly benefits student learning. Furthermore, the researcher discovered that students currently live in a very technological world and use tablets daily for texting and learning mathematics. Post-lecturing remotely and interviewing the students about the benefits of tablets, the researcher discovered that students see tablets as useful and extremely enjoyable and relate to using technology in the future. It is therefore envisaged that if their learning environment mirrors how they engage with the world, they are likely to excel in their education. Webster (2022) similarly highlights several advantages of remote learning. These include the flexibility to study from any location, which helps students balance personal, family, and work responsibilities, and improved access to quality education for those in rural or underserved communities. Remote learning also supports self-paced, individualised study, allowing learners to spend more time on areas they find difficult. From a financial standpoint, it lowers expenses related to commuting, clothing, and learning materials, making education more accessible. Additionally, it equips students with digital competencies that are increasingly valuable in both academic and professional settings.

In consideration of the above, the researcher concluded that tablet devices can transform the lecture room into an interactive mathematics learning environment. While interactive learning is more hands-on, the real-world process of relaying information in lecture rooms, Webster (2022) associates passive learning with listening to lectures or rote memorisation of information. In interactive learning, students are invited to participate in a conversation through the tablet, online reading, and mathematics programmes through role-playing and group exercises in lecture rooms

(Alex, 2021; Brooke et al., 2022). Alex (2021) further emphasises that interactive learning is learning that encourages independent study using tablets. In agreement, Buzzard (2020) asserts that tablets have done wonders for interactive learning in mathematics, as they inspire students and keep the lecturer-student relationship vital.

In addition, the researcher observed that engaging students who are raised in a hyper-stimulated environment sharpens critical thinking skills, fundamental to the development of analytic reasoning. A hyper-stimulated environment, according to Webster (2022), refers to interactive learning, which is more hands-on, with the real-world process of relaying information in learning and non-learning specific settings. Gerber (2023) further asserts that the traditional style of passive learning relies on a student listening to a teacher's lecture or rote memorisation of information, figures, or equations. However, with interactive learning, Audi (2023) posits that students are invited to participate in the conversation, role-playing, or group exercises in class. This approach is critical, as Kaya and Kutluca (2024) point out, “Active learning, not passive learning, makes it impossible to sleep through a class.” When a learning environment is fuelled with participation, students feel part of the solution. They feel that their voice is important and is being heard; more importantly, they feel engaged. A student imagines and logically reasons about making decisions from an open-ended question as opposed to just regurgitating memorised information. Also, according to Kulik and Fletcher (2020), interactive learning teaches students how to collaborate and work successfully in groups, an indispensable skill as workplaces become more team-based in structure. Students can continue interactive learning in the lecture room by talking to their peers and asking open-ended questions about the mathematics homework to get a conversation going. As a result, a question asking students about their experience during the completion of homework most often gets a noncommittal challenge in response. Instead, students should try some of these specific but still conversation-starting questions to continue learning in the lecture room. Brooke et al. (2022) conclude that students can also explore online mathematics learning games and activities with their peers that serve as extensions of what they learned in their lecture rooms. Some of those mathematics learning games using tablets include marble, mancala (an ancient strategy game), Monopoly, card games, Uno, Numero, and Domino games.

2.3 INTEGRATION OF TABLETS IN A MATHEMATICS LECTURE ROOM

Lecture rooms can allow students more time to develop and absorb the concepts important for a particular mathematics lesson. Through the integration of tablets, students can develop a better understanding of mathematics as well as its connection to other subjects. Tablets can do much more than improve test scores. The college experience overall can become more enjoyable, leading to increased attendance (Kaya & Kutluca, 2024). Colleges should incorporate tablets to enhance students' learning experiences, engage students in more effective activities, increase efficiency for lecturers, and adapt to all students' learning needs. Due to the large percentage of students showing strong interest in the integration of tablets in a mathematics lecture room, the next step should be the implementation of tablets in the lecture room by TVET colleges, because students understand mathematics more when using the device.

According to Alex (2021), learning methods have undergone a great deal of change over the past 100 years, making it necessary to consider new models of learning and the way information is translated to students. Currently, for the North West (NW) educational system to provide students with new opportunities for success, tablet devices are becoming more prevalent in the lecture rooms. According to Gerber (2023), tablet devices are unique in that they are highly portable, have a flat touch screen interface, and offer application programs that can be downloaded directly to the device. Furthermore, Brooke et al. (2022) assert that tablet devices can transform traditional lecture rooms into places that utilise 21st-century, efficient technology resources. In addition, Alex (2021) reports that constant access to important educational resources transforms the learning experience for students. Buzzard (2020) further notes that this prevailing and versatile tool provides many ways to enhance education. For example, in a mathematics classroom, tablets can engage students, but the explanations as to why engagement occurs include the important factors of new technology, the interactive and visual nature of the apps, the gamification of learning, and the hands-on aspect of touchscreens (Buzzard, 2020).

Currently, according to Kulk and Fletcher (2020), tablets can help to revolutionise the way learning is conducted in the mathematics lecture room. The researcher also discovered that tablets significantly transformed higher education and created more

opportunities for academic development. This was emphasised by Bara (2023) when highlighting that tablets have revolutionised higher education by enhancing accessibility, promoting interactive learning, and providing new opportunities for academic growth and collaboration.

Enhanced Learning Accessibility: Tablets make learning materials available anytime and anywhere, enabling students to carry e-textbooks, lecture notes, and multimedia resources in a portable digital format. This flexibility supports independent study and accommodates diverse learning styles, including visual, auditory, and kinaesthetic preferences.

Interactive and engaging learning: With tablets, instructors can leverage interactive applications, simulations, and educational software that transform traditional lectures into immersive learning experiences. Features such as touchscreens, styluses, and annotation tools allow students to engage directly with content, improving understanding and retention.

Facilitating collaboration and communication: Tablets enable students and faculty to collaborate effortlessly through cloud-based platforms, discussion boards, and shared documents. Real-time editing, peer-to-peer feedback, and virtual group work foster academic collaboration, bridging gaps caused by distance or scheduling conflicts.

Integration of multimedia and technology: The capability to incorporate videos, interactive quizzes, and augmented reality content on tablets enriches the learning environment. Students can explore complex concepts through visualisations and virtual labs, which enhance comprehension and support experiential learning.

Academic development and efficiency: By providing access to research databases, journals, and educational apps, tablets accelerate knowledge acquisition and facilitate research skill development. Students can organise notes, schedule tasks, and manage projects efficiently, boosting productivity and time management essential for higher education success.

Supporting inclusive education: Tablets also contribute to inclusive learning by offering features like text-to-speech, adjustable text sizes, and language translation

apps. This ensures students with disabilities or language barriers have equal opportunities for academic participation and development.

Overall, Bara (2023) posits that tablets have significantly transformed higher education by making learning more interactive, accessible, and collaborative. They provide diverse tools for academic development, equip students with digital literacy skills, and create a more engaging and inclusive educational experience, preparing learners for the demands of a technology-driven world. This was observed during the online learning of mathematics by UNISA students during the COVID era. Therefore, it is necessary to determine if the devices have a similar effect in NW College lecture rooms, more specifically in Level 3 mathematics. The tablet is more than just digital textbooks for students to refer to; it also serves as an interactive, engaging device to enhance students' learning experiences (Coughlan et al., 2025).

According to Bara (2023), students can receive personalised instruction based on their own learning needs, which can be detected by many of the applications and e-books on tablets. Moreover, Brooke et al. (2022) believe that tablets allow for many different lessons to always materialise within one lecture room. Furthermore, Brooke et al. (2022) emphasise that the device can provide remediation, independent work, group activities, and enrichment. For example, students who may need alternative explanations of certain mathematics concepts can individually navigate themselves to a tutorial video that may be found on the web or on an application. Other students may practise skills on different applications of mathematics, while others can research to delve further into topics to broaden their knowledge.

In support of the above, the researcher observed in one institution that students learning with tablets can take control of their learning, push themselves to all extremes, and create new opportunities for success. Colleges are continually looking for ways to help students achieve better marks in mathematics. Ground-breaking products such as tablets are becoming highly sought after for use in lecture rooms and are user-friendly for students of all ages. According to Alex (2021), it has been found that the use of tablets has become almost second nature to many students. With so many students able to navigate the devices and use them outside of the lecture room, Coughlan et al. (2025) suggest that instruction by integrating tablets should be adapted for students to be in control of their own learning. Moreover, Alex (2021)

stresses that colleges that have established a place for tablets in their teaching have seen surprising and exciting results.

Colleges across the nation have spearheaded the movement of integrating tablets into lecture rooms. The researcher observed that as students are growing up in an era of technology, it is often difficult for lecturers to create memorable learning experiences for them, as it was during traditional methods of teaching. For this reason, Kulik and Fletcher (2020) argue that it is necessary to incorporate the use of tablets as an enhancement to the curriculum to reach millennial-aged students. As a result, students are going mobile across NW colleges, and lecturers are adjusting their instructional and operational practices to reap learning benefits. As technology is continuously evolving, Prensky (2018) concludes that the next major shift to incorporate 21st-century technology into the lecture room has been through tablet devices.

2.4 THE USE OF TABLETS IN MATHEMATICS LEARNING

The following section focuses on the application of tablet PCs and related technologies in learning mathematics, both face-to-face and at a distance. Discussions, according to Audi (2023), in this section centre on students' peer learning, student feedback regarding peer learning, the use of tablet PCs in mathematics tutorials, and one-to-one mathematics consultations. Furthermore, examples and preliminary results of the authors' research on staff and student satisfaction, as well as reflections on the impact of these technologies on learning, are presented. Additionally, the advantages and disadvantages of these technologies in these settings are outlined in this study.

2.4.1 The students' peer learning

Kulk and Fletcher (2020) assert that learning mathematics in colleges often requires students to copy solutions to problems from the board so that they can observe the expert's approach to problem-solving. In addition, Bara (2023) posits that this method of learning is still prevalent among students in colleges. Traditionally, in mathematics, students shared their views directly with lecturers and clarified their queries at the right moment. Furthermore, according to Brooke et al. (2022), books, notes, materials, and the question-and-answer pattern were the generalised ways of learning that helped students engage with mathematics more effectively. Moreover, according to Alex

(2021), students could easily access laboratories, workshops, clinics, and other resources on campus to gain practical knowledge of the subject. Practical knowledge of mathematics requires preparation beforehand, often through PowerPoint presentations. According to Coughlan et al. (2025), production of PowerPoint slides in mathematics is possible but time-consuming and allows little flexibility when problem solutions are prepared before class, as this does not permit modifications during class.

It has been observed that tablet PCs, with their capacity to create electronic handwriting, can transform students' experiences in learning mathematics. For example, Bara (2023) agreed by stating that students can now display questions and step-by-step solutions clearly to peers, respond quickly to unplanned peer questions, and most importantly, record all details of learning using screen capture and voice recording software. Gerber (2023) further posits that tablet technology was used to record peer tutoring in college mathematics, with the software Camtasia Studio edited and rendered to formats that could be delivered online or via mobile devices used by students (Gerber, 2023).

Tablets equipped with smart pens and digital notebooks, according to Alex (2021), can effectively record problem solutions along with peer explanations as students write. Bara (2023) further believes that these devices allow for the conversion of handwritten notes into a digital format, capturing audio recordings, and enabling cloud synchronisation. This integration of features like audio recording and cloud synchronisation, according to Gerber (2023), enhances the learning experience by providing a comprehensive digital record of the problem-solving process. Roschelle et al. (2020) posit that students can also categorise and search notes digitally, share them easily with classmates and teachers, and collaborate effectively. The eco-friendly aspect of these devices further contributes to their appeal in educational settings (Gerber, 2023).

In line with the above, the researchers observed in the Level 3 NW mathematics classroom that tablet PCs, aided by editable screen video and voice capture, can record problem solutions along with peer explanations as students write. Furthermore, according to Alex (2021), such software captures anything displayed on the screen, so videos, internet sites, and simulations can easily be included and recorded. Moreover, Kaya and Kutluca (2024) emphasise that it was noted that lectures in the

first-year subject Mathematics, both on-campus and via distance education, were recorded and made available to all students through the College's Learning Management System. Contrary to the popular belief among many college students, Alex (2021) asserts that this did not decrease on-campus class attendance. In fact, students commented that they attended class for the interaction, the chance to ask questions, and for peer learning.

2.4.2 Students' feedback on peer learning

In this study, Audi (2023) tested whether using iPads would lead to a better understanding of the mathematics class content and more interaction between the lecturer and the students. According to Audi (2023), when students attending peer learning in mathematics were surveyed about the use of tablet PCs, 54 out of 120 responded. Notably, 75% indicated that they preferred their peers to write on a computer, while 98% said that writing during peer learning helped their understanding of mathematics (Audi, 2023). Even better results were obtained in Mathematics Research at one college, where 9 out of 13 students responded to the survey, and all agreed that writing during peer learning aided their understanding of mathematics. In a further evaluation by Adams (2025), 23 college mathematics students involved in peer learning were surveyed, and all student responses were overwhelmingly positive. Most students commented on the visibility of the handwriting and annotations of the PowerPoint slides on the large screen, although this was qualified by comments encouraging peers to ensure their handwriting was legible.

In the same study by Adams (2025), 15 distance education students were sent a CD on peer learning and similarly asked to comment. The main responses were associated with the ease with which the material came alive for them through voice and screen capture of solutions in action (Audi, 2023). They also noted the advantage of having such a peer learning CD for later revision. Typical student comments included: i) Used them mostly as revision. ii) I often paused the lesson when a new problem was displayed, solved the problem, and then played the lesson to see if I was correct. iii) I found this useful as there were some problems not included in the printed study materials. iv) It's easier to understand a lesson, as you get the information portrayed as well as explained in a peer learning context. v) Most of the questions I had were also explained. vi) Another point for me was that I was able to pick up vital

information during peer learning that is summarised well by the peers, sometimes in explanations that cannot be made in a book. vii) To be honest, without these online screencasts, I would not have understood concepts or passed this course. viii) I couldn't attend all of the lectures, so this peer learning allowed me to go at my own pace (Audi 2023). It was apparent from the above comments that not only does the recorded lecture provide real-time modelling of mathematical thinking and reasoning, but it also offers more opportunities for self-directed learning. Self-directed learning (SDL), according to Ross (2020), is the process of learning in which the student takes the initiative for their learning and holds themselves responsible for it. During this process, students are responsible for organising and managing their own learning activities and needs. SDL encourages students to take responsibility for their own learning, identify gaps in their knowledge, and critically appraise new information.

2.4.3 The use of the tablet PC in tutorials

Tablet PCs have been increasingly used in on-campus mathematics tutorials, according to Audi (2023), to enhance student learning. In addition, Roschelle et al. (2020) believe that they provide a touch-screen interface that allows for interactive learning, making it easier for students to engage with mathematical concepts. Furthermore, Novita and Herman (2021) assert that research indicates that tablet PCs can improve student attention and learning outcomes, as they facilitate real-time feedback and collaborative learning. To add on that, Alex (2021) believes that studies have shown that tablet technology can promote meaningful engagement in instructional mathematics, allowing for more reflective and adaptive teaching practices. Overall, tablet PCs are seen as a valuable tool in modern mathematics education, enhancing the learning experience for students (Webster, 2022).

This agrees with what the researcher is teaching, in a university where they are a part-time online lecturer, tablet PCs were used in on-campus mathematics tutorials to assist mathematics students. The tablet PC was wirelessly connected to a data projector, enabling the researcher to move around the lecture room and hand the tablet PC to a group of students, allowing them to write on the screen for all other students in the classroom to see. This wireless technology overcame the previous disadvantage of tablet PCs, which required the lecturer to remain stationary (Engelbrecht & Borba, 2024). In one mathematics lecture room, students were given

a set of mathematics questions on a particular topic (Engelbrecht & Borba, 2024). Each group chose a question and worked on the solution by hand. After a few minutes, they were then asked to write their solution on the Tablet PC, so the class could see the solution as it unfolded, like asking students to go to the whiteboard. Students in the lecture room spent time giving and listening to presentations, working in small groups, and discussing ideas that arose from a group problem or student-presented solution through the tablet PC.

The advantage of using a tablet PC, according to Brooke et al. (2022), is that writing is usually easier to read; the screen is projected; and the student does not have to physically go to the front of the class. The latter also has the effect of changing the power structure of the lecture room by giving control of the pen to the student, with the focus on the screen rather than on the student. While this method was not formally evaluated, students in the class were willing to try it and were keen to use it in subsequent sessions (Aldossry, 2023). Initially, it took a short time for students to get used to writing on the screen. In a numeracy course for engineering students, while some students were initially uncomfortable writing on the Tablet PC, this approach proved to be very useful as it allowed them to participate with minimal speaking (Audi 2023). It also provided valuable information to the lecturer, as it was possible to identify gaps in the knowledge and understanding of individual students that may have remained undetected (Bara, 2023).

From the student responses to the evaluation of the online tutorials, it was concluded that students valued the interaction and real-time responses, gained confidence in seeking assistance from their tutor, and found that it broke down feelings of isolation, making the experience much easier and more effective.

2.4.4 The use of the tablet PC in one-to-one mathematics consultation learning

Previously, distance education university students in Johannesburg, according to Sangporn and Sangporn (2024), were provided with mathematics consultation using a Tablet PC and Messenger. Thirteen students responded to a survey conducted by Engelbrecht and Borba (2024) about the usability and usefulness of electronic handwriting in online consultations. All students surveyed found this method more effective than traditional phone and email consultations for mathematics learning. This approach to mathematics consultation was also used for face-to-face sessions, where

a typical mathematical explanation of a solution was captured on Tablet PCs rather than on paper.

Audio mathematics consultation lessons by Sangporn and Sangporn (2024) were recorded using screen and voice capture software. Once the session was recorded in a suitable format, it could be given to the student immediately or emailed. The student could then listen to the recording at their convenience. Moreover, in one example, according to Oates (2024), a nursing student was learning how to rearrange equations. This example is often found in the context of drug calculations in nursing (Sangporn & Sangporn, 2024). A whole recorded session of mathematics consultation with students took about 30 minutes and was 20 MB in size. As this would have been too large to send, a short excerpt of the session, about six minutes long (5 MB), was edited out by lecturers and sent to the student via email.

At times, according to Adams (2025), a captured lecture is not an appropriate way to convey information. Often, students do not need to listen to a whole lecture, and while a lecture can be divided into parts, it may be more useful to simply record a session focusing on concepts where students get “stuck.” Moreover, according to Webster (2022), the advantages are that those recordings are normally quite short, can be quickly captured and sent to students, and can be used in a variety of circumstances. These learning objects can also form part of a bank of resources available for future use. An example within the college editing process is the screenshot of a recording from a one-to-one session with a mathematics student and a screenshot of a lecturer explaining errors in a student’s exam, which were contained within the college editing suite (Prensky, 2018). The use of tablets and related technologies in mathematics learning by college senior mathematics students was intended to foster good teaching and effective learning for students in their early years of university, allowing them to study independently, whether they are in large groups, small groups, individual consultation situations, classes, or remote from a lecturer in distance learning situations. In this example, a student asked for feedback on a question that was answered incorrectly in the mathematics examination, and the lecturer provided informative feedback to the student.

The college examination questions, according to Prensky (2018), were scanned to the lecturer’s computer and annotated using the Snipping Tool, available for download as

part of the free Microsoft Tablet PC Experience Pack. The recording, 1.9 MB in size, was six minutes long and was emailed straight to the student by the lecturers. College students often have difficulty converting decimal hours to hours and minutes. In the example given to foster good teaching and effective learning, the question of converting 0.4 of an hour was explained first by visually considering the position of 0.4 of an hour on an imagined 10-hour clock and then converting that to a 12-hour clock (Buzzard, 2020). It was further explained by examining the language for 0.4 of an hour and finally by asking the student to calculate what 1.7 hours would be. This “quick tip” was then embedded into the online course material.

2.4.5 Students’ comments on learning with tablets

Kulik and Fletcher (2020) assert that more students in courses taking part in tables report that, when they used this method of communication for their studies, they do not want to go back to the old method of e-mail or phone. Furthermore, students highlight that without video snippets for worked examples, they would have really struggled to write them down. Moreover, students could interact directly, in real-time, with a lecturer to seek assistance on specific questions and do so in a manner that allowed uninterrupted concentration on the task at hand. This, for students, resulted in a much better outcome in terms of learning and retention of knowledge compared to the ad hoc nature of e-mail.

2.4.6 Overall students’ feedback on learning with tablets

According to Prensky (2018), ten distance education college students in Johannesburg who have used Tablet PCs since 2016 have commented positively on the learning advantages offered by these technologies. All requested their own Tablet PCs after trialling the devices for a semester in their classes. One student remarked that she observed a marked positive change in her fellow students’ evaluations and that she had become more visual in her learning approach, noting that the tablet had slowed the pace of her lecturer. Students using Tablet PCs for mathematics learning stated that these devices: i) saved precious time in class, ii) were much less cumbersome than using a whiteboard or overhead projector once set up, iii) made them wonder how they ever managed without them, and iv) provided invaluable graphical representations of data. However, some comments included v) "I would like

to use the whole whiteboard; how can I do that with a tablet? I had some trouble getting it to work." The number of Tablet PC users at the Johannesburg college across all faculties increased considerably in 2019 when funding became available to purchase additional machines as part of the college's learning and teaching initiative (Bara, 2023).

This demonstrates the potential of Tablet PCs and associated technologies for learning mathematics in college settings. It presents several ideas on how Tablet PCs can be used in learning mathematical sciences, both face-to-face and online at a distance. The use of tablets and related technologies in learning college mathematics, according to Audi (2023), can help students grasp mathematical procedures and develop advanced mathematical proficiencies. Moreover, subject matter can now be presented in ways that encourage new directions and approaches as Tablet PCs become more affordable. In addition, Webster (2022) asserts that tablet PCs can create an environment that maximises student learning opportunities, empowering both students and lecturers. When used to their full potential, they capture clear and recordable mathematical thinking in action and can provide purposeful and timely feedback (Gerber, 2023). As college students move into flexible learning environments, the Tablet PC is an essential tool; likewise, teachers at all levels of education are exploring ways to use technology to engage their students. In some instances, a Tablet PC can be a simple adjustment; in many cases, however, it will necessitate professional development in the pedagogical use of these new technologies. The benefits for distance or remote students are obvious, but all students can benefit when they review difficult concepts in their own time (Alex, 2020). The challenge, according to Audi (2023), is to create learning objects that engage and assist in live interaction, which is the best way to learn in online settings, as this provides two-way interaction through video conferencing.

2.5 CREATIVITY AND HANDS-ON LEARNING OF MATHEMATICS WITH TABLETS

Kulik and Fletcher (2020) assert that a tablet provides a highly interactive learning environment that supports effective and efficient learning, as students can find clues to enhance future outcomes and comprehension using drawing-related approaches and techniques. In contrast to traditional classrooms, Dias and Deodalo (2025) believe

that high-tech interactive lecture rooms are designed so that students can formulate their ideas and share them with others. These lecture rooms can serve as successful learning environments that support students' creative experiences and unlock their imaginative potential (Buzzard, 2020). It has been observed that interactive learning is a more hands-on, real-world process of relaying information in lecture rooms. Passive learning relies on listening to lecturers' instructions or rote memorisation of information, figures, or equations. However, with interactive learning, students are invited to participate in the conversation through technology, such as mathematics programs, or through role-playing group exercises in the lecture room.

In addition to engaging students who are raised in a hyper-stimulated environment, interactive learning sharpens critical thinking skills, which are fundamental to the development of analytic reasoning. According to Buzzard (2020), analytical reasoning in mathematics is about performing some mathematical operation on a given statement to find the probable result. Questions based on analytical reasoning test a student's analytical ability. Dias and Deodalo (2025) further assert that analytical reasoning refers to the ability to examine information, whether qualitative or quantitative, and discern patterns within it. Moreover, analytical reasoning involves deductive reasoning without specialised knowledge, such as comprehending the basic structure of a set of relationships, recognising logically equivalent statements, and inferring what could be true or must be true from given facts and rules. Buzzard (2020) further states that analytical reasoning is axiomatic in that its truth is self-evident.

Open-ended questions, according to Thurm and Barzel (2021), are essential for fostering critical thinking and decision-making in students. Toyon (2021) further believe that they allow students to explore concepts deeply, engage in meaningful dialogue, and express their thoughts creatively. Buzzard (2020) posits that by asking open-ended questions, lecturers can encourage students to analyse information, evaluate different perspectives, and synthesise their understanding, leading to higher-order thinking skills. This approach, according to Roschelle et al. (2020), not only enhances students' ability to make informed decisions but also builds their confidence and self-advocacy skills, as they learn to express their ideas freely and explore possibilities.

In agreement with the above, it was the researcher's observation that a student who can explore an open-ended question with imagination and logic learns how to make decisions, as opposed to simply regurgitating memorised information. Engelbrecht and Borba (2024) assert that open-ended questions are essential for fostering critical thinking and creativity in students. They encourage students to explore their thoughts, express opinions, and share experiences, leading to deeper understanding and problem-solving skills. By asking open-ended questions, educators can create a more engaging learning environment that promotes imagination and logic, allowing students to make informed decisions rather than merely regurgitating memorised information. Additionally, interactive learning teaches students how to collaborate and work successfully in groups, an indispensable skill as workplaces become increasingly team-based in structure. This study posits that highly interactive classroom environments that utilise tablets can provide various opportunities for students. An environment that fosters a deeper bond among students and between students and their lecturer supports greater engagement in mathematics lecture activities. In traditional college settings, each lecture period lasts approximately 60 minutes, and lecturers must plan their lessons to fit within that time constraint.

Thus, the traditional lecture room approach, which inherently offers less time, does not provide ample opportunities for students to interact with their lecturer or peers during activities, according to Kulik and Fletcher (2020). Additionally, Dias and Deodalo (2025) assert that students can benefit from sharing their work, interacting on assignments, exchanging thoughts with their peers, and collaborating in the lecture room. Audi (2023) emphasised that technologies supporting efficient classroom activities can be used to establish highly interactive environments. During many classroom activities, students do not frequently have opportunities to share and develop their learning. Classroom interaction using tablets, for example, mirroring tables, transferring files in real time, and projecting instructional objects, can offer students innovative and creative experiences (Prensky, 2018).

In early 2010, when the researcher was still a lecturer at a college, it was probably the norm for an entire institution to have only a handful of computers, centralised in a lab and used sparingly. That has changed because students have grown up in a technology-rich environment, which promotes the use of technology based on

students' interests and skills rather than on lecturer selection or district-provided technology. However, according to Dias and Deodalo (2025), passive learning still has its place, as students need to memorise facts and figures just as they did before. More colleges have turned to interactive learning to inspire students and maintain a vital teacher-student relationship.

A college student struggling to understand the meaning of surface area while learning SAVOGOs for a mathematics homework assignment demonstrated innovative and creative strategies by using a tablet to grasp the mathematical terminology in the assignment.

By following these tips, you can effectively use a stylus on your tablet for homework, making your study sessions more enjoyable and productive. Now picture that same student doing homework with a stylus on the tablet and encountering the word "volume" in relation to geometrical objects. The student can simply tap on the word, and the definition appears on the tablet screen. Similarly, a student who has trouble visualising a square pyramid can use their tablet to watch an animation instantly or open a three-dimensional programme to plot points and see how a square pyramid is constructed. Over the past five years, tablets have transformed the technology market as well as the classroom environment. As a result, according to Webster (2022), students have an enhanced learning experience that can improve their understanding of the subject when lecturers integrate tablets into their classrooms.

2.6 TABLET FOR ANYTIME, ANYWHERE EDUCATION

Brooke et al. (2022) assert that anytime, anywhere learning is the concept of delivering lessons to students whenever they want, using a tablet device. This application, according to Coughlan et al. (2025), is an online learning platform that comprises video lessons, assignments, and activities that can be personalised for each student's level of learning. Moreover, the application enables students to work on skills that are specific to them at any time. Dias and Deodalo (2025) further assert that students can work at their own pace and constantly refer to appealing video tutorials that are always readily available at their fingertips. In addition, Bara (2023) notes that for abs students

who have been absent, missed a lesson, or require reteaching, tablet technology enables learning to take place anytime and anywhere.

Ultimately, the tablet is a sleek, user-friendly device that can help to motivate all types of students to succeed (Prensky, 2018). In essence, a user-friendly device describes a software interface or hardware device that is easy to use. The tablet, according to Bara (2023), should be friendly to both students and lecturers because it is not difficult to learn or understand. While "user-friendly" is a subjective term, several common attributes are found in user-friendly interfaces: i) A user-friendly interface is simple, not overly complex, but instead straightforward, providing quick access to common features or commands. ii) Likewise, a good interface is clean and well-organised, making it easy to locate different tools and options. iii) Moreover, to be user-friendly, an interface should be intuitive and must make sense to the average user, requiring minimal explanation for how to use it. iv) Furthermore, an unreliable product is not user-friendly, as it will cause undue frustration for the user. Therefore, a user-friendly product should be reliable and should not malfunction or crash (Kulik & Fletcher, 2020).

A tablet, according to Thurm and Barzel (2022), allows for many different mathematics lessons to materialise within one lecture room. In addition, Brooke et al. (2022) assert that the device can provide remediation, independent work, group activities, and enrichment in the teaching and learning of mathematics. For example, students who may need another explanation of certain concepts in mathematics can individually navigate to a mathematical tutorial video that may be found on the web or on an application. Dias and Deodalo (2025) further state that other students may practice skills on different applications while others can research to delve further into mathematical topics to broaden their knowledge. Coughlan et al. (2025) conclude that students learning mathematics with tablets can take control of their learning, push themselves to all extremes, and create new opportunities for success.

The tablet for anytime, anywhere education assisted students in accessing Academic Support Technologies (AST) and Student Profiler. These two programmes are installed in the college labs, lecturers' laptops, and students' tablets to improve learning and curb the spread of COVID-19, as the college decided to pilot the use of the tablet with Level 3 students.

2.6.1 Academic Support Technology (AST)

According to Maasz and Schlöglmann (2019), AST is a home-grown South African digital publishing company that is passionate about transforming the way learning occurs in the typical lecture room. Their innovative solutions bring learning into the digital age using tablets. Additionally, AST comprises a team of educators, businesspeople, technologists, developers, thinkers, dreamers, and collaborators. Moreover, AST consists of a diverse group of creative and professional individuals who share a common ideal: they believe that they can change the world by improving the way education is delivered.

According to the researchers' observations, AST is designed primarily for use as a high-impact presentation resource to immediately support lecturers in delivering the curriculum in their normal teaching and learning environments. McPherson and Foncha (2022) support the idea by stating that AST is designed to enhance teaching and learning experiences by providing lecturers with high-impact resources. It enables lecturers to deliver vibrant, full-colour lessons in an engaging audiovisual format, capturing and holding students' attention effectively. This tool is particularly beneficial in normal teaching environments, supporting both lecturers and students in their academic pursuits. Tutor is also effectively used by students for self-study in the Student Support Service (SSS) resource centre, in computer laboratories, and on tablets. Furthermore, Tutor according to Audi (2023), energises the lecture room environment using proven neuroscientific principles to ensure students enjoy a premium learning experience that boosts motivation and builds confidence incrementally. Likewise, Tutor by AST is a library of curriculum-based, interactive digital content specifically developed and published to support lecturers and students at South African TVET Colleges. AST is used by colleges to increase the academic achievement of students, particularly those who may be at risk of diminished academic performance. Effective tutoring programmes, according to Bara (2023), provide motivation, personal individual attention, direct instruction, and error correction to increase students' academic skills in mathematics. Furthermore, Gerber (2023) asserts that a variety of specific academic support strategies have been identified that have the potential to assist struggling students as well as prevent academic problems from developing in the learning of mathematics. Students benefit from having access

to consistent, premium-quality lessons that incorporate innovative instructional design techniques, enabling them to focus on the mathematics content in a whole new way (Buzzard, 2020).

2.6.2 AST for Level 3 students

AST, according to Brooke et al. (2022), is indeed collaborative and student-centred, as it emphasises active learning and student engagement. Alex (2021) posits that this approach allows students to take ownership of their learning, fostering a sense of collaboration and teamwork. Collaborative Learning: Students engage in group projects and discussions, enhancing their communication and teamwork skills. Student-Centred Approach: This method shifts the focus from teachers to students, encouraging them to explore and construct their own understanding of mathematical concepts (Bara, 2023). Active Participation: Students are encouraged to participate actively in their learning, which leads to deeper understanding and retention of the material. Collaborative and student-centred pedagogies in mathematics, as evidenced by Brooke et al. (2022), meaningfully advance learners' critical thinking and problem-solving capacities. The researcher observed that AST is collaborative and student-centred, helping students understand and correct their own errors in mathematics, and aligns with the above definitions. It provides a candid evaluation of students' academic strengths and areas for improvement within a nurturing environment, while directing them to relevant support services when necessary. According to Sriraman (2017), AST also equips students to find their own answers and models how to seek help when they do not know something by asking for help in front of their peers. Students reported benefits from having access to consistent, premium-quality mathematics lessons, incorporating innovative instructional design techniques that allow them to focus on the content in a whole new way.

Webster (2022) further found that students responded positively to clear and accessible explanations delivered with energy and enthusiasm, which sustained their engagement and cultivated a favourable disposition towards mathematics. Wherever possible, abstract concepts are simplified and graphically presented using colour and motion. For example, in mathematics, having direct access to the same content used in lessons allows students unlimited opportunities to revisit and review knowledge concepts and thoroughly prepare for upcoming assessments. Gerber (2023) asserts

that AST keeps students motivated because no internet is required, it saves time, is self-paced, and is easy to use as the programme is also installed on their tablets.

AST is built for TVETs' printable mathematics paper activities, with no internet required, and is for NCV and Nated students. AST saves time and offers the following subjects: Mathematics, Mathematical Literacy, English, Life Orientation, and Science. The platform covers Mathematics NCV Levels 2 to 4, providing students with comprehensive access to all Level 3 topics, including SAVOGOs, to support continuous and active learning. A student is active in mathematics when he/she participates in seeking mastery of the available material. Activities are structured to enable students to be hands-on with their active learning, allowing them to engage with the process of summarising the contents they have learned. More specifically, active learning has the following effects: i) It makes learning more interesting and fun. ii) It fosters appreciation of learning, and iii) above all, it helps students practice self-expression, critical thinking, and self-initiated inquiry (Alex, 2021).

2.6.3 Advantages of AST

Tutoring, according to Dias and Deodalo (2025), offers numerous advantages that can significantly impact a student's academic performance and personal development. Here are some of the key benefits of academic support tutoring: Personalised Learning: Audi (2023) posits that tutoring allows for tailored instruction that addresses individual learning needs and difficulties, leading to better understanding and retention of knowledge. Studies, according to Alex (2021), show that students who receive tutoring tend to improve their academic performance, with individualised instruction quickly identifying and addressing problem areas. Buzzard (2020) believes that tutors can provide a detailed review and practice of concepts learned in class, offering additional exercises and practical examples to solidify understanding. Webster (2020) asserts that tutoring can boost a student's confidence and academic motivation by providing individualised support and guidance, helping them overcome difficulties and improve performance. Webster (2020) further believes that tutors can offer specific strategies and targeted practices for standardised tests, improving test performance. In addition, Bara (2023) further asserts that tutoring offers the flexibility to schedule sessions at convenient times and work independently, which can be beneficial for

students with busy schedules or special needs. Aldossry (2023) posits that tutors can provide targeted instruction to address specific areas where a student may be struggling, such as math, science, reading, or writing. Finally, according to Colliot et al. (2024), tutors often play a dual role as mentors, providing emotional and academic support, which can be crucial for a student's overall well-being and success. These advantages reflect how academic support tutoring enhances the learning experience and drives student success.

Based on the above advantages, researcher observed that AST:

(i) Prompts student responses and focuses attention on the topic while keeping the session on track.
(ii) Centres more attention on the student rather than the lecturer.
(iii) Encourages students to become active learners, thus helping to build their self-confidence.
(iv) Enables assessment of the student's knowledge and understanding of mathematics, demonstrating an effective learning strategy that the student can apply independently.

AST, according to Maasz and Schlöglmann (2019), identifies and assists individual students who need additional support in general course topics, providing academic tutoring from knowledgeable tutors in the learning of SAVOGOs. AST combines collaborative learning and effective study techniques to help students better understand essential mathematics content. Above all, it promotes independent mathematics learning and individual confidence, with the goal of tutoring being to facilitate students' mathematical success and resolve immediate academic crises. As a result, graduation and retention rates at TVET colleges are improved, as many students struggle to graduate due to performance issues in mathematics.

2.6.4 Expectations for mathematics students

Students are expected to ask questions about mathematical content and engage in relevant discussions with the tutor. Additionally, students should pose mathematical questions based on problems or material they have reviewed and studied before the tutoring session. Furthermore, students should approach the sessions with an open

mind, a positive attitude, and a willingness to participate in mathematical activities. It is important to note that learning sessions are not a substitute for attending mathematics classes; therefore, students are encouraged to attend class regularly. Students should attempt all work beforehand and bring it to their session, allowing the tutor to better identify and address their needs. AlwaysThey should avoid bringing blank mathematics assignments; instead, they should come prepared with their mathematics papers, notes, books, assignments, and other learning materials. Finally, during mathematics learning, students should be respectful, use appropriate language, and exercise patience.

2.6.5 AST for lecturers

Academic support tutoring for lecturers, according to Higgins (2025), involves providing structured academic assistance to students, enhancing their understanding of course content, and promoting deep learning. In addition, McPherison (2022) assert that tutoring sessions are led by trained tutors who have completed the same qualification as the students and have a good academic background in the subject. Furthermore, Oates et al. (2024) posit that these sessions are compulsory for students and provide opportunities for them to ask questions, clarify lecture content, participate in learning activities, and receive guidance on assignments, tests, and examinations. Regular participation in tutorials can significantly benefit students academically by improving their understanding of course material, strengthening problem-solving and critical thinking skills, and helping them prepare more effectively for assessments (Gerber, 2023).

In line with the above, lecturers at the three campuses where this study was conducted immediately experienced benefits from having a library of dynamic model mathematics lessons, relevant practice activities, and interactive group quizzes available at their fingertips to energise and support mathematics lesson delivery right inside the lecture room. Lecturers save valuable time on lesson preparation, content creation, and presentation, relieving time stress and gaining expanded opportunities to engage students. Moreover, the tutor dramatically enhances any lecturer’s presentation capabilities. By utilising the tutor, lecturers are also provided with a valuable tool to support their colleagues, even outside of their own subject expertise. AST is designed for TVET colleges, offering subjects such as Mathematics, Mathematical Literacy,

English, Life Orientation, and Science. For mathematics, tutor content is developed to support a structured approach to the presentation of learning material, including proper concept theory, appropriate application of methods and techniques, repetition to reinforce correct application, validation of learning with immediate feedback, and tips and tricks for support. The tutor in mathematics lectures explains content without engaging the students with questions. Furthermore, the tutor answers the students' questions rather than encouraging them to draw upon prior knowledge and skills to figure them out or to consult the lecture notes, textbook, or other reference materials. Additionally, the tutor solves homework problems instead of prompting the students to solve them.

2.6.6 Educational approach

From the researchers' observations, the Tutor in Mathematics content is developed to educate and support mathematics students by imparting knowledge through the presentation of learning materials. Mullis and Kelly (2022) also believe that the Tutor in mathematics content is developed to educate and support mathematics students by providing a structured framework for teaching and learning. The Mathematics Teaching and Learning Framework for South Africa emphasises understanding and conceptual learning, seeking to bring about measurable improvements in learner outcomes.. Effective teaching involves a combination of pedagogical content knowledge and content knowledge, which are essential for teaching mathematics effectively. Resources like the Gamma Tutor project offer interactive digital tools to support mathematics education, making it accessible in under-resourced schools. These frameworks and resources are designed to enhance the teaching and learning experience in mathematics education.

In addition, students apply and demonstrate their learning in interdisciplinary subject areas, such as mathematics, through computational thinking (CT) based projects. Moreover, mathematics students utilise new skills in multifaceted ways, with hands-on opportunities to think critically, solve mathematical problems, and develop important academic skills such as written and verbal communication, planning, and research. Furthermore, essential meta-skills developed for students include self-sufficiency, teamwork, goal setting, and internet safety and literacy. These mathematics skills support student success throughout their college academic careers as well as in their personal and professional lives.

2.6.7 Student Profiler Shaping the Learner (SPSTL)

Williams et al. (2022) describe SPSTL as a computer-based programme suited to the 4th Industrial Revolution, usable online or offline through a college server in low-connectivity environments. Students access this system through tablets, and it is fast gaining popularity among TVET colleges in the NW. The system offers quick, efficient, and cost-effective screening and assessment throughout the year. It provides a variety of screening batteries that can be used in a manner that suits each college.

Literacy and numeracy are core communication skills that are vital to academic success. Through profiling at the pre-entry support stage, the essential foundations for these competencies are identified and applied to ensure each student is placed appropriately. Literacy and numeracy are among the most important information-processing skills necessary for the development of students at a TVET college at all levels. For this study, emphasis is placed on numeracy, which encompasses the knowledge, skills, behaviours, and dispositions that students need to use mathematics in learning SAVOGOs. It involves recognising and understanding the role of mathematics in the world and having the dispositions and capacities to use mathematical knowledge and skills purposefully. By informing the learner system, this profiler assists the college in identifying and enrolling students with sufficient mathematical competence to meet the demands of college-level mathematics (Williams et al., 2022).

Numeracy, according to Audi (2023), is the ability to understand, reason with, and apply simple numerical concepts. It is the numerical counterpart of literacy and is essential for managing and responding to the mathematical demands of life. In addition, Roschelle et al. (2020) highlight that numeracy encompasses a range of skills, including number sense, operation sense, computation, measurement, geometry, probability, and statistics. Furthermore, Webster (2022) posits that a numerically literate person can effectively use mathematics in various aspects of life, such as financial literacy, critical thinking, career advancement, and everyday tasks. The researcher's experience, as outlined above, affirmed that numeracy is the ability to reason and apply basic numerical concepts. Basic numeracy skills involve a sound understanding of the four fundamental arithmetic operations: addition, subtraction,

multiplication, and division. For example, if one can understand simple mathematical equations such as 2 + 2 = 4, then one would be considered to possess at least basic numeric knowledge. The researcher also discovered that substantial aspects of numeracy include number sense, operation sense, computation, measurement, geometry, probability, and statistics. A numerically literate student can manage and respond to a Level 3 mathematical syllabus at college. Identifying these traits through screening, SPSTL plays a pivotal role in guiding students toward offerings that are well-matched to their abilities at the time of college registration. A practical example of this is seen when students with solid numeracy skills choose engineering courses that incorporate mathematics, creating a strong foundation for successfully navigating and mastering SAVOGOs.

2.7 STUDIES THAT USED TABLETS IN MATHEMATICS LEARNING

Globally, literature on studies that used tablets for mathematics learning includes the development of (i) Firstly, Abalona Christians School (ACS) (2025) in Texas, USA, (ii) Secondly, a study conducted by Audi (2023) on the learning of Euclidean geometry using tablet devices, (iii) then followed by a study conducted by Arvanitaki and Zaranis (2020) on students' intensive satisfaction and relationships created when learning through the use of tablets, (iv) Fourthly, a study by Aldossry (2023) described a study comparing the effects of a worksheet condition and a tablet condition on academic engagement in a school setting, (v) The fifth was a study by Novita and Herman (2021) on the use of mobile technology in the classroom, which can help to deepen and enhance the learning process, (vi) Finally, a study conducted by Sacristàn and Enriquez (2023) on the utilisation of tablet devices in a higher education setting. Literature synthesised in the following sections refers to the authors mentioned above.

It is often a challenge to improve mathematics success for at-risk students, but the use of tablets can support and enhance learning for individual students (Dias & Deodalo, 2025). Prior research conducted by Abalona Christian School (ACS, 2025) in Texas, USA, concludes that using tablet devices in school classrooms can help increase achievement and have a massive impact on learning due to the empowerment that tablets have on students. In addition, Abalona et al. (2025) report on a study examining the effects of tablet-assisted learning on students' achievements, retention, attitudes towards mathematics, and attitudes towards tablet-assisted learning. In that study, one

group of students learned using tablets while another group of students received traditional learning. This study indicates that the students who were exposed to tablet-assisted learning significantly outperformed students who were exposed to traditional learning on the achievement post-tests. Moreover, the findings also indicate that the results of a mathematics attitude scale test for students who were exposed to tablets showed a more positive attitude towards tablet-assisted mathematics learning.

Secondly, Audi (2023) on the learning of Euclidean geometry using tablet devices supports the notion that the level of enthusiasm for learning and academic achievement in geometry was increased through the incorporation of tablets into the school's geometry curriculum. The study further found that students who used tablet-based learning scored better results on tests of achievement compared to students without tablets, who scored lower results. In addition, students liked their contact sessions more and developed more positive attitudes when their sessions included tablet-based learning. In agreement, Borba et al. (2025) assert that tablets allow students to view necessary academic material at their own convenience, truly making learning highly accessible. Richardson (2022) further agreed that the use of tablets has permitted students to use their time more wisely by having the flexibility of deciding when and where they can complete their work.

Furthermore, Arvanitaki and Zaranis (2020) on students' intensive satisfaction and relationships created when learning using tablets sought to see the effect tablets had on school mathematics ability with low-performing students. An action research study was employed using a pre- and post-assessment and observations over six weeks. For the duration of that study, tablet devices, according to Abalona et al. (2025), were used as a tool to remediate performance in mathematics learning. Several applications for tablets were utilised that were useful and related to the goals of the students. Furthermore, the device was the prominent tool used for the presentation of the content and learning strategies. As a result of the study, the students improved a full grade level in their learning of mathematics according to the reading inventory used as the data collection tool.

Likewise, Borba et al. (2025) assert that students had noticeably developed control over their own learning strategies and a more positive attitude towards the learning of mathematics. Specific examples that emerged from that study and helped to keep the

students' attention were the manipulative touch screen, promoting the use of several modalities such as visual and tactile/kinaesthetic (Borba et al., 2025). Additionally, students recorded their own reading and were able to play it back and listen to their own mistakes, which helped to enable them to have a higher level of sensory stimulation, allowing students to engage in learning tasks using technology (Borba et al., 2025).

Moreover, Aldossry (2023) compared the effects of a worksheet condition and a tablet condition on academic engagement in a school setting. Results from that study reveal that more academic work was completed correctly in less time, and higher levels of active engagement were demonstrated in the tablet condition as compared to the worksheet condition. This investigation reinforced the notion that students completed more correct work in the same amount of time using tablets than students who did not use tablets. This study concludes that tablets provide positive effects and promote active student learning.

Novita and Herman (2021) further assert that the use of tablets in the classroom can help to deepen and enhance the learning process. This application is an online learning platform that comprises video lessons, assignments, and activities that can be personalised for each student’s level of learning. Students can work on skills that are specific to them. Likewise, students can work at their own pace and constantly refer back to appealing video tutorials, always readily available at their fingertips. The study further asserts that for absent students, or students who missed a lesson, or need re-teaching, tablets allow for an anytime, anywhere education. The tablets allow for many different lessons to always materialise within one classroom. The study further reports that the device can provide remediation, independent work, group activities, and enrichment. For example, students who may need another explanation of certain concepts can individually navigate themselves to a tutorial video that may be found on the web or on an application. Other students may practise skills on different applications, while others can be researching to delve further into topics to broaden their knowledge. Moreover, students learning with tablets can take control of their learning, push themselves to all extremes, and create new opportunities for success.

A study conducted by Sacristán and Enriquez (2023) utilised tablet devices in a higher education setting. Results from that research showed a significant positive impact on students' performance and an overwhelmingly positive student perception of their learning experience when using tablet devices. The tablet devices provided students with a more interactive and collaborative learning experience. Moreover, the results of the attitudinal survey used in the study conveyed that those students showed a significantly greater positive attitude towards their course compared to other students who did not use the devices. Highlights from the study include students' abilities to better focus on the lessons, real-time assessments and feedback, and ease of communication with other classmates and the teachers. The effectiveness of tablets on learning mathematics in the above studies was also highlighted and observed.

In comparison to the studies conducted in South Africa (SA), according to Novita and Herman (2021), the schools in which the studies took place considered implementing a tablet programme into the schools as a way to improve performance in mathematics. The coordinating administrators elicited that the school believed that integrating tablets into classrooms gave mathematics students greater opportunities to be highly engaged in their learning of mathematics. Additionally, tablets would help to increase opportunities for differentiation, using applications that are selected to meet students at their individual mathematical learning levels. According to Alex (2021), the teachers commented that the main goal for the tablets' implementation in the learning of mathematics was engagement in activities. Teachers also highlighted that they have hopes that with the tablet devices, learning mathematics can reach higher levels of Bloom's taxonomy, creating more one-to-one opportunities in the mathematics classroom and meeting the demands that are now placed on students to become familiar and fluent with personal tablet devices (Gerber, 2023).

In addition, another teacher in the school where the study took place reports that having these devices in their schools helps to level the playing field for the mathematics students in their province. Moreover, the other teacher, according to Webster (2022), asserts that digital mathematics learning is important and that there are so many resources now available online for building student skills that we need to take advantage of. Furthermore, the immediate access to research opportunities that these tablet devices can provide is too valuable to pass up. With a great deal of

technology available, this school province chose Apple tablet devices because of the numerous applications that are available (Buzzard, 2020). To solidify the decision to purchase tablets, site visits were done at other schools that had successfully implemented tablet devices.

Additionally, a provincial technology committee, according to Baras (2023), attended tablet mathematics workshops in Johannesburg, SA. Before making final decisions, Webster (2022) asserts that the province was in contact with many mathematics teachers from different parts of SA who had found success with the tablet devices. The said province, according to Dias and Deodalo (2025), specifically took notice of one school that started a mathematics one-to-one initiative. They watched their mathematics programme grow, followed how they built it, and wanted a model like what was seen. Audi (2023) asserts that with over 6,000 mathematics students enrolled in this school system, the province wanted to initially supply students with tablets where most mathematics improvements could be made.

For the onset of the programme, according to Gerber (2023), the province decided to begin the implementation with the Grade 10 mathematics population. The reason behind this decision lies in the fact that Grade 10 is the lowest level of mathematics students participating in the high school assessments. The intentions, according to Higgings (2023), were to determine if learning with tablets at this level would make a difference in how students performed in mathematics examinations. It was expected to expand the programme by one grade level each year until mathematics students reached Grade 12. To utilise the tablet devices to their greatest capacity, McPherison (2022) asserts that it was a priority for the province to select applications that were aligned with the provincial mathematics curriculum. In addition, Gerber (2023) posits that the mathematics coordinating administrator emphasised that, “Application selections must be relevant and connected to the mathematics curriculum and the academic standards. Furthermore, Brooke et al. posit that the tablet is a tool to enhance the mathematics curriculum, and the way the tool is used is how the devices can connect and enrich academics.” Sacristán and Enriquez (2023) further state that there were specific criteria used to ensure that the applications being purchased met the learning needs of the mathematics students. Initially, applications were recommended by other provinces that found success with the tablet devices. Those

recommendations, according to Alex (2021), were used during the pilot programme the previous year. This list was further evaluated and reviewed by Grade 10 mathematics teachers, and final decisions were made based on this input.

Additionally, if a teacher found an application during the school year that was deemed valuable, a request could be made and reviewed for purchase (Kulik & Fletcher, 2020). If funds allowed, the application would be purchased and centrally pushed out to all the tablet devices. The coordinating mathematics administrator, according to Buzzard (2020), stressed the importance of having the latest versions of the applications for a variety of reasons, including the fact that new versions of software can increase productivity in mathematics. For this initiative, Alex (2021) further posits that it was at the discretion of the classroom mathematics teacher to update all the tablets. The teachers could easily instruct all mathematics students to open the Apple App Store and select the “update all” option to keep the apps up to date across all devices; hence, there was no schedule that the province followed to update all the applications (Novita & Herman, 2021).

2.8 THE EFFECTIVENESS OF TABLETS ON LEARNING MATHEMATICS

The South African Association for Research in Mathematics, Science and Technology Education (SAARMSTE, 2023) reports that during the learning of mathematics using tablets, the learning environment was completely paperless. The mathematics lecturers had to ensure that a set of applications was installed on students’ tablets prior to the start of the lecture. According to Gerber (2023), Nearpod Apple applications were used by mathematics students in learning mathematics and had the following benefits: i) Enabled lecturers to use their tablets to manage content on students' iPads synchronously; ii) Combining of presentation, collaboration, and real-time assessment tools into one integrated solution; iii) Students received content and submited their responses on the Nearpod application, while the lecturer monitored the activities in the lecture room and received the results of each student; iv) According to Bara (2023), the application also included Air Sketch, which allows PDF documents or images to be annotated live and projected to the entire class, functioning as an interactive whiteboard. Audi (2023) further states that Blackboard allows the lecturer to upload documents in any format, post announcements, upload media, manage

course rosters, and possibly post students' grades. Students can save these files on their tablets and view them even without an internet connection.

Bara (2023) further observes that tablet applications allow mathematics students full access to the e-text version of the book for bookmarking and related notes. Moreover, Alex (2021) asserts that Quick Office enables students to edit any Word file, Excel sheet, or PowerPoint presentation. Webster (2022) further asserts that these files are provided remotely by the lecturer through Blackboard. Furthermore, Audi (2023) posits that Dropbox allows students to store all their mathematics files, documents, and photos on multiple remote tablets simultaneously after class hours for home editing. One of the main advantages of a tablet-based mathematics classroom, according to Gerber (2023), is that the entire course delivery is not predetermined, as the lecturer adapts the lecture to the progress and needs of the mathematics students. Thus, the mathematics lecture becomes dynamic and changes in real time. According to Alex (2021), the quick feedback from mathematics students using Nearpod was one of the major advantages of using tablets and enhanced content delivery. Overall, most mathematics students found the tablet-based class engaging and agreed that it presented the class content more effectively (Buzzard, 2020).

Brooke et al. (2022) assert that the integration of tablet PCs in introductory mathematics courses for engineering students has been shown to have a positive impact on average student performance. Novita and Herman (2021) have demonstrated that the use of tablet PCs enhances learning experiences, particularly in technical courses like engineering mathematics. For instance, Webster (2022) highlights that a study at the University of Toronto found that students taught with tablet PC-based instruction had the greatest impact on the bottom half of the class, leading to improved learning and performance. Similarly, according to Roschelle et al. (2020), a pilot study at a university reported positive impacts on the learning environment and perceived learning impact from using the iPad in engineering courses. These findings suggest that tablet PCs can be effectively utilised in engineering mathematics education to enhance student engagement and performance (Audi, 2023).

Pursuant to the above paragraph, the researcher discovered that the preliminary results presented in South Africa demonstrate that integrating tablet PCs in

introductory mathematics courses for engineering students has a positive impact on average student performance. According to Simsek and Can (2020), the use of tablets increases interaction between the lecturer and the students, rendering the class more dynamic and tailored in real time to the students' needs in mathematics. Additionally, Bara (2023) further states that it has been demonstrated that mathematics students were more engaged in tablet-based classes and maintained their concentration until the end of the mathematics class.

In colleges, lecturers have used tablets to enhance their lectures in engineering, mathematics, computing, and chemistry. For example, in mathematics, the researcher found that tablet PCs are an easily adopted technology that can positively affect student attention and mathematics learning. In distance education, tablet PCs have also proven to be useful facilitators of communication with remote online students, allowing both lecturers and students to use electronic handwriting to impart and receive knowledge and skills. The researcher also discovered that when students use tablet PCs, they become integral parts of the lesson, and that the tablet PC classroom environment is more effective than the traditional format of learning. For instance, mathematical disciplines, according to Simsek and Can (2020), rely heavily on the use of symbols and graphs, which students traditionally copy to learn mathematical concepts step by step.

Simsek and Can (2020) further state that the unique features of tablet PCs, graphics tablets, or digital pens allow users to easily write symbolic and graphical information electronically, providing students with tools to explore different paths to a solution or to adjust the learning process based on audience reaction. In mathematics, for example, Gerber (2023) believes that this section details some of the ways tablet PCs and related technologies have been used to foster effective learning for students in the early years of college study, independent of whether they are in large groups, small groups, in individual consultations, in classes, or remote from a lecturer in distance learning situations.

2.9 BENEFITS OF TABLET USE

According to Borba et al. (2025), students expressed a desire for greater satisfaction with their school experience. They wanted to complete more tablet-based activities and enhance their personal skill set and understanding of tablets. The following

sections highlight how students can use tablets to enhance learning, improve adaptability, increase engagement, and maximise efficiency.

2.9.1 Enhanced learning of mathematics

One way that tablets enhance learning is by stimulating higher-order thinking. Furthermore, mathematics students expressed positive attitudes toward the tablets and indicated that the use of the tablet devices enhanced their learning experience. In the study by Aldossry (2023), the students followed along and took notes while a peer used a tablet to write on the PowerPoint slides. Writing on a PowerPoint mathematics presentation is one of the main applications of digital linking, which allows students to annotate their presentations directly from their tablet screens when the document is in a Microsoft Office program. The tablet and projector act as an interactive whiteboard, using touch detection for user input, such as scrolling and right-clicking, in the same way as standard PC input devices (Williams et al., 2022). This is a helpful tool at all levels of education and serves as an innovative way for mathematics students to demonstrate their work on the board while allowing their classmates to see instantly what they have done.

Colliot et al. (2024) assert that students interacted with a program on their tablets for virtual tangrams, dissection puzzles consisting of seven flat shapes called tans, which are combined to form other mathematical shapes. Since the tangrams were virtual, mathematics lecturers and students could manipulate the size of the tangram and demonstrate how mathematical shapes fit together. The use of virtual tangrams enhanced students' spatial reasoning and narrowed the gap between lower and higher achievers in mathematics. This is a direct result of how tablets improved these students' mathematical learning experiences.

Novita and Herman (2021) examined secondary school mathematics students' perceptions of the combination of flipping the classroom and integrating tablet technology. In that study, the teacher provided mathematics notes to the students, who were responsible for downloading and studying them before attending class. The teacher then used digital ink technology on the previously studied notes to address the students' mathematics questions. When asked about the effectiveness of this model, one mathematics student observed that the tablet assisted the teacher

because, instead of writing on the board, the mathematics teacher could engage the class and gain a better understanding of their comprehension.

Furthermore, according to Aldossry (2023), in the single tablet mathematics classroom, the teacher used the tablets to create mathematics notes, annotate existing PowerPoints, and employ specific mathematical software, such as Virtual TI and Mathematics Journal. These software programs, according to Colliot et al. (2024), have mathematical equations and figures built in for more efficient use in a mathematics class. Using these programmes allowed mathematics students to archive the lecturer's notes and access them at any time. On a scale of one to five, with five being strongly agree, a survey showed that students appreciated the constant availability of the archived mathematics notes. According to Buzzard (2020), the mean of the survey was 4.37, ± .17, indicating that students also agreed that the tablet increased the teacher's effectiveness during class and promoted mathematics student learning.

According to Aldossry (2023), in a one-to-one tablet mathematics classroom in one school, there was an additional benefit of being able to analyse and critique problems directly on the tablets. The teachers described the benefits as "two-fold," demonstrating that mathematics students took ownership of their learning in the classroom. According to Simsek and Can (2020), the concrete evidence comes from the 16% increase in scores on an identical test given to students in a tablet mathematics classroom compared to students in a traditional mathematics classroom. Webster (2022) believes that the teacher found this to be true for both one-to-one and single tablet mathematics classrooms. All the studies, according to Colliot et al. (2024), agree on a common conclusion: students experienced an enhanced mathematical learning experience because of the use of tablets, which increased their ability to comprehend the material. Consequently, student mathematics achievement also improved.

Tablets, according to Alex (2021), help mathematics students learn more effectively by aiding their conceptualisation of scale, space, and other difficult concepts. According to the international and South African studies (2023) referenced above, tablets have proven to make a difference in mathematics learning. Mathematics teachers often work at a pace that exceeds many students' ability to grasp concepts,

while students who require more time can greatly benefit from viewing mathematics video tutorials on their tablets as many times as needed to understand challenging concepts. Additionally, Buzzard (2020) posits that tablets make mathematics learning enjoyable due to the many educational apps that can be downloaded for free or purchased. These apps use games or game-like techniques to help students learn and retain information on various mathematics topics. Tablets enhance the learning of mathematics through audio/visual elements that help keep students engaged (Audi, 2023).

Tablets, according to Webster (2022), assist mathematics students with different learning styles and abilities, as not all students learn in the same way. Some are visual learners, while others are auditory learners. Furthermore, Audi (2023) believes that tablets enable mathematics students to learn more effectively and retain more information. Additionally, Webster (2022) asserts that tablets facilitate data collection anywhere, as mathematics students can take their tablets with them into the field, whether on a nature walk to identify different mathematical shapes and animals or in the school mathematics lecture room to record various formulae and shapes for lessons. Moreover, Bara (2023) posits that students generally embrace the use of tablet devices, eager to use technology, and they are often quicker at troubleshooting problems than lecturers. Finally, Colliot et al. (2024) believe that students can submit homework assignments via their tablets, and some teachers use the free file-sharing app Dropbox to post assignments. Students can also download posted assignments and upload completed work when finished.

2.9.2 High adaptability

Using tablets in the mathematics lecture room expands students' ability to individualise their learning. Tablets can be helpful for students with special needs as well as those with varying learning styles (Aldossrt, 2023). For example, multiple representations of the same mathematical topic, along with interactive formats, according to Audi (2023), can be easily shared using tablet technology. Similarly, various representations of space, shapes, and measurements support students who learn in different ways and enhance their chances of comprehension (Fister & McCarthy, 2021). The researcher observed that multiple representations allow students to see the same mathematical

expression or relationship presented in more than one form. Furthermore, according to Kaya and Kutluca (2024), this strategy is particularly useful for assisting mathematics students in understanding the meaning of algebraic symbols, but can be effectively utilised with most mathematics skills and concepts. Moreover, Gerber (2023) believes that multiple representations and visualisations were used as an intervention to promote students' mathematical creativity and as a psychometric tool to measure their creative thinking abilities in mathematics.

When learning is individualised from student to student, according to Bara (2023), it increases their chances of understanding and success. Alex (2021) believes that one form of technology that has been used to support auditory mathematics learners is the Talking Tactile Tablet (TTT). Webster (2022) further adds that, as the name suggests, this tablet can speak to students with visual impairments and tell them what they are looking at. This, according to Aldossry (2023), makes elements in mathematics, such as graphs, more accessible and allows students to work at their own pace. This device, according to Buzzard (2020), contains audio files that correspond with each visual, so when the visual is touched, the audio plays aloud. It was found that students with visual impairments using TTT performed better on mathematics tests than those using current accommodation tools that do not have integrative audio capabilities (Engelbrecht & Borba, 2024).

Not only do tablets help students with visual challenges, but they also allow students with individual education plans (IEPs) to utilise accommodations for their unique academic needs. Novita and Herman (2021) conducted a study in a special school through eighth grade to assess students on the autism spectrum, examining the effects of a class-wide intervention using tablet applications for basic mathematics activities on their independent task completion and mathematics performance. This study, according to Gerber (2023), found that the tablets were easily adapted to the needs of each student. Additionally, Bara (2023) believes that students became more independent in completing tasks and improved their assessment scores. The tablet allowed for more practice, encouraged students to work at their own paces, and catered to each student's individual skill set (Kulik & Fletcher, 2023).

The generalisability of these results is limited by the small data set and the fact that the study was performed in a school with students who all required individualised help.

A more applicable representation of this study would involve a larger data set and include an inclusive classroom to determine if tablet use helps students succeed in the regular classroom. Nonetheless, the experiment demonstrated the adaptability of tablets to assist diverse learners. Everyone learns differently, which makes the individualised learning capabilities of tablets beneficial for any student, regardless of whether they have a disability. The creation of an individualised educational experience has received a positive response from parents and students alike. In addition to supporting students' individual needs, tablet integration can increase students' motivation to learn (Masoabi & Alexander, 2020).

2.9.3 Increased engagement in learning mathematics

Active engagement with tablet devices supports sustained attention in mathematics classrooms by providing interactive, responsive learning experiences. Learning today is a constructive process that builds on prior knowledge and allows students to develop brain pathways to access new and old information (Roschelle et al., 2020). In addition, engagement in learning mathematics, according to McPherson and Foncha (2022), helps students to create more pathways in their brains. Interaction, communication, and collaboration are just some of the ways to engage mathematics students. For example, group scribbles and classroom presenter are two programmes for tablets that are designed to increase students' active engagement and participation in the mathematics classroom. Furthermore, group scribbles allow for an interactive improvisation of mathematics classroom tools such as sticky notes, bulletin boards, whiteboards, pens, and pencils.

These boards can be made public so that mathematics students and teachers can actively communicate and collaborate through the programme. Similarly, Novita and Herman (2021) believe that in a mathematics classroom, presenters allow mathematics students to write on their own tablets and have it appear on the projection screen. According to Simsek and Can (2020), the students' writings in a mathematics classroom can then be organised by the teacher's tablet. This appearance of notes on the projection screen provides a class-wide work ethic, as opposed to an individual one. In support of the above, Roschelle et al. (2020) assert that this active involvement

in the mathematics classroom makes a class engaging and decreases the possibility for a student to be distracted from the lesson.

Roschelle (2020) further suggests that tablets can streamline classroom routines by automating time-consuming tasks such as graph construction and equation notation, shifting the instructional focus from passive transcription to active mathematical engagement. For example, Bara (2023) believes that if mathematics students have copies of the class notes available and archived on their tablets, they can engage in mathematics class discussions more attentively. Roschelle et al. (2020) further highlight that archived mathematics notes allow students to review explanations independently, supporting more thoughtful and timely questioning. Additionally, the class has more time to be exposed to the expert thinking methods of the mathematics teacher.

In the study by Thurm and Barzel (2022), the students surveyed were also asked if the tablets allowed them to pay more attention in class. One student responded, “I found that I didn’t waste time during class copying down information, so I was better able to focus on what was being taught.” Another said, “It most definitely made the lesson easier to follow! All I had to do was follow the problem steps rather than write everything down, which is hard to do while trying to comprehend.” As a result, these students were able to engage in the lesson and comprehend the information at a deeper level because of the tablet integration. Using digital ink, students have the opportunity for greater engagement in class discussions. Higgins (2025) takes digital ink and applies it to different specific mathematical practices, such as generalising the hexagon theorem. In what he calls “scribing,” students can collaborate and communicate by using tablets. Scribing gives students the chance to see the work of other students, engaging them in others’ learning processes and furthering their level of understanding.

Higgins (2025) found that scribing improved class discussion and allowed students to focus on the ideas of the lesson rather than on listening to the teacher. It also motivated students to gain the best understanding they could of the topic. Practices such as the TTT study show that through communication and collaboration of students with tablets, students are actively engaged in class more than in a traditional classroom. They are more likely to participate in the lesson, as well as comprehend

the material better than they otherwise would have if the tablets were not used (Ross, 2020). Although in many instances tablets are seen to be an anti-social activity, the way mathematics students are using them in the classroom allows for more social interaction, participation, practice with concepts, and confidence with the content.

2.9.4 High efficiency

In the teaching and learning of mathematics, one of the greatest benefits tablets bring to the mathematics classroom is increasing efficiency. It was observed that the tablets have the power to maximise success and learning in mathematics within the allotted class time. Students also report that using tablets saves time in the mathematics classroom and is easier to use than a whiteboard or an overhead projector (Novita & Herman, 2021). The only limitation to the efficiency of the tablet in a mathematics classroom was the time it took to set up. Once mathematics students had their tablets set up, they were able to use the technology to its full potential. The accessibility of the tablets and their speed can improve mathematics learning by decreasing the time it takes to receive feedback on mathematics homework, assessments, and lecturers' comments from days to minutes (Roschelle et al., 2020). In the mathematics scribing activity by Prensky (2018), students can have immediate feedback because they effortlessly share their work and are then required to defend their ideas in a mathematics class, as opposed to writing down what they think and waiting for a mathematics teacher to correct and return it.

The access to immediate feedback addresses misconceptions in class and makes mathematics homework more effective. Tablets also provide the efficiency of preparing complex graphs or concept maps before the start of mathematics class so that students can spend more time comprehending the material and less time copying it (Roschelle et al., 2020). In the study by Gilmore et al. (2020), the students agreed that the tablet was effective when asked if it was an efficient way to discuss the mathematical content. Students in a mathematics classroom observed that teachers had more time to cover the material they needed to get through, which allowed for more questions to be answered by the mathematics teachers. Another way students were able to experience an improvement in efficiency with tablets was through their immediate access to searchable notes from a mathematics classroom. This feature

saves students time studying and looking for the correct model for their current mathematics homework. The main benefit of tablet efficiency is to provide mathematics teachers and students with more effective class time and easier and faster access to mathematics class resources.

2.10 FACTORS NEGATIVELY INFLUENCING TABLET INTEGRATION

While the benefits of tablet use in mathematics education are well-documented, a number of substantial barriers remain that slow the broader adoption and integration of emerging technologies and programmes. According to Ross (2020), these limitations include the cost, concerns about misuse, the training needed for integration, and the reliability of new technologies.

2.10.1 Cost of the equipment

The cost of equipment, such as tablets, according to Maasz and Schlöglmann (2019), is a significant limitation for many schools. This limitation, however, receives minimal attention in the existing literature, likely because studies examining tablet use are inherently conducted in contexts where device access has already been secured. According to Thurm and Barzel (2022), many schools lack the funds to invest in tablets for every mathematics student. Grants that provide funding for purchasing these devices are available to schools, highlighting the goal of enhancing their mathematics students' learning experiences. Even when tablets are accessible, many mathematics teachers express concerns about their ability to manage student misconduct involving technology (Roschelle et al., 2020).

2.10.2 Concern about misuse

The ability to customise and instantly alter the content on tablet technologies, according to Bara (2023), provides users with a constant feeling of amusement, which can make it hard for mathematics teachers to use them as an instructional tool, especially where mathematics teachers are unable to monitor their mathematics students' screens (Toyon, 2021). Mathematics students must be able to ignore distractions that tablets can provide and focus their attention on the tablets' instructional purpose (Williams et al., 2022). One common misconception is that supplying mathematics teachers and students with tablets is enough to successfully

implement new programmes that will enhance learning in mathematics classrooms (Borba et al., 2025). While the use of tablets is supposed to bring changes to the traditional way that mathematics teachers used to teach, students used to learn, but still don't prevent some mathematics students from taking advantage of these changes and using them as they want. Second, tablets in higher education, according to Toyon (2021), have also affected human interaction in mathematics classrooms. Since their widespread adoption in the early 2000s, tablet devices have increasingly supplemented traditional instruction in mathematics classrooms, with students gaining access to a broader range of digital learning tools beyond the classroom environment (Gerber, 2023). This shift, however, raises concerns about student dependence on technology and its potential impact on sustained classroom engagement.

2.10.3 Training needed for integration

Mathematics teachers must be trained in how to use the tablets, be able to demonstrate their use to students, and understand where they can be best applied within their mathematics lessons (Toyon, 2021). When asked why they do not implement tablets, students admit that they are hesitant to use something they only have a limited understanding of. Mathematics students need to be instructed on how to use the tablets and kept up to date on the latest models and their functionalities (Audi, 2023). In addition, the researcher believes that teachers must ensure that the training provided is sufficient so that, upon its conclusion, mathematics students are ready to integrate tablets into their learning.

2.10.4 Reliability of tablets

Brooke et al. (2022) also identified tablet unreliability as a barrier to mathematics students' use of the devices. Sometimes, in a mathematics class, tablets fail to work with no explanation. So, to prepare for this ahead of time, mathematics students must think of something to replace the lost mathematics activities (Audi, 2023). Having a backup plan for every mathematics activity would be as if mathematics students were planning two full activities for every mathematics lesson they are learning (Simsek & Can, 2020). This, according to Dias and Deodalo (2025), is extremely time-consuming

and thus can make the idea of using tablets very unappealing to mathematics students when they are looking for ways to improve their classroom activity experiences.

Julaihi (2022) avers that the factors influencing tablet integration are parallel to those influencing any other technology. However, Kulik and Fletcher (2020) believe that there are some added concerns to integrating tablets into a mathematics classroom, one of which involves the setbacks of training mathematics students. Based on the researcher's observations, mathematics students tend to be proficient with computer technology; however, despite an interest in integrating tablets, they are reluctant or unable to invest the time required to learn a new technological tool. In addition, the researcher believes that schools implementing tablet technology need a way to train mathematics students to use tablets. Adams (2025) agreed by reporting that traditional ways of training are professional development days in which mathematics students are introduced to new methods or programmes that are usually sequential and progress in a linear pattern through different levels of difficulty.

According to Alex (2021), most of the time, mathematics students across multiple disciplines engage in the same learning development programmes with these tablet models. One can wonder if this is enough to help mathematics students effectively implement the new form of tablet technology. Studies like that of Enriquiz (2020) assert that traditional methods of training are not an effective way to implement learning development for mathematics students in tablet technology. Additionally, Toyon (2021) believes that one reason the traditional method of learning development is not effective is that all mathematics students have different levels of skill and confidence with tablets. The researcher noted that more confident and skilled mathematics students, especially digital natives, have little need for introductory tablet training.. Conversely, the researcher observed that some mathematics students will not benefit from any type of specialised training until they receive preliminary training on general tablet use, such as connecting to Wi-Fi or changing settings. The researcher further observed that sequentially learning mathematics with a teacher is also less effective for mathematics students because there is no one right way to learn how to use a tablet, and many mathematics students have different interests.

Moreover, Coughlan et al. (2025) emphasise that the applications that are relevant for mathematics students in one discipline may not be relevant for other disciplines. For

instance, mathematics students will not want to sit through a class on history applications because they have no use for them (Webster, 2022). The researcher's experience revealed that tablet proficiency does not follow a linear progression; once the foundational skills are acquired, the focus shifts to identifying which applications are best suited to a given teacher's mathematics classroom. Therefore, there is no one mould that mathematics students can fit into, as they have in past traditional learning development methods. Another reason traditional learning development does not work is that there is simply too much to learn in one learning development day and too much to remember after one session.

According to Badenhorst and Rammile (2023), mathematics students most likely will not remember how to use many of the applications taught to them during their sessions, as they might not have scheduled time to practice and therefore struggle to apply the new techniques and applications in their own mathematics classrooms. Even with the newly implemented training method proposed by McPherson (2022), learning development administrators acknowledged that mathematics students would be unable to retain or master all content within a short training period. Despite the shortcomings of traditional learning development in implementing tablet technology into mathematics classrooms, through this training, mathematics students can realise the benefits of using tablets. This idea is exemplified in a study done by Gerber (2023), the Director of Academic Technology at a school of technology.

Gerber (2023) further notes that mathematics students were always enthusiastic about learning new uses of their tablets and showed a commitment to learning them. Nevertheless, McPherison (2022) asserts that mathematics students with only traditional learning development were unable to transfer skills from their training into their mathematics classrooms. The researcher believes that those mathematics students were hesitant to use tablets, believing that using tablets would take too much time and increase the risk of misunderstanding. Teachers are then left to find a new way to train mathematics students to implement tablets into their mathematics classrooms.

Higgins (2025) reports some of the benefits and downsides of integrating tablets into the learning of mathematics. Some mathematics students found that the tablet had limitations, such as the lack of familiar programmes like Microsoft Word and

PowerPoint. Students also had trouble transferring work to other devices or onto the tablet because it did not have a USB port. Other mathematics students noted that they did not feel that note-taking and other writing were efficient on the tablet (Higgins 2025). For this reason, mathematics students are concerned about the realistic potential and possibility of implementing tablets. Many teachers were also concerned with the mathematics students' responsibility for owning a tablet. Teachers think that tablets are fragile and not durable enough to be tossed into a backpack.

According to Oates et al. (2024), cases are needed to keep tablets in good shape. Sturdy tablet devices are needed to make sure they last in the hands of mathematics students. The consequences of a broken tablet can mean a mathematics student does not have the ability to participate in certain mathematics activities in class, or the school and family must provide more money to get a new tablet for mathematics students. Other negative influences worthy of consideration concerning tablets surfaced from the schools that Julaihi (2022) researched. He felt tablets prevented the development of writing skills, and students' preferred mathematics textbook availability was found to be limited. Teachers also asserted that it was hard to plan mathematics lessons on the tablet and again expressed concerns about tablet implementation.

2.11 STUDENTS' ATTITUDES TOWARDS LEARNING MATHEMATICS

According to Williams et al. (2022), students' attitudes towards mathematics play a fundamental part in the learning of the subject. Attitudes towards mathematics are often more divided among students relative to other discipline areas. Williams et al. (2022) found that negative attitudes towards a subject area may obstruct the learning of mathematics. In agreement, Arvanitaki and Zaranis (2020) assert that the attitudes and feelings construed towards mathematics have been associated with poor mathematics performance in schools. Moreover, Prensky (2018) asserts that students with negative attitudes towards mathematics are less likely to excel in the subject area compared to students who hold a more positive attitude. According to the researcher's observation as a teacher and a lecturer, a positive attitude towards mathematics predicts mathematics achievement in students. Additionally, as a former teacher and lecturer, she observed higher mathematics scores in students who showed more interest in mathematics and perceived themselves as being better at it. The researcher also believes that, to improve student attitudes and achievement in mathematics, it is

important to understand the connection between the two. At first glance, it might seem like an obvious correlation, but it is evident that if a student has a good attitude towards maths, they will be more inclined to learn, try harder, and their performance will be better.

In the researcher's experience in the teaching and learning of mathematics at high schools, TVET colleges, and universities, attitude towards mathematics plays a crucial role in the learning processes of mathematics. It affects students' achievement in mathematics. Students' attitudes toward mathematics are shaped by the interplay of pedagogical approaches, institutional support structures, family influence, and students' broader orientations toward schooling. Usually, the way that mathematics is represented in the mathematics classroom and perceived by students, even when teachers believe they are presenting it in an authentic and context-dependent way, stands to alienate many students from mathematics. In her experience, the researcher discovered that a positive attitude towards mathematics leads students towards success in mathematics.

According to Gerber (2023), attempts to improve attitudes towards mathematics at lower levels provide a base for higher studies in mathematics. Brooke et al. (2022) support the idea by stating that attempts to improve attitudes also cause an effect on the achievement of mathematics for Level 2 students. In support of the above, the researcher asserts that a student with a positive attitude towards mathematics is more confident when learning mathematics, enjoys mathematics, is motivated to do more, actively engages during mathematics lessons, gets more practice, and achieves more. Furthermore, the researcher believes that a student with higher achievement in mathematics has more confidence in their abilities, sees the value of mathematics, and has a positive attitude towards mathematics.

The above can be summarised by a cycle of attitudes and achievement as follows:

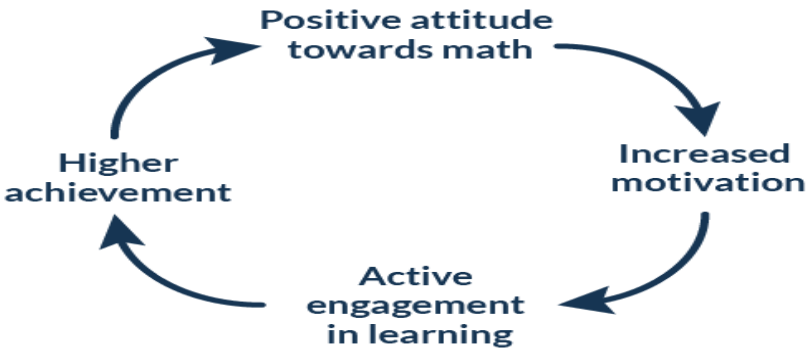


Figure 2.1: A cycle of attitudes and achievement (Gerber, 2023)

Mullis and Kelly (2022) note that students' attitudes toward mathematics and its learning have been subject to numerous studies in the past six decades. These studies treat such attitudes as both desirable learning outcomes and correlates of mathematics achievement. So, when students display a positive attitude towards mathematics, improvements can be seen in emotions, motivation, confidence, engagement, working memory and numerical processing.

Roschelle et al. (2020) further assert that many Likert-type attitude scales have been devised to measure significant constructs underlying mathematics-related attitudes, such as confidence, anxiety, and utility of mathematics. The psychometric properties of these attitude scales may be culture and age-dependent. As part of a research project called the Singapore Mathematics Assessment and Pedagogy Project (SMAPP), an effort was made to develop and validate an attitude toward learning mathematics scale that can be used with lower secondary school students in Singapore. So, with that scale, it was found that having a positive attitude acts directly on students' memory and learning systems. Improvements in each of these areas certainly contribute to greater mathematics learning abilities and educational outcomes, but they also make for healthier, happier mathematics students overall. Therefore, instilling positive attitudes and promoting a growth mindset in the learning of mathematics as early as possible is so important.

The SMAPP research explains the use of exploratory and confirmatory factor analyses to reduce an initial 57-item questionnaire to one with 24 items that cover these six dimensions: Checking solutions, Confidence, Enjoyment, Use of IT in mathematics learning, Multiple solutions, and Usefulness of mathematics. Positive attitudes are

desirable learning outcomes for most school subjects, including mathematics. They are also important and positive correlates of mathematics achievement.

Numerous studies, including large international comparative studies, such as the Trends in Mathematics and Science Study (TIMSS), have included student attitude as a significant variable of interest (Roschelle et al., 2020), because, according to the National Mathematics Advisory Borba et al. (2025) of the United States, “Students’ goals and beliefs about learning are related to their mathematics performance.” Well-known scales developed by different researchers have been modified and used extensively in many studies, and comprehensive reviews of this research area have been provided by researchers over the past five years, such as Maasz and Schlöglmann (2019). Comprehensive reviews of the research found that negative attitudes towards mathematics are far more common than they should be. Things like insecurity, apathy, and mathematics anxiety can greatly impact a student’s learning environment and their overall achievement in mathematics. Luckily, instilling a positive attitude early could be the key to improving achievement. Reinforcing positive attitudes can break the cycle, boosting learning outcomes and motivating children to learn, grow, and improve.

The psychometric properties of attitude scales toward the learning of mathematics may be culture-dependent because the practices of learning are strongly influenced by cultural milieu, which Mazana (2024) referred to as the pedagogical flow of different countries. Furthermore, the responses gathered from mathematics students using such scales also depend on their age. As part of a research project called the Singapore Mathematics Assessment and Pedagogy Project (SMAPP), an effort was made to develop and validate an attitude toward learning mathematics scale that can be used specifically with lower secondary school mathematics students (Grade 7, age 13+) in Singapore. This questionnaire was used to measure the attitudes of participating mathematics students towards mathematics and its learning before and after the SMAPP intervention. Hence, the research question of the paper was: What were the psychometric properties of the SMAPP Attitudes toward Learning Mathematics (ALM) questionnaire?

2.11.1 The description of the design and validation process undertaken

According to Julaihi (2022), the way in which mathematics students identify themselves, also known as self-efficacy, is an indication of how well they perform on different mathematical tasks and their academic performance. For example, Williams et al. (2022) studied the relationships between students' attitudes towards mathematics and their performance. The researchers used multiple questionnaires and assessments with middle school mathematics students to collect data. The results showed that a significant correlation exists between students' attitudes towards mathematics and their performance. Arvanitaki and Zaranis (2020) confirmed these results in a study that collected information on mathematics students' attitudes. This study explored the attitudes of secondary school students towards mathematics using a student questionnaire. The research showed that secondary school mathematics students who had a more positive attitude towards mathematics achieved better academic performance. Raschelle (2020) further asserts that the way in which the subject area is taught in the classroom affects students' attitudes towards mathematics.

Alex (2021) found that in a study with middle school mathematics students, encouraging and motivational experiences provided for learning mathematics can help students be successful. Positive situations improved students' attitudes towards learning mathematics, which facilitated the progression of their attitudes. Similarly, research conducted by Kulik and Fletcher (2020) focused on technology tools, specifically tablets, and the role they play in influencing students' attitudes towards mathematics. Outcomes revealed that mathematics students who use tablets in the classroom report more positive attitudes towards mathematics compared to students who do not use the devices. Roschelle et al. (2020) strongly believe that mathematics should be taught using engaging materials and interactive methods to promote a more positive attitude towards the subject.

Webster (2022) examined the use of tablet-aided learning on students' attitudes towards mathematics. Using two groups of high school students, one group followed a tablet-based curriculum while a second group participated in a more traditional learning environment. Results indicated that students had more fun and preferred learning mathematics with tablet devices. Moreover, tablet-aided learning, according

to Buzzard (2020), improved students' satisfaction and attitudes towards receiving instruction. Using tablet devices in educational settings can help provide students with positive experiences, leading to more positive attitudes towards mathematics (Bara, 2023). Scholars have offered a variety of definitions for students' attitudes toward mathematics in the literature. For example, Kulik and Fletcher (2020) define attitude towards mathematics as the liking or disliking of the subject; a tendency to engage in or avoid mathematical activities; a belief that one is good or bad at mathematics; and a belief that mathematics is useful or useless. Aldossry (2023) offers a simpler definition, defining attitude as a positive or negative emotional disposition towards mathematics. Therefore, when defining attitudes towards mathematics, both aspects of belief and emotion should be considered. We adopt the definition by Enriquiz et al. (2020) because it better addresses students from both cognitive and social perspectives.

2.12 IMPORTANCE OF TABLETS GLOBALLY, NATIONALLY, IN SA AND PROVINCIALLY

Tablets, according to Coughlan et al. (2025), play a crucial role in global and national education systems, offering access to a wide range of learning materials and enhancing the learning experience. In South Africa, tablets are used to track student progress, facilitate learning through educational software, and provide direct communication between students and educators. Alex (2021) further asserts that the government aims to provide every school child in South Africa with digital workbooks and textbooks on a tablet device, reflecting the importance of tablets in the country's educational landscape.

2.12.1 Global Importance of Tablets

Tablets, according to Audi (2023), have emerged as essential digital tools worldwide due to their portability, versatility, and interactive features. Key aspects include:

- **Educational Enhancement:** Tablets facilitate blended learning, interactive lessons, and access to e-books and multimedia resources, which help learners engage with material in novel ways. Studies from the United States, Australia, and Europe show tablets improve collaboration, learning motivation, and critical thinking.

- **Accessibility and Inclusivity:** Tablets provide a portable alternative to desktops and textbooks, making education more accessible in remote or under-resourced regions.
- **Professional and Personal Use:** Beyond education, tablets support professional presentations, communications, remote work, and personal tasks, reflecting their widespread integration into daily life.
- **Technological Adoption:** Tablets accelerate user familiarity with digital technologies, contributing to technology literacy across all age groups.

2.12.2 National Importance (South Africa as a case study)

Higgins (2025) asserts that in South Africa, tablets play a key role in addressing educational challenges, including large class sizes, under-resourced schools, and promoting equity:

- **Enhanced Academic Achievement:** Studies in the North West show that students' attitudes toward using tablets, especially perceived enjoyment, usefulness, and ease of use, strongly correlate with better academic outcomes.
- **Blended Learning Facilitation:** Tablets allow the integration of digital technologies with face-to-face instruction, creating interactive and collaborative learning environments.
- **Monitoring and Engagement:** Lecturers and parents can track students' progress, making learning processes more transparent and facilitating timely support for struggling learners.
- **Cost-effectiveness:** Tablets reduce reliance on physical textbooks and classroom materials, providing a long-term, scalable solution for resource-constrained educational systems.
- **Equity and Inclusion:** Tablet projects in rural schools aim to bridge the digital divide, ensuring students in historically disadvantaged communities have access to modern learning technologies. Projects funded by the Department of Rural Development and Land Reform (DRDLR) have shown positive lecturer attitudes and emerging digital competencies among both lecturers and students.

2.12.3 Provincial Importance (Eastern Cape & North West examples)

According to Gerber (2023), provincially, tablet integration in South Africa has targeted rural and under-resourced areas:

- **Eastern Cape University Case Study:** Research with students and lecturers revealed that tablets enhanced research skills, collaboration, and engagement in learning. Strengths highlighted included easy access to information and the ability to learn collaboratively. Weaknesses noted included distractions such as social media usage. Recommendations include providing training and structured tasks to maximise educational benefits.
- **High Schools in Johannesburg and Rural Provinces:** Surveys reveal high ownership and usage rates among students, with strong positive attitudes toward tablets. Proper integration improved learners' engagement, motivation, and the ability to perform digital assignments, although off-task behaviours remain a concern.
- **Teacher Training and Competency:** Provincial tablet projects include teacher training to increase digital literacy and confidence in using tablets for instruction. Studies indicate that when teachers are sufficiently trained, tablets can significantly enhance classroom efficiency and educational outcomes.

Table 2.1: Cross-Level Summary according to Gerber (2023)

Level	Key Benefits	Considerations / Challenges
Global	Learning engagement, collaboration, accessibility, portability, and professional use	Device cost, connectivity, and potential distraction
National	Student performance, blended learning, equity in access, cost reduction, parental engagement	Teacher readiness, student discipline, and maintenance costs
Provincial	Research skills, localised training, improved collaboration, and targeted rural inclusion	Limited resources, infrastructure constraints, and off-task behaviour

Enriquezz (2023) posits that tablets are transformative tools enabling enhanced learning outcomes, access, and equity at multiple levels from global to provincial contexts. Their effectiveness depends on structured integration, support systems, positive attitudes toward technology, and adequate training for both teachers and learners. In South Africa, ongoing projects demonstrate promising results, especially in rural areas where tablets bridge historical educational inequalities while promoting interactive and collaborative learning.

2.13 GENERAL OVERVIEW OF TABLET DEVICE IN EDUCATION

Literature, according to Gerber (2023), generally indicates that tablets are increasingly incorporated in schools and colleges due to their portability, intuitive touch interface, multimodal capabilities, and potential to facilitate collaborative learning. Tablet devices, according to Buzzard (2020), provide multimodal interaction (text, video, audio), ubiquitous access, instant feedback, and app-based learning. Compared to laptops and smartphones, tablets allow more seamless engagement with Mathematics L3 through size, portability, and touch interaction. Webster (2022) posits that teachers and lecturers' knowledge, professional development, and pedagogical confidence are critical for effective tablet use. Models such as TPACK, SAMR, and Technological Acceptance Models inform effective integration into Mathematics L3 instruction. In addition, Alex (2021) asserts that blended learning environments combining traditional instruction with tablet use improve student engagement. Audi (2023) further asserts that evidence indicates improved conceptual understanding, problem-solving skills, and engagement when tablets are appropriately integrated when learning Mathematics L3 with TD. Limitations, according to Brooke et al. (2022), include dependence on lecturer support, uneven access to devices, and insufficient empirical research on specific educational apps' effectiveness. Furthermore, Kaya and Kutluca (2024) posit that tablet constraints are connectivity issues, device malfunctions, and software limitations. Pedagogical constraints, according to Gerber (2023), are lecturers' digital literacy, lack of structured professional development, and insufficient guidance on app selection. Gerber (2023) further highlighted contextual constraints such as socio-economic disparities, school infrastructure, and classroom management challenges.

2.14 CONCLUSION

The literature in this chapter was reviewed extensively, referring to the global, African and provincial perspectives as well as the use, importance, and integration of tablets in the lecture room. It explored the implications for policy and practice, and students' peer learning, as well as comments on learning with tablet devices. It further added the broad insights into tablet affordances and pedagogical potential, progresses to systematic analyses of learning outcomes, and then drilled down into teacher-mediated classroom practices, student outcomes, and context-specific challenges. Students' attitude towards learning mathematics and the importance of tablets globally, nationally, in SA and provincially were also explored. A general overview of the use of tablet devices in Mathematics Level 3 was also examined. In addition, the chapter interrogated creativity and hands-on learning with tablet devices, tablets for anytime, anywhere education and literature on mathematics learning. Furthermore, the effectiveness of tablets on learning mathematics, the benefits of tablet use, and factors negatively influencing tablet integration in the lecture room were also examined. Finally, students' attitudes in the learning of mathematics and the importance of tablets globally, nationally, in SA and provincially were also explored.

In conclusion, after reviewing how tablets can generally be used in the mathematics classroom and recognising their benefits and drawbacks, this literature review detailed how tablets can be used in a mathematics classroom setting. Many of these studies on tablet usage in mathematics classrooms were performed at the secondary, middle, and elementary levels, with far fewer at the university and college level. The purpose of this study is to fill this research gap at the college level. It is for this reason that this study explores the impact of the use of tablets on Level 3 North West TVET College students' performance and attitudes in learning to calculate the surface area and volume of geometrical objects by comparing the results to the existing literature.

CHAPTER THREE

THEORETICAL FRAMEWORK

3.1 INTRODUCTION

In Chapter 2, the literature reviewed different frameworks and clarified the relationship between the proposed research and previous research, both empirical and theoretical, to aid in understanding the topic of study. This review is organised into several sections to create an outline that supports the research purpose within this study. This chapter begins by stating the Affective, Behavioural, and Cognitive (ABC) Model used to frame this study. The ABC Model of Attitude, according to Mazana (2024), also known as the Tripartite Model, serves as a useful theoretical framework for developing measures of mathematics attitude using the Attitudes Toward Mathematics Inventory (ATMI). Mazana (2024) further asserts that the ABC Model of Attitude is based on a hierarchical model described by Giri (2021), who conceptualises attitude as an amalgam of three separate measurable components: Affect (A), Behaviour (B), and Cognition (C).

In this study, the affective component of attitude demonstrates how students feel about learning mathematics. From the researchers' experience, the affective component often reflects students' initial reactions, which may be positive or negative, such as fear-based or excitement-based responses towards learning mathematics. Furthermore, the behavioural component of attitude refers to students' intentions or what they would do, which can be informed by their attitudes or cognitions. For example, in this study, if students are afraid of learning mathematics (their affect), they might run from or avoid (their behaviour) engaging with the subject. It is the researcher's observation that the cognitive component involves what students think about mathematics and what occurs when they pause and truly reflect on the subject. Mazana (2024) aligned himself with the researcher's observation by stating that the cognitive component of mathematics involves how students think about the subject and the processes they engage in when reflecting on it. Piaget's Theory emphasises that students learn through active engagement and interaction with their environment,

progressing through stages of cognitive development that influence their understanding of mathematics. Cognitive Activation is crucial for students' engagement in problem-solving tasks, which can enhance their mathematical performance. Understanding the cognitive load during learning can also impact students' ability to solve complex mathematical problems, highlighting the importance of instructional strategies and prior knowledge. Additionally, mathematical content knowledge encompasses the understanding of fundamental principles and concepts, which is essential for teachers to effectively explain and address student misconceptions. These elements collectively illustrate how students' cognitive processes shape their engagement and understanding of mathematics.

From the ABC Attitude Model, affect is the emotional component consisting of feelings and emotions associated with the attitude object, which in this study pertains to calculating the surface area and volume of geometrical objects in mathematics. Behaviour is the action component that includes predispositions to act in a particular way towards the mathematical attitude object in this study. Cognition is a mental component comprising the beliefs and perceptions that students hold regarding their attitudes towards mathematics. In this study, all three components must be present before an attitude toward the subject can be established. Moreover, Mazana (2024) further asserts that a particular attitude may consist of a positive emotion, such as feeling happy in a mathematics classroom (affect), the intent to learn more mathematics (behaviour), and the belief that mathematics is easy to learn (cognition). Students may exhibit a favourable or unfavourable attitude towards mathematics.

3.2 RELATED THEORIES

The Affective, Behavioural and Cognitive (ABC) Model was used to frame this study. Giri (2021) applied the ABC model to investigate students’ attitudes and performance in mathematics. This theory was deemed relevant for this study as it explains the reasons behind the attitudes displayed by students towards learning mathematics. In accordance with the ABC model, this study focused on investigating aspects of attitude, including students’ self-confidence in mathematics, anxiety, enjoyment, perception, and intrinsic motivation.

3.2.1 ABC Model

The ABC Model was deemed suitable for this study because it evaluates personal beliefs and their impact on functional thinking in the learning of SAVOGOs. In this model, Affect is associated with the emotional component, which includes feelings, attitudes, and emotions related to mathematics. Additionally, Behaviour, as an action component, involves students' predispositions to act in a certain way towards their attitude towards mathematics. Finally, Cognition is a mental component that encompasses the beliefs and perceptions students hold about the subject matter. According to Dennis (2025), for an attitude towards a phenomenon or object to exist, all three components must be present: Affect, Behaviour, and Cognition. Dennis (2025) further asserts that a positive attitude arises when the hope to improve performance instils in students the determination, stamina, and desire to overcome the challenges of learning and strive for the success they seek. Giri (2021) warns that students may exhibit either a favourable or unfavourable attitude towards learning mathematics.

Based on the researchers' experience of more than twenty years in teaching and lecturing mathematics, students acquire attitudes over time through direct experiences of learning the subject or by receiving information about it. Dennis (2025) asserts that students use the learned attitudes to guide their overt behaviour regarding mathematics learning. This often results in consistently favourable or unfavourable patterns of reaction towards the subject. Attitudes are considered precursors to mathematics learning behaviour. In predicting behaviour based on a particular attitude, Giri (2021) suggests that there should be a correspondence between measures of attitude and those of behaviour. Consequently, the researcher observed that students' attitudes towards mathematics reflect their evaluation of the learning content. Giri (2021) further asserts that attitudes can be expressed through verbal or non-verbal actions and emphasises that several researchers have attempted to measure attitudes using different instruments. In this study, attitudes were measured using the validated ATMI, created by Tapia and Marsh (2004).

Dennis (2025) proposes three measures of behaviour: observable actions performed by the subjects and recorded by an investigator, individual commitment to perform the behaviours, and self-reported behaviour. However, Buzzard (2020) notes that the last

two measures can only be considered when it becomes difficult to make direct observations of the observable behaviours. In this study, observable actions represent an observational method that involves examining students' attitudes both in and outside the classroom when learning SAVOGOs. During this process, the lecturer acted as the observer, collecting data while teaching. The lecturer spent three months teaching students in their classroom, which served as a natural environment. Performance and attitude were assessed when students learned using both the traditional textbook method and tablet devices. Students' attitudes towards learning mathematics were also evaluated during interviews conducted with six identified students in the classroom environment. During these interviews, the lecturer made observations as unobtrusively as possible to ensure that students were not aware they were being studied. In this study, direct observation was not difficult to perform; consequently, the last two measures were not considered, which aligns with Buzzard's (2020) statement above.

According to Giri (2021), a high correspondence between attitude and behaviour measures can be achieved through standard scaling measures like the Likert scale, which was adopted in this study. The Likert scale survey question in this study used a five-point scale, sometimes referred to as a satisfaction scale, ranging from one extreme attitude to another. In this study, the Likert scale ranged from "Really Agree" to "Really Disagree" and was employed to ascertain how students felt about studying mathematics using both the traditional textbook method and tablet devices. The researcher observed during the teaching and lecturing period that students' attitudes had the potential to impact their individual work performance. For instance, Level 3 mathematics students underperformed in their mathematics results from 2018 to 2020, partly due to the belief that the Mathematics Level 3 Paper 2 was the most difficult of the two papers. Giri (2021) asserts that multiple studies support the idea that a positive attitude directly affects performance positively, while a negative attitude diminishes performance in all respects.

Attitude, according to Bara (2023), refers to a learned tendency of a student to respond positively or negatively towards an object, situation, concept, or person. Bara (2023) further believes that attitude is regarded as a belief held by individuals that reflects their opinions and feelings and can sometimes be manifested in behaviour. However,

Webster (2022) asserts that attitudes, behaviour, and feelings are interrelated in such a way that people's attitudes determine their behaviour towards objects, situations, and people. Adams (2025) further asserts that these three components also influence the relationships that exist among the variables of attitude, behaviour, and feelings. Giri (2021) defines attitude as a hypothetical construct that cannot be observed directly in students but can be inferred from measurable reactions to the attitude object. According to Adams (2025), attitude is multidimensional and considers three components: affect, cognition, and behaviour. In this study, the three components were measured to determine the attitudes of students in learning mathematics. Affect is associated with the emotional component, which consists of feelings, attitudes, and emotions related to mathematics.

Affect is also linked to emotions, beliefs, and perceptions of the subject of mathematics. Emotions encompass the feelings of enjoyment or pleasure in learning mathematics, or seeing it as boring, difficult, and dull. For example, in this study, Level 3 mathematics students found studying the subject boring, difficult, and dull due to challenges in understanding the content. Beliefs, according to Adams (2025), are related to students' confidence in their ability to learn mathematics, whereas vision represents students' perceptions regarding the subject. In this study, students demonstrated confidence in learning Mathematics Level 3 Paper 1 content; however, their vision regarding Mathematics Level 3 Paper 2 was negative, as evidenced by their performance in previous years' results.

Finally, cognition represents students' perceived usefulness of the subject of mathematics. The understanding of SAVOGOs in this study is deemed very important for students, as this information will be applicable in the working industry in the future. Conversely, according to Williams et al. (2022), behaviour is connected to students' motivation to learn, which is reflected in their actions, commitment, and performance in class. It was evident in this study that students were not motivated to learn SAVOGOs, as reflected in their performance in assessments, tests, and examinations. Using these components to understand students' attitudes and performance towards learning SAVOGOs, the following aspects were measured in this study:

- Self-confidence, anxiety, enjoyment (affect)

- Intrinsic motivation (behaviour)
- Perceived usefulness (cognition) (Albert Ellis,1955)

3.2.1.1 Affect

(i) Self-confidence in mathematics

According to Sacristán and Enriquez (2023), self-confidence in mathematics refers to students' perceptions of themselves as mathematics learners, which includes beliefs about their own ability to learn and perform well in the subject. In this study, students perceive themselves as unable to learn and perform well in mathematics due to their performance in the subject. Limi (2025) found that self-confidence is an important factor that influences students' learning and affects their performance in mathematics. It was discovered in this study that Level 3 mathematics self-confidence was not developed for the learning of SAVOGOs; as a result, their performance in mathematics was negatively affected. Furthermore, Williams et al. (2022) argue that students with high self-confidence believe in their abilities and can be successful in learning mathematics, thus overcoming the fear of failure.

Engelbrecht and Borba (2024) emphasise that such students are ready to take on mathematical challenges that can enhance their academic performance. In contrast, students with low self-confidence do not believe in themselves and tend to avoid tackling mathematics challenges. In this study, Level 3 mathematics students did not believe in themselves, as they avoided tackling Question 1 about pyramids in Paper 2, resulting in poor performance in mathematics. Therefore, according to Dennis (2025), this results in minimised chances of expanding students' mathematical skills and success. This study aims to enhance students' self-confidence, preparing them to take on mathematical challenges to improve their academic performance. Pursuant to the above statements and deliberations, the researcher recommends that it is essential to study students' attitudes towards their own confidence and how that attitude relates to performance in mathematics.

(ii) Mathematics anxiety

Mathematics anxiety, according to Thurm and Barzel (2022), is defined as an emotional response to mathematics, whereby students experience negative reactions

to studying mathematical concepts and taking tests. Accordingly, Dennis (2025) asserts that mathematics anxiety includes feelings of tension, helplessness, and distress, which impede the ability to concentrate and consequently affect the learning of mathematics. In this study, it was discovered that students experience feelings of tension, helplessness, and distress that affect their performance during the Mathematics Paper 2 examination. This study aims to address these challenges by leveraging tablet-based technology as an intervention tool. Kulk (2016) further asserts that mathematics anxiety is believed to impact students' attitudes and motivation to learn mathematics, and consequently, their performance in the subject.

The study by Prensky (2018) established that mathematics anxiety is negatively correlated with metacognitive knowledge, which is the ability to reflect on, understand, and control one's learning. For example, in this study, the more anxious the students were, the less metacognitive knowledge they possessed, which ultimately hampered their performance in the subject. The primary cause of students' anxiety in this study is Question 1 in the Level 3 Mathematics Paper 2, which typically involves interpreting pyramid-related questions. A comparative study conducted by Engelbrecht and Borba (2024) in higher education institutions reveals a negative correlation between mathematics anxiety and performance, indicating that anxiety significantly impacts performance. The researcher believes that since anxiety is related to students' attitudes and performance in mathematics, it is worth examining the level of anxiety among students learning SAVOGOs.

(iii) Enjoyment of mathematics

Prensky (2012) asserts that enjoyment of mathematics refers to the extent to which students enjoy doing and learning the subject. Simon et al. (2025) further assert that students' enjoyment while learning can influence their behaviour and the cognitive aspects of their attitude. Additionally, according to Webster (2022), students may learn mathematics because they find it enjoyable and interesting. Prensky (2018) posits that interest and enjoyment affect both the degree and continuity of engagement in learning, as well as the depth of understanding of mathematical content. This suggests that the more students enjoy doing mathematics, the more likely they are to engage in problem-solving, thereby enhancing their learning and performance in the subject. With respect to enjoyment, students' learning and performance, according to Mullis

and Kelly (2022), are related. Therefore, it is worth evaluating students' enjoyment of mathematics to monitor their learning and performance in SAVOGOs.

3.2.1.2 Behaviour

- Intrinsic motivation

According to Brooke et al. (2022), intrinsic motivation is related to both interest and the desire to learn mathematics. In addition, McPherson and Foncha (2021) note that students are intrinsically motivated to learn mathematics if they have the desire to do so after finding mathematics interesting. Oates et al. (2024) believe that motivation is the driving force behind learning. Moreover, Gilmore et al. (2020) emphasise that intrinsic motivation affects the degree of student engagement, career choice, and performance. Therefore, studying motivational variables related to cognition, including aspects such as awareness, perception, reasoning, and judgment, as they pertain to attitude and performance in learning, is crucial.

3.2.1.3 Cognition

- Perceived usefulness

Perceived usefulness, according to Masoabi and Alexander (2021), refers to students' perceptions of the importance of mathematics in their everyday lives and in the future. Chor and Toh (2021) posit that the perceived usefulness of mathematics influences students' attitudes towards the subject. The researcher further observed that when students recognise the importance of mathematics in their lives, they become motivated to study, practice, and learn SAVOGOs. This study reveals that students demonstrated positive cognition towards mathematics after learning with tablet devices, despite previously having negative emotions towards the subject when learning traditionally. According to the researcher, the positive cognition towards mathematics following the use of tablet devices indicates students' recognition of the value of mathematics in their lives and future careers. Williams et al. (2022) state that the usefulness of mathematics is a positive predictor of success. Therefore, it is worthwhile to study the relationship between the value of mathematics, attitudes, and performance in the context of NW TVET colleges.

The three components are further illustrated in Figure 1

Figure 3.1: Ellis's ABC (1955), model of attitude and learning

Affect is about how students feel internally,
Behaviour addresses what students do, their actions, and
Cognition is about what students think.

3.2.2 Cognitive Learning as a contribution to the body of knowledge

According to Adams (2025), cognitive learning is an active style of learning that focuses on helping students maximise their brain's potential. This approach facilitates the connection of new information with existing ideas, thereby deepening memory and retention capacity. Alexander and Masoabi (2021) further assert that cognition refers to the brain's mental processes that absorb and retain information through experience, senses, and thought. In this study, it became necessary to expose students to cognitive learning, as a learning environment where students possess strong cognitive skills is likely to be successful. It is important to note that well-trained and fully engaged students can learn quickly and be highly productive by handling multiple complex mathematical tasks without the need for a teacher's assistance.

3.2.2.1 Components of Cognitive Learning

According to Adams (2025), cognitive learning theory explains how students actively encode, store, retrieve, and process information during learning. Unlike traditional learning processes that focus on memorisation, cognitive learning theory persuades learners to develop problem-solving skills by observing and categorising experiences and forming their own ideas or solutions. The following are fundamental aspects of cognitive learning:

- **Comprehension**

Masoabi and Alexander (2021) assert that, for cognitive learning to be efficient and beneficial, students should understand the reason why they are learning a specific subject in the first place. In this study, students understood the reasons for learning mathematics and defined mathematics as the study of patterns, a study that includes manipulating and expressing ideas about patterns symbolically and quantitatively.

- **Memory**

Cognitive learning, according to Adams (2025), discourages rote memorisation, as it proves largely ineffective in the acquisition of mathematical knowledge. In this study, it should be noted that having a deep understanding of SAVOGOs improves students' ability to relate new knowledge to previous experiences or information.

- **Application**

In this study, cognitive learning strategies assisted students in applying new information or skills in the learning of SAVOGOs. These strategies encouraged students as they continued to develop problem-solving skills in this study.

3.2.2.2 Benefits of Cognitive Learning

According to Adams (2025), cognitive learning theory enhances lifelong learning because students can build upon previous ideas and apply new concepts to already existing knowledge. Adams (2025) further asserts that students become more confident in approaching tasks as they gain a deeper understanding of new topics and learn new skills in learning mathematics. In addition, Alexander and Masoabi (2021) concur with Adams (2025) that cognitive learning improves students' comprehension of acquiring new information when learning mathematics. Students can develop a deeper understanding of new mathematics content. Moreover, Masoabi and Alexander (2021) assert that cognitive learning equips students with the skills they need to learn effectively and are thereby able to develop the problem-solving skills needed to apply in solving challenging tasks. In this study, through experiential learning, students were able to recycle and use the same learning methods that worked previously, and this helped them learn new things much faster, as they already knew what worked for them in obtaining new knowledge. Moreover, cognitive learning in this study taught students to form a range of different concepts when using tablet

devices, such as easily perceiving and interpreting information that could boost creativity and lead to innovations when studying during the learning of SAVOGOs.

3.2.2.3 Cognitive Learning Strategies

Several psychologists, according to Creswell and Clark (2023), have shaped the concept of cognitive learning through research. They came up with the following theories and learning strategies to be implemented in any learning environment.

- **Learner-centred strategy**

According to Creswell and Clark (2023), Jean Piaget termed learning as relating information to already existing knowledge, and each learner starts with their own knowledge and experience. According to Jean Piaget's theories, learning begins with the accumulation of some basic knowledge and advances deeper into the field over time (Creswell & Clark, 2023). Piaget suggested three vital components of learning. The first is accommodation, which is taking new information into account by modifying what students already know. The second is assimilation, which refers to the arrangement of new knowledge inside students' heads alongside what students know. Finally, equilibration is balancing what students already know with the new information they are trying to acquire. Piaget also believed that as students learn, they strike a balance between the use of assimilation and accommodation. In this study, assimilation is regarded as the cognitive process of making new mathematical information fit in with students' existing understanding of the world. Essentially, when students encounter something new, they process and make sense of it by relating it to things they already know.

Furthermore, assimilation and accommodation both work in tandem as part of the learning process, whereby some information is incorporated into students' existing schemas through the process of assimilation. In addition, other information leads to the development of new schemas or total transformations of existing ideas through the process of accommodation. This process, known as equilibration, allows students to find a balance between applying their existing knowledge and adapting their behaviour to new information. In this study, the learning process of SAVOGOs involved

attempting to interpret new information within the framework of existing knowledge (assimilation), making small changes to that knowledge in order to cope with things that do not fit those existing frameworks (accommodation), and eventually adjusting existing schemas or forming new ones in order to adjust to a new understanding (equilibration) of SAVOGOs.

- **Meaningful Experiences strategy**

David Ausubel made a clear distinction between meaningful learning and rote learning (Creswell 2018). According to him, material that is closely related to what the learner already knows is meaningful and tends to be more effective. Learners with a relevant mathematical background find it easier to incorporate new information. For example, in this study, during mathematics instruction in the lecture room, there was an emphasis on the meaningfulness of each session in relation to the mathematical task at hand. Additionally, background mathematical information on the new material was essential. Finally, new mathematical information was presented to learners in a sequence that built on concepts they had already understood.

- **Learning Through Discovery strategy**

Jerome Bruner is a psychologist whose theory succeeded Piaget's theory of cognitive development, focusing on learning through discovery (Creswell & Clark, 2023). According to Creswell and Clark (2023), Bruner's theory identified three stages of cognitive representation: enactive, iconic, and symbolic. Enactive refers to the representation of knowledge through actions; iconic refers to the visual summarisation of images, while symbolic implies the use of words and symbols to describe experiences. In this study, students were able to represent knowledge, summarise images, and use words and symbols to describe experiences using tablet devices. Through his study of cognitive learning with students, Jerome Bruner suggested that learners should discover information for themselves. He believed that learners review previously learned material even as they gain new knowledge. According to Creswell and Clark (2023), Bruner's interpretation of cognitive learning theory in a college environment can be practised by allowing students to learn new skills and acquire

knowledge through new tasks and challenges. In this study, students were challenged during the learning of SAVOGOs and encouraged to discover information for themselves to solve real-world problems they faced in real-life situations.

3.4 INTEGRATING THEORY INTO USING TABLETS AND THE PERFORMANCE AND ATTITUDE IN CALCULATING SAVOGOs'

The ABC model primarily pertains to the tripartite model of attitudes in psychology, which consists of three interrelated components: Affective (A) – Emotional responses or feelings toward an object, task, or situation (e.g., enjoyment, frustration, or motivation when using a tablet). Behavioural (B) – Observable actions or behavioural intentions influenced by attitude (e.g., the frequency or way a student engages with a tablet for learning tasks). Cognitive (C) – Beliefs, thoughts, or knowledge about the object or activity (e.g., beliefs about the usefulness of tablets for performing arithmetic operations like SAVOGO—an assessment or operational task).

3.4.1 Application to using tablets

In educational or performance contexts, the affective component, we notice that students' positive or negative feelings toward tablets influence willingness to use them; enjoyment may increase engagement. Behavioural Component: The actual usage patterns—how frequently one uses tablets, follows interactive instructions, or participates in exercises. Cognitive Component: The perception of tablets' efficacy as tools for learning (belief that tablets improve understanding, speed, or accuracy in computation). For example, even if students feel positively about tablets (affective) and believe they work (cognitive), actual use (behavioural) may depend on factors such as accessibility, comfort, or prior technical skill.

3.4.2 Attitude in Calculating SAVOGOs

When integrating ABC into performance tasks like SAVOGOs calculations, three interrelated dimensions are considered. The affective dimension refers to students' emotional orientations toward the task, including feelings of confidence, anxiety, or frustration experienced during numerical computation. The behavioural dimension

encompasses the study habits and problem-solving strategies employed by students, such as practicing calculations, applying mathematical formulas, or engaging with digital tools. The cognitive dimension pertains to students' conceptual knowledge of formulas, problem-solving principles, and their understanding of the underlying processes involved in SAVOGO.

3.4.3 Mapping the ABC components

Educators can assess whether performance deficits are due to affective issues (e.g., anxiety blocking efficiency), behavioural barriers (e.g., insufficient practice or engagement), or cognitive gaps (e.g., misunderstanding formulas or principles).
Interventions can then be targeted: tutorials or scaffolding for cognitive improvement, tablet-based gamified exercises to enhance affect and engagement, and practice routines to modify behaviour.

Combining tablets and the ABC model for improving SAVOGOs performance implies: Designing digital learning interventions that engage all three components. From an affective standpoint, such interventions should be designed to evoke positive emotional responses toward the task, fostering confidence and reducing anxiety. Behaviourally, they should encourage consistent and meaningful interaction with the digital tools, promoting active engagement in the learning process. Cognitively, the interventions must provide accurate content knowledge and timely feedback that deepens students' understanding of SAVOGO processes. Furthermore, monitoring inconsistencies across the affective, behavioural, and cognitive dimensions is essential for diagnosing barriers to proficiency. For instance, a student who demonstrates positive affect but low behavioural engagement may signal underlying accessibility or usability challenges within the digital environment.

The ABC model provides a structured framework to interpret and enhance attitudes and performance in tasks involving technology (tablets) and calculation exercises (SAVOGOs). It helps educators and researchers diagnose which component—emotion, behaviour, or cognition—dominates, aligns, or conflicts, ultimately informing design and pedagogical choices.

3.5 SUMMARY OF THE MAIN ASPECTS THAT WERE COVERED

In this chapter, the theoretical framework underpinning the study was explored by looking at the ABC model and cognitive learning as a contribution to the body of knowledge.

3.6 CONCLUSION

This chapter outlined the conceptual framework that underpinned this study, specifically Ellis's ABC model of attitude and learning. One aspect that was not well defined in the model, which the researcher found necessary for this study, was the cognitive learning component. The researcher considered emphasising the cognitive learning component as her contribution to the body of knowledge in this study. Furthermore, this study does not focus on memorisation or repetition of mathematical content and knowledge. Instead, mathematics lecturers taught students the mathematical fundamentals of lifelong learning. Finally, the students in this study learned mathematical skills and strategies that enhanced their mathematical performance in college, including how to think critically and how to make lasting connections between mathematical topics.

CHAPTER FOUR

RESEARCH DESIGN AND METHODOLOGY

4.1 INTRODUCTION

In Chapter 3, the theoretical framework was organised into several sections to support the research purpose of this study. The Affective, Behavioural, and Cognitive (ABC) model framed this study. This chapter begins by restating the research problem, research aims and objectives, research questions, and the hypothesis of the study. It further presents the research paradigm, research setting, intervention programme, research design, and the research methods adopted to answer the research questions, along with the rationale for employing those methods. The population sample, participants, and sampling procedure are also discussed. The chapter then examines the various data collection tools used by the researcher, including pre-test and post-test questionnaires, as well as semi-structured interviews. Subsequently, the chapter addresses data analysis, the validity and reliability of the data, and the ethical considerations of the study. It concludes with a summary.

4.2 AIMS AND OBJECTIVES

4.2.1 The aim of the study

This study aims to determine the impact of using tablets on TVET Level 3 students' performance and attitude in calculating SAVOGOs.

4.2.2 The objective of the study

The following objectives were formulated to achieve the above aim.
The study intends to:

- Establish how Level 3 students' performance compares with using tablet devices as opposed to the traditional textbook method of learning.
- Investigate how Level 3 students' attitudes compare with using tablet devices as opposed to the old traditional textbook method of learning.

- Determine challenges experienced by Level 3 students when learning SAVOGOs using tablet devices.
- Determine the benefits of learning SAVOGOs with tablet devices.
- Suggest a model maximising performance in mathematics at TVET colleges using mobile devices.

4.3 RESEARCH QUESTIONS AND HYPOTHESIS

In this study, the main research question was:
What is the impact of using tablets on TVET Level 3 students' performance and attitude in calculating SAVOGOs? To unpack the main question, the following sub-questions gave a complete and comprehensive landscape of the problem statement.

(i) How do Level 3 students' performance differ when using tablet devices as opposed to the traditional textbook method of learning?

(ii) How do Level 3 students' attitudes vary when using tablet devices as opposed to the old textbook method of learning?

(iii) What challenges do Level 3 students experience when learning SAVOGOs using tablet devices?

(iv) What benefit do Level 3 students experience when learning SAVOGOs using tablet devices?

(v) Which model can maximise performance in mathematics at TVET colleges using mobile devices?

- The null hypothesis of the study:

There is no variation in performance and attitude when a cohort of TVET Level 3 students calculate SAVOGOs using tablet devices as opposed to the traditional textbook method.

- The directional hypothesis is as follows:

Groups of TVET Level 3 students calculating SAVOGOs using tablet devices improved performance and attitude as opposed to the traditional textbook method.

4.4 RESEARCH METHODOLOGY

4.4.1 Research Paradigm

According to Creswell and Clark (2023), a paradigm incorporates the accepted traditions, theories, models, approaches, structures of reference, bodies of study, and methodologies; it can also be referred to as a model or framework for knowledge and understanding. Furthermore, the paradigm in this study influenced the way research was performed, as well as the understanding of respective strengths and weaknesses that may indeed be important. According to Creswell and Clark (2023), four beliefs usually reviewed in research are constructivism, post-positivism, transformative paradigms, and pragmatism. In this study, the discussion of the appropriate paradigm for the study was explored together with the scholarly motivations. The purpose is to enable the researcher to concentrate on the pragmatic worldview that frames the knowledge and understanding of the study.

- Pragmatic Worldview

According to Creswell and Clark (2023), the pragmatic paradigm refers to a worldview that focuses on “what works” rather than what might be considered absolutely and objectively true or real. Early pragmatists rejected the idea that social inquiry using a single scientific method could access truths regarding the real world. In short, Borba et al. (2025) assert that pragmatism is a worldview that underpins most mixed-methods research. Creswell and Clark (2023) further note that the pragmatic worldview is a problem-oriented philosophy that views the best research methods as those that help to answer the research questions most effectively. Borba et al. (2025) further assert that pragmatism is a research philosophy based on the epistemology that there is no single way to learn, but many ways of understanding, because there are multiple realities. In addition, Eshetu and Wakuma (2024) believe that knowledge of these multiple realities is gained through an integration of multiple research methods encompassing both qualitative and quantitative approaches.

This integration is informed by the pragmatist position that truth lies in what best serves the understanding of a particular research problem, rather than in a predetermined commitment to either quantitative or qualitative approaches (Eshetu & Wakuma, 2024). Through this lens, the researcher seeks a richer and more nuanced understanding of how the problem(s) under study manifest in practice. Therefore, the focus of pragmatists is on addressing research questions and solving practical problems rather than on selecting methods to meet the requirements associated with qualitative or quantitative research. From this perspective, pragmatism is an

appropriate background for mixed-methods research. The mixed-methods approach enhances a more detailed understanding of research questions and results, leading to a balanced conclusion on the challenges and opportunities related to the research problem. Mixed-methods research favours, although it is not always pragmatic, the pragmatism paradigm.

From an epistemological perspective, pragmatism leans more towards mixed methods than post-positivism. To achieve the goals of this study, it was framed by the pragmatic worldview because pragmatism offers an experience-based, action-oriented framework. In addition, the purpose of this research is to help the researcher address issues related to the performance and attitudes of students in learning to calculate SAVOGOs in a practical sense. Pragmatism is more significant in research because it can be more suitable than other major philosophical approaches, recognising that there are many ways of interpreting the world and undertaking research. Moreover, pragmatism first emphasises that knowledge is based on experience; secondly, it encourages researchers to analyse organisational practices through experience as well as action. Furthermore, pragmatism is a reasonable and logical way of doing things or thinking about problems that is based on dealing with specific situations instead of ideas and theories. In this study, the process of undertaking a pragmatic study begins with identifying a mathematical problem facing Level 3 students and viewing it within its broadest context in the teaching and learning of the subject. This leads to the bigger idea or overarching understanding that the teacher has used in the planning of the lesson. In the teaching and learning of mathematics at Level 3, a research inquiry that seeks to better understand and ultimately solve the mathematical problems faced by Level 3 students should be conducted. It is for these reasons that the researcher explored the pragmatic worldview for framing the knowledge and understanding of this study.

4.5 Research Design

Research design, according to Creswell and Clark (2023), is the framework of research methods and techniques chosen by a researcher. This design allows researchers to refine methods that are suitable for the subject matter and set up their studies for success. According to Chor and Toh (2021), mixed methods research

(MMR) is a methodological approach that intentionally integrates both quantitative and qualitative research techniques within a single study or across study phases to answer complex research questions more comprehensively than either method alone. Giri (2021) further asserts that the approach is grounded in the pragmatic paradigm, which prioritises the research question over strict adherence to a specific philosophical stance, permitting the blending of methodologies suitable for obtaining valid and actionable knowledge. Key features of mixed methods research, according to Giri (2021), include Integration of data: Combining qualitative and quantitative information so that findings complement and inform each other. Triangulation: Using multiple methods to confirm or cross-validate results. Comprehensiveness: Offering both breadth (quantitative) and depth (qualitative) insights. Flexibility: Allowing adaptation of methods across different stages of the research to solve complex problems. Researchers adopt mixed methods designs for reasons including:

Triangulation: Validating and converging results from multiple research methods.
Complementarity: Using qualitative data to elaborate on quantitative findings. Development: Informing the design of quantitative or qualitative instruments based on preliminary findings. Initiation: Exploring contradictions to generate new research questions. Expansion: Increasing the scope and depth of inquiry by combining multiple methods. Within MMR, the quantitative component often provides generalisability, while the qualitative component adds nuanced understanding, allowing for contextual insights that illuminate underlying phenomena.

4.5.1 Types of mixed methods designs

Common mixed-method designs differ primarily in sequence, priority, and integration of qualitative and quantitative strands: Convergent Parallel Design: Data collected simultaneously; analyses conducted independently and merged later. Explanatory Sequential Design: Quantitative data collected and analysed first, followed by qualitative data to explain initial results (Hassan & Sani, 2025). Exploratory Sequential Design: Qualitative data collected first to explore phenomena and develop hypotheses; quantitative data collected subsequently to test or validate findings. Embedded Design: One method (quantitative or qualitative) is nested within the other as secondary data to strengthen the primary research component. Multiphase or

Transformative Designs: Multiple phases alternating methods across time or integrating theoretical frameworks targeting social justice or context-specific outcomes (Salazar & Wild, 2022).

In this study, the Explanatory Sequential Design (ESD) was used because it is a two-phase, sequential mixed-method approach, beginning with a quantitative phase, followed by a qualitative phase aimed at explaining and contextualising initial quantitative results (Toyon, 2021). Because the qualitative stage is guided by quantitative outcomes, this design is particularly effective for understanding trends, patterns, and anomalies detected in statistical analyses, providing insights into causal mechanisms or participant perspectives. Typical Phases of an Explanatory Sequential Study are Quantitative Phase (Phase 1): Collect numerical data using surveys, experiments, or existing datasets. Analyse using descriptive, inferential, or predictive statistical techniques. Identify key patterns, significant findings, or outliers requiring further exploration. Transition Phase: Determine which aspects of quantitative results require qualitative exploration. Design qualitative instruments, such as interviews or focus group guides, targeting themes or variables identified as significant (Hassan & Sani, 2025).

Qualitative Phase (Phase 2): Collect data focused on explaining quantitative results. Use thematic analysis, coding, or other qualitative techniques to interpret findings. Explore participant perspectives, contextual factors, or unexpected outcomes.
Integration and Interpretation: Combine findings from both phases. Qualitative insights explain, deepen, or contextualise quantitative outcomes. Draw coherent conclusions that reflect both statistical evidence and the lived experiences of participants (Hassan & Sani, 2025). The explanatory sequential design offers several notable advantages. It clarifies quantitative findings by providing explanatory narratives, while enabling targeted qualitative exploration grounded in prior quantitative evidence — an approach that conserves both time and resources. This sequencing also facilitates richer interpretation and more comprehensive conclusions, making it particularly well-suited to complex research questions that demand both generalisable and context-specific insights.
The 120 students were the total population of all the registered Mathematics Level 3 students at TVET College. This is the population from which a sample of 60 students

was drawn. It was simple to draw this sample as students were taught by the same teacher. Students were grouped at the beginning of the Level 3 academic college years to formulate a heterogeneous group of 20 students in a lecture room. It is for this reason that the sample in this study was created by three groups of 20 students in each lecture room taught by the same lecturer.

To address the research questions, this study employed a quasi-experimental research design. Abrahamson (2022) defines quasi-experimental research as being like experimental research in that there is manipulation of the independent variable. However, it differs from experimental inquiry because it may lack random selection, a control group, active manipulation, and/or random assignment. Typically, this type of study is conducted in cases where a control associate cannot be created or random selection cannot be performed. Creswell and Clark (2023) assert that a quasi-experimental research design consists of the following four categories:

i) One-group designs (post-test only and pre–test–post-test),
ii) Non-equivalent control group designs (post-test only and pre-test to post-test),
iii) Time-series designs (basic, interrupted and control), and
iv) Developmental designs (longitudinal, cross-sectional, and cohort-sequential).

Creswell and Clark (2023) further assert that the one-group designs (post-test only and pre-test-post-test) are further divided into two categories, which are:

i) One-group post-test-only design, and
ii) One-group pre-test-post-test design.

Between the two categories of one-group designs, this study was guided by a one-group pre-test–post-test design because it is the best at minimising problems related to the absence of a comparison or control group. According to Abrahamson (2022), a one-group pre-test–post-test design is a quasi-experimental research design in which the same dependent variable is measured in one group of participants before (pre-test) and after (post-test) a treatment is administered.

Creswell and Clark (2023) also assert that when using a one-group pre-test–post-test design, we measure scores before and again after a treatment, then compare the difference between pre-test and post-test scores. The advantage is that the researcher can compare scores after a treatment to scores on the same measure for the same participants prior to the treatment. The disadvantage, according to Creswell and Clark (2023), is that the one-group design does not include a no-treatment control group or a business-as-usual comparison group and is therefore still prone to many threats to internal validity, including those associated with observing the same participants over time (e.g., testing effects and regression toward the mean). The researcher did not choose the one-group post-test-only design because it is most susceptible to threats to internal validity and lacks a comparison or control group. Abrahamson (2022) further emphasises that a one-group post-test-only design is a quasi-experimental research design in which a dependent variable is measured for one group of participants following a treatment. Finally, in this study, the researcher chose the one-group pre-test–post-test design as explained in the paragraphs above.

4.6 Research Approach

Research methodology, according to Vos et al. (2024), is the path through which researchers conduct their research. According to Creswell and Clark (2023), research questions and hypotheses may be addressed through one of three recognised approaches: qualitative, quantitative, or mixed methods, each serving different epistemological and methodological purposes. This study adopted a mixed methods approach, as it involves the collection of both qualitative open-ended and quantitative closed-ended data in response to the research questions or hypotheses. Moreover, Vos et al. (2024) assert that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone.

The four major types of mixed methods approach, according to Creswell and Clark (2023), are the convergent design, the explanatory sequential design, the exploratory sequential design, and the transformative embedded design. This study used the explanatory sequential design to statistically determine the relationship among the variables and to make sense of the experience using a qualitative approach (Creswell

& Clark, 2023). Vos et al. (2024) further emphasise that the explanatory sequential design is one in which the quantitative data is collected in the first phase and analysed first in sequence, then explained by the qualitative results obtained in the second phase. It is considered explanatory sequential because the initial quantitative phase is followed by the qualitative phase.

In addition, Abrahamson (2022) asserts that the choice of a research design relates to three decisions: firstly, the timing of the use of collected data, which refers to the order in which data are used in a study; secondly, the relative weight of the quantitative and qualitative approaches, which refers to the emphasis given to each; and finally, the approach to mixing the two datasets, referring to how the two datasets are related or connected. The selection of the research design in this study was based on the nature of the research problem and the issues being addressed. These included students' performance in mathematics, researchers' personal experiences of underperformance in mathematics, and the lecturer conducting the lessons for the study.

4.6.1 Population and Sampling

Population

MacMillan et al. (2018) refer to a population as an aggregate or totality of all the objects or events, subjects or members that conform to a set of specifications and to which we tend to generalise the results of the research. The population in this study consisted of Mathematics Level 3 students at a TVET college. Even if the total population of the college was about 1,020 NCV students, the population targeted was 120 Mathematics Level 3 students.

- Sampling strategy

According to Cohen and Kelly (2020), a sample consists of a subset or elements of the population considered for actual inclusion in the current study. Vos et al. (2024) further state that a sample implies part of a population, of which the sample is a smaller section. To select participants for the study, a quasi-experimental one-group pre-test-post-test design sampling method was employed. According to Creswell and Clark (2023), a limitation of this design is that participants were not randomly assigned to groups. Opting for a Level 3 mathematics class comprised of comparable characteristics to the same Level 3 groups ensured that participants represented the

identified population at a TVET college and satisfied the conditions of the stated design above.

Within this quasi-experimental framework, students were purposively selected based on their pre-existing classroom groupings. Thus, in the lecture room where the students participated in this study, they were grouped at the beginning of the Level 3 academic college years to form a heterogeneous group of 20 students. "Heterogeneous," according to Salazar and Wild (2022), means a composition of different constituents or dissimilar components. It is for this reason that the sample in this study was created with 20 students in each group of participants on campus. Three groups, each consisting of twenty (20) students, were taught by the same lecturer, constituting a sample frame of 60 students for this study.

4.7 INSTRUMENTATION AND DATA COLLECTION TECHNIQUES

In mixed methods research, data collection is directed by the study's research questions and hypotheses. Consequently, the data collection procedure must align with the type of mixed methods design employed in the study. This requires using procedures derived from concurrent forms of data collection, where both quantitative and qualitative data are collected simultaneously, or from sequential forms of data collection, in which one type of data is collected and analysed before the second type is gathered.

4.7.1 Data Collection Instruments

The following instruments were used to collect data: pre-test and post-test questionnaires, along with semi-structured interviews. A pre-test, according to Engelbrecht and Borba (2024), is an assessment conducted before instruction or an intervention to measure baseline knowledge or skills, while a post-test is conducted afterwards to evaluate learning gains or the impact of the intervention. According to Toyon (2021), the pretest serves several key purposes: it gauges students' baseline understanding and prior knowledge, identifies existing misconceptions and knowledge gaps, and informs educators and researchers about areas requiring focused attention. Collectively, these functions establish a reference point against which changes in knowledge or performance following instruction or intervention can be meaningfully

evaluated. On the other hand, Mazana (2024) assert that a post-test is given after instruction or intervention to measure the knowledge, skills, or outcomes acquired by the teacher's guide. Mazana (2024) further emphasises that the post-test enables educators and researchers to measure learning gains and improvements, assess the effectiveness of a given instructional method, programme, or treatment, and identify areas where students or participants continue to struggle despite the intervention. Finally, it provides feedback to students or program participants and guides future teaching strategies. Salazar and Wild (2022) assert that a questionnaire is a research instrument used to gather data from individuals about their opinions, behaviours, attitudes, knowledge, or characteristics. Hassan and Sani (2025) further emphasise that it serves as a primary tool for both qualitative and quantitative research studies, allowing researchers to reach many participants efficiently. Questionnaires can be administered in various forms, such as paper-based, online surveys, or interviews.

A semi-structured interview is a qualitative data collection method that relies on an interview guide with a set of pre-determined topics or questions, while allowing flexibility in how questions are asked and the order in which they appear. Unlike structured interviews, it enables the interviewer to probe, follow up, and explore new ideas that emerge during the conversation (Hassan & Sani, 2025). The content covered was surface area and volume of geometrical objects and application questions. These types of questions were used to test the impact of the intervention. The pre-test and post-test consist of Questions 1.1 – 1.5.2 and 2.1.1 -2.4.1. See Appendix A.

Two tests were administered, each lasting one hour and thirty minutes, with an additional ten minutes allocated for reading the instructions. In this study, the same test was used for the pre-test and post-test. The semi-structured interviews and the ATMI were administered for a week each since they had eight and 10 questions, respectively. See Appendices H and I. In this study, six students were interviewed and participated in the ATMI accordingly. Six students were selected based on their performance, ranging from the highest to the lowest achiever.

The interviewer did not strictly adhere to a formal classification of questions. Instead, more open-ended questions were posed, allowing for a conversational flow with the interviewee rather than a direct question-and-answer format. The Attitudes Toward

Mathematics Inventory (ATMI), created by Tapia and Marsh (2004), was also utilised. College mathematics examiners designed the pre-tests and post-tests on the topics of surface area and volume of geometrical objects to measure the performance of the two groups simultaneously. Semi-structured interview questionnaires, which included the tablet approach to learning mathematics and traditional textbook approaches, were developed and used during the interview process.

4.7.2 Data Collection Techniques

The three classes of Level 3 students at a TVET Campus were given a pre-test, which was conducted after using a traditional method of learning SAVOGOs to establish baseline scores for SAVOGOs performance. Following the collection of data, a post-test, which referred to a test administered after learning SAVOGOs using a tablet device, was conducted to collect quantitative data after analysing the pre-test results. This test was further used to assess the interconnection between learning performance and SAVOGOs among Level 3 mathematics students. A comparison was made between learning with a tablet and the traditional method of instruction. The results of students taught using the traditional method were compared to those of students taught using tablet devices in the learning of SAVOGOs. Additionally, students' attitudes towards SAVOGOs were compared between the use of tablet devices and the traditional teaching method of learning.

To gather qualitative data, semi-structured interview questionnaires focusing on the tablet approach to learning mathematics and the traditional textbook method were administered during the interview process with the participating students at the end of the quantitative data collection. To ensure the validity of this study, a survey was used to determine students' attitudes towards the learning of SAVOGOs. According to Tapia and Marsh (2004), the ATMI has been confirmed as the definitive instrument for assessing student attitudes in the learning of mathematics. Therefore, in this study, students completed the ATMI for both the traditional method and during the use of tablets to explore the impact of tablet devices on student attitudes in the learning of SAVOGOs.

4.8 DATA ANALYSIS AND INTERPRETATION

A mixed methods approach, according to Creswell and Clark (2023), gains its value when researchers analyse quantitative and qualitative data together. McMillan and Jones (2022) further emphasise that mixed methods allow for the insights from one method to inform the use of another. The focus of this study was on the notion of mixing or combining the two methods by following inferential quasi-experimental data analysis and interpretation. Descriptive statistics, according to Williams et al. (2022), are typically distinguished from inferential statistics. The author further emphasises that, with inferential statistics, researchers attempt to reach conclusions that extend beyond the immediate data alone, whereas with descriptive statistics, researchers are simply describing what is or what the data shows.

Inferential analysis, according to Williams et al. (2022), involves making predictions or inferences about the population based on the sample data. It requires statistical methods to estimate parameters (e.g., means, variances) and to test hypotheses. In addition, the Cronbach alpha coefficient was employed to assess the internal reliability of the quantitative data.

4.8.1 Analysing quantitative data

The study design compared the outcomes of the dependent variable, students' mathematics academic performance, and student attitudes between groups using the traditional method and those using tablet devices in the learning of SAVOGOs. Three groups of 20 students each participated in the study; they were first taught mathematics using traditional instruction and were later instructed using tablet devices. The procedures for analysing data quantitatively were as follows:

- Data preparation
- Data transformation
- Regression analysis
- ANCOVA application

i. Data preparation

After groups of students had completed writing the pre-test, post-test, and attitudes inventory, the collected data were organised. To ensure anonymity, all attributes, including students' names and identification numbers, were obscured. Once all the necessary information was collected, the data were entered into the Statistical Package for the Social Sciences (SPSS), a statistical analysis program. According to Creswell and Clark (2023), SPSS comprises a set of software programs used for editing and analysing various types of data. The primary application of this program is to analyse scientific data related to the social sciences. Additionally, the mean average was applied as a parametric test using ANCOVA, with measures of central tendency and t-testing employed to validate the hypotheses where the data appeared as standard.

ii) Data transformation

The transformation of data technique, according to Creswell and Clark (2023), is used to change the data format. Data formatting is used for coding the data in different ways. Data is coded so that it can be read, recognised, and used by different applications and programmes. Masoabi and Alexander (2021) assert that discriminable types of data can be inserted into SPSS and the structure changed as per the system requirements and specifications. This means that even if the operating system can be changed by the researcher, SPSS can still operate on old data. In this study, the attitude of students in mathematics was theoretically justified with a reliable instrument demonstrating content and construct validity of data (Eshetu & Wakuma, 2024). For example, Likert-type scales that range from “Strongly agree” to “Strongly disagree” were used as responses to the inventories that collected the data. In conducting the Cronbach's alpha reliability analysis, the Likert-type scale was treated as a continuous variable, a common convention in parametric diagnostic procedures applied to such instruments. Creswell and Clark (2023) also assert that Cronbach’s alpha is a statistical measure of internal consistency that evaluates how well a set of items measures the same underlying construct. It produces a value between 0 and 1, where higher values indicate greater reliability among the items. According to Williams et al. (2022), key interpretation points are follows:

- 0 → No correlation between items (completely unrelated).
- 1 → Perfect correlation (items are essentially identical in responses).

- Common benchmark: A value of 0.7 or higher is generally considered acceptable for reliability in many research fields.
- 0.7 – 0.8 → Acceptable/minimally reliable.
- 0.8 – 0.9 → Good reliability.
- Above 0.9 → Excellent reliability, but may indicate redundancy (items might be too similar).
- Above 0.95–0.99 → Often considered *too high*, suggesting that some items may be unnecessary duplicates.

The formulae to be used to calculate Cronbach's alpha reliability range, according to McMillan and Jones (2022), is $\propto = (\frac{K}{K-1})(\frac{S_y^2 - \sum S_i^2}{S_y^2})$. In this formula, K is the number of items we got, and since we have five items, K is going to be five (5). S_y^2 is the variance of the total scores and $\sum S_i^2$ stand for the individual variances, i.e. variance for Question 1, Question 2 and so forth, then we add them together. The table below shows the calculated value of the formula above. A dataset assessing students' attitude towards mathematics using a 5-point Likert scale (1 = Strongly Agree, 5 = Strongly Disagree) is presented below. There are 5 items and 60 respondents with S_y^2 representing the variance of the total scores and $\sum S_i^2$ indicating the individual variances, i.e. variance for Question 1, Question 2 and so forth, then they are added together using Excel. McMillan and Jones (2022) further highlighted important considerations that Cronbach's alpha measures reliability, not validity. A high alpha means items are consistent, but they might still measure the wrong construct. It assumes all items measure the same trait on the same scale.

This table-based calculation illustrates the practical estimation and interpretation of Cronbach's alpha, confirming the reliability of multi-item scales. Cronbach's alpha coefficient measures the internal consistency, or reliability, of a set of survey items. This statistic helps determine whether a collection of items consistently measures the same characteristic. Cronbach's alpha quantifies the level of agreement on a standardised 0 to 1 scale. Higher values indicate higher agreement between items. Cronbach's alpha values indicate that response values for each participant across a set of questions are consistent. For example, when participants give a high response for one of the items, they are also likely to provide high responses for the other items. This consistency indicates the measurements are reliable and the items might

measure the same characteristic. Conversely, low values indicate that the set of items does not reliably measure the same construct. High responses for one question do not suggest that participants rated the other items highly. Consequently, the questions are unlikely to measure the same property because the measurements are unreliable.

Table 4.1: Table scores for attitude towards mathematics

Students	Item1	Item2	Item3	Item4	Item5	TOTAL
S1	4	5	4	5	4	22
S2	3	4	4	4	3	18
S3	5	5	5	4	5	24
S4	4	4	4	4	4	20
S5	3	3	4	3	3	16
S6	4	4	5	4	4	21
S7	5	4	5	5	5	24
S8	4	5	4	4	4	21
S9	3	3	3	3	3	15
S10	4	4	4	4	4	20
S11	4	5	4	5	4	22
S12	3	4	4	4	3	18
S13	5	5	5	4	5	24
S14	4	4	4	4	4	20
S15	3	3	4	3	3	16
S16	4	4	5	4	4	21
S17	5	4	5	5	5	24
S18	4	5	4	4	4	21
S19	3	3	3	3	3	15
S20	4	4	4	4	4	20
S21	4	5	4	5	4	22
S22	3	4	4	4	3	18
S23	5	5	5	4	5	24
S24	4	4	4	4	4	20
S25	3	3	4	3	3	16
S26	4	4	5	4	4	21
S27	5	4	5	5	5	24
S28	4	5	4	4	4	21
S29	3	3	3	3	3	15
S30	4	4	4	4	4	20
S31	4	5	4	5	4	22
S32	3	4	4	4	3	18
S33	5	5	5	4	5	24
S34	4	4	4	4	4	20
S35	3	3	4	3	3	16
S36	4	4	5	4	4	21
S37	5	4	5	5	5	24
S38	4	5	4	4	4	21
S39	3	3	3	3	3	15
S40	4	4	4	4	4	20
S41	4	5	4	5	4	22
S42	3	4	4	4	3	18
S43	5	5	5	4	5	24
S44	4	4	4	4	4	20
S45	3	3	4	3	3	16
S46	4	4	5	4	4	21
S47	5	4	5	5	5	24
S48	4	5	4	4	4	21
S49	3	3	3	3	3	15
S50	4	4	4	4	4	20
S51	4	5	4	5	4	22
S52	3	4	4	4	3	18
S53	5	5	5	4	5	24
S54	4	4	4	4	4	20
S55	3	3	4	3	3	16
S56	4	4	5	4	4	21
S57	5	4	5	5	5	24
S58	4	5	4	4	4	21
S59	3	3	3	3	3	15
S60	4	4	4	4	4	20
						8,430508
Varience	0,498305	0,498305	0,366102	0,40678	0,498305	2,267797

The table above indicates the score for attitude towards mathematics. The table was used to calculate Cronbach's reliability range. The formula below indicates the calculation of Cronbach's alpha reliability range.

$$\propto = \left(\frac{K}{K-1}\right)\left(\frac{S_y^2 - \sum S_i^2}{S_y^2}\right)$$

$$= \left(\frac{5}{4}\right)\left(\frac{8.430508 - 2.267797}{8.430508}\right)$$

$$= 0,913752$$

A Cronbach's alpha of 0.914 indicates a strong correlation among the scale items,, suggesting that they measure a cohesive construct. This level of internal consistency is generally considered acceptable for this academic research, allowing the researcher to confidently use the scale for drawing conclusions.

To complete this research properly, the data were interpreted in an inferential form, and it was imperative to analyse the collected data for testing the hypothesis and answering the questions in this study. This section includes the interpretation, presentation, and analysis of the findings resulting from this research study. The interpretation and data analysis were conducted in two stages. Part 1 focused on the questionnaire results and dealt with a quantitative analysis of the data. Part 2 involved a qualitative interpretation of the results from the conducted interviews.

iii) Regression Analysis (RA)

McMillan and Jones (2022) assert that regression analysis (RA) is used to comprehend the relationship between dependent and independent variables that are stored in a data file. In this study, the results of students instructed using the traditional teaching method were compared with those of students instructed using tablet devices in learning SAVOGOs. RA also emphasises how changes in the merit of an independent variable can impact the dependent variable. In this study, the tablet device influenced the dependent data collected after using the traditional textbook method. It should be noted that the fundamental purpose of regression analysis is to understand the relationship between different variables. Furthermore, the focus of regression analysis in this study was to comprehend the relationship between the traditional method and the tablet method in learning SAVOGOs.

In this study, regression analysis was used to estimate the relationships between a dependent variable, often called the outcome or response variable and one or more independent variables, also known as predictors or features. In this study, the dependent variable is performance after intervention (post-test), and the independent variable is the method of study. The most common form of regression analysis is linear regression, which aims to find the line (or a more complex linear combination) that best fits the data according to a specific mathematical criterion.

iv) ANOVA Assumptions

Analysis of variance (ANOVA), according to Creswell and Clark (2023), can help the researcher determine which method is more appropriate for accomplishing a task. In particular, using ANOVA in this study, the researcher discovered the feasibility and efficiency of the tablet method by comparing the results between the traditional textbook method and data collected after using the tablet device. Sundrani (2025) further assert that it is a statistical approach to contemplate events, processes, or groups, and to identify the variance between them. For a covariate to be suitable for analysing data, a reasonable correlation between the covariate and the dependent variable should be established. A covariate, according to Mullis and Kelly (2022), refers to the traditional method and the use of tablet devices, whereas the dependent variable refers to students' mathematics performance and student attitudes. Creswell and Clark (2023) further note that before running an ANCOVA, a data analysis test and a series of assumptions must be met. In this study, the following passage will comprehensively describe the assumptions related to (1) sample size, (2) outliers, (3) linear relationships, and (4) homogeneity of regression slopes.

Sample size

According to Sundrani (2025), employing a one-way ANCOVA analysis requires the size of the treatment group and the control group to be similar in size. In this study, with 20 students in each of the three control groups and the same three treatment groups with 20 students each to be used after the intervention, the sample size requirements for the one-way ANCOVA were met.

(1) Outliers

Prior to running an ANCOVA, it is necessary to examine the data to determine whether there are any significant outliers. If the data set contains outliers, they could negatively affect the testing, reducing the accuracy of the results. In this study, an outlier was defined as a data point that deviates significantly from the remaining observations, potentially reflecting measurement variability or experimental error. After an outlier was observed in this study, it was never excluded from the data set, as doing so could cause serious problems in statistical analyses. To mitigate the effect of the outlier, the researcher compared the minimum and maximum scores with the standard deviation

and the mean value. Standard deviation in this study was a measure of how spread out the numbers were, indicating how far one was from the mean. It also served as a means of outlier detection and removal using z-scores. Furthermore, the researcher employed a threshold of three standard deviations to identify outliers. Specifically, the mean plus three standard deviations determined the upper limit, and any value exceeding this limit was marked as an outlier. The lower limit was calculated as the mean minus three standard deviations.

The interpretation of the lower limit was that any value less than this limit would be regarded as an outlier. After identifying outliers, they needed to be removed statistically. A z-score was also calculated to indicate how many standard deviations a value is from the mean. The formula for z-scores was observed and used. The calculated z-score facilitated the creation of a new column in the data frame, which was generated using a statistical formula. From there, the researcher filtered out the rows with a z-score of three or below. As a result, the researcher was able to identify the number of outliers that needed to be statistically filtered and removed. The researcher then used the new data frame to plot a histogram for the generated data and subsequently drew a bell curve on the same histogram.

3) Linear relationship

A linear relationship must exist between the covariate and the dependent variable to properly use ANCOVA analysis (Alexander & Masoabi, 2021). Through the SPSS test of linearity, the relationship between the pre-test and post-test mathematics scores must be linear at a statistically significant level. Based on the mathematics test of linearity, the probability of the test statistic must be less than the diagnostic alpha value of 0.05. The null hypothesis mentioned in Section 4.4, which stated that there was no variation in attitude when a cohort of Level 3 students learned SAVOGOs using a tablet compared to when they did not, was rejected, indicating that the assumption of linearity was met. In this study, the calculated t-value (t-test), degree of freedom (df), p-significance value, and the difference between means were used to reject or falsify the null hypothesis. The null hypothesis stated in Section 4.3 indicated the opposite of the mathematical results expected by the researcher; that is, it was contrary to the alternative hypothesis.

The calculated statistically significant relationship was used to argue that there was no relationship between performance and attitude when a cohort of TVET Level 3 students calculated SAVOGOs. In this study, TVET Level 3 students calculated SAVOGOs using tablet devices as opposed to the traditional textbook method. If the p-value of the hypothesis test was less than the significance level (e.g. $\alpha = .05$), then the null hypothesis was rejected. After rejecting the null hypothesis, the researcher concluded that there was sufficient evidence to state that the alternative hypothesis was true. In this study, the alternative hypothesis stated that groups of TVET Level 3 students calculating SAVOGOs using tablet devices improved performance and attitude compared to the traditional textbook method.

In summary, when the expression was observed in this study, it reflected a statistically significant relationship between performance, attitude, and the use of tablet devices. Statistically significant meant that the mathematics pre- and post-test results obtained were statistically significant and acceptable. In this study, we rejected the null hypothesis. Emphasising this statement, the researcher concluded that there was sufficient evidence to accept the alternative hypothesis mentioned in Section 4.3, stating that “Groups of TVET Level 3 students calculating SAVOGOs using tablet devices improved performance and attitude compared to the traditional textbook method.” In this study, sufficient evidence to accept the alternative hypothesis means that the directional hypothesis is true. This indicates that the relationship was considered statistically significant, and the results obtained were accepted as statistically significant.

4) Homogeneity of regression slopes

Homogeneity of regression slopes suggests that the slopes between the covariate and the dependent variable were similar across the experimental and control groups. In this study, covariate variables referred to the results after using the traditional method and the tablet devices, whereas the dependent variable referred to students’ mathematics performance and attitudes. Additionally, the experimental group referred to students’ mathematics performance and student attitudes, whereas the control group referred to the use of the traditional method and tablet devices. This homogeneity indicated that there was no interaction between the independent and

covariate variables. To meet the assumption, there needs to be no significant interaction between the covariate, which was the traditional method, and the use of tablet devices, together with the post-assessment scores.

If a significant interaction were evident, it would be unsuitable to use the ANCOVA analysis because the correlation between the pre-test scores and the dependent variable, students' mathematics performance and student attitudes towards mathematics would differ for all combinations of the factors. Should the calculated values fail to reject the null hypothesis, it would indicate that there is homogeneity of regression slopes. According to Mullis and Kelly (2022), to control for the possible effects of a confounding variable, the one-way ANCOVA was necessary to analyse the comparison based on the covariate variable of the pre-test results.

In this study, the scores on the pre-test after using the traditional method of learning were used as the covariate variable to regulate all pre-existing differences between the groups. The one-way ANCOVA test was used to compare the differences in the mean of the dependent variable among the same groups at different stages while controlling for the pre-test differences. Interpreting the results of the ANCOVA analysis revealed whether there was a statistically significant difference between the group means. If the p-value or significance level, according to Mullis and Kelly (2022), was below 0.05, the results were interpreted as statistically significant, meaning that it would be unlikely to occur in the sample if there were no effect in the population. A larger p-value would mean that the data do not provide a reason to conclude that the means differ.

To address the second research question regarding the effect of tablet devices on student attitudes, a t-test was employed to compare the means of the dependent variable, students' attitudes, between the two groups, as the assumption of normality was met. Only two different approaches were compared, which means that the t-test was an applicable method to analyse the data. Furthermore, the t-test is designed to identify any significant difference between two approaches on a continuous variable. This test assessed whether the means of the two learning methods were statistically different from each other. Additionally, the t-test was appropriate for the use of continuous dependent variables in this case, students' attitudes and performance in

learning mathematics. The t-test addressed the research question by comparing the means of the two learning methods in one group, referring to the students learning with the devices and the students without the devices. The test helped to determine whether there was a statistically significant difference in the mean scores between the two learning methods, which can be representative of the population.

Mullis Kelly (2022) asserts that for t-tests, samples must be randomly selected from the population. However, due to the difficulties of random sampling in educational research, studies have found that the t-test is quite robust despite violations of these assumptions. If the assumption of normality was not met, non-parametric tests would be used. Interpreting the results of the t-test revealed whether the group means were significantly different. When reporting the result of an independent t-test, the researcher included the t-statistic value, the degrees of freedom (df), and the significance value of the test (p-value). Additionally, the researcher considered the difference between means. The format of the test result was t(df) = t-statistic, p = significance value. Therefore, for the example above, the researcher reported the result as t(7.001) = 2.233, p = 0.01 and rejected the null hypothesis since $p<0.05$, that is, $0.01 < 0.05$, as observed in the above example. In this study, the null hypothesis "There is no variation in performance and attitude when a cohort of TVET Level 3 students calculate SAVOGOs using tablet devices as opposed to the traditional textbook method" was rejected since the significance level is less than 0.05.

Looking at the p-value or significance level disclosed whether the difference found in the sample of 60 mathematics students was related to a difference in the population of 120 mathematics students. Mullis and Kelly (2022) further emphasise that the smaller the significance level, the less likely there would be a difference in the sample if there were no difference in the population. If a statistically significant relationship was evident, the p-value should be as small as possible. For example, it could be $0.01 < 0.05$. The significance level should fall below the cut-off point of 0.05 if the values found are very unlikely to occur when there is no difference in the population.

4.9 Linear regression from SPSS showing summary of findings

Table 4.2: Linear regression results

Regression

Descriptive Statistics

	Mean	Std. Deviation	N
PostTest	19,9667	8,61604	60
Pretest	12,5167	7,60796	60

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,978[a]	,957	,957	1,79543

a. Predictors: (Constant), Pretest

b. Dependent Variable: PostTest

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4192,966	1	4192,966	1300,718	<,001[b]
	Residual	186,968	58	3,224		
	Total	4379,933	59			

a. Dependent Variable: PostTest

b. Predictors: (Constant), Pretest

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	6,097	,449		13,579	<,001	5,199	6,996
	Pretest	1,108	,031	,978	36,065	<,001	1,047	1,170

a. Dependent Variable: PostTest

Table 4.2 above is from SPSS showing findings to interpret H1 using $(\beta) = 1.109,\ R^2$ =,957, F= 1300.718 and $P - value\ < .001$.This indicates that the hypothesis 'Groups of TVET L3 students calculating SAVOGOs using tablet devices improved performance and attitude as opposed to the traditional textbook method of learning' is supported.

Table 4.3: Summary of findings from SPSS

Hypothesis	Regression Weight	Beta Coefficient (β)	R^2	F	P-Value	Hypothesis Supported
H_1	$Post \rightarrow Pre$	1,108	.957	1300.718	$< .001$	Yes

Table 4.3 is a simple summary of 4.2, indicating that the hypothesis is significantly supported since $P - value < .001$. The F-statistic of 1300.718 suggests that there is a strong relationship between the independent variable (tablet device/method of study) and the dependent variable (post-test performance).

The following regression outputs were calculated from SPSS by the researcher.

Here is a step-by-step interpretation:

1. F-Statistic ($F = 1300.718$)

- The F- statistic measures overall model significance, testing whether at least one predictor variable explains a significant portion of variance in the dependent variable.
- Given that F is very high (1300.718), which indicates that the regression mod el fits the data extremely well relative to a model with no predictors (null model).

2. P-value ($P < 0.001$)

- The p-value associated with the F- test or individual coefficients tests the null hypothesis. H_0: "coefficient"=0 (no effect).
- A p- value less than 0.001 means there is less than 0.1% probability that the observed relationship is due to random chance.
- Interpretation: We can reject the null hypothesis with high confidence, concluding the predictor reliably explains variation in the dependent variable.

3. R-squared ($R^2 = 0.957$)

- R^2 represents the proportion of variance in the dependent variable explained by the model.
- Here, $R^2 = 0.957$ means 95.7% of the variability in the dependent variable is accounted for by the predictor(s).
- This is exceptionally high and indicates a very strong model fit.

4. Beta Coefficient ($\beta = 1.108$)

- The Beta coefficient quantifies the change in the dependent variable for each one- unit change in the predictor, holding other variables constant (if multiple regression)
- Interpretation: For every one-unit increase in the independent variable, the dependent variable increases on average by 1.108 units.
- The positive sign of β indicates a positive relationship.

Combined Interpretation

- The regression model appears highly significant and predictive, with the indep endent variable(s) strongly associated with the outcome.
- Statistically: F-test and p-value: Shows the model is reliable, R^2: Indicates almost all variability in the outcome is explained, and Beta: Indicates a positive and substantial effect size.
- Practically, this suggests a strong and meaningful relationship, not merely stat istically significant.

Interpretation: The model is statistically strong, explains almost all variability, and the independent variable has a substantial positive effect on the dependent variable.

Statistically significant

The results provided in Tables 4.2 and 4.3 indicate that the hypothesis of post-test performance influenced by the tablet device/method of study is statistically significant. The F-statistic of 1300.718 suggests that there is a strong relationship between the independent variable (tablet device/method of study) and the dependent variable (post-test performance). The p-value of less than 0.001 indicates that this relationship is statistically significant, meaning that the influence of the tablet device on the post-

test performance is likely real and not due to random chance. The R-squared value of 0.957 indicates that 95.7% of the variance in the post-test performance can be explained by the independent variable, tablet device/method of study. The beta coefficient of 1.108 suggests that for every unit increase in tablet device usage, the post-test performance increases by 1.108 units. This information is crucial for understanding the impact of the tablet device on the post-test performance and for making informed decisions based on the results.

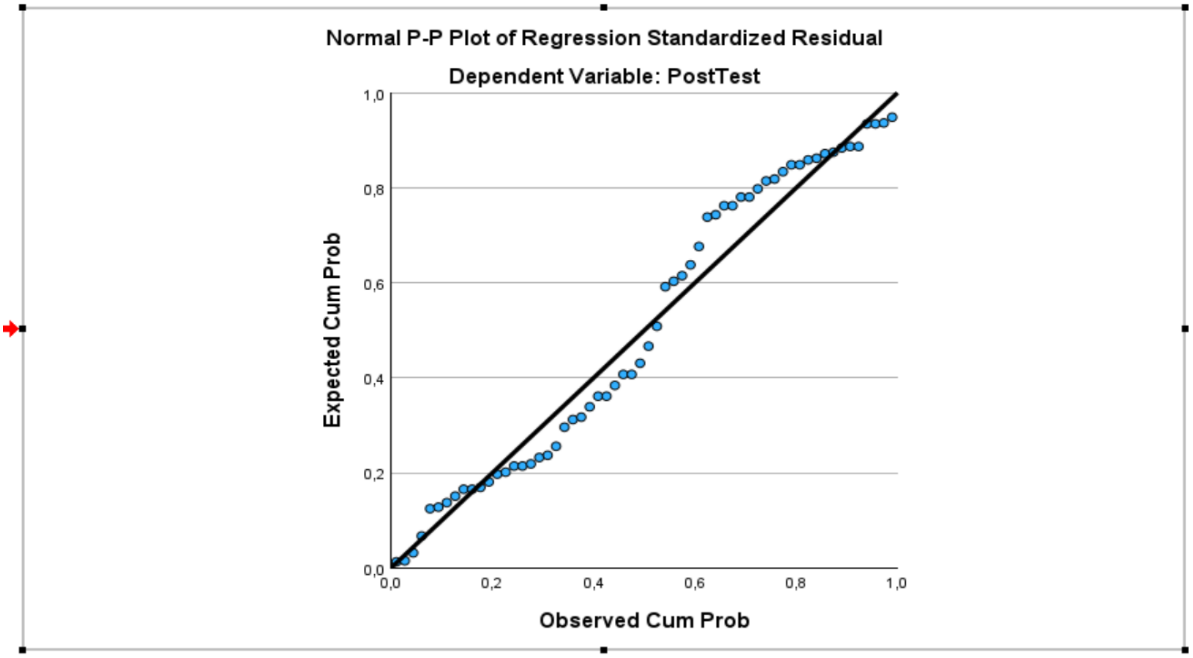


Figure 4.1: Normal plot of regression analysis

4.9.1 Qualitative data analysis

The quantitative and qualitative databases were analysed separately in this study. The analysis followed a two-phase approach, first analysing the quantitative data as the first phase and then the qualitative data as the second phase. In this study, the quantitative results were used to plan the qualitative follow-up semi-structured interview questions. One important area is that the quantitative results can inform not only the sampling procedure but also the types of qualitative questions to ask students in the second phase. The semi-structured interview questions, like all good qualitative research questions, were general and open-ended.

Qualitative research explores and provides a clearer understanding of the challenges related to mathematics performance in a more complex way than the generalised results from pre- and post-test questionnaires in mathematics. This approach was used to gain insights into how students feel, think, and act, as well as about the mathematical information they possess. Engelbrecht and Borba (2020) recommended a preparatory analysis process outlining five steps to analyse data: (i) preparing raw data transcription, with the researcher duplicating the data and formulating basic codes for recognised themes; (ii) reading the text closely to gain knowledge and awareness of the themes from the content; (iii) generating categories and coding; (iv) reducing overlapping coding; and (v) formulating ideas about experiences that are noticeable in the text. In this study, thematic analysis was the approach used to analyse qualitative data. It applied to a set of texts, such as transcripts from the semi-structured interviews. The researcher subsequently examined the data to distinguish common topics, themes, ideas, and thoughts of meaning that emerged frequently.

The qualitative data analysis occurred in three phases. Phase 1 included the researcher transcribing the data from the mathematics students' interviews and creating initial codes for recognised themes. Phase 2 incorporated previously categorised and coded data to establish and refine categories and generate new interpretations. The final segment of the qualitative data analysis comprised making sense of the central ideas that emerged from the data. Coding strategies for each phase are discussed in subsequent paragraphs. To initially analyse the data, interview results were transcribed, read several times, and coded to identify patterns and common themes that emerged. Creswell and Clark (2023) define codes as words or short phrases that symbolically assign a summative, salient, essence-capturing, and/or evocative attribute to a portion of language-based or visual data. The codes used were derived from the categories or themes evident in the text. Moreover, Creswell and Clark (2023) assert that this method was used to examine the data for descriptive purposes, identifying common themes recurring in the interviews. The codes assisted in identifying concepts that appeared likely to help in understanding and addressing the questions in this research study.

Phase 2 of coding the interview transcripts grouped codes from the first phase to create categories and relationships between the initial codes. Moreover, the interview

data were further organised to ensure that all categories and codes were relevant and significant in addressing the objectives of the research study, as stated in Paragraph 4.3.2. The most central themes emerging from the data were utilised to examine the research questions stated in Paragraph 4.4. Phase 3 of the qualitative data examination made sense of the first two phases of analysis. According to Engelbrecht and Borba (2024), this phase focused on creating significant themes to generate meaning from the mathematics students' interview data. Furthermore, Engelbrecht and Borba's (2024) general inductive analysis was conducted in this third phase to derive greater generality from the raw data categories to make conclusions.

Moreover, this phase focused on the central ideas that emerged from the participating mathematics students' interviews and how this data related to the theoretical framework, the ABC model structuring this study. The concepts that emerged from this third phase helped to further understand the context surrounding the tablet integration experience as it relates to students' performance and attitudes. A document analysis form was used to review answer scripts for Level 3 students that were related to the research questions. The participating students' answer scripts were collected to gain additional information about how their approaches to answering questions were adapted to incorporate technology used to support the integration of tablet devices.

4.10 THE DATA PRESENTATION PROCESS

To explain the complexity of the process by which the TVET college implemented tablet instruction in a mathematics classroom, a triangulation method was used to understand the impact tablets had on student performance and attitudes towards mathematics. Triangulation, according to Creswell and Clark (2023), is an effort to explore and explain complex human behaviour using a variety of methods to offer a more balanced explanation to readers. It is also a procedure that enables the validation of data and can be used in both quantitative and qualitative studies. In this study, triangulation of different data sources was employed by collecting both quantitative and qualitative data. Academic performance was measured using pre-tests and post-tests, followed by semi-structured interviews. Students' attitudes were evaluated using the Attitudes towards Mathematics Inventory (ATMI) tool. The main

study began with the transcription of interview texts, followed by coding and categorising them, and finally formulating themes.

After all the interviews with the six participants were conducted, they were listened to by the researcher and then transcribed verbatim. This was followed by a process of reading and re-reading the transcripts. The same process was applied to analysing the responses from the Attitudes towards Mathematics Inventory completed by students, as well as to interpreting the scripts of the tests they wrote. The notes recorded and documented from the interviews, the Attitudes towards Mathematics Inventory, and the tests students took were highlighted for important information in view of the coding process that began thereafter. Coding, according to Creswell and Clark (2023), is a qualitative data analysis strategy in which some aspect of the data is assigned a descriptive label that allows the researcher to identify related content across the data.

Initially, 125 different codes were identified, and eventually, only about 80 of those codes were deemed significant. Next, the process of identifying patterns and categories began, resulting in eighteen categories. Through careful analysis and consideration of all the data, eight broad themes were identified.
The themes identified were:

- Enhanced contingencies that improved students' performance and attitude in learning SAVOGOs.
- Reflections on determining the best method for learning and attempting SAVOGOs questions.
- Promotion of problem-solving skills through collaboration.
- Personal fulfilment and happiness, as well as improvement and empowerment of students.
- Students' role, contributions and participation in the use of TD at TVET colleges.
- Challenges students are likely to encounter when learning SAVOGOs with TD at TVET colleges.
- The future of TD in the TVET sectors when learning SAVOGOs.

- The need for the participation and involvement of college lecturers at TVET colleges when students are learning SAVOGOs with TDs. See Table 4.4 in the appendices.

Table 4.4 indicates abbreviated codes yielded matching categories, a summary of subthemes and finally eight themes used in this study. They were all found from the interviews conducted with the six participants, followed by a process of reading and re-reading the transcripts and listened to by the researcher as well as transcribed verbatim. The same process was applied to reading and interpreting the responses to the Attitudes towards Mathematics Inventory that students completed, as well as analysing the scripts that the test students wrote. The notes recorded and documented from the interviews, the Attitudes towards Mathematics Inventory, and the tests students took were highlighted for important information in view of the coding process that began thereafter. Coding, according to Creswell and Clark (2023), is a qualitative data analysis strategy in which some aspect of the data is assigned a descriptive label that allows the researcher to identify related content across the data. Initially, 125 different codes were identified, and eventually, only about 80 of those codes were deemed significant. Next, the process of identifying patterns and categories began, resulting in 18 categories. Through careful analysis and consideration of all the data, eight broad themes were identified as indicated in Table 4.4. See Appendix D. Below is a diminution example of how the researcher moved from codes, categories and finally to themes.

Table 4.5: An illustration of the researcher's progression from codes to categories to themes

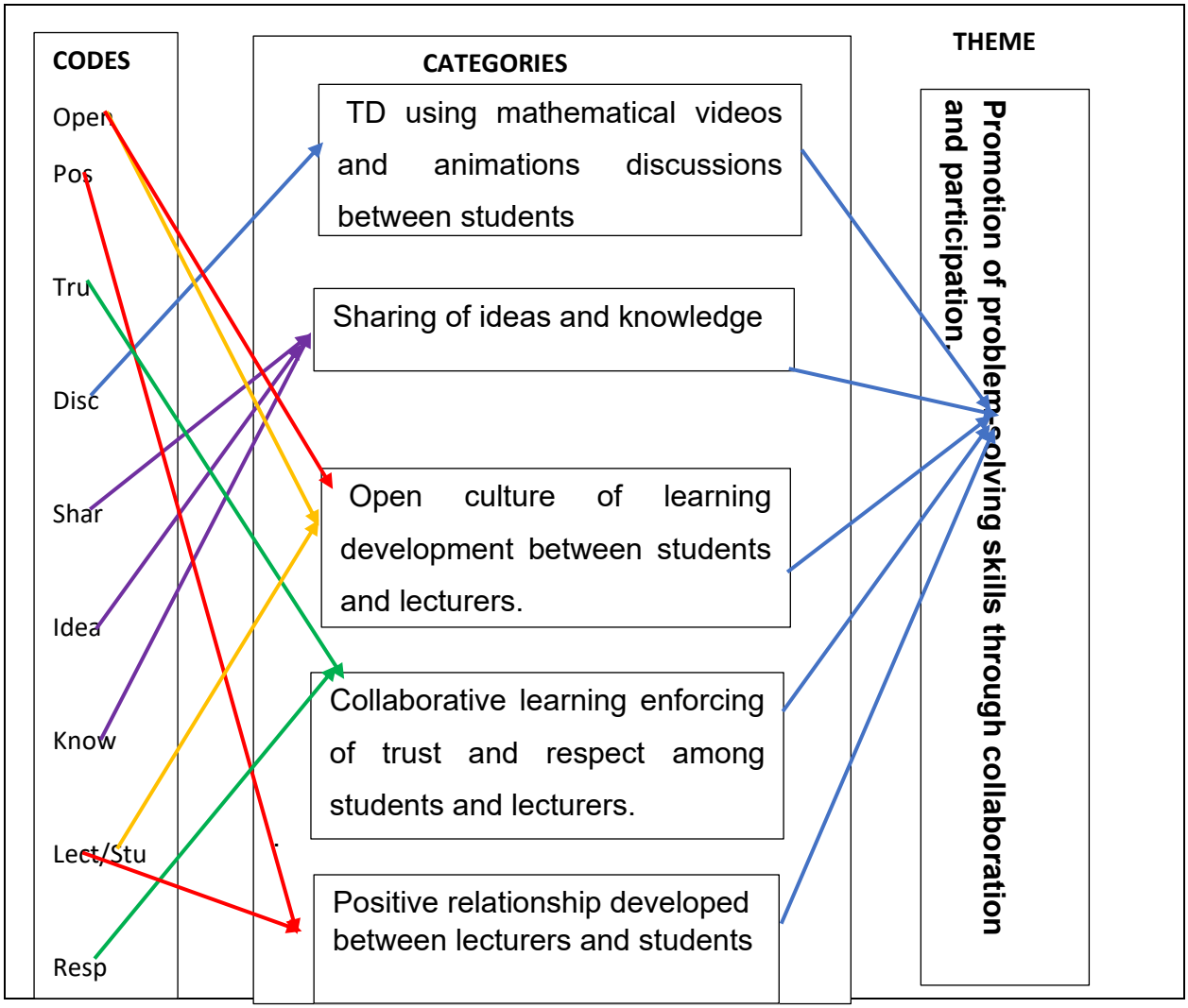


Table 4.5 is an example of how the researcher moved from codes to categories and finally to themes. As explained above, after identifying codes, the researcher recognised patterns to establish categories, which were subsequently abstracted into themes.. For example, codes: share, idea, and know were clustered for a category “Sharing of ideas and knowledge”, and finally, all the categories merged to the theme “Promotion of problem-solving skills through collaboration and participation.” The above Table 4.5, is a schematic illustration of the process followed to get the eight themes used in this study.

4.11 METHODOLOGICAL NORMS

Reliability and validity, as described by McMillan and Jones (2022), are two main aspects of credibility and trustworthiness that researchers and various stakeholders can employ to validate the correctness of a study. In this research, a mixed-method approach was used to assess the quality and rigour of the data collection instrument. However, for qualitative research, it is also necessary for the researcher to include a section on credibility to evaluate the quality and rigour of this aspect of the study. The purpose of validity and reliability is to measure the quality and rigour of quantitative research. Rigour, according to McMillan and Jones (2022), refers to academic relevance and critical thinking skills, such as interpreting and analysing mathematical data. During the analysis of mathematical data in this study, the researcher made connections between historical periods and current events, using both primary and secondary sources. The goal was to support an argument or position and arrive at a novel interpretation of a historical event after conducting extensive research on the topic of this study.

For the quantitative part, the researcher employed reliability and validity to measure the quality of the study. In contrast, for the qualitative part, the researcher utilised credibility and trustworthiness to assess the quality and rigour of the study. Consequently, this study considered the trustworthiness criteria for qualitative research, as suggested by Sundrani (2025), including credibility, confirmability or auditability, dependability, and transferability or fittingness.

4.11.1 Validity and reliability for a quantitative study

4.11.1.1 Validity

According to McMillan and Jones (2022), validity concerns whether the research is credible and accurate, and whether it assesses what it is intended to examine. Similarly, Borba et al. (2025) emphasise that validity is a primary criterion for evaluating the attributes and acceptability of research. In quantitative research, validity measures how accurately the study answers the questions and hypotheses it was commissioned to address, as outlined in Paragraph 4.3 of this chapter. For research to be deemed credible and to ensure there is no uncertainty regarding the integrity of

the data, it is essential to achieve high validity. In this context, a test refers to a standardised instrument used to assess the research questions in Paragraph 4.3. One type of test employed in this study is a questionnaire, which is a set of questions formulated and designed by the researcher to extract crucial Level 3 mathematical information about SAVOGOs from students. In this case, the most appropriate tests were Level 3 mathematical questionnaires and interviews about SAVOGOs, which aimed to establish the actual Level 3 mathematical information on the ground.

Instrument validation is a series of processes performed according to a specified procedure to verify whether an instrument meets the expected quality standards. Conversely, Creswell and Clark (2023) believe that the following heterogeneous procedures can be used to justify the instruments and the data: content validity, internal validity, utility criterion, and external validity.

i. Content validity

Content validity, according to Creswell and Clark (2023), is related to a type of validity in which different elements, skills, and behaviours are adequately and effectively measured. For content validity, the research instruments and the data were reviewed by experts in the field of research. Masoabi and Alexander (2021) assert that, based on the reviewers' comments, the obscure and unclear questions were amended and the difficult items reworded. Also, McMillan and Jones (2022) assert that the ineffective and non-functioning questions can be discarded altogether. In this study, content validity was accomplished using a pre- and post-tests on the topic of SAVOGs, administered to measure student performance before and after the intervention. The two tests administered to a group of students were developed by the researcher in collaboration with campus mathematics examiners and experts who set college assessments and internal examinations. For validity, the tests were given to five students from the population, not from the sample. In this study, students reported that the test was too long, so the researcher shortened it. In addition, the report stated that the test was complicated because students did not understand the phrased words; therefore, the researcher simplified the test. Moreover, another report by the students indicated that the test was not testing performance in SAVOGOs only, but rather was testing other Level 3 mathematics content. In this case, the researcher noticed students' lack of understanding of the relations between the slant height (h_s),

perpendicular height ($h_{\perp}$) and the base edge (l) for square, triangular and hexagonal pyramids. Thereafter equations like $h_s^2 = h_{\perp}^2 + \frac{1}{4}l^2$ for the square pyramid was explained again to students by their lecturer to indicate that it might look like a Pythagorean Theorem $a^2 + b^2 = c^2$ for a right-angle triangle, but the one for a square pyramid assists in calculating the missing side or information for a square pyramid only. In addition, the lecturer made it clear to students that Pythagoras Theorem $a^2 + b^2 = c^2$ for a right-angle triangle, is still part of SAVOGOs as it is used to calculate the missing sides only for a right-angle triangle. Furthermore, the lecturer emphasised that these three equations $h_s^2 = h_{\perp}^2 + \frac{1}{4}l^2$ for square pyramid, $h_s^2 = h_{\perp}^2 + \frac{1}{12}l^2$ for the triangular pyramid and $h_s^2 = h_{\perp}^2 + \frac{3}{4}l^2$ for hexagonal pyramid, explain the relationship between $h_s, h_{\perp} and\ l$ only for all three pyramids. Then, after this exercise, the test was reported as content valid.

ii. Internal validity

In this study, internal validity refers to the extent to which the researcher can assert that no other variables, apart from the one being studied, caused the results. For example, the researcher should be able to conclude that learning mathematics using tablet devices improved performance in mathematics, as opposed to the traditional textbook method. The researcher must assert that no other factors contributed to the improved performance in mathematics, aside from the use of the tablet device. Additionally, the researcher should be able to conclude that learning with the tablet device alone enhances students' performance in mathematics. Internal validity in this study also encompasses the method of verifying cause-and-effect relationships between the test situation and the research outcome. It refers to the research's ability to rule out other potential causes for a result. In this study, the researcher eliminated other possible explanations for the findings to ensure internal validity.

Furthermore, the study met the following three requirements, leading the researcher to presume a cause-and-effect relationship: Firstly, there is a simultaneous change in the cause (the use of the tablet device in learning mathematics) and the effect (improved performance in mathematics). Secondly, regarding time, the cause precedes the effect, as improved performance in mathematics results from the use of

tablet devices. Thirdly, there are no other plausible explanations for the correlation found in the study, other than the dependent and independent variables mentioned above. Finally, to enhance the internal validity of the research data and instruments, the researcher employed the following six approaches recommended by Bara (2023): member checks, triangulation, long-term observation at the research site, peer examination, participatory or collaborative modes of research, and addressing the researcher's bias.

- *Member check*

In qualitative research, according to Creswell and Clark (2023), a member check, also known as informant feedback or respondent validation, is a technique used by researchers to improve the accuracy, credibility, validity, and transferability or fittingness of a study. In this study, member checking was conducted during the interview process through three interview styles to promote discussion between the students and the researcher.

The first style, confrontation, is effective only when there is a trusted, warm, and open relationship between the lecturer and students. In this study, the lecturer strived to build rapport with the students to obtain honest and open responses. During an interview, the lecturer restated or summarised information and then questioned students to determine accuracy. This style encouraged discussion, empowering students to confidently defend their views when challenged.

The second style, dialogue and power, focused on the inherent power struggle between the lecturer and the students. In this study, the lecturer was aware of this imbalance of power and promoted student discussion by valuing their opinions and reinforcing equal collaboration between the two.

Member checks were also carried out verbally throughout the interviews. The lecturer constantly checked their understanding of the phenomenon by utilising techniques such as paraphrasing and summarising for clarification. It was best for the lecturer to ask permission to revisit the students at the time of the semi-structured interviews. Interviews allowed students to express their emotions and thoughts about their experiences in learning mathematics and provided the lecturer with a better

understanding of the situation. Member checks were also conducted at the conclusion of the study to enhance its credibility and validity. In addition, member checks completed after the study involved sharing all findings with the students and the lecturer involved. This allowed both students and the lecturer to critically analyse and comment on the findings. The students either affirmed that the summaries reflected their views, feelings, and experiences or indicated that they did not. In this study, the students affirmed the accuracy and completeness of the findings, which contributed to the study's credibility. In conclusion, the lecturer restated and summarised information and then questioned the students to determine accuracy. During this process, the students either confirmed that the summaries reflected their views, feelings, and experiences in learning mathematics or stated that they did not. Although these member checks were not without fault, they served to decrease the incidence of incorrect data and misinterpretation in this study. The overall goal of this process was to provide findings that were authentic, original, and reliable.

- *Triangulation*

According to Creswell and Clark (2023), triangulation is a method used to increase the credibility and validity of research findings. In addition, Bara (2023) asserts that credibility refers to trustworthiness and how believable a study is, emphasising that validity concerns the extent to which a study accurately reflects or evaluates the concepts or ideas being investigated. Creswell and Clark (2023) further assert that triangulation involves combining theories, methods, or observers in a research study, ensuring that fundamental biases arising from the use of a single method or observer are overcome. From the researchers' perspective, triangulation is an effort to help explain the complex attitudes of students in learning about SAVOGOs by using a variety of methods to offer a more balanced explanation to readers.

Moreover, Creswell and Clark (2023) assert that triangulation is a procedure that enables the validation of data and is used in both quantitative and qualitative studies. In this study, to ensure that triangulation was observed, a quantitative survey was followed by several qualitative semi-structured interviews with students. For example, the interview results with Level 3 mathematics students were compared and cross-checked with pre- and post-test results in Level 3 mathematics written by students, as well as records of ATMI completed by students. The researcher believed that mixing methods was a form of triangulation in research that mitigated the weaknesses found

in a single method. The first research method involved questionnaires in the form of pre-tests and post-tests completed by students. The second research method consisted of semi-structured interviews with students to determine their perceptions of the use of tablets compared to traditional methods of learning. Data from the interviews were analysed, and draft themes arising from the analysis were forwarded to the students for their feedback. After the lecturer completed observations with students regarding their attitudes towards learning about SAVOGOs, an observation report was generated and subsequently shared with students for their feedback. Finally, the Attitudes Towards Mathematics Inventory was administered to students to measure their attitudes towards mathematics, and the data were analysed using the Statistical Package for the Social Sciences.

There were five different types of triangulations explained briefly in this study. The first was data triangulation, which employed a variety of information or data sources to increase the validity of the results. Theory triangulation was the second type, involving the use of different theoretical perspectives to make inferences about a distinct set of data. This method was the most difficult and time-consuming. The third type was investigator triangulation, where several investigators were involved in the analysis process. The findings of each were then compared to develop a better understanding of how each investigator viewed the data collected. In this study, the findings were similar, and this similarity heightened confidence in the study.

Environmental triangulation was the fourth type, employing the use of environmental triangulation, limited to studies where the findings can be influenced by certain environmental factors. This type of triangulation uses different settings, locations, and other factors such as time, day, and season in which the study took place. In this study, students were grouped at the beginning of the Level 3 academic college year to form heterogeneous groups of 20 students in a lecture room. Three groups of 20 students each were taught by the same lecturer, but in different lecture rooms. To mitigate the environmental factors in this study, the lecture rooms were identical in terms of resources, and students were taught by the same lecturer.

The last type was methodological triangulation, which used different qualitative and quantitative methods to check for the consistency of the findings generated. In this

study, different methods yielded the same results, leading to the conclusion that validity was established. While this method is popular, it consumes time to analyse information yielded from different methods. In this study, methodological triangulation involved using more than one method to study the impact of using tablet devices in studying SAVOGOs as opposed to traditional learning methods. Furthermore, methodological triangulation in this study was found to be beneficial in confirming findings, more comprehensive data, increased validity, and enhanced understanding of the phenomena studied. To ensure methodological triangulation, the collected qualitative data complemented and clarified the quantitative findings by helping to identify common themes. Qualitative data also aided in understanding mathematical interventions for promoting 'pulling' factors and overcoming 'pushing' factors among Level 3 mathematics students. Moreover, in this study, methodological triangulation was used to enhance the analysis and interpretation of findings. As data were drawn from multiple sources, it broadened the researcher's insight into the different issues underlying the phenomena being studied.

Long-term observation at the research site

According to Coughlan et al. (2025), observation is one method for collecting research data, involving watching a participant and recording relevant behaviour for later analysis. In this study, the observation method during semi-structured interviews had the advantage of providing direct evidence of the phenomenon being studied, making it more objective. The interview process in this study was video recorded, as it enabled the researcher to engage with the students. I used recorded interviews so that I could forego taking notes and have a genuine one-on-one conversation with the students, picking up on verbal and non-verbal cues along the way. Furthermore, I re-watched the recordings for details that might have been missed, as students went into extensive detail about past performance and workflow. With the ability to review, I took a second look at facts, figures, and other specifics that I might want to confirm with a reference or compare to another student's answer.

- *Peer examination*

Peer examination, according to Creswell and Clark (2023), requires the researcher to work together with one or several colleagues who hold impartial views about the study. The impartial peers examine the researcher's transcripts, final report, and general

methodology. Buzzard (2020) further asserts that in qualitative research, peer review has long been used to validate research before it is published. According to the researchers' view, the supervisor, internal and external moderators, and finally Turnitin validated this research study before it could be published. With this study, there were regular conversations with the supervisor, who always gave advice through emails on how to modify the study. There were also regular workshops with experienced student researchers, doctors, and professors that the researcher attended twice a year at the University of South Africa. During those workshops, presentations were made by doctors and professors to remind junior researchers about different methodologies to be used for different research studies. Student researchers, including the researcher, also presented their studies for modification.

Threats to validity

Strategies are necessary in experimental design to minimise threats to validity (Simsek & Can, 2020). To limit the likelihood of any threats in this study, the three classes were taught by the same lecturer, who has twelve years' experience teaching Level 3 and Level 4 students. This lecturer was selected based on his experience as a Level 3 lecturer and his proficiency in the use of technology. Simsek and Can (2020) warn that location may pose a threat to internal validity. To address this concern, the same physical building and classroom were used to instruct all three groups of students. To mitigate the threat of changes in students as they grow and develop throughout life, affecting data collection, the lecturer taught over the same period, and all students were at Level 3 of their studies; therefore, students' maturation did not present a threat. Moreover, the three groups attended college lectures for a total of 180 instructional days, all following the same schedule, beginning at 7:30 in the morning and dismissing at 3:00 in the afternoon.

Another threat was associated with mortality. Creswell and Clark (2023) describe this threat as occurring when individuals leave the experiment for various reasons, which may include a lack of parental consent, moving away, or absence. The mortality threat for this study was controlled by including only data from students who completed the pre-test, post-test, and all instruction in between with the same lecturer. Students who did not meet these criteria were excluded from the study. Those who were not eligible

could not participate, as they were not an equivalent measure to students who received full instruction in the participating lecturer's classroom.

In addition, according to Creswell and Clark (2023), the next set of threats pertains to instrumentation. By employing similar forms of the pre-test and post-test questionnaires created by college mathematics examiners, the instruments remained consistent. The scoring procedures were identical and followed a provided marking guideline. Using the same instruments throughout the entire study helped control this threat.

iii. External validity

To check for external validity, Williams et al. (2022) inquire whether “the research design is such that the results and findings of this study can be generalised beyond the subjects investigated to a broader population.” Thus, according to Creswell and Clark (2023), external validity is concerned with the applicability of the findings in other settings or with other subjects. Bara (2023) further asks, “How generalisable is the research design to the other situations or subjects in our research?" External validity, also known as generalisability, is defined by Creswell and Clark (2023) as the nature of a research outcome that validates the inferences that it represents something bigger than the specified observations on which it was based. With the provision that a class at the research site was developed to create heterogeneous groupings, the outcomes from this study would be valid for other students in mathematics and related colleges with the same student body demographics.

- Threats to external validity

To address concerns regarding challenges to external validity, this study was designed to be suitable for all members of the population (Creswell & Clark, 2023). The composition of the class was a carefully selected sample of the Mathematics Level 3 students at the research site. At the beginning of the first term of the college academic year, students were grouped to create diverse groupings. When forming classes within the college, an equal number of competent students, students with special needs, English First Additional Language students, and academically challenged students were considered. Additionally, a similar number of males and females were allocated to the respective classes. The fundamental demographics and competency levels in

each lecture room were comparable. The arrangement of the lecture rooms effectively created a prototype situation for a descriptive quasi-experimental study.

4.7.1.2 Reliability of data collected

Data and the reliability of findings are among the main prerequisites for any research proceedings. According to McMillan and Jones (2022), reliability pertains to the consistency, replicability, and dependability of the results obtained from the research. Creswell and Clark (2023) further state that, since data in quantitative research is in numerical form, obtaining similar results is not a subject for debate. However, Bara (2023) asserts that data in qualitative approaches is in narrative form and subjective, making it difficult and demanding for a researcher to achieve identical results. Reliability, according to Creswell and Clark (2023), is enhanced through supporting documentation such as field notes, recordings, and the agreement of others in the same situation.

In this study, reliability focused on checking whether the data collection instruments were reliable. In other words, if the researcher were to take the questionnaire she used and apply it in another country or five years from now, would it still yield the same results? Reliability can be assessed in three ways: conducting a pilot study, using a tried-and-tested instrument, and employing an adapted instrument. In this study, reliability was established through a pilot study and by using a tried, tested, and adapted ATMI instrument as well as employing an adapted instrument.

- Pilot study

Pilot studies, according to McMillan and Jones (2022), play a crucial role prior to conducting a full-scale research project. Creswell and Clark (2023) further assert that pilot studies are small-scale, preliminary investigations that aim to determine the feasibility of crucial components of the main study. In addition, Chor and Toh (2021) assert that pilot studies should be scrutinised in the same way as full-scale studies. Therefore, in this study, a pilot study was conducted with a sample that did not include participants from the main study and was used to refine the data collection instruments.

Firstly, the researcher administered a test to five students from the population who were not part of the main study sample. Based on their feedback, the researcher

shortened and simplified the test. Secondly, the researcher also interviewed the same cohort to assess whether the interview questions were overly long, confusing, too sensitive, or relevant to the study. Based on their responses, the researcher refined the data collection instrument. For measuring attitudes towards mathematics, the researcher used the ATMI, a tried, tested, and adapted instrument created by Tapia and Marsh (2004). According to Tapia and Marsh (2004), the ATMI has been confirmed and published as a reliable instrument for quantifying students' attitudes towards the learning of mathematics. As a well-established instrument, the researcher did not pilot it, as it had already been tried and tested. However, the researcher adapted it for the NW TVET College in this study and provided only post-research articles or publications on this instrument. Once the pilot study was completed, the researcher wrote a report on the pilot study, and upon approval, proceeded with the main research for this study.

- Reliability of the test instrument

Interpretation of the t-test using volume of pyramids with categories reveals that with $|t| \approx 3{,}27, the\ p-value\ for\ df \approx 3-6 < 0.05 \rightarrow statistically\ significant.$ The test instrument was reliable, and the tablet had an impact on the learning of pyramids.

The directional hypothesis was supported. Groups of TVET L3 students calculating SAVOGOs using tablet devices improved performance and attitude. Refer to Appendix C.

4.12 Trustworthiness for a qualitative study

This study considered the trustworthiness of qualitative criteria as suggested by Giri (2021), such as credibility, confirmability, dependability, and transferability of the study. Credibility refers to the qualitative part of the study, and the following are subsections:

4.12.1 Conformability

According to Gerber (2023), conformability refers to the researcher's ability to demonstrate that the data represent the participants' responses rather than the researcher's biases or viewpoints. The researcher established confirmability by describing how conclusions and interpretations were drawn, illustrating that the

findings were derived directly from the data. In reporting qualitative research in this study, conformability was demonstrated by providing rich quotes from the students that depict each emerging theme. In addition, to verify how well the data collection instrument aligns with the specifics of the field, dependability was also considered in this study.

4.12.2 Dependability

Dependability, according to Creswell and Clark (2023), refers to the consistency of the data over similar conditions, and this can be achieved when another study concurs with the decision trails at each stage of the research process. Creswell and Clark (2023) further assert that through the researcher's process and descriptions, a study would be deemed dependable if its findings were replicated with similar participants in similar conditions. This study addresses dependability by detailing each step in the research process and sending transcriptions to students for checking.

4.12.3 Transferability

Transferability, according to Creswell and Clark (2023), refers to the applicability of findings to other settings or groups. A qualitative study is said to meet this criterion if the results are meaningful to individuals not involved in the study and if readers can relate the results to their own experiences. Researchers should provide sufficient information about the informants and the research context to enable readers to assess the findings' potential for being transferable. However, Eshetu and Wakuma (2024) further assert that the criterion of transferability depends on the aim of the qualitative study and may only be relevant if the research intends to make generalisations about the subject or phenomenon. In this study, transferability refers to whether the findings can be applied to a similar context in another country. The context of this study is a TVET College in the North West Province of South Africa. Thus, transferability occurs when the researcher applies the results to a similar TVET college context in another country, making them useful there as well.

The question is whether the instrument and results can be transferred to a similar context in another country, including local contexts. To clarify, the instrument and results of this study can be transferred to another TVET college in a different country. Credibility is also used to measure the quality and rigour of the study. When

addressing the quality and rigour of this study, the researcher focused on the data collection instrument and the findings. The question was: Can the instrument and findings be trusted? The answer was affirmative, based on the trustworthiness of the data collection instrument and the procedure employed by the researcher.

4.12.4 Sample integration validity

According to McPherson and Foncha (2022), sample integration validity in mixed methods research (MMR) ensures that the quantitative and qualitative samples are appropriately related so that meaningful comparison, inference, or meta-inference can occur in practice. This addresses whether the selection, size, and characteristics of the qualitative and quantitative samples allow the integration of findings across methods, rather than treating the dataset independently. In this study, the quantitative component was administered to 60 students in a TVET college to measure performance and attitude in learning SAVOGOs. For the qualitative component, a purposive sample of six students was drawn from the same college population to conduct in-depth interviews exploring reasons for adherence and non-adherence. To ensure integration, the qualitative participants were selected as representative subsets of the quantitative sample with regard to key characteristics such as age, gender, and treatment type. The findings from the interviews are then used to explain or contextualise patterns identified in the study.

Sample integration validity was ensured in this study through alignment of samples for qualitative participants, who are not randomly chosen from an unrelated population; they correspond directly to subgroups identified in the quantitative data. For the facilitation of meaningful comparison, because the qualitative insights reflect the same population as the quantitative data, the researcher validly related patterns between numeric trends (quantitative) and experiential explanations (qualitative). Properly integrating the underlying samples strengthens the credibility of the meta-inferences drawn from both datasets. Practical tools in this study, such as mixed-methods matrices, joint displays, or threading, help operationalise this integration, showing how data points across samples converge. Practical tools are critical for operationalising the integration of quantitative and qualitative data in mixed methods research (MMR). These tools allowed the researcher to systematically compare, relate, and combine

data points across different samples, thereby demonstrating convergence and complementarity between datasets.

Mixed-methods matrices, according to Hassan and Sani (2025), serve as tabular frameworks where each row typically represents a case or participant and columns capture both qualitative and quantitative data, facilitating cross-case and within-case comparisons, enabling identification of patterns. Joint displays, as the second tool, involve graphical or tabular tools designed to integrate data visually, and are applied at multiple stages, such as data collection, analysis, interpretation, and reporting in this study. Mixed methods researchers use several techniques to integrate findings. Statistics-by-themes displays map quantitative outcomes alongside qualitative themes, while side-by-side or cross-case displays compare data across cases or groups. The Pillar Integration Process (PIP) offers a structured four-stage approach comprising listing, matching, checking, and pillar building, which iteratively aligns quantitative and qualitative findings to produce integrated conclusions. Together, these approaches enable the clear identification of convergence where qualitative and quantitative data align. The final tool was threading or following a thread, which involves tracking a specific theme, question, or finding through multiple components of a study. For example, a qualitative interview theme can generate hypotheses tested with quantitative surveys, which were then re-examined qualitatively to deepen understanding.

4.12.5 Benefits of using these tools

Tools in this study operationalise integration, move beyond parallel or disconnected analyses. They enhance transparency by clearly showing how conclusions are derived from combined datasets. Tools support meta-inference development by generating higher-order insights that neither dataset alone could provide. They also facilitate reporting and allow audiences to intuitively grasp how different data types contribute to conclusions. In summary, by using mixed-methods matrices, joint displays, and threading, researchers can rigorously demonstrate how datasets converge or diverge across samples, producing a more nuanced and holistic understanding than separate analyses would allow. These tools not only improve the interpretative depth of MMR studies but also enhance methodological transparency and reporting quality.

4.12.6 Practical implementation steps

Firstly, according to Engelbrecht and Borba (2024), the researcher identifies integration strategies like building, connecting, and merging. Secondly, the researcher selects a tool suited to the research design and type of data. The third step would be to populate the framework (matrix or display) with quantitative results and qualitative codes and themes. The researcher iteratively matches and aligns related data points. Finally, the researcher identifies areas of convergence, divergence, and gaps and draws integrated interpretations as meta-inferences for discussion and reporting. Participants for the qualitative phase were purposively selected from the 60 students who completed tests. We chose participants who represented the full range of experiences identified in the study's outcomes, ensuring coverage of both high- and low- scoring categories on the key quantitative measure. Interviews continued until thematic saturation was achieved at six participants. Ethical approval for re-contacting survey participants was obtained, and voluntary consent was reaffirmed prior to interviews.

4.12.7 Integration across phases

The selection in the qualitative phase is contingent on the quantitative results, forming a deliberate bridge between the phases. This connection allows the study to integrate breadth (quantitative) and depth (qualitative), as the qualitative participants are chosen specifically to explain or expand the general trends detected in the survey data. This phased selection strategy aligns with the explanatory sequential design by maintaining a logical progression: broad, representative data collection is followed by focused, interpretive inquiry. It ensures that each method’s strengths complement the other, enhancing the overall validity and credibility of the findings. Integrated findings emerge from the connection of both datasets, allowing for corroboration, clarification, and a comprehensive understanding of the research problem. This deliberate sampling approach ensures that inferences drawn from the study are coherent, trustworthy, and grounded in both statistical and contextual evidence.

4.13 RESEARCH ETHICS

This section discusses permission, privacy, confidentiality, potential harm, voluntary participation, and related ethical considerations. Ethics in a mixed methods study, according to Creswell and Clark (2023), pertain to important issues arising in both quantitative and qualitative research, which must be addressed before the commencement of the study and during data collection and analysis. In this study, permission was sought from the UNISA Ethics Committee, the Department of Higher Education and Training, and the principal and campus managers of the TVET college where the study was conducted, along with consent from the students and their lecturer. Voluntary participation in this study refers to the free will exercised by students in deciding whether to take part, and no one was compelled to participate. Furthermore, students were provided with various pieces of information, including the scope of the study, the expected outcomes, and any issues they should be aware of. They were informed that participation must be voluntary and that they had the right to withdraw at any time without penalty for doing so. The researcher noted that voluntary participation is a crucial aspect of research as it helps prevent harm, both psychological and, in some cases, physical, affecting both students and researchers.

The next ethical issue concerning student participants is anonymity. In this study, the researcher assured students that their identities would be protected, so neither the researcher nor the readers of the findings could identify the responses given by the students. Students were informed that no identification numbers or names would be included on the questionnaires, and they were encouraged to use pseudonyms. Confidentiality and anonymity are distinct concepts. In this study, confidentiality was maintained by protecting the students' identities, while the difference from anonymity is that the researcher can identify the responses given by the students. The researcher assured complete anonymity, which increased the likelihood of student participation and enhanced the accuracy of the results. Additionally, the researcher emphasised that any information collected from the students would remain confidential and would not be traceable back to them.

4.14 LIMITATIONS AND DELIMITATIONS OF THE STUDY

Limitations, according to Simon et al. (2025), are the shortcomings, conditions, or influences that cannot be controlled by the researcher, which place restrictions on the methodology and conclusions. Delimitations, according to Mouton (2023), are those characteristics that limit the scope and define the boundaries of the study. Simon et al. (2025) further emphasised that delimiting factors include the choice of objectives, the research questions, variables of interest, the theoretical perspectives adopted, and the population selected for investigation. In this study, schools and private TVET colleges were not included; furthermore, this study was limited to Mathematics Level 3 students only in TVET colleges in the North West Province of South Africa. The researcher also excluded other levels, as the study was conducted with Level 3 mathematics students who precede Level 4, the exit level.

4.15 RESEARCHER'S CONTRIBUTIONS TO THE STUDY

The researcher developed the following model after observing improvements in mathematics results due to the use of tablet devices. This initiative, which combines the use of tablet devices, includes essential considerations for the development and support of both students and lecturers. Providing students with ample time to become familiar with the technology and design appropriately allows for a greater chance of a successful programme. The researcher also recommended that TVET colleges consider supplying students with training on the use of tablet devices in an educational setting. It was clear that many students possess tablets for personal use outside the classroom, but lack the knowledge and education on how to use these devices for learning mathematics. The researcher intended to educate students about the possibility of remote learning, enabling communication with lecturers and other students.

Distance learning, as asserted by Limi (2025), is an approach to studying in which lectures are broadcast or lessons are delivered by correspondence, without the need for face-to-face attendance at the college. Distance education, also referred to as distance learning, online learning, and e-learning, involves the physical separation of lecturers and students during instruction, utilising various technologies to facilitate communication between students and lecturers, as well as among students themselves. Smartphones are used to provide quick answers. In some situations, a

student may refrain from seeking clarification on a question in an open classroom setting, as they can easily use their smartphone to find the answer they need. Thus, by incorporating audio and video, lecturers and students bring learning to life.

The technology of the Fourth Industrial Revolution (4IR) has enabled lecturers to be technology-oriented and responsible not only for teaching but also for learning. They consider the needs of each student in a heterogeneous classroom, creating a student-centred learning environment that enhances creativity, curiosity, and motivation to learn. The model demands a significant transformation in lecturers' roles, shifting from the traditional transmission of knowledge to a catalytic and coordinating role in the use of tablet devices. A catalyst is a person or thing that precipitates an event or change. Therefore, the revolution and evolution of tablet devices as a catalyst have contributed to improvements in students' performance and attitudes towards learning SAVOGOs. In the research model designed by the researcher, the evolution of tablets is viewed as a process of developing new ideas or products through a series of small changes. It was also found that tablet devices improved students' abilities to conduct research, make informed judgments, and present their ideas and learning in a way that enhances their understanding. Moreover, the model addresses the need to curb the spread of COVID-19 by discouraging face-to-face learning.

4.16 ASSUMPTIONS

Assumptions, according to McMillan and Jones (2022), are somewhat out of one's control; however, if they are not presented, the study becomes irrelevant. This study assumed that the students would answer the pre-test and post-test questionnaires to the best of their ability and respond to the interview questions honestly, truthfully, and to the best of their knowledge. The study also assumed that all students who participated had passed the Mathematics Level 2 examination. Additionally, it was assumed that the participating lecturer was well-educated, knowledgeable, and experienced.

4.17 SUMMARY OF THE MAIN ASPECTS THAT WERE COVERED

In Chapter 4, the research design and methodology, the aim and objective of the study, as well as the research questions and hypotheses, were explored. Additionally, the

research paradigms, population, sampling, as well as instrumentation and data collection techniques were thoroughly elaborated. Furthermore, quantitative and qualitative data presentation and analysis by emphasising data collection techniques were thoroughly explored. In this chapter, the inferential quasi-experimental data analysis and interpretation were followed by transforming data into Cronbach's alpha of 0.913 and regression analysis, with the output calculated from SPSS. The findings were $\beta = 1{,}108;\ R^2 = 0.957; F = 1300.718; P - value < .001$ and a supported hypothesis. The statistical significance of the calculations, the methodological norms, research ethics, limitations and delimitations, including sample integration validity, was also thoroughly explored. Finally, the chapter looked at the researcher's contributions to the study and the assumptions.

4.18 CONCLUSION

This study incorporated quasi-experimental quantitative and qualitative data implemented at a TVET college, located approximately east of NW in a suburban setting. The purpose of this study was to examine and understand the impact of tablet devices on Level 3 NW TVET College students' mathematics performance and attitudes in learning to calculate SAVOGOs. The sample for this study included data collected from 120 students in three Level 3 classes taught by the same lecturer from a campus. The two teaching sessions used different instructional delivery methods, one utilising tablet devices while the other employed traditional textbook-based instruction. Data collection consisted of pre-test questionnaires to measure the baseline of achievements for both the treatment and control sessions. Data collection also consisted of post-test questionnaires to assess student performance after the intervention method and the Attitudes towards Mathematics Inventory to gauge students' outlooks on the subject.

To examine data on academic performance, an ANCOVA statistical technique was utilised to compare the differences in the mean of the dependent variable across different sessions. To address students' attitudes towards mathematics, a t-test analysis was utilised to compare means of the student attitudes dependent variable between the two teaching sessions to determine if the difference was statistically significant. Measures were put in place to minimise threats to validity and reliability. At

the culmination of the quantitative data collection phase, the participating students were interviewed to gather qualitative data. The interviews were transcribed and coded to see if the interview outcomes supported or contradicted the quantitative data results. The investigation and evaluation of the design of the research and data collected are presented in Chapter 5.

CHAPTER 5

FINDINGS OF THE STUDY

5.1 INTRODUCTION

The purpose of this study was to determine the impact of using tablet devices (TD) on Level 3 TVET college students' performance and attitude in calculating SAVOGOs in mathematics. The preceding chapter focused on the research design and methodology used to collect data for this study and provided explanations of how it was done. To understand and find out the impact tablets had on students' performance and attitudes towards mathematics, multiple data sources were used to triangulate the data. The multiple sources of data helped to create a more complete understanding of this research study. The results of the study were organised around the central question:

What is the impact of using tablets on TVET Level 3 students' performance and attitude in calculating SAVOGOs?

To unpack the main question, the sub-questions provided a complete and comprehensive landscape of the results:

(i) How do Level 3 students' performance differ when using tablet devices as opposed to the traditional textbook method of learning?
(ii) How do Level 3 students' attitudes vary when using tablet devices as opposed to the old textbook method of learning?
(iii) What challenges do Level 3 students experience when learning SAVOGOs using the textbook method of learning?
(iv) What benefits do Level 3 students experience when learning SAVOGOs using tablet devices?
(v) Which model can maximise performance in mathematics at TVET colleges using mobile devices?

The unfolding of information in this chapter consists of reports on a small-scale pilot study followed by the main study. In this study, a pilot study was conducted to check the reliability of research instruments.

5.2 CLASSROOM SETTING

The context in which this study took place, along with the administration of the tablet devices, is described to provide a comprehensive understanding of the results. The lecture room designed for this research study consisted of five rectangular tables, each seating four students. The tables were arranged in group pods, with a central whiteboard. To manage the dissemination, collection, and storage of the tablet devices, the researcher developed a collection system criterion. The carts were equipped with cords and power strips to charge the tablets while in storage. All devices were labelled with identification numbers assigned to the students. At the beginning of each lesson, students were called to the tablet cart by number to retrieve their devices. Prior to the initial distribution of the tablets, all devices were preloaded with the appropriate applications and had wireless connections configured. The installation of applications was centrally managed by the college IT Unit; therefore, students were unable to install any applications themselves, as the management of applications, along with the configuration and settings on the devices, was also centrally controlled.

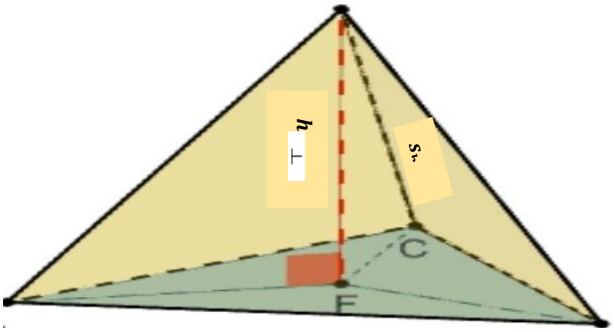
5.3 PILOT STUDY

The pilot study was conducted over approximately three months with two Level 3 mathematics students who did not participate in the main study. It commenced with the students completing a pre-test on SAVOGOs after learning using a traditional textbook method. The results of the pre-test were unsatisfactory; consequently, the researcher introduced an intervention method to improve performance. The students then learned SAVOGOs using a tablet device as part of the intervention, followed by a post-test and their responses to a template for the attitude towards mathematics inventory. This was then followed by the researcher marking the scripts.

The participants were informed about ethical issues and were required to sign a confidentiality letter. This covered issues of anonymity and voluntary participation in the study. Fortunately, no major issues emerged. After being addressed by the researcher, who explained her research proposals, the students appeared enthusiastic, and both signed the confidentiality letter.

5.3.1 Results of the pilot study

In this study, during the piloting phase, two students reported that the test was too long, prompting the researcher to shorten it. The pilot test included Questions 1 to 3. Question 3 of the pilot study was as follows: Use a tetrahedron with a slant height of $\sqrt{1729}\ cm$ and a perpendicular height of $37\ cm$ to determine the surface area and volume of a pyramid.



In addition, the report stated that the test was complicated because students did not understand the phrase "tetrahedron." The researcher simplified the test by explaining what a tetrahedron is. However, the report from the students still indicated that the test was too long and complicated due to ambiguous words like "tetrahedron." Question 3, which stated: “Use a tetrahedron with a slant height of $\sqrt{1729}\ cm$ and a perpendicular height of $37\ cm$ to determine the surface area and volume of a pyramid,” was scraped from the test for the study. Thereafter, students were expected and motivated to redo the question in the lecture room.

Further results on the pilot study indicated that the test was not testing performance in SAVOGOs but rather was testing other Level 3 mathematics content. In this case, the researcher noticed students’ lack of understanding of the relations between the slant height (h_s), perpendicular height ($h_\perp$) and the base edge (l) for square, triangular and hexagonal pyramids. Thereafter equations like $h_s^2 = h_\perp^2 + \frac{1}{4}l^2$ for the square pyramid were explained again to students to indicate that the equation might look like a Pythagorean Theorem $a^2 + b^2 = c^2$ for a right-angle triangle, but the one for a square pyramid assists in calculating the missing side or information for a square pyramid only. In addition, the researcher made it clear to students that Pythagoras Theorem $a^2 + b^2 = c^2$ for a right-angle triangle, is still part of SAVOGOs as it is used to calculate the missing sides only for a right-angle triangle. Furthermore, the

researcher emphasised that these three equations $h_s^2 = h_{\perp}^2 + \frac{1}{4}l^2$ for square pyramid, $h_s^2 = h_{\perp}^2 + \frac{1}{12}l^2$ for the triangular pyramid and $h_s^2 = h_{\perp}^2 + \frac{3}{4}l^2$ for hexagonal pyramid, explain the relationship between $h_s, h_{\perp} \; and \; l$ only for all three pyramids. Then, after this exercise, the test was reported as content valid. So, the following Question 1, students thought was testing Pythagoras' theorem only, and finally it was included in the question paper for the main study, as it was clarified to the students.

Thus, the question was rephrased as:
The table below summarises the relations between the slant height(h_s), perpendicular height($h_{|}$), and the base edge (l) for triangular, square and hexagonal pyramids. Label by indicating which is triangular, square and hexagonal pyramids.

OBJECT		
A	B	C
$h_s^2 = h_{|}^2 + \frac{1}{4}l^2$	$h_s^2 = h_{|}^2 + \frac{1}{12}l^2$	$h_s^2 = h_{|}^2 + \frac{3}{4}l^2$

Later interviews were conducted with the two students. They firstly tested the language used in each interview question in terms of understanding and substance, and secondly, to collect qualitative data and to see if answers were sufficient to address the research questions. The interviews with the two participants were held after writing the pre- and post-test questionnaires. Thereafter, the interviews were recorded, transcribed verbatim, and then the ATMI was administered. Since the ATMI is a tried, tested, and published instrument, the researcher did not pilot it. The researcher, however, adapted it for the NW TVET College in this study.

5.3.2 Some findings from interview questions of the pilot study

The debate over whether findings from a pilot study may be included in the main study is ongoing. However, Simon et al. (2025) mention that in qualitative studies, since there are no drastic changes in the methods of the main study, researchers can use all or some of the data from the pilot study in the main study. To be on the safe side,

the researcher in this study has refrained from reporting the findings in the main study and has instead included some here in the pilot study section. Hence, some findings from the pilot study worth noting were those whose questions had to be modified for clarity.

In the interview schedule for the pilot study, five questions were drafted, which were changed to eight for the main study. The language of the questions was altered to make them more specific, as the researcher realised that some questions were too vague. For example, one of the questions in the pilot study was, “What kind of challenges were experienced when calculating mathematics?” It was rephrased as, “Mention the challenges experienced when calculating the surface area and volume of geometrical objects (SAVOGOs)” in the main study. Another question from the pilot study was, “Can you calculate the surface area and volume of a pyramid?” This was rephrased as, “Can you calculate the surface area and volume of a square pyramid?” in the main study.

The two participants consistently expressed their excitement about using the tablet device. Both explained that they were able to engage in self-study with the tablet and collaborate with their researcher and fellow students. This excitement became evident when they were asked to indicate the benefits of using the tablet device.

In response to the question, PS1 said:

PS1: *Definitely, with a tablet device, it is very easy because one could always check from a search engine. What I liked about the search engine is that one always gets different, more detailed definitions and explanations. Unlike the traditional textbook method, one gets the same outdated definition. One other benefit is that we are able to identify the square pyramid. We can now understand the relations between the slant height(h_s), perpendicular height($h_\perp$), and the base edge (l) for triangular, square and hexagonal pyramids. That is an achievement on our side.*

To the same question, PS2 said:

PS2: *The benefits were that, with a tablet device, one can navigate formulae and other SAVOGOs information that is needed. There is direct communication with the tablet device as it connects all major stakeholders: that is, students, parents and researchers. With the traditional textbook method, tasks or handwritten notes can be lost in no time, accidentally or intentionally. This has never happened with a tablet*

device: feedback or concern is out there for further reference. Forgetfulness is no longer a challenge. Neither for researchers nor students.

5.3.3 Benefits of the pilot study

The pilot study, although it was incomplete, small-scale, and of a short duration, was a valuable lesson and gave a thorough overview of how shortcomings could be improved in the main study. Furthermore, the findings from the pilot study highlighted many similarities in the views of participants, which showed that the voices of participants were strong.

Lessons kept in mind when the semi-structured interviews and tests were designed for the main study included:

- Increasing the number of interview questions from five questions to eight questions to get more information from the interviews.
- Making the interview questions more specific.
- Shortening the test by removing Question 3
- Avoiding ambiguous words when setting the test for the study

5.4 MAIN STUDY DATA PRESENTATION

The main study is reported under themes formulated in Table 5.1 below.

5.4.1 Enhanced contingencies that improved students' performance and attitude in learning SAVOGOs

TDs provided students with sufficient time to engage, interact, and concentrate on the SOVOGOs content, as well as target their attention on calculating questions on different shapes like squares, rectangles, triangles, and hexagonal pyramids. This occurred through many interactions between students and TDs throughout the learning process, from mastering the operation of the device to specialising in using the Bing AI App. Additionally, this was also the case in this study, where the goal was clear, and the interactions, collaborations, and engagements were very fruitful and beneficial in highlighting students' experiences in learning with TDs. It also provided an enhanced contingency that improved performance and attitude in learning

SAVOGOs. This is evident from the results presented in the sections: 1) Students' challenges in the learning of SAVOGOs in calculations of different shapes, and 2) Experiences and improvement gained by students through engaging with the SAVOGOs' content through the operation of TDs.

5.4.2 Students' challenges in the learning of SAVOGOs in the calculations of different shapes

Students learned SAVOGOs using the Traditional Textbook method (TTBM) of learning and thereafter wrote a pre-test to establish academic baseline performances. In this study, the descriptive labelling used to identify and anonymise students was S1 for student number one, S2 for student number two, S3 for student number three, and so forth until S60 for student number sixty. For seven weeks, students were taught SAVOGOs using the TTBM of learning. The duration of the teaching and learning was to ensure students fully understood the concept, as it involved lots of shapes and formulae. In addition, for students to fully understand the concepts, they were given three consecutive days to revise and self-study to prepare for the pre-test. The pre-test was written by sixty Level 3 mathematics students in June 2024 in a hall which accommodated all the students who did not take part in the pilot study. This pre-test consisted of two questions, with Question 1 consisting of Sub-Questions 1.1 – 1.5.2, whereas Question 2 was composed of Sub-Questions 2.1.1 and 2.4.1.

The pre-test questions were presented to students to highlight their performance and attitude in the content of SAVOGOS after learning traditionally. Level 3 students had one and a half hours to answer the questions under the supervision of trained external invigilators hired by the college to oversee both internal and external examinations. The researcher marked the students' answer scripts to assess their performance after learning SAVOGOs through traditional methods. Following the analysis of the pre-test, a semi-structured interview was conducted with six students based on their performance in the pre-test, and the ATMI was also administered to them. Below is the percentage of unsatisfactory scores achieved by 60 students in the pre-test.

I recorded and analysed the disappointing results and subsequently shared them with the students. Below is the students' unsatisfactory performance after learning using the traditional textbook method.

Table 5.1: Marks in percentages before intervention from S1 – S60

STUDENTS	MARKS
S1	8
S2	15
S3	21
S4	27
S5	30
S6	35
S7	26
S8	24
S9	12
S10	20
S11	16
S12	14
S13	4
S14	7
S15	22
S16	17
S17	18
S18	6
S19	5
S20	15
S21	3
S22	9
S23	11
S24	13
S25	19
S26	16
S27	23
S28	10
S29	5
S30	16
S31	8
S32	4
S33	7
S34	11
S35	19
S36	3
S37	14
S38	6
S39	12
S40	9
S41	2
S42	13
S43	2
S44	19
S45	3
S46	8
S47	10
S48	5
S49	6
S50	4
S51	8
S52	7
S53	21
S54	11
S55	9
S56	7
S57	3
S58	20
S59	18
S60	15
Mean	12,51667
Standard d	7,544295

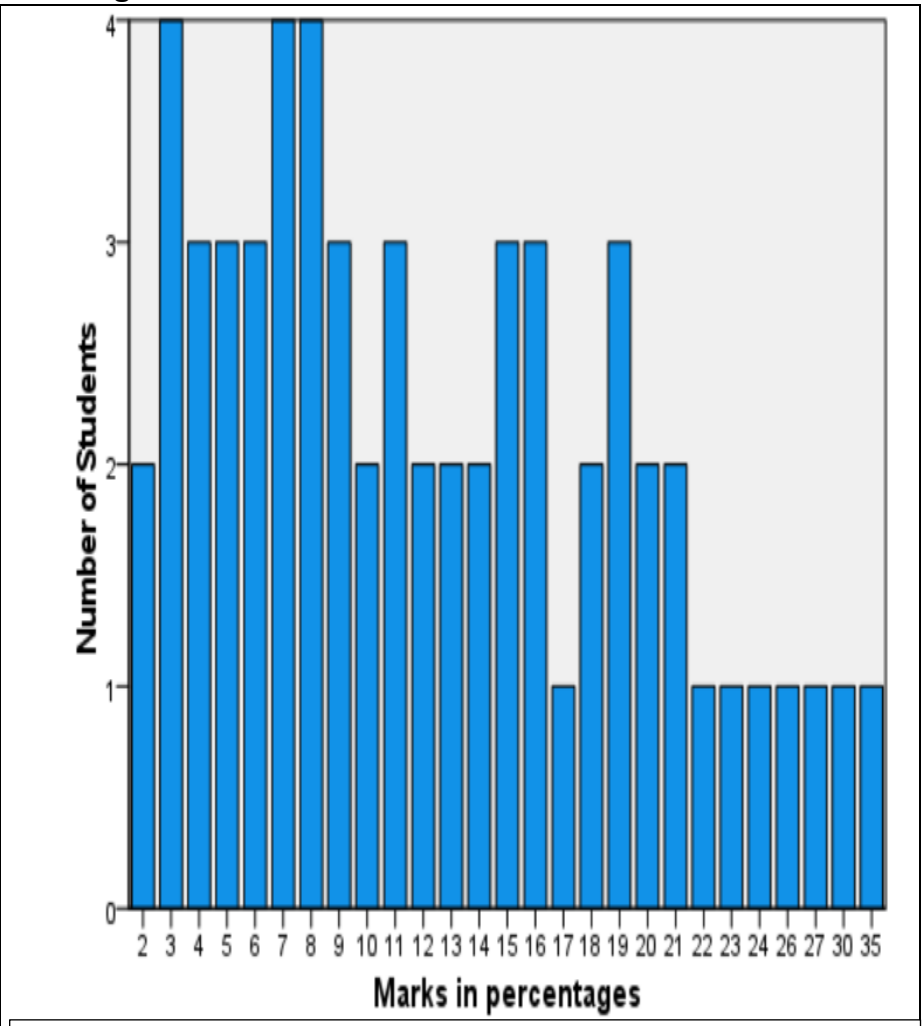


Figure 5.1: Graphical representation of Pre-Test Percentages from S1 to S60

Table 5.1 and Figure 5.1 above indicate that fifty-eight students scored below the required mathematics pass percentage of 30%. Students' unsatisfactory performance is illustrated in Table 5.1 and Figure 5.1, where the researcher noted that only two students passed with scores of 30% and 35%. This prompted the researcher to test for normality to determine whether the data met the assumptions required for parametric analysis.

5.5 Inferential analyses of variance

Inferential statistics, according to Mullis and Kelly (2022), refer to branches of statistics that allow researchers to make predictions, generalisations, or decisions about popul ation based on data collected from a sample. Inferential statistics goes beyond merely

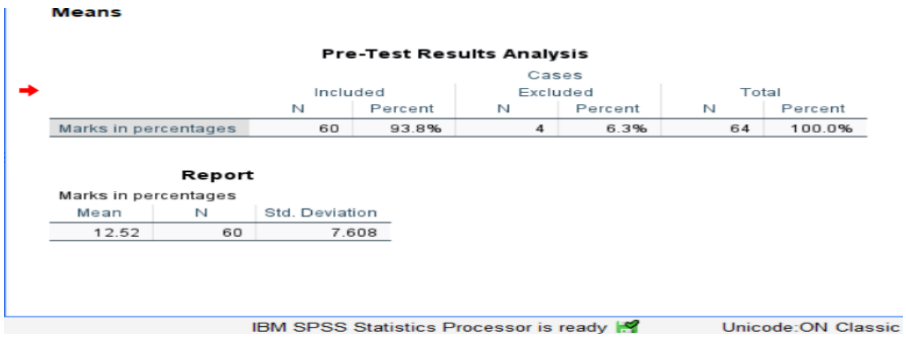
describing the data one has to making informed statements or conclusions about a larger population. It uses sample data to estimate population parameters, test hypotheses, and make predictions about the population's characteristics. This process accounts for uncertainty and variability inherent in sampling. In addition, McPherson and Foncha (2022) highlighted the key components of inferential statistics as sampling, estimation, hypothesis testing and prediction.

1) Sampling: Collecting a subset of data from the population to infer results.
2) Estimation: Using sample statistics (like mean or proportion) to estimate population parameters. Common methods include point estimates and confidence intervals.

3) Hypothesis Testing: Assessing whether data support a specific belief or theory about the population, often using p-values or test statistics to make decisions.

4) Prediction: Using the sample data to make forecasts about future observations or trends in the population (Engelbrecht & Borba, 2024).

In this study, the mean of the pre-test calculated from ANCOVA, together with the standard deviation in Table 5.2, was used together with the calculated pre-test sample mean. The pre-test sample mean from Table 5.2 and the deviation, sample variance and sample standard deviation were calculated as well in Table 5.2 below.
Table 5.2: Pre-test Results Analysis



Means

Pre-Test Results Analysis

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Marks in percentages	60	93.8%	4	6.3%	64	100.0%

Report

Marks in percentages

Mean	N	Std. Deviation
12.52	60	7.608

IBM SPSS Statistics Processor is ready Unicode:ON Classic

The average test score of Level 3 mathematics students on a standardised examination test was 10.52. The researcher wanted to test for normality to determine whether the data met the assumptions required for parametric analysis and selected a sample of 60 students from the total number of 120 Mathematics Level 3. The sample has a mean score of 12.52 with a standard deviation of 7.608. The researcher wants to conduct a hypothesis test at the 0.05 significance level.

Step 1: Define the Hypothesis

Null Hypothesis $H_0: \mu = 10{,}52$ (no difference from the claimed mean)

Alternative Hypothesis $H_1 : \mu > 10.52$ (population mean is higher than claimed)

Step 2: Identify the Test and Assumptions

$$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}}$$

Step 3: Calculate the Test Statistic Where

- Significance level: $\alpha = 0.05$
- Degrees of freedom: $df = 59$
- Sample standard deviation: $s = 7.608$
- Sample mean: $\bar{x} = 12.52$
- Hypothesised population mean: $\mu_0 = 10.52$
- Sample size: $n = 60$

Step 4: Compute the t-statistic

The one-sample t-statistic formula is:

$$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}}$$

$$t = \frac{12.52 - 10.52}{7.608/\sqrt{60}} = \frac{2.00}{7.608/7.746} \approx \frac{2.00}{0.982} \approx 2.037$$

Step 5: Determine the critical t-value

For a one-tailed test at $\alpha = 0.05$ and $df = 59$:

$$t_{0.05,59} \approx 1.671$$

Our computed $t = 2.037 > 1.671$, so we are in the rejection region. We are rejecting the null hypothesis " There is no variation in performance and attitude when a cohort of TVET L3 students calculate SAVOGOs using a tablet device as opposed to the traditional textbook method". The rejection region highlights the significance of the observed sample mean relative to the hypothesis population mean. Then the

directional hypothesis " Group of TVET L3 students calculating SAVOGOs using tablet devices improved performance and attitude as opposed to the traditional textbook method.

Step 6: Describe the normal distribution curve

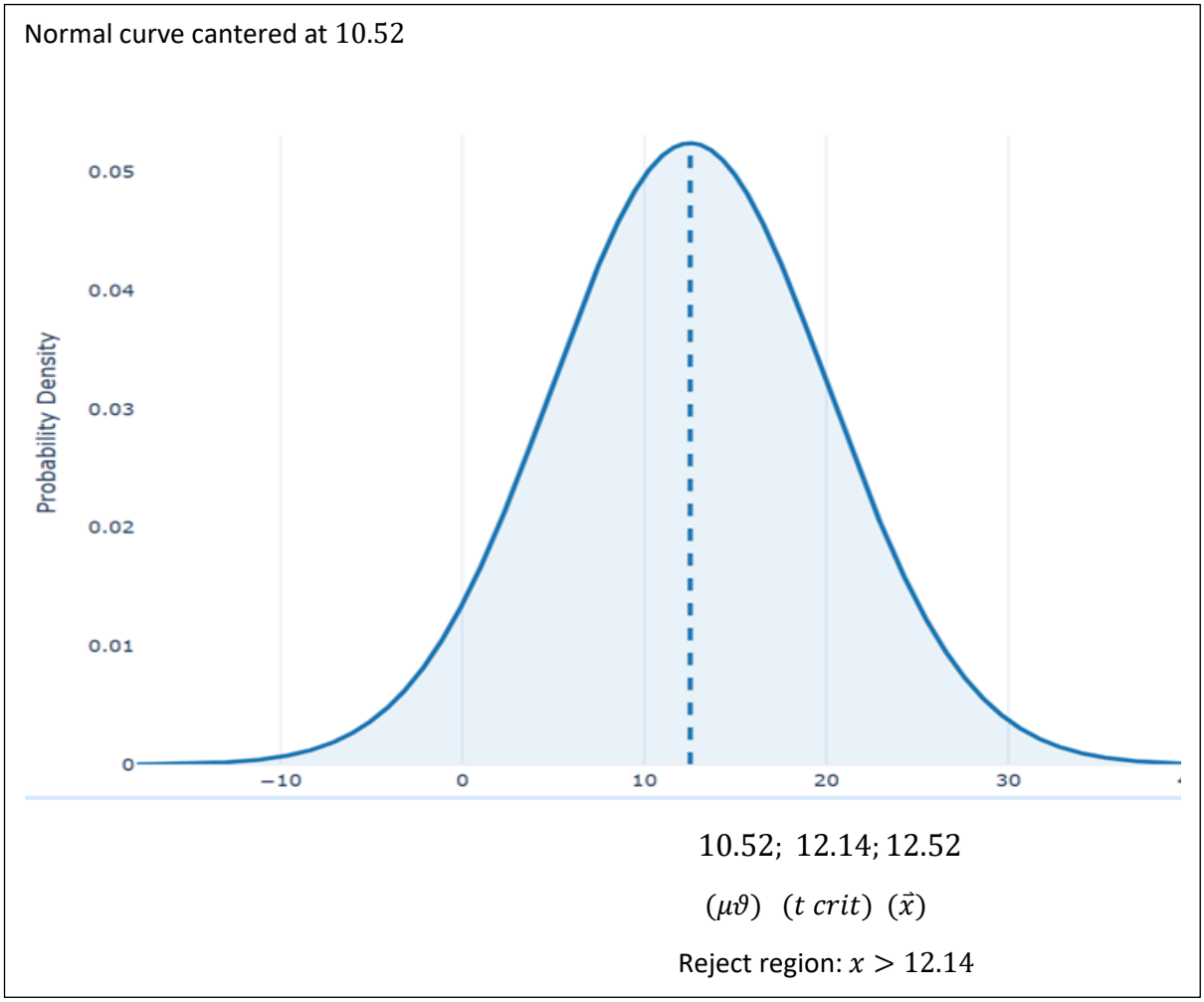


Figure 5.2: Normal distribution curve

The normal distributive curve is bell-shaped and symmetrical for large df, but a bit heavier in the tails than the normal curve. Important points are mean $t = 0$ (under $H_{0)}$, critical value at $t = 1.671$ (right tail, 5%) and observed $t = 2.037$ (falls in the rejection region). The researcher can visualise this as the observed $t - value$ 2.037 exceeds the critical value 1.671. This indicates statistical significance: we reject H_0 in favour of the alternative hypothesis $H_1 : \mu > 10.52$ The shaded right tail beyond 1.671 represents the 5% significance region. The t-statistic: 2.038 > 1.671 → Reject H_0. This bell curve shows the normal distribution based on the parameters $\mu = 12.52. \sigma =$

7.608 . The shaded area represents the probability density, and the dashed line marks the mean. The curve highlights the significance of the observed sample mean relative to the hypothesis population mean.

This prompted the researcher to conduct a t-test using SPSS. The t-score is a ratio of the difference between two groups to the difference within the groups. Additionally, a t-test employs a t-statistic, which is compared to t-distribution values to determine if the results are statistically significant. At this stage, the study analysed the pre-test quantitatively, and the comparison of the two means was conducted after the post-test was completed.

Table 5.3: Pre-test T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Students Marks in Percentages	60	12.52	7.608	.982

One-Sample Test

Test Value = 0

	t	df	Significance One-Sided p	Significance Two-Sided p	Mean Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
Students Marks in Percentages	12.744	59	<,001	<,001	12.517	10.55	14.48

One-Sample Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
Students Marks in Percentages	Cohen's d	7.608	1.645	1.253	2.032
	Hedges' correction	7.706	1.624	1.237	2.006

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation.
Hedges' correction uses the sample standard deviation, plus a correction factor.

A one-sample t-test was performed to compare the mean marks of the pre-test percentages of Mathematics Level 3 students against the population mean. It can be noted from Table 5.4 that the mean value of pre-test percentages (M = 12.52, SD = 7.608) was not significantly different from the population mean; t (59) = 12.744, p < .001. To clarify the performance displayed, the researcher conducted interviews with six participants based on their responses.

The purpose of the interviews was to probe students for more detailed information about their experiences when learning SAVOGOs and to explore their attitudes and opinions in their own words. Furthermore, through the interviews, the researcher aimed to gain a richer understanding of the causes of underperformance after learning SAVOGOs traditionally. In the student interviews, participants made candid confessions regarding their misunderstandings. Some of the students' misunderstandings were evident from their pre-test responses, which supported their statements.

When I asked the students what contributed to their underperformance in the pre-test, S6 commented:

S6: *With TTBM of learning, there is a lot of misunderstanding, as there is no Bing AI to search for terminologies which are needed to prepare for a test. If you don't understand terminology, and you don't have a dictionary in the lecture room or at home, it means conceptual understanding won't materialise for satisfactory performance in a test.*

To the same question, S3 said

S3: *The benefits of the textbook method are limited because most of the time, the lecturer simply reads from the textbook, and we simply take notes that are not up to standard, which results in a misunderstanding of concepts and terminologies.*

Traditional methods of learning refer to a setting where a lecturer communicates with a group of students in a typical classroom environment. Students attend classes for a fixed duration and learn about SAVOGOs, often gaining hands-on experience for practical work. Although many colleges make use of technology, the teaching-learning process still involves handwritten notes, assignments, tests, etc. The curriculum follows a standardised pattern using textbooks approved by the government and the education board. Moreover, students are completely dependent on the lecturer for acquiring knowledge of the subject, hence leading to unsatisfactory performance.

Another cause of misunderstanding, which was very common and was also confirmed in this study, was textbook contents that were not up to standard. This was highlighted by S1.

S1*: Sometimes, the content with TTBM of learning is not up to standard, hence unsatisfactory performance. So, one must keep on calling the lecturer to clarify*

content, and now this is becoming time-wasting. That is why my unsatisfactory performance was due to my wasting time by waiting for the lecturers to come and clarify the content and concepts.

S5 also echoed the same sentiment and said:

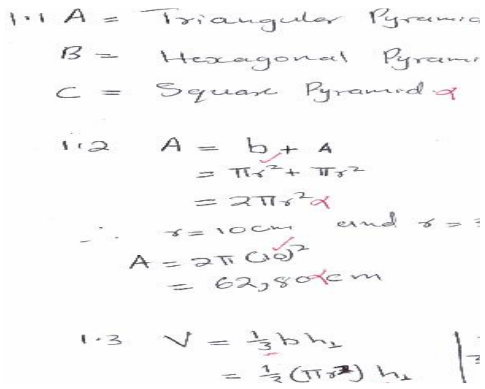
S5: *New content is limited. We seldom get up to standard content from a textbook.*

From students' interviews, five students said that a lack of up-to-date content when learning traditionally contributed to a misunderstanding of concepts, which led to unsatisfactory performance.

Students were also uncertain about their work due to a few limited examples when learning traditionally. S4 indicated her concern about a few examples.

S4: *For me, the uncertainty was caused by the TTBM, which has fewer examples and activities for students to practice on their own while at home. I wish I can have something with many different examples and activities in different shapes and sizes to understand the usage of different formulae. Remember, when expected to calculate the surface area and volume of pyramids, one must know how to identify shapes, and this is a challenge on our side. I remember the lecturer giving examples about the areas and perimeters to be used when calculating the volume and surface area of different shapes. During that lesson, we were uncertain about the content as we didn't know how they connected them.*

Upon marking the scripts, the researcher discovered that some students attempted only Questions 1.1 -1.4, and none of them attempted Question 2. This was evidence to conclude that there was a misunderstanding of concepts when using the TTBM of learning. Also, it was evident that students had limited information and misunderstood many concepts, which led to confusion for students when learning with the TTBM. For example, Extract 1 shows S1's response to Question 1.1.

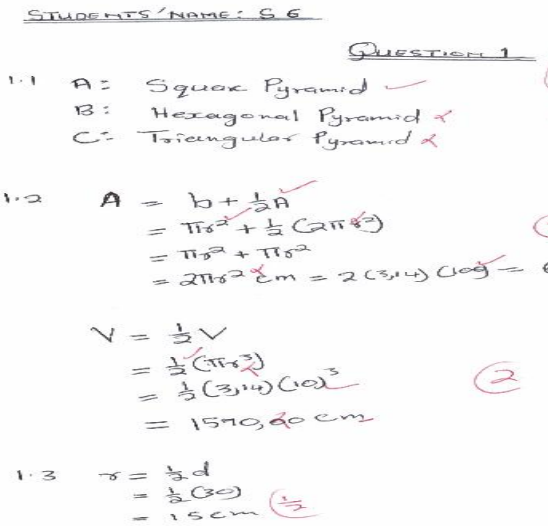


Extract 5.1: S1's response

When S1 was asked about challenges experienced when answering Question 1, he said.

S1: *"Eish… The challenge was the identification of formulae which seem to be similar when one looks at them. That is why the labelling of the table in Question 1, indicating which formula is for triangular, square and hexagonal pyramids, was not an easy task for me. I was uncertain and confused about which formula to attach with which figure. I attempted Question 1.2 but could not answer the volume of a sphere because I could not figure out the correct formula to use. To add on the unsatisfactory performance in the test, it was difficult to identify the base area and perimeter to assist in the calculation of the volume and surface area of the given shape.*

Also, S6's work is displayed in Extract 2



Extract 5.2: S6's Response

Mostly, students were uncertain about the correct method and formulae to be used.

When S6 was asked about how she interpreted SAVOGOs' content when using TTBM, she said.

S6: You know, the problem is the reading and understanding of important SAVOGOs' contents to enable us to attach a meaning to what is expected of us during the test. Especially the formulae and correct units. Look at my attempt for Question 1, I was just guessing the labelling of the table, and fortunately, I managed to match the square pyramid correctly, guesswork, you know. Also, I am not yet sure of the concept of square, triangular and hexagonal pyramids. As for 1.2, I kept on missing the correct formulae to be used. In addition, for 1.3, I only remembered that a radius is half of a diameter and could not answer the question correctly.

To the same question, S3 had a different view and said:

S3: *For me, a textbook is user-friendly as there is no charging involved. The textbook is always there for you, whether load shedding or not.*

When I followed up on the S1 script, I discovered that the student lacked conceptual understanding, uncertainty in the choice of relevant information due to a few examples and outdated content. Furthermore, the inability to attempt questions and incorrect choice and application of formulae contributed to unsatisfactory performance. When asked why question two was not attempted, S1 said:

S1: *Iyoooo, I was so uncertain about attempting question two due to a content misunderstanding and a lack of conceptual understanding caused by a few examples. For the question which requires us to determine the volume of a sphere and the total surface area of the square pyramid, to be honest, I was so clueless and uncertain about which formula to use. This really disadvantaged my performance*.

This was evident from the S1's response, who left Question 2 blank, which expected her to determine the volume of the sphere and the total surface area of the square pyramid.

Extract 5.3: S1's response

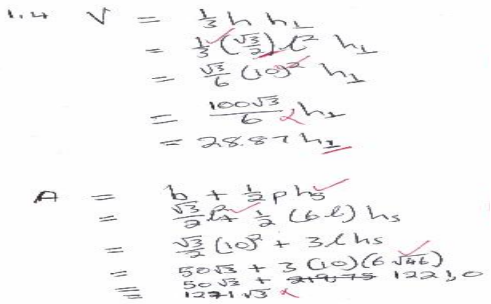
This simply indicates that when students learned traditionally, they lacked conceptual understanding, which was supposed to assist in scoring satisfactory pass percentages. Hence, misunderstanding of concepts and unsatisfactory performance.

I made a follow-up question.

R: Are there any other misunderstandings for your unsatisfactory performance other than the one you mentioned?

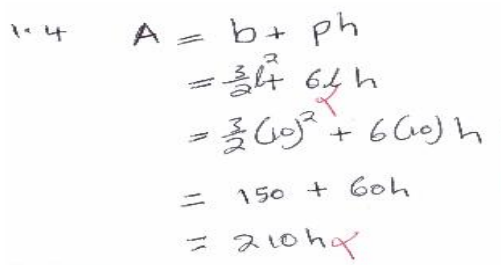
S6: Look, Ma'am, I tried to calculate the volume and surface area for Question 1.4, but I was unable to write the correct units as I was not sure as to whether I should write cm, cm^2 *or* cm^3. *Misunderstanding of units and dimensions, as well as confusing formulae, makes one uncertain about the correct units to be used.*

Extract 5.4 represents S6's responses, which indicate the state of uncertainty which he had when coming to the writing of the correct units, for the final answer.



Extract 5.4: S6's response

Extract 5.5 represents S4's response to Question 1.4, which required him to calculate the volume and surface area of a hexagonal pyramid with a base edge of 100 mm and a slant height of $6\sqrt{46}$ cm.



Extract 5.5: S4's response

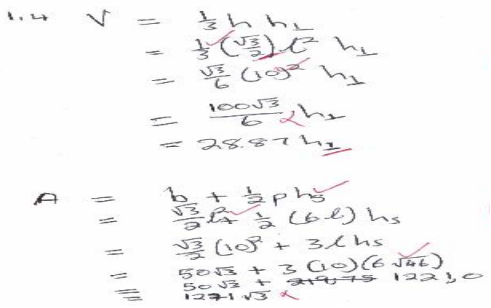
Question 1.4 about the volume and surface area of a hexagonal pyramid was incorrectly attempted by S4.

In responding to the unsatisfactory performance caused by a misunderstanding of concepts and SAVOGOs' content, S4 indicated the way they were disadvantaged by TTBM of learning:

S4: *Yes, Terminologies are a challenge. If I didn't understand the term used in the question paper, it means I won't be able to answer the question. For example, I really didn't figure out the shapes of the square, triangular and hexagonal pyramids. Also, when coming* to interpreting $'b'$ in the formulae $V = \frac{1}{3}b\boldsymbol{h_{\perp}}\ and\ A = b + \frac{1}{2}ph_s$ and $'p'$, for the given pyramid, that was something I couldn't understand, hence *my unsatisfactory performance and incorrect attempt for Question 1.4.*

S6 added by indicating that the inappropriate application of formulae and the omission of numbers and variables disadvantaged us after learning traditionally.

The following extract represents S6's response to the question that required her to calculate the volume and surface area of a hexagonal pyramid with a base edge of 100mm and a slant height of $6\sqrt{46}cm$.



Extract 5.6: S6's response

In this attempt, it can be observed that the formula for the volume of a hexagonal pyramid was incorrectly written as $V = \frac{1}{3}(\frac{\sqrt{3}}{2})l^2h_{\perp}$ instead of $V = \frac{1}{3}(\frac{3\sqrt{3}}{2}l^2)h_{\perp}$.

When the researcher noticed that Question 2 was not attempted, she enquired about the reasons thereof.
S4 responded with a lot of doubts and uncertainty in her face and shared the same sentiments with S1 about the interpretation of '$b' and 'p'$formulae for the volume of the sphere and the surface area of the square pyramid. Her response was:

S4*: I did not understand the concepts about formulae for calculating the volume of a sphere and for calculating the surface area of a square.*

Probed further about her understanding of the formulae, S4 said:

S4*: Iyaaah neh, when I was studying, I saw letters like* $'b' and 'p'$ *in formulae for different pyramids, but to my surprise, they were substituted differently, and I did not know the reason behind that. To add on that, I don't understand their meaning.*

From the researcher's observations, S4 has a similar problem to S1, who mentioned the same misunderstanding of the formulae $V = \frac{2}{3}bh$ for sphere and $A = b + \frac{1}{2}ph_s$ for calculating the surface area of a square. Gerber (2023) supported the idea by emphasising that the variables referred to are for the base area and perimeter.

S4 left Question 2 about a model made up of a solid square pyramid blank. When the researcher tried to find out if students could differentiate between a square and a rectangular pyramid, the response was:

S4: I remember Question 2 was about a model made up of a solid square pyramid. The minute I hear about a square pyramid, I couldn't have a picture of that figure, and if one does not have knowledge about a picture, it would be difficult even to remember the formulae, and one starts to be uncertain about what he is supposed to do.

S1: Eish, differentiating between a square and a rectangle was not fully understood. The disadvantage was that I only knew about their four sides.

But S6 could not miss that one, and confidently explained, thinking that he was correct and said:

S6: I think I have full knowledge about that. A square has four equal sides, and a rectangle has four sides with equal opposite sides. The only terminologies I am not well conversant with are the hexagonal pyramids and their volumes.

Realising that students did not answer the previous question properly, the researcher asked students the same question, but selectively, not a comparison question, as follows:

R: Can you identify a square pyramid? S4 responded:

S4: Iyooo, not really, I don't understand pyramids, the only knowledge I have is that a square has four sides. You see, Ma'am, even though I asked one question about labelling different pyramids, I did not get it correct. I feel the TTBM of learning disadvantaged me, as I did not know how to approach the question. I was doubtful and uncertain about SAVOGOs' content; hence, I just left it unanswered.

To the same question, S6 responded with mixed feelings, saying:

S6: I think I understand pyramids, bu…..t, ehm, I am not sure…..I think I can identify all pyramids, but the challenge is the writing of their formulae. You find that where you think you got the formula correct, there is an omission of one number or variable.
For the base area of a hexagonal pyramid, S6 ommitted 3 when writing the formula for base area as follows: $b = \frac{\sqrt{3}}{2}l^2$ *instead of* $b = \frac{3\sqrt{3}}{2}l^2$ *and also could not conceptualise a hexagon as a figure with six equal sides. Without that conceptual knowledge, S6 would never calculate the perimeter as* $p = 6l$ *to be substituted in the formula* $A = b + \frac{1}{2}ph_s$ *for the surface area of a hexagonal pyramid.*

The researcher probed further by asking low-order questions as a way of understanding the challenges students encountered in learning space, shape and orientation.

R: *What do you know about the four sides of a square?*

A level of misunderstanding and uncertainty was observed in S4 responses.

S4: I am not sure if the opposite sides are equal or all the sides. I remember reading about the parallel side. Eish, the content was not clear.

A conceptual understanding of pyramids was noticed from S2's response, who said:

S2: For me, the concept square was easy to understand. All four sides of a square are equal.

To dig dipper about the cause of unsatisfactory performance. The researcher then enquired the following from the students:

Researcher: Can you calculate the surface area and volume of a square pyramid?

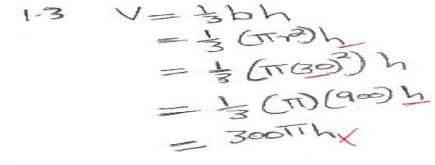
S5 responded with uncertainty:

***S5:** Eish, I don't know where to start, as I am uncertain about the concept. To be honest, I once heard about the pyramids, and my knowledge is limited when coming to SAVOGOs' conceptual understanding.*

A level of uncertainty and misunderstanding was still noticeable in S5's response.

***S5:** For pyramids, there are still some concepts that need to be understood. I think I still need to learn how to differentiate between heights because apparently, there are two types of heights, which are disadvantaging my performance.*

This different view of S5's response is displayed in Extract 6.



Extract 5.7: S5's response

S3 indicated her misunderstanding and confusion around Question 1, leaving it unattempted, and omitted formulae in her responses..

S3: *I could not answer Question 1.1 because it had three different formulae with the same letters slant height(h_s), perpendicular height($h_{\perp}$), and the base edge (l). When looking at them, they were all written in the same place and location of the formula. The only difference was $\frac{1}{4}; \frac{1}{12} and \frac{3}{4}$ next to l^2. Hence, the uncertainty and confusion about which formulae belong to which pyramid. As a result of misunderstanding, I left the question unanswered.*

It can be observed from the responses above that students felt textbooks are not an essential part of their academic journey. The method did not help students to understand SAVOGOs' concepts, provide in-depth knowledge, and support their learning beyond the classroom.

Some students guessed formulae to be substituted in Question 1. For example, S6 said:

S6: *I did not know which formulae belonged to which pyramid, but through guesswork, I ended up labelling "A" question correct, but "B" and "C" were incorrectly labelled. The misunderstanding and uncertainty were about the units displaced on the variables and the disadvantages of not understanding terminologies like square, hexagonal and triangular pyramid.*

From the findings, the group that stood out the most was the misunderstandings. At least 11 different misunderstandings could be documented in this study through the method of collecting data. These misunderstandings were mentioned 33 times.

Table 5.4: Misunderstanding when learning traditionally

No Bing AI for understanding teminologies	Outdated content due to trasditional text book method of learning	Uncertainty in differentiating area and volume of pyramimds	Lack of conceptual understanding	Incorrect substitution in formulae	Incorrect usage of units	Lack of prior knowledge	Omission when writing a formular	Incorrect identification of space and shapes	Uncertainty due to few examples and lack of understanding	BODMAS Rule
11	4	29	7	8	5	3	6	8	15	4

In Table 5.4, the highest misunderstanding noticed was uncertainty in differentiating areas and volume of pyramids, with 29%, followed by uncertainty due to a few examples and a lack of understanding. The table is further emphasised graphically in Figure 5.2 below.

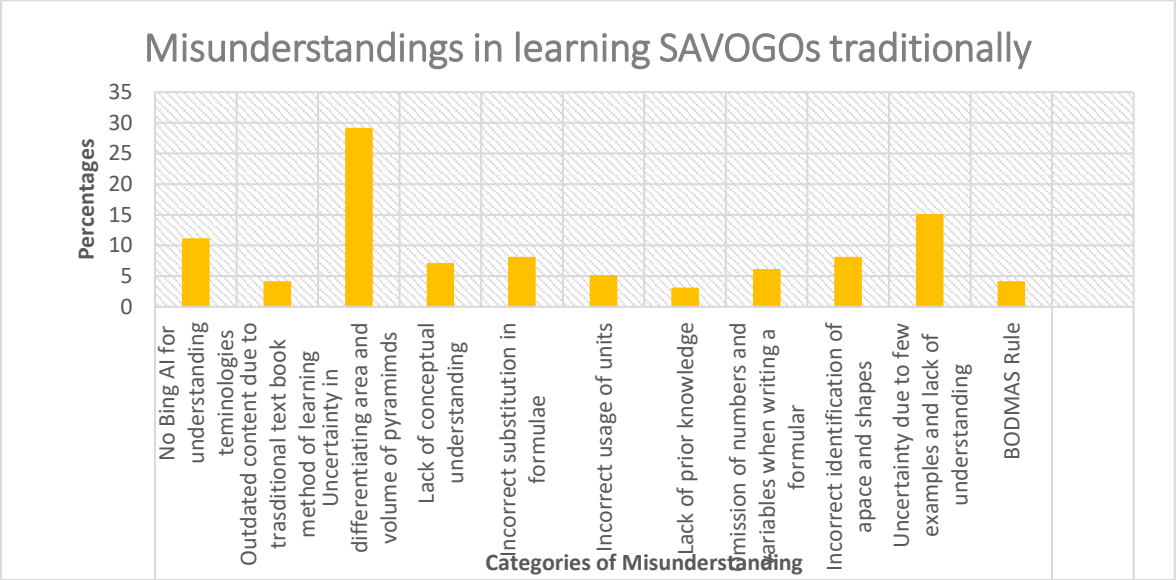


Figure 5.2: Misunderstanding in SAVOGOs

Figure 5.2 is a graphical representation of the misunderstanding experienced when learning SAVOGOs traditionally. There were about 11 misunderstandings, and the worst misunderstanding was the one with 29, followed by the one with 15%.

Table 5.5 classifications on SAVOGOs that students lack mathematical knowledge were stated five times, and Figure 5.3 emphasises the categories in which they were mentioned.

Table 5.5: Students' lack of conceptual knowledge in SAVOGOs when learning traditionally

Finalising area and volume with correct units	Content, terminologies, language and words usage	Identification and writing the correcformula	Incorrect application of formulae	Lack of concept understanding
16	24	16	30	14

In Table 5.5, the largest area indicating students' lack of conceptual knowledge in SAVOGOs when learning traditionally is the incorrect application of formulae with 30%. It is also caused by content, terminologies, language and word usage, which is indicated by 24%.

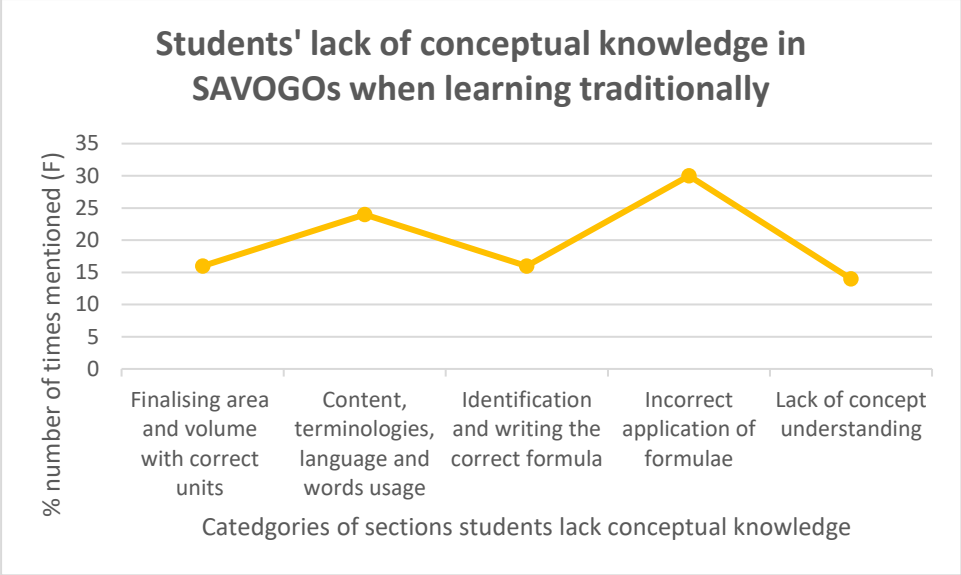


Figure 5.3: Students' lack of conceptual knowledge in learning SAVOGOs traditionally

Figure 5.3 emphasises students' lack of conceptual knowledge in learning SAVOGOs traditionally, which is mostly indicated by incorrect application of formulae during assessments.

The following classifications related to the learning of SAVOGOs, which students struggle with, were mentioned 14 times; the table below indicates the percentage of times each was mentioned.

Table 5.5: Areas students grappled with in the calculation of SAVOGOs traditionally

Areas students grappled with in the learning of SAVOGOs traditionally	
Categories of sections students grappled with	**Frequency for number of times mentioned**
Identifying missing dimensions of geometrical objects	29%
Finding different shapes contributing to the combination of geometrical objects	16%
Grappling to understand that $'b'$ in the formulae $V = \frac{1}{3}b\boldsymbol{h_{\perp}}$ and $A = b + \frac{1}{2}ph_s$ means calculate the base area of	55%

the given pyramid and $'p'$, perimeter of the given pyramid	

The unsatisfactory performance reflected in Table 5.5 above, observed after learning traditionally in Mathematics Level 3, prompted the researcher to investigate the attitudes students had towards mathematics. The ATMI played an important role in the teaching and learning processes of mathematics, as positive attitudes correlate with higher student performance. The ATMI was administered after the pre-test was analysed and the interviews conducted. Furthermore, the ATMI was a survey composed of ten questions designed to measure college students' attitudes toward mathematics. Unlike other mathematics assessments, the ATMI was designed to be brief while also capturing multiple factors that contribute to one's attitude towards mathematics. Moreover, the ATMI was a validated test aimed at developing and exploring the validity of a Chinese version of the ATMI for Taiwanese undergraduates, and further to examine the measurement invariance across gender.

Since the ATMI was a validated test conducted in various studies, including the above, it was found suitable for this study. In this study, all 60 students attempted the ten ATMI questions, and none of them was missing during the writing of the survey. Below is the table indicating 60 students' participation in the ATMI. The categories measured in the ATMI were also indicated in Table 5.6 below.

Table 5.6: Frequency table for ATMI before intervention

Frequency table for ATMI before intervention											
		SAVOGO is a very important and necessary topic to learn	I want my skills in learning SAVOGO to grow	I get happy when I solve a SAVOGO problem	SAVOGO problems helps to grow my mind and teaches me to think	SAVOGO problems are important in everydays life	SAVOGO is one of the most important subject to study	Learning SAVOGO will be helpful in any job I want to get when I am older	I can think of many ways that use mathematics outside	Mathematics is my most feared subject	My mind goes blank and am unable to think clearly when I
N	Valid	60	60	60	60	60	60	60	60	60	60
	Missing	0	0	0	0	0	0	0	0	0	0

The researcher then started to analyse the attempted ATMI categories individually.

Table 5.7: Analysis of the attempted ATMI

Fields	SAVOGOs	I want my	I get happ	SAVOGOs	SAVOGOs	SAVOGOs	Learning S	I can think	Mathemat	My mind g
Strongly A	0	0	0	0	0	0	0	0	60	60
Agree	0	8	0	0	0	0	2	0	0	0
Neutral	0	33	0	0	41	0	0	0	0	0
Disagree	0	19	0	0	19	0	8	0	0	0
Strongly D	60	0	60	60	0	60	50	60	0	0

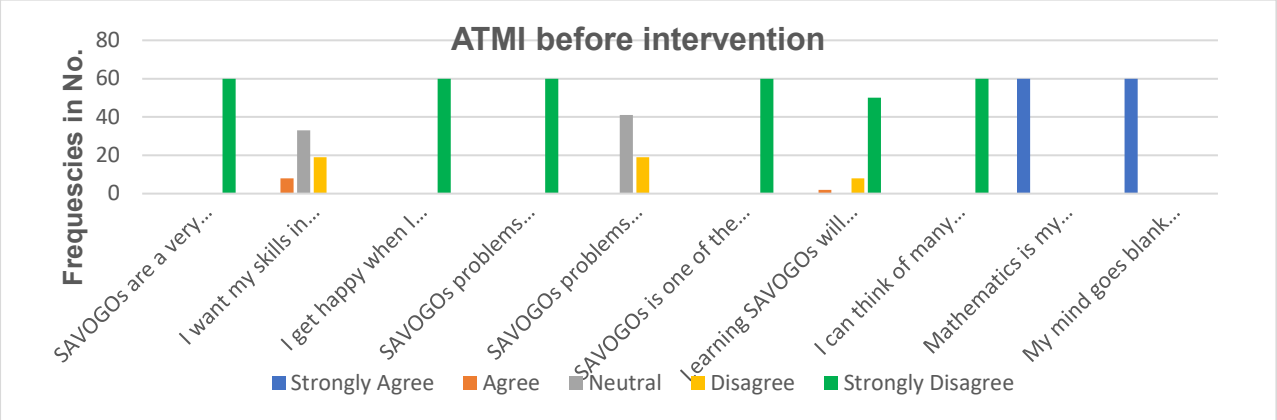


Figure 5.4: ATMI before intervention

Table 5.7 and Figure 5.4 indicate the analysis of ATMI from 60 students before intervention. All 60 students strongly disagree that SAVOGOs is a very important and necessary topic to learn. To indicate that the traditional method is disadvantaging students, 60 students strongly agreed that their minds go blank and they are unable to think clearly when they learn mathematics. The analysis was supported by Table 4.1, indicating scores for attitude towards mathematics. The table was used to calculate Cronbach's reliability range. The formula below indicates the calculation of Cronbach's alpha reliability range.

$$\propto = \left(\frac{K}{K-1}\right)\left(\frac{S_y^2 - \sum S_i^2}{S_y^2}\right)$$

$$= \left(\frac{5}{4}\right)\left(\frac{8.430508 - 2.267797}{8.430508}\right)$$

$$= 0,913752$$

Data with a Cronbach's alpha of 0.914 indicates that the items in the scale are strongly correlated, suggesting that they measure a cohesive construct. This level of internal consistency is generally considered acceptable for this academic research, allowing researchers to confidently use the scale for drawing conclusions.

5.5.1 Experience and improvement gained by students through engaging with the SAVOGOs' content through the operation of TDs

The interviews held with students and responses served as the source of data for this subtheme. Data indicating students' improved performance after the intervention are displayed below.

Table 5.7: Summary of the pre-test and the post-test scores indicating improved performance for S1 to S60

RESULTS		
STUDENTS	PRE-TEST	POST-TEST
S1	8	13
S2	15	21
S3	21	30
S4	27	32
S5	30	36
S6	35	44
S7	26	31
S8	24	30
S9	12	18
S10	20	30
S11	16	25
S12	14	23
S13	4	9
S14	7	15
S15	22	31
S16	17	27
S17	18	24
S18	6	11
S19	5	10
S20	15	24
S21	3	9
S22	9	14
S23	11	17
S24	13	19
S25	19	29
S26	16	26
S27	23	32
S28	10	16
S29	5	11
S30	16	26
S31	8	17
S32	4	11
S33	7	12
S34	11	21
S35	19	29
S36	3	8
S37	14	23
S38	6	11
S39	12	21
S40	9	19
S41	2	7
S42	13	22
S43	2	8
S44	19	27
S45	3	9
S46	8	14
S47	10	18
S48	5	11
S49	6	12
S50	4	10
S51	8	15
S52	7	16
S53	21	31
S54	11	21
S55	9	18
S56	7	13
S57	3	8
S58	20	31
S59	18	28
S60	15	24

Students were asked how they learned SAVOGOs prior to learning with TDs, and how they have improved performance post TDs.

R: *How did you approach the learning of SAVOGOs before TD, and how have you now improved?*

The following student mentioned that she improved from the TTBM of learning to the student-centred learning approach she learnt from the TD process.

S3: *The TD with the programme Bing AI, which is more fun, engaging, makes learning mathematics easier and more active, with the activities allowing us to move about and engage with the environment and also allows us to ask questions and develop the self-discovery method. To the same question, S4 voiced the following:*

S4*: In essence, what I am excited about is that, instead of learning traditionally, it's always better to discover concepts on your own. I am so proud of myself because of the discovery learning method I am experiencing. You know what, Ma'am, in discovery learning, we learn by exploration. We enjoy it because of its effective learning technique that encourages engagement and encourages students to learn new things based on their interests.*

S4 continues to mention how she learnt from the TD methodology using videos, animations, and AI.

S4: *The app broke down the process with interactive animations and personalised quizzes, transforming a daunting SAVOGOs task into an engaging learning experience. As a student, you end up feeling empowered by the AI tools.* S5 added and said:

S5*: I remember during the lesson, the researcher was present in the lecture room while we were solving SAVOGOs activities. We tried to ask questions as we used to during the TTBM, but she did not allow herself to assist. She did not give us answers, she kept on saying, and students have the necessary equipment to assist yourself, to get the meaning of concepts and to get relevant examples from. In order to make us aware that collaboration is important, the researcher kept on saying, " You have your friend next to you to assist if you don't know how to operate the tool and also to use the app." Immediately, we started and realised that the researcher expected us to discover concepts ourselves, then we started communicating with each other, using the Bing AI to discover information on our own. After that, we started seeing learning from our own perspective within a learning environment and realising a brighter future, especially since we can be quite creative when we're left with our own devices. I*

remember very well that the researcher reminded us that Bing is a chat box and a search engine at once.

The following participants were also encouraged by the discovery approach, but not using it for activities in a lecture room, rather, she used it mostly whenever he studies the SAVOGOs topic before it was introduced so that he can have a better prior knowledge. The method was also used in the preparation of assessments.

S3*: I remember studying to prepare for the next coming lesson as we were advised, and at the same time preparing for the test that is coming. Along the process, I came across the terminology 'tetrahedron' with slant height and perpendicular height. The question required me to determine the surface area and volume of the tetrahedron. You know, I didn't know what a tetrahedron is, and I knew that if one does not have a picture in mind, one wouldn't answer the question. Immediately, I thought of the discovery method, I watched the video, and typed the terminology in Bing AI for definitions. To my surprise, I saw the peel of an onion coming out in layers, one after the other, the outside peel first until I saw the white part inside. So, information from Bing AI, mathematical videos and animations was unfolding like the peel of an onion.*

If a student doesn't peel an onion properly, she will end up with tears on their eyes. The same applied to the information from Bing AI, mathematical videos and animations, if not read carefully, one can end up with tears of misconception, uncertainty and underperformance.

S3 continued and said*: The potential of AI and mathematical videos in education is truly transformative. Unlike traditional one-size-fits-all methods, AI and mathematical videos can cater for the unique needs of each student. I searched for the meaning of a tetrahedron until I found it. You know, I really unpacked the question until I understood that a tetrahedron is a regular triangular pyramid. The regular triangular pyramid has an equilateral triangle as its base and three isosceles triangles as its lateral surface. Then the definition assisted with the calculation of the surface area and volume of the pyramid.*

I emphasised**:** *A triangular pyramid is a geometric shape that has a triangular base and three triangular faces. It has a vertex, common to all three lateral faces of a*

triangular pyramid. If all three triangular faces are equilateral, then such a pyramid is called a tetrahedron. A pyramid is a polyhedron that has a base and three or more than three triangular faces that meet at a point above the base (the apex). Moreover, triangular pyramids are formed solely from triangles. The three triangular sides slant upwards to form the triangular base. As it is formed from four triangles, a triangular-based pyramid is also called a tetrahedron.

S2 added to what the researcher and S3 said:

S2: *Because of Bing AI, mathematical videos and animations found from the TD, I know that the base of the pyramid could be based on different types of triangles. If all the faces are equilateral triangles or triangles whose edges are all of equal length, the pyramid is called a regular tetrahedron. If the triangles have edges of various lengths, the pyramid is an irregular tetrahedron.*

S2 continued about the experience she had with the app.

S2: *You know, I love AI tutors, mathematical videos and animations as they can provide real-time feedback and answer questions in a way that mimics a human interaction. I would like to thank my lecturer for introducing TD S8 with an AI tool to be used for learning.*

Through this observational experience, students were able to bring to light aspects that typically remain hidden in conventional teaching methods. The TD approach highlighted this through the interview session that the correct use of language and words is a crucial aspect of learning.

This awareness now plays a huge part in how questions are formulated, and this is also seen as an improvement.

S5: *I think it would be better when lecturers are developing questions for assessments, not to use words like tetrahedron, but rather, a regular triangular pyramid, for our conceptual understanding. For us students, it would be easy to attach a meaning to a triangular pyramid rather than a tetrahedron when writing a test. Remember, for a test, we won't be allowed to use Bing AI for meaning. If the word tetrahedron is used, the*

question should be specific on which tetrahedron is being referred to, for example, 'A tetrahedron is a regular triangular pyramid…' For linking a tetrahedron to a triangular pyramid. This will assist students to know the term by linking it with other mathematical terms that can be used. As students, those are concern that are causing uncertainty and underperformance. What I like about TDs, they usually teach students about the importance of teamwork.

S2 also added his voice to this by saying that he is now also aware of how to answer questions after learning SAVOGOs with TD. He reminded us about:

S2: When lecturers are setting question papers for assessments, wording must be precise. I remember when I was unable to calculate the volume and surface area of a square pyramid due to a lack of interpreting $'b'$ *for base area and* $'p'$ *for perimeter. With the correct interpretation of variables, the area and volume can be easily calculated to give accurate values. S1 continued and said:*

S1: So, the use of TD taught me that, when answering a question paper, I should make sure I understood the terminology before attempting the question. Unlike the TTBM, which often operates with a "one-size-fits-all" approach, neglecting the diverse learning styles and paces of students, AI tools, mathematical videos and animations revolutionise this by creating a personalised learning journey for each student.

S5: Through an adaptive and personalised learning platform, which I also got through a virtual tutor, the learning style based on my understanding was adjusted, and all the uncertainty and misunderstanding I had during the TTBM were no longer noticed. With TD, I became a confident student with improved performance.

S1 further noted that using TD encouraged a greater focus on personalised learning, a process that tailors instruction to each student's individual needs by adapting to diverse learning styles and paces. This personalisation helps the students in the way they learn best and improves performance. For example, visual learners may get more graphics and animations, which teach them to focus more on real-life situations when learning SAVOGOs. It is clear from what S1 said that with TTBM, the needs of students were not catered for.

S1: *I feel so confident and certain about the practical example we found when learning with TDs. I discovered some shapes with animations whilst I was studying. For example, the question was about the graphic artist students who were tasked with an assignment to design a solid cone. In this example, shapes and animations which I couldn't remember previously were given. What I'm driving at was the real-life situation that we were able to discover through the animations of showing what a cone is, how it looks like was available with AI through TDs.*

S4 also showed some excitement in improved performance.

S4: *The example went on to use an ice cream cone. We saw an empty cone and a cone with ice cream. We discover the difference between the two when coming to calculations. What came to my mind was that even in a real-life situation, there is a difference between a cone with an ice cream and one without an ice cream. The one without an ice cream means no ice cream to be eaten, and this implies no added shape to be calculated. We further realised that, with calculations, to eat an ice cream in a cone means the addition of another shape to be calculated. Finally, the calculation will be for the total surface area and volume of a cone and a half circle. But for an empty cone, like the one the graphic artist student is designing, it will be only the calculation of the volume and surface area of that cone alone. Unlike with the TTBM of learning, we could not differentiate between a cone containing an ice cream and an empty cone. Personalised learning, focusing more on real-life situations when learning, is what we are focusing on now.*

S6 related the experience of misreading questions and over-enthusiastic self-confidence that sometimes makes them lose points when answering questions, assignments and tests, and this student wouldn't have picked this up if it wasn't for her learning with videos, animations and math manipulatives, helping to visualise math concepts both in mobile learning environments and computer-based environments.

S6 mentioned that:

S6*: Iyoooo Ma'am, previously, I would get so excited, thinking I knew the question and start calculating without reading properly and having understood SAVOGOs contents.*

This will give me a false impression that I obtained the correct answer. With TTBM of learning, we were very quick to answer without getting the context of the question. We did not read the entire question for proper understanding, and this resulted in blank spaces for unanswered questions. To our disappointment, this resulted in underperformance and incompetence in mathematics. Basically, the mathematical videos, animations and math manipulatives that helped visualise math concepts both in mobile learning environments and computer-based environments through TD gave us an idea of how to improve on reading for understanding. The Bing AI that prompted us to ask questions and its ability to answer follow-up questions, admit mistakes, and reject inappropriate information boosted our confidence tremendously.

However, S6 also highlighted that this self-confidence can also be positive if it can be coupled with access to a wealth of resources when applying Bing AI through the TD. She mentioned that:

S6: *What I mentioned about self-confidence is what I experienced as a student, but it does not mean that my fellow strongest students could not apply it after learning traditionally. What I noticed is that they could answer all the questions, and that assisted them in completing the question paper on time during the test and examinations. The challenge was that completing the question paper on time does not necessarily mean all the answers written are correct. In conclusion, coupling confidence with access to a wealth of resources assisted all types of students, whether you are a low, moderate, or strong or fast learning student. We, as TVET students, are proud of being exposed to the TDs and the programme AI, Videos, animations and math manipulatives used to help visualise math concepts both in mobile learning environments and computer-based environments.*

5.6 Reflections on determining the best method for learning and attempting SAVOGOs questions

Data presented on students' reflections on determining the best method for learning and attempting SAVOGOs questions has been divided into the following subthemes: (i) TDs removed students' desolation, (ii) Reflecting on the focus TD placed on

observing students, (iii) Students' reflections on TDs, mathematical videos, and animations, (iv) TD provided a new focus on student-centredness, problem-solving skills, and focus on anticipated students' responses.

5.6.1 TDs removed students' desolation

Students usually study alone in their lecture rooms, and the idea of collaborating with other students in these spaces was, for the most part, uncommon during their learning process. Students also felt that their textbooks were their own domain and space. Those who participated in this study revealed that the process of learning with TDs has brought them out of desolation. For example, when students were asked to describe their general impressions and experiences of learning SAVOGOs with TDs.

S3 pointed out that:

S3: *As far as learning with a textbook is concerned, I am like in desolation because I'm working all alone. I'm not used to other students. I only go to them for my personal engagement and so on, and that's the only thing you can do with your fellow students, accompanying each other after school, and then we are done.*

The same student further mentioned that because of his exposure and learning SAVOGOs with TD as well as with the researcher present, she found that:

S3: *At times (before TD), you got scared to go to the lecture and fellow students, but now you get to them and other students to help you with SAVOGOs content.*

S4 shared the same view and said that:

S4: *For me, TD was very informative because I could learn relevant mathematical terminologies for answering questions on SAVOGOs, for example, instead of just being locked in my lecture room alone and desolate. Taking you outside of that daily desolation that we usually experience as individual students in the lecture room with the textbook method, that is how it is normally done every day.*

Three of the six students interviewed mentioned learning with TD in a collaborative format, and that it brought them out of desolation, and it was mentioned at least five times amongst them.

5.6.2: Reflection on the focus TD placed on observing students

The observation process of students in the process of learning SAVOGOs with TDs was a novel idea for the researcher as a participant in the teaching with TD, and together with the participating students, I reported that this stage was an eye-opener for us.

When students were asked how and to what extent they had improved their participation in learning and collaboration with TD, S4 said:

***S4**: What I enjoyed about the lesson the lecturer was presenting was the observation of the lecturer operating the TD and me being given the opportunity to just sit and observe, uhm, because when you are in a lecture room, you have the sole responsibility of learning, I could just sit and focus on the lecturer demonstrating how to learn with TDs. Yeah. I wish I could do more of that. An innovative idea.*

S5 resonated with the previous sentiment:
***S5:** Habitually, I only observe when a lecturer is drawing attention to a portion in a textbook, but that task could be specific to a certain portion of what I was supposed to have done. Yeah, so I used to observe, are other students doing the work? And how are they performing, but not realising that these can be my weak points of not doing the given task, and I didn't realise that part of identifying what might be the misconception of SAVOGOs that might prevent me from doing the given task. I never approached it in the context of observing myself and another student's weak points in learning SAVOGOs.*
The researcher further prompted him to be more specific with the following question:
***R:** Describe the improvement and the specific element learning with TD which facilitated your improvement.*
The S4 corroborated S5's view that observing TD was an eye-opening experience, adding that it offered a new perspective through the student's lens. He stated that:

***S4**: Being a participating student in the learning with TD, also being part of the TD lesson by a lecturer, I had the opportunity to view other students and the lecturer, for me that was an eye opener and I had a better opportunity to focus more on their actions of using TD and realising that, once I get to learn SAVOGOs once again I will implement it with my own personal study. I also realised that the TD would assist with the learning process of SAVOGOs and provided me the ability to put myself with other students and try to learn with them and sit with them…. So, I got to see it from a student perspective within a learning environment.*

S6 was impressed by how the observation part of TD made him reflect on how observation can assist in thinking about it as an alternative form of learning. He stated that:

***S6:** Observation has actually a high level of learning we ever had because we are looking at the other students and lecturers communicating with mathematical videos and animation, we can say we have noticed that, or I have observed that, or it seems like there was a problem with this, let's get over that stumbling block quicker because why did fellow students do this and not that. This is the misunderstanding because we observed what these students did and how they did it, how they behaved, etc.*

With regards to this, he goes on further to say that:

***S6:** With the TTBM method of learning in my hands, I go blind because I just go on with what I have in front of me, and don't have the other knowledge which TD brings forth, like, I don't have the knowledge of how to approach it, "his facial expression, his sighs, his frustrations and so on." Because with TDs we are looking at explanations audibly, visually and kinaesthetically and through TDs we are busy assessing all of it. That is what I am saying, it is a high level of learning. You can now change your learning method because, through observation, you realised that there are more students committing the same misunderstanding.*

S5 also mentioned the following in connection with the aspect of TDs:

S5: *We were observing other students learning SAVOGOs with TD, but when using AI, mathematical videos and animations for personal study, you also get some ideas of how SAVOGOs content is supposed to be learned, understood and applied during*

assessment. And obviously, this wasn't for examination purposes; it was just to be there to see how another person does the learning with TD. So that also helped me in the understanding of SAVOGOs.

The same student went on to point out that:

S5*: I want to say, being an observer within the operation of the TD process, what's nice this time is that I wasn't part of learning without being hands-on. I had to be an observer. I got to sit as an observer having my own TD, just to view from outside the box in other words because there was, normally I am inside the box, but now I got the opportunity to be out of that box and to see how other students operate and learn with TD, so for me what was beneficial is getting to see another student learning the same topic that I might have done before.*

All six of the students who were interviewed, or 100% of the participants, mentioned the observation stage of TD in many different and positive ways, and it was mentioned at least 15 times in their responses on various other issues. It appears that the observation stage of learning with TDs is a positive aspect of TDs and a stage from which students can learn a lot and improve their learning remotely.

5.6.3: Students' reflections on TDs, mathematical videos and animations

Many students reported that reflecting and debriefing collaboratively on the use of TD, mathematical videos, and animations was not something they bothered with alone after learning traditionally. Also, they did not bother using mathematical videos in a group where different inputs can be heard, and ideas can be used in the next learning to improve the lessons for future reference. Many students mentioned that it is really a time to reflect on the learning with TDs using AI, mathematical videos and animations to improve the learning style, and it is a time which is utilised well. When students were asked *what other learning improvements did, they make and which of them stood out for them.*

S5 said:

S5: *In normal traditional classes, we don't reflect on a lesson, we just look at the lecturer presenting, and we receive whatever, and that's it, you tick the lesson off*

without gaining. We never reflect, but with TDs, it at least gave you that time to reflect and collaboratively to reflect, and each one has a say in the debriefing stage and see how this lesson was delivered by the lecturer and received by the students. Usually, we don't do that with the traditional textbook method of learning. That will make more effective use of students' time, and often we spend so many hours and minutes on a topic, and then it's gone to waste, and students don't retain the necessary information.

S1 added:

S1: *When we learn a SAVOGOs topic with TD using mathematical videos and animations, we come and discuss (debrief) where those things, like the misunderstandings we came across during the learning process, we ask ourselves, did we get it correct? Like in the times of what we were doing there, as much as we have debriefed and reflected, which is an important part for lecturers to look at. And important for lecturers to get involved and encourage students also to reflect on their learning, maybe in a collaborative way.*

The same student emphasises the debriefing stage further by stating that:
S1: *It is about planning the topic before the lesson and checking with mathematical videos, and coming back to plan again to improve, so it always works that way.*
Three of the six participants commented on the debriefing stage of TDs, and it appears that it was taken as a very positive aspect of TD and learning, which students did not think about much. It was also seen as an important aspect for students to reflect on their learning with TDs, as well as for lecturers in terms of instructional leadership. The aspect of debriefing and reflection was mentioned roughly 15 times.

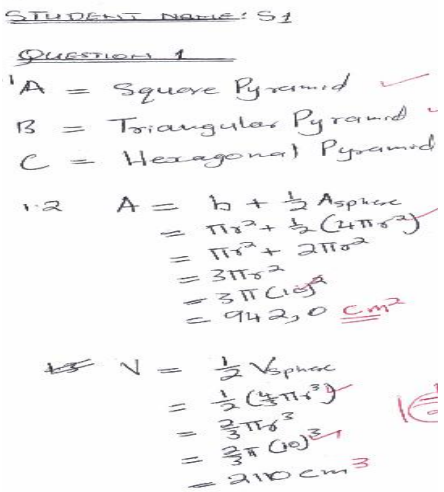
5.6.4 TD provided a new focus on student-centeredness and problem-solving skills

The researcher asked students questions about their impressions and experiences of learning SAVOGOs with TD. The following question was asked:
R: *How did the TD learning improve your ability to focus on thinking and learning? If it did, can you give an example? If it did not, please explain why not?*

The following student mentions how she enjoyed learning with TD and how she also enjoyed using AI, mathematical videos and animations for more information. S1 also reiterates that SAVOGOs in mathematics is a topic most students struggle with.

S1: *I could see how most of us enjoyed working in groups with TD, because with traditional method of learning we don't often work in groups for example, it was nice to feel the vibe from mathematical videos and animations, the programme was very encouraging, and in the interview with our lecturer we also liked the student-centred approach as we were actively involved. We did not get everything correct during the post-test, but we were inspired, and the learning went by quickly, and I think we can have more student-centeredness with TD. It was nice to see that I can enjoy mathematics and SAVOGOs, which is normally a topic that I used to dislike.*

The following are extracts from learners' responses to the test after intervention. In responding to Question 1, which required students to label the table by indicating which formula is for triangular, square and hexagonal pyramids, S1 did extremely well. Another question required the students to calculate the surface area and volume of the hemisphere. S1's response after intervention to Question 1.1 is captured in Extract 9 with an improved percentage of 13% as compared to the initial 8% S1 got before intervention.



Extract 5.8: S1's response to Question 1.1 and 1.2

When the researcher asked for the kind of challenges students experience when calculating surface area and volume of geometrical objects (SAVOGOs), their responses were as follows:

S1 indicated that the challenges are minimal since with TD, mathematical animations and videos, he can seek the meaning of some terminologies.

***S1**: "Look, I managed to get Question 1.1 in Extract 8 correct, which is about indicating which formula is for triangular, square and hexagonal pyramids."*

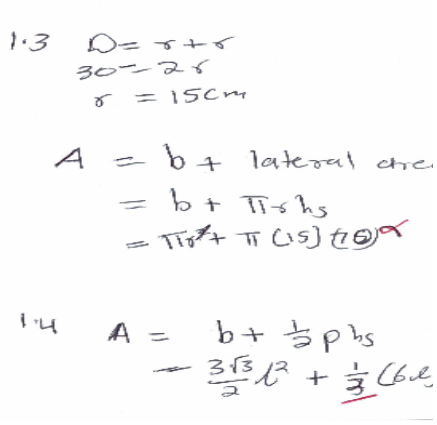
S2 further indicated the engagement she experienced:

***S2:** And then also the positive thing was for me to really engage and get engaged, and how I got involved, and how much I enjoyed seeing improved performance.*

S4 also mentioned that he found the adoption of the student-centred approach to be an improvement in his learning and reflection. Furthermore, he appreciated the student-centred approach, noting that the use of mathematical videos was instrumental in fostering student independence and building confidence. S4 concluded that:

***S4:** Fine, what I liked about the TD is that it does take on a problem solving approach as well as a student-centred approach, which gives the student the opportunity to actually sort of having learning in their own hands so having learning in their own hands gives them that responsibility for their own learning which I found an improvement from my way of learning and performance.*

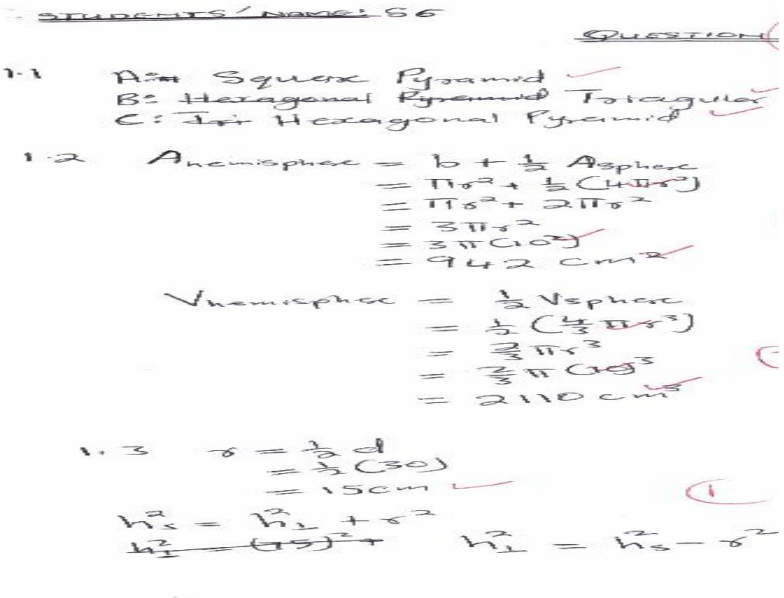
The following are extracts for S4's responses with respect to Questions 1.3 and 1.4 after intervention. In responding to Questions 1.3 and 1.4, which require students to calculate the surface area and volume of a hemisphere using $\pi = 3.14$, and to calculate the surface area and volume of a hexagonal pyramid with a base edge of 100 mm and a slant height of $6\sqrt{46}\,cm$ respectively, S4 indicated some improvement when attempting the questions because some parts of the formula were interpreted correctly in Extract 9.



Extract 5.9: S4's response to Questions 1.3 and 1.4

There was a remarkable improvement in the calculation above, as initially S4 wrote correct values, then thereafter the student doubted what he wrote, which is normal for any student during learning. What I noticed above is not a lack of knowledge, even if the student could not finish the calculation, but uncertainty which a student can work on. I also noticed an improvement for 1.4, where S4 wrote the area of a hexagonal pyramid partly correctly because the correct formula should be A = $\frac{3\sqrt{3}}{2}l^2 + \frac{1}{2}(6l)h_s$. In this case, the only part the student could not write correctly was $\frac{1}{3}$ instead of $\frac{1}{2}$ in the formula for calculating the area of a hexagonal pyramid.

Below is S6's response to Questions 1.1, 1.2, and 1.3 after intervention.



Extract 5.10: S6's response to Question 1.1, 1.2, &1.3

For S6, there was a great improvement after intervention, as there was a percentage improvement of 50% after intervention, as compared to 35% before intervention. Questions 1.1, 1.2 and 1.3 were excellently attempted because of the tablet intervention. This is evidence that this student understood what was needed in the learning of SAVOGOs when using mathematical videos and animations through tablet devices.

S6 expressed her excitement as follows:

S6: *I would say what I learnt also is sometimes the student can actually guide fellow students in a group work effort and application of TD instead of the lecturer being the one to play the facilitator, so what I am saying is what I am learning from this is that sometimes it's also good to provide students with independence in their learning because now they have to speak in front of the whole class expressing their innovative discovery and thinking about the mathematical videos and animations they watched.*

Innovative-thinking education encompasses a multifaceted approach that elevates principles of creativity, collaboration and problem-solving abilities essential for success once students ultimately find themselves in the ever-evolving workplace.
Another student saw the value of using student-centred learning during and after the learning with TD was completed.

S4: *Uhm an element that I had used and applied more during learning on was the student -centred approach, we were not necessarily put in groups because of time constraints but I have used the student-centred approach and problem-based questions as well and what the lecturer would do was actually to take questions from past exam papers and would give it to us to solve it by researching from the TD.*

S1 corroborates and mentions that it also changed the way he learned in a student-centred approach and that it challenged both the students and the lecturers. For example, he states that:

S1: *I really enjoyed learning with TD as the lecturer would start to challenge us through problem solving and student-centred learning, and she would start to appreciate us also and our knowledge because lecturers were thinking they must just transfer knowledge without understanding, but with TD, they realised that sometimes students have knowledge themselves and different methods how they approach SAVOGOs with the aid of TD and our lecturers were able to appreciate that.*

From the six student interviews, it was revealed that students enjoyed learning with TD, mathematical videos and animations in general, and liked the student-centred approach most. It was also revealed through the interviews that they will look at SAVOGOs' questions differently and how they interpret them.

After learning with TD, when participants were asked by the researcher what did you enjoy most about learning with TD, participants had the following to say: they would like more of these TD processes so that more knowledge can be discovered by students. If lecturers can go around and see what students are doing wrong. The following were their comments:

S2 *said: I would love to do more of these types of sums with TD.*
S3 *added: Teamwork is the best because we learn better from peers, and mathematical videos are installed in our TD.*
S4 *agreed with S3: I must say, working with each other is better than working alone.*
S5 *emphasised that: It would be beneficial to us if lecturers could interact with students during the learning with TD for facilitation, guidance and control purposes.*

After intervention with TD, when the participants were asked by the researcher what they enjoyed most about learning with TD, S1 had the following to say.

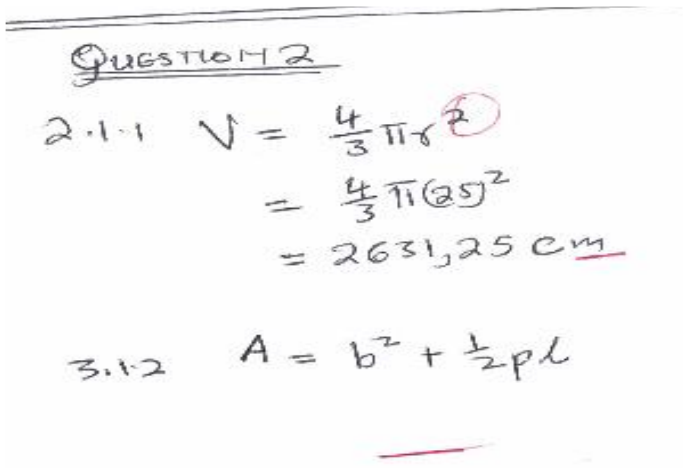
S1: *The engagement with fellow students, lecturers and their devices.*

To the same question, S6 added:

S6: *And the engaging Ma'am, you see, when it comes to mathematics, we don't normally do group work, we normally do individuals, especially when we use the textbook method, so my group work skills when learning with TD were lifted (raised).*

S3: *I think someone has mentioned it before, but the questions, you really need to read the SAVOGOs questions properly.*

S2: *Because I had the opportunity to engage with my fellow students and engage with mathematics experts through search engines, mathematical videos and animations, my confidence and attitude toward mathematics were uplifted.*



Extract 5.11: S6's response

S6's response to Question 2 about the volume of the sphere after intervention is captured in Extract 5.11.

S6 did not get Question 2 correct, but what was exciting was that the student attempted the question after intervention, which was not attempted before intervention. Question 2.1.1 was about the volume of the sphere. The student wrote $v = \frac{4}{3}\pi r^2$ instead of $v = \frac{4}{3}\pi r^3$. This shows that the student understood the concepts; it might be because of the pressure or examination anxiety that the student wrote an incorrect power of r. Looking at 2.1.2, the correct formula for calculating the total surface area of the square pyramid was written as $A = b^2 + \frac{1}{2}pl$, but from there, no substitution was made to complete the question. Because S6 managed to identify the correct formula for 2.1.2, this indicated a great improvement after the intervention, as these questions were not attempted before the intervention.

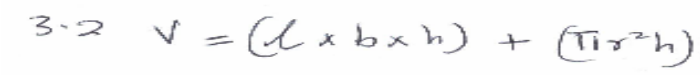
S6: *Ma'am my error in thinking was confusing the calculation of volumes for certain shape with area and perimeter because it is more or less the same, so instead of using cubed for volume I used to put the square for the power of the radius, so confusing powers, so being uncertain about units when calculating perimeter, area and volume was the main challenge students struggled with.*

When students were asked in the interview whether they would like to learn more about TD and being involved in student -centeredness, the following student answered as follows:

Researcher: *Would you like to learn more about TD and being involved in a student-centred approach?*

S6 said:

S6: *Yes, every time we learn all the subjects due to the cleverness of TD with programmes like mathematical videos, animations and AI. Look at my ability to write formulae after intervention.*



Extract 5.12: S6's response to Question 2.3

Before the intervention, this question was not attempted by many students, but after the intervention, more students attempted the question. The formula for checking if 250 000 $cm^3$of concrete would be enough to build two structures of the model was correctly written as $V = (l \times b \times h) + (\pi r^2 h)$.

I also asked participants about their attitude towards mathematics after learning with TD using mathematical videos, animations and an AI programme. The following were some comments students had regarding the student-centred and problem- solving approach adopted after learning with TD.

S4's response was:

S4: *This session was useful because we received a clearer view of the actual learning, and this boosted our confidence and attitude. The learning took place as a student-centred approach with TD.*

S5 shared the same view and said that:

S5: *Learning with TD improved our attitude. Students will be more prepared for a student-centred and problem- solving approach.*

S1 shared the same sentiments and said:

S1: *Students will be motivated with a positive attitude to solve the SAVOGOs questions through the operation of TD and following the mathematical videos and animations, as it is a new approach for them.*

I then recorded and analysed the post-test pleasing results and thereafter gave them to the students.

5.6.5 Focus on anticipated students' responses

The researcher recorded and analysed the post-test results, which were pleasing, and subsequently shared them with the students. Below is the students' satisfactory performance, which led the researcher to conclude that the tablet intervention significantly improved students' performance. It was also noted that in the pre-test results, only two students passed, whereas in the post-test results, eleven students passed, as indicated in the pre- and post-test table below:

Table 5.8: Summary of the pre-test and post-test percentages

TESTS	Number Wrote	Competent Students	Incompetent	Pass%
PRE-TEST	60	02	58	04%
POST-TEST	60	11	49	19%

The above analysis shows a percentage increase of 19% in the post-test compared to the 4% pass rate in the pre-test. A 15% increase in the pass percentage indicates that

learning SAVOGOS with a tablet device improved students' performance. While the pass percentage may seem small, a closer examination of the results table for the pre-test and post-test reveals that every student demonstrated improved results after learning with the tablet device. This improvement is also evident in Figure 5.5 below, which indicates a shift in percentages as a result of enhanced performance.

Table 5.9:Pre- and post-test percentages

PRE and POST-TEST RESULTS			
NUMBERS	STUDENTS	PRE-TEST	POST-TEST
1.	S1	8	13
2.	S2	15	21
3.	S3	21	30
4.	S4	27	32
5.	S5	30	36
6.	S6	35	44
7.	S7	26	31
8.	S8	24	30
9.	S9	12	18
10.	S10	20	30
11.	S11	16	25
12.	S12	14	23
13.	S13	4	9
14.	S14	7	15
15.	S15	22	31
16.	S16	17	27
17.	S17	18	24
18.	S18	6	11
19.	S19	5	10
20.	S20	15	24
21.	S21	3	9
22.	S22	9	14
23.	S23	11	17
24.	S24	13	19
25.	S25	19	29
26.	S26	16	26
27.	S27	23	32
28.	S28	10	16
29.	S29	5	11
30.	S30	16	26
31.	S31	8	17
32.	S32	4	11
33.	S33	7	12
34.	S34	11	21
35.	S35	19	29
36.	S36	3	8
37.	S37	14	23
38.	S38	6	11
39.	S39	12	21
40.	S40	9	19
41.	S41	2	7
42.	S42	13	22
43.	S43	2	8
44.	S44	19	27
45.	S45	3	9
46.	S46	8	14
47.	S47	10	18
48.	S48	5	11
49.	S49	6	12
50.	S50	4	10
51.	S51	8	15
52.	S52	7	16
53.	S53	21	31
54.	S54	11	21
55.	S55	9	18
56.	S56	7	13
57.	S57	3	8
58.	S58	20	31
59.	S59	18	28
60.	S60	15	24
SUM	N/A	751	1198
Mean	N/A	12,51667	19,96667
Max	N/A	35	44
Min	N/A	2	7

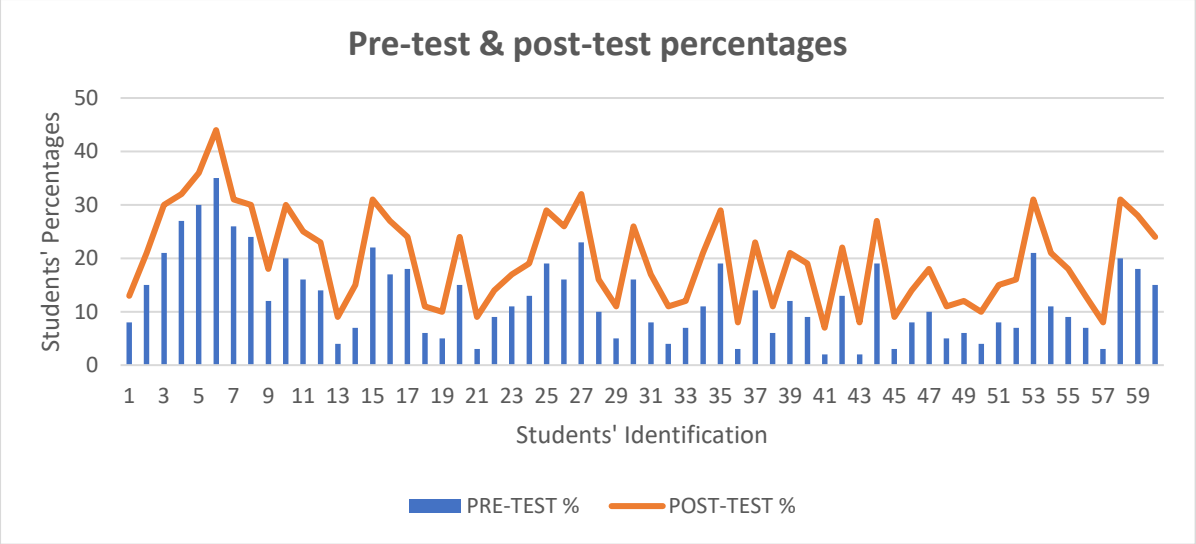


Figure 5.5: Representation of the pre-and post-test data graphically indicating the shift of percentages of S1 to S60

A shift is noticed in Table 5.8, Table 5.9 and Figure 5.5. In Figure 5.5, the pre-test is indicated in blue, whereas the post-test is in red. It was noted that students' marks improved throughout, as the graph for the post-test remained above that of the pre-test. Being above indicates that the marks for the post-test are higher than those for the pre-test. This indicates improved performance after learning mathematics with TD.

S6 commented as follows:

S6: *Well, one would know how to learn with TD, and it helped us to improve our performance and attitude. Because we know how to learn with a tablet device, we are asking ourselves what would be the expectations. The thing that might come up to help us to highlight those things in our learning with a tablet device and the misunderstanding also helped us in that area.*

S2 shared the same view and said:

S2: *Learning with TD shows that one can learn actual responses from the mathematical videos watched. So, it makes you think and critically think about discovery learning.*

I asked the students about what else they think can assist in improving the performance in mathematics.

S1 responded and said:

S1: *I think breaking learning up into some small intervals can reduce the uncertainty and misunderstanding students have, and can address the anticipated answer that students had before interpreting the question properly.*

The following students mentioned that the anticipated student's response when learning made them become more proactive in thinking. S4 commented that:

S4: *Being proactive. TD always answer what I anticipated. Predictions according to my experience with learning the SAVOGOs topic are what I had before attempting the question, but I would never have voiced them or focused on them if it wasn't for the TD. Pre-learning with TD was usually about rote learning, which refers to a type of learning where students memorise subject content. It is usually accomplished through repetition of facts. I improved a lot because of this aspect of TD (to anticipate, predict). Anticipation. Etc., is a powerful aspect of TD.*

S4 agreed with the same sentiments and said:

S4: *Writing down our expected responses and misunderstanding helps us to address those responses during the learning process as well.*

S6 corroborates the previous student's view and adds that the lecturer participating in the learning with TD assisted him. He states that:

S6: *What I picked up from the lecturer was writing down the student's expected responses (and misunderstandings). It helps the lecturer to address those responses during the teaching and learning process. I never thought of that all this time in my learning as a mathematics learner. I will use this in the future in my learning to say what I expect my fellow students to do when collaborating, and then categorising the misconceptions in SAVOGOS so that I can learn from them.*

All six students, or 100%, mentioned the anticipated student responses, and most of them found it to be an eye-opener and something which was not paid attention to previously in their learning of SAVOGOs traditionally. Amongst the six students who mentioned this, it was mentioned roughly fourteen times.

With regard to the participants' final comments, the following remarks and experiences were of particular interest in relation to anticipated student responses. S1 said:
S1: *Great to anticipate student responses and improved performance in the learning of SAVOGOs with TD. Inspires us students to evaluate different learning approaches for learning to have an optimal effect. Very insightful and inspirational.*

S2 added and said:

S2: *There is so much improvement in performance and attitude in learning with TD and the applications of mathematical videos. S4 echoed her voice and said:*

S4: *I learnt other views of learning, such as the anticipated student responses through collaboration with other students.*

As we were entering the last stage of performance the following students recorded the following about their attitudes towards learning mathematics.

S4 made a follow-up about the student-centred approach.

S4: *Exciting! The tests and students learning SAVOGOs with TD are taking a student-centred approach. I can't wait to observe students' positive attitude towards mathematics!*

S1 added and said:

S1: *We are getting closer to a refined learning method with only a few challenges.*

A chart recording the above will show the results of how the TD approach can provide reflection for students.

Table 5.8: Students' reflections on the best method in learning SAVOGOs

Students' reflections on best method in learning SAVOGOS				
Removing students' desolation when learning	Reflecting on the focus TD placed on observing students when learning SAVOGOs	Students' reflection on the debriefing stage of TD and ChatGPT-4	TD providing a new focus on student-centred and problem-solving learning	Focus on the anticipated students' responses
8	26	24	18	24

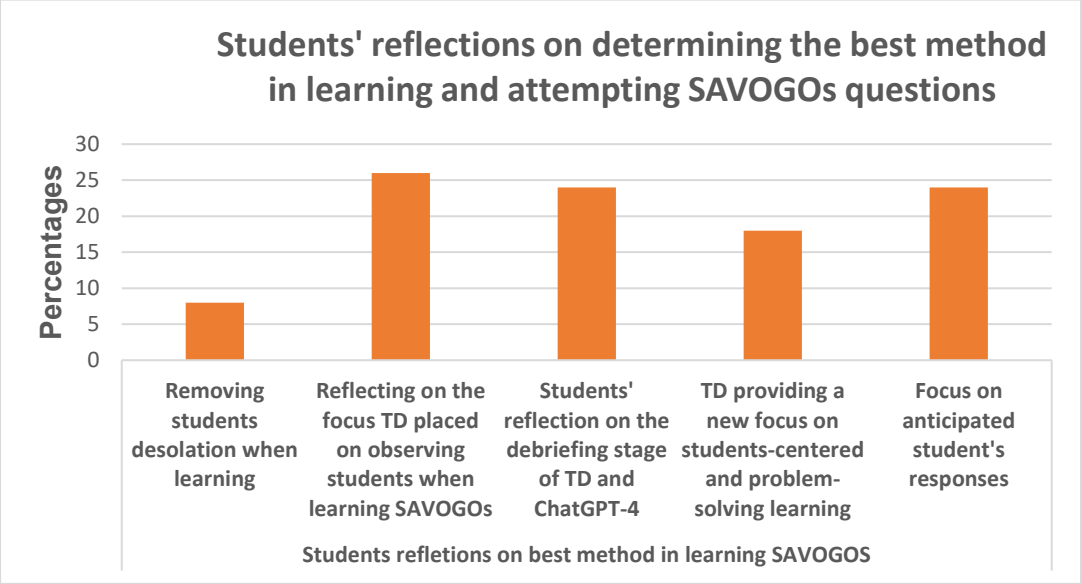


Figure 5.6: Students' reflections on determining the best method of learning

5.7 Promotion of problem-solving skills through collaboration and participation

Collaboration and participation are at the heart of learning with TD. As one participant mentioned, *"Collaboration is learning with TD, so you should not ask how a TD is; you should ask how the collaboration is.*" Furthermore, learning with TD cannot occur without participation, and many aspects of participation in mathematical videos come into play in the operation of TD. These include creating an open learning culture, sharing ideas and knowledge, cultivating respect and trust among students and lecturers, and fostering a positive, non-threatening, and non-judgemental atmosphere. This environment allows for decisions to be made freely, without fear of judgement

regarding one's ability to operate a TD. The subthemes identified under this theme were: (i) discussions between students using mathematical videos and animations; (ii) sharing of ideas and knowledge; (iii) an open culture of learning development between students and lecturers; (iv) collaborative learning that reinforces trust and respect among students and lecturers; and (v) an open culture of learning development between lecturers and students.

5.7.1 TD using mathematical videos and animations, discussions between students

When students were asked what their general impressions and experiences were in learning SAVOGOs collaboratively with TD and mathematical animations, the students had very positive responses. Many students mentioned the discussions that ensued from being part of learning with TD when the following question was asked.

R: *What impact did TD and mathematical videos have on you when learning SAVOGOs?*

S2 said:

S2: *I think it is very good, for myself but also for my fellow students, so they can discuss and we can discuss, so it challenges you to think critically. We have to argue about SAVOGOs' content.*

S1 agreed with S2 and said:

S1: *For me SAVOGOs' discussions with my fellow students were really a great experience because we don't often have time that we set aside to discuss SAVOGOs content we're learning. But with a tablet device, we can chat and open a discussion immediately.*

S3 explained how TD collaboration leads to a deep level of discussion on content, questioning and answering techniques, delivery, student management and terminology.

For example, S3 explained that:

S3: *But we never get to discuss the SAVOGOs' content, where we sit down together as students and say, okay, this is a square pyramid and then what kind of questions to ask. Ok, and if we develop a question like we say we don't say calculate the area of a square pyramid, instead we ask how much material of cover you will need, you see we don't say those kinds of things. It never comes to my mind. Or I think that will help me now in future when I am alone and with fellow students, just to emphasise when I'm learning and taking notes, to emphasise that this is the area.*

S3 points out the importance of lecturers' involvement and for them to learn from what emerges when misconceptions arise.

S3: *There are basically many misunderstandings about the topic SAVOGOs, because when we're answering assessments for assignments, we take one question, discuss using TD and mathematical videos. Immediately when a lecturer points out a misconception, we analyse the misconceptions for that question. So, that's what I was not doing before when learning traditionally, and lecturers can also learn from that, by taking us as students on working together and then analyse the questions together, always when the time allows to discuss and come up with an informative and mathematically sound solution.*

The discussions which continued post-learning SAVOGOs with TD were also highlighted by some students. For example, students also mentioned how easy it was for them to continue with discussions post- learning SAVOGOs with TD.

For example, S4 and S3 referred to the discussion in the following way:

S4: *We shared and discussed our experiences after learning SAVOGOs with TD, before the debriefing with the researcher, and there was also an informal debriefing with each other, beyond learning with TD.*

S3 commented positively and said:

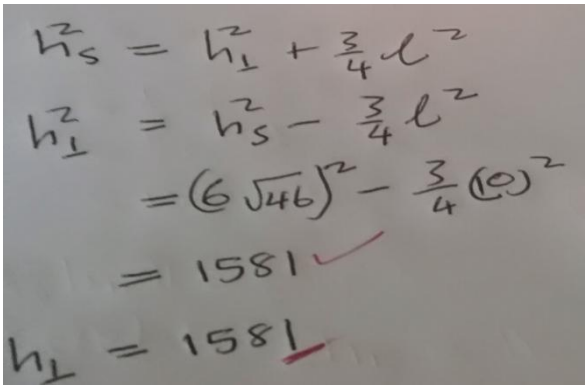
S3: *Even after learning with TD, I found it so easy to discuss content issues and matters much easier with my fellow students at the campus, and this is a plus which came from learning with TD. This is now done more regularly, and previously, I only looked at my peers and never interacted and engaged with them in this way.*

All four students, or 100%, in the process of learning SAVOGOs with TD, referred to how the participation and collaboration through TD and animations brought about good and deep healthy discussions, debates, and arguments around content and context in Mathematics Level 3. Two students mentioned that it even continued after the operation of TD and mathematical videos was completed. The four students referred to the concept of discussions at least 15 times.

With regards to the above aspect, S2 and S4 also recorded the following in their scripts, respectively.

S2: *We were very hands-on. We interacted well, and there was a lot of enthusiasm. Enjoyable and fruitful exercises.*

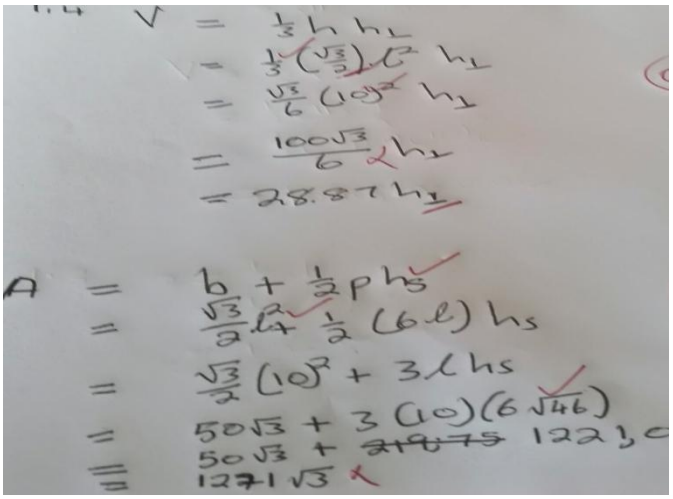
S4: *It is interesting to view our work with improved performance. Look at my script with an improved performance.*



Extract 5.13: S4's response to Question 1.4

In the above extract, S4 was responding to Question 1.4, which instructs: calculate the volume and surface area of a hexagonal pyramid with a base edge of 100 mm and a slant height of $6\sqrt{46}$ cm. S4 immediately realised that she needs to calculate $h_\perp$ by

using the formulae $h_s^2 = h_\perp^2 + \frac{3}{4}l^2$ for a hexagonal pyramid. S4 managed to calculate the perpendicular height correctly, but forgot to put the answer under the square root sign as required. Also, he forgot to write the unit, which was supposed to be cm. Above all, the choice of the formula and substitution was 100% correct, which shows a great improvement after intervention. The continuation of this student's work is represented in Extract 5.14.



Extract 5.14: S4's continuation of response to Question 1.4

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After analysing student's scripts, I realised the following improvement:

R: *Good and great improvement in the answering of question after TD intervention. When looking at the discussions amongst students, they were going on without one over-powering the other, and each one gave a hearing to everyone. Constructive and healthy discussions were taking place after learning with TD.*

5.7.2 Sharing of ideas and knowledge amongst students, lecturers and HODs

The collaborative and participative nature of learning with TD and mathematical videos encouraged the sharing of ideas in most of the learning and activities. It was also a powerful way to get the views and opinions of fellow students on issues such as learning SAVOGOs, observations and the debriefing stages.

Students were then asked the following question:

R: *To what extent did the involvement of the researcher as a participant observer in the learning process of SAVOGOs impact the improvement of learning and performance?*

For example, the following student points out how important the sharing of ideas is in connection with using mathematical videos:

S1: *So, I felt that the sharing of our ideas was very good. It was very good hearing other students' input, their views, their opinions, their approaches, hey, that was remarkable, and then I just realised more and more that learning with TD and mathematical videos needs to be a priority. You know, that is the basis on which our misunderstanding will be clarified or corrected. So, truly, I really enjoyed listening to my fellow students and my lecturer, which was a good experience. I think the sharing and the opportunity to work together and be creative together, and share ideas.*
S4 emphasised the sharing of common experiences between students and also the lecturer of the TD process. For example, S4 mentioned that:

S4: *We get to share common experiences, Yah neh, which I thought was uncommon… . We became more open to sharing knowledge with other students, including lecturers.*

In the next section, he reiterates how important this is in terms of teaching and learning and for the whole TVET sector:

S6: *For me, the greatest benefit was the sharing of experiences of learning with a TD and getting to learn how the other students would learn by questioning for example, that is, what I enjoyed about learning with a TD is that in learning sometimes we are questioned as students, this can also be better than just giving us the introduction, rather to question us and have us take a major role in bringing the introduction into their learning process. So, I would say guaranteed that learning with TD, mathematical videos, and the ability to write emails is a benefit for the entire TVET sector, because students of different ages and levels get to share their experiences with each other.*

S2 alluded to the previous student and states that:

S2: *I know when I start operating a TD to learn, my fellow students are going to do that and so on, which is peer learning, and somebody in the group can come along and say, " What you do is good, can you explain to the rest of the group." This is what I do as a student. So, we must work out a strategy to use whatever works within, so we have a platform to share things about learning SAVOGOs with TD.*

All six students, or 100 %, commented very positively about the sharing of ideas that TD afford in various ways, such as in teaching and learning, sharing of knowledge and working together. The six students referred to the concept of sharing at least 12 times in their discussions.

Students further commented as follows:

S5: *The collaborative approach brings in new ideas as it stems from a collective input of experienced students after learning with TD.*

S6: *When working together as students, you learn from others. The group has a lot of offers.*

S5: *Great experience to share views and ideas with fellow students, taking fellow students' interests at heart.*

S3: *I want to emphasise that the sharing of ideas during learning SAVOGOs was good.*

5.7.3 Openness between students and lecturers

The following comments were made when the researcher asked the following question:

R: *How did the participation and the collaboration between the students together with lecturers in the learning process with TD bring about an open, positive and supportive environment, and how did your relationship with your fellow students as well as lecturers change through the process of learning with TD?*

S2 points out that:

S2: *I think students must be open-minded and must also be hands-on in their studies. I also think that lecturers and students must have an open mindset to enable learning to flow progressively with understanding.*

S2 goes further to mention the importance of using high-performing students to assist struggling students (peer learning). She also indicates the high-performing students' ability and the need to keep the learning with TD and discussions on track. She states that:

S2: *What the other student and you (researcher) were very good at was asking us students the following questions. What do you think about the process of learning with TD so far? What can be changed? Are you happy with the method of learning? Is getting feedback very good?*

The researcher also asked whether some felt restricted in any way because of their other, more knowledgeable students' superior knowledge.

R: *Do or did you perhaps feel restricted in any way, having more knowledgeable students in the learning of SAVOGOs with TD?*

S1 mentioned that:

S1: *Yeah. I don't think the students had a problem with more knowledgeable students, and for me as well, I would like to think that we've always had this open relationship with each other since we learned with TD. Uhm, so now I don't feel that I was restricted like before when students were using their textbooks alone.*

S3: *In the lecture room, everybody listened to each other's ideas, like everyone was given equal opportunity to share their experience and discovery, as well as their ideas in terms of the SAVOGOs' content.*

The same student noted that the open learning environment fostered by the TD encouraged him to seek knowledge from both peers and the lecturer. This openness manifested in practical ways, such as inquiring about how a TD functions or discovering and learning to use new mathematical video software he had previously been unaware of. Through collaboration and active participation, the TD facilitated this

learning by cultivating a spirit of openness in him. The student illustrates this point by noting that:

S3: *Approaching someone for a mathematical video, a software used to learn SAVOGOs, and with this, you learn some informative stuff and then when one student said there is a certain software that you can use, all because of the openness of some students and the lecturers.*

On the issue of learning from others, as far as software packages are concerned, S2 also echoed a view by the previous student.

S2: *I learnt about mathematical videos and animations from our group when learning with a TD. The culture of openness also engendered a culture of improvement in students due to them being observed when demonstrating what they excel about and them observing fellow students learning SAVOGOs.*

R: *You mentioned observing. How do you feel about other students observing you?*
S4 responded:

S4: *It's becoming more open, and I didn't feel any problem; other students fear observing you during learning when requested to demonstrate your expertise about your discovery. Learning with TD brought this about. Yeah, I think it will help like to observe other students how they get to understand SOVAGOs topic as much as you know how to operate the TD, so it means you are more open to improving. The aim is to improve through demonstration.*

When asked what the benefits were for him with regard to the learning with TD, S5 mentioned that:

S5: *We became more open to sharing knowledge with other students, and sharing knowledge with each other was done in such a friendly manner and an open way, which for me was very beneficial. Learning with TD created the platform for us to converse with each other in an open and trustworthy way, and I would say that this should be a process that can be implemented within the TVET sector.*

S6 agreed with S5 and added:

S6: *Truly speaking, I can mention the following benefits: There is faster learning. I have discovered that tablets help students learn more material faster. There is accessibility, which means that a tablet can store hundreds of books in one device, making learning resources more accessible, especially for students in remote or underfunded schools. In addition, TD are cost-effective, which refers to the fact that E-textbooks on tablets cost less than print textbooks. Finally, one can mention the interactivity and dynamism of a TD. Tablets are more interactive and dynamic than traditional textbooks.*

S1 added on what S6 said: *With TD, there's a lot of engagement and motivation with tablets, which can improve engagement, motivation, and knowledge retention.*

In connection with the above, I also commented:

R: *There was constructive engagement, and very interactive and a few misunderstandings were cleared.*

All the students, that is 100% of the students, reflected positively about the openness that did and must prevail in the learning with TD process between students and between students and lecturers. It appears that students see the value of having an open relationship in order to cultivate an open culture at TVET colleges. This aspect of TD was mentioned 20 times by the students.

5.7.4 Collaborative learning, enforcing trust and respect amongst students and lecturers

When students were asked to what extent the learning with TD with the researcher as a participant brought about respect and trust between students and between students and lecturers, the responses were varied, but positive.

The researcher asked participants the following general question.

R: *In which way and to what extent did the TD through participation and collaboration bring about respect and trust amongst the members (students and students as well as students and lecturers)?*

The following student, for example, pointed out that he learned to value his peers, his relationship with his fellow students, as well as the lecturers, improved. He states that:

S2: *This learning with TD also resulted in participants respecting one another more, so you learn to value other students. You will also see that my relationship with my fellow students also improved, and with you (researcher as lecturer), it also improved.*

S2 further warned that lecturers should not take the position of the 'know it all' but listen carefully to students' views as well. He reinforces by saying that:

S2: *Like the lecturers and HoDs never did say I know everything, but the lecturer listened and respected what the other students were saying, and that was very good. We can pick up the respect in the following questions: What do you think about the process of learning with TD so far? What can be changed? Are you happy with this? You gave feedback here, getting feedback, and that was very good. You respected that student even though you are the lecturer.*

S1 corroborated the previous participant's views and mentioned that:

S1: *Like I said before, I think the respect… we feel that everybody's got something to contribute. I mean you've got different experiences and views, you have different personalities, uhm, but I mean together we've got the same goal, and it's almost as if the group of students is more representative of what we deal with in the lecturer room because you also sit with different personalities. And the trust. And so on, that's what I think.*

S1 continued further by saying:

S1: *I also think the sharing and the opportunity to work together and be creative together and share ideas, also the respect, I think, we respect each other, despite the knowledge or lack of the knowledge.*

The trust that ensued between the students and the lecturers also penetrated the trust whenever assistance was needed, and students could depend on and trust one another to assist in terms of obtaining help with things from one another, such as software and geometrical drawings in space, shape and orientation as well. For example, S3 highlights that:

S3: *When someone is saying okay, I will draw this structure (drawing) using a certain software. So, I trust that okay whenever I struggle, I know that there is something (software) that can assist me.*

S3 continues:
S3: *Everybody trusted one another and respected one another; we like it. We were interested in one another, we respected one another.*

S4 emphasises the importance of the trust and respect aspect amongst the students, but also amongst students and lecturers when being part of the TD process. At the same time, he mentions how the sharing of experiences and knowledge about teaching and learning itself and other experiences through collaboration and participation amongst students, brought about growth.

S4: *Ok, uhm, I would say it brought about great trust and a relationship between us because of sharing our experiences and knowledge with each other before and after the learning has taken place, both in an informal and in a formal manner, getting to hear that there are common experiences as well as uncommon experiences. There was respect for my views, and vice versa, and the TD is a good platform for bringing about more respect and trust amongst fellow students and amongst students and lecturers.* Learning with TD provided an opportunity for trust and respect to grow because we as an example, I can say no one spoke over each other's words during discussions.
S4 was further asked the following question.

R: *Did working together in collaboration and participation bring students closer together?*

S4 continued and said that working together in collaboration also brought about co-learning:

S4: *Everybody had a fair opportunity to speak and share their perception of learning and having the opportunity to share of their experiences and knowledge also brought us closer I would say it brought us closer together, for example I got to be with a student that is not only in NCV, he is also in a different program registered for mathematics and through learning with TD I got to interact more with him which I never did before and this brought about great closeness between students registered in different programs. In the process, I learnt from him, and he learnt from me.*

S2 also commented about the closeness, which also aids co-learning between students and lecturers, which developed between them when he spoke about trust and respect.

S2: *There was this great closeness between students, which was good, and this also resulted in students respecting one another more. This was a direct result of the collaboration and participation present in learning with TD.*

On the issue of closeness that developed between students and between students and lecturers, the researcher also observed it and recorded it as follows in his comment.

There was a positive closeness, and there was good teamwork developing between students and lecturers. Students were also excited to see the next revised learning method.

S3 reiterated about the respect and trust that is built between students, but also between students and lecturers and the lecturers also learnt from the process, not just the lecturers, as the manager also became a co-learner in the learning with TD process. For example, he pointed out that:

S3: *For me, learning with TD is and was powerful. It builds trust in the process. It builds trust for the students. It also gives the lecturer a clear picture of really where his students are at. What we are saying, what each one was saying, was respected. Different views were respected, and it is co-learning and even the lecturers learn.*

All six participants in this study reported strongly and positively about the respect and trust that TD brought between students and between students and lecturers. The concept of trust and respect was mentioned 18 times.

5.7.5 Open culture of learning development between lecturers and students

Asked how the TD brought about a positive environment and in which way they experienced the lecturer as positive and supportive. S2, for example, on different occasions said:

S2: *Yeah, like I said, learning with TD is very positive for me, and you bringing it to us already sets a nice positive platform for us to venture forward with fellow students.* S2 emphasised the point:

S2: *Look I'm relatively new to Mathematics Level 3, first year, because I was doing L2 last year. I don't know Level 3 lecturers too well, so I got to know them as being very supportive and very positive this year. So, I like that. I like that they drive us, like you want things done, and you want to change things. So, that says it's very positive. So, I would say it's a very positive thing which gave a positive vibe. The relationship is excellent, yeah, the relationship is the best. I am now friends with other students, and they will now pop in here and ask how it is going, and it is very positive, so there is like a positive relationship, and our interactions have improved in a massive way. Okay, I think there was a good spirit. It was positive, and the other thing is that there is a nice synergy developing between us.*

Students were further prompted with the following question:

R: *How did the participation and the collaboration between the students together with lecturer in the learning process with TD bring about a positive and supportive environment, and how did your relationship with your lecturer change through the learning process?*

S1 answered as follows:

S1: *I think this is a great opportunity for students and lecturers to work together, and it has never been done before, and I think you must embrace the fact that other students also have input.*

So basically, then I would say it was positive to be in support of it, and we were supportive and supported because we have that positive relationship here at this campus as well. So, I would say participation and collaboration brought about a positive relationship and supportive culture.

S4 echoed S1's views and said that:

S4: *It provides an opportunity for students to actually work together on a specific topic to develop conceptual knowledge because it will provide a mutual development for all students involved as well as for the lecturer because now the lecturer gets an opportunity to actually share and to view all students' conceptual knowledge inside of a lecture room and in that way it actually builds a better relationship because we are now more involved, we socialise more on a conceptual level as well as a personal level.*

When speaking about their experiences of learning with TD and working together and in participation, students mentioned the positive attitude which developed between team members. For example, S3 pointed out that:

S3: *Firstly, especially the teamwork. It developed like a positive attitude towards working together (with each other) because it brought us out of desolation.*

The same student was asked further about how it feels to work collaboratively versus working alone, through the following question.

R: *So, what benefits were there for you working participatively vs alone, for example, when we learn collaboratively with TD?*

S3 mentioned that it helped him in building a great relationship with fellow students and their approachability, which all resulted from participating in learning with TD. For example, he said that:

S3: *So, it helped me to know and to have a better understanding of my fellow students. Yeah, to work with lecturers as well, because I used to have some image, but now I know that at any time, you are the person that I can approach. So, working with fellow students helped me to have a different idea about them. So, my relationship with my fellow students improved quite dramatically for us being part of the process is what we benefited. It brings about a positive atmosphere working in a lesson with TD now, that's what I'm saying. Like, now I even have a different view of my performance in SAVOGOs.*

On improved understanding and relationships between students and lecturers, S3 proceeded to say that:

S3: *We are understanding each other better and understanding content better, because at times you perceive the lecturer as someone who will identify faults. So, I think it will help not just the lecturer but also all students to be open to suggestions and allow students to make mistakes as well. And when we work together, we can help other students as well, and they can help us as well and create a positive atmosphere and a supportive atmosphere amongst students.*

On the same question, asked about working alone versus in collaboration and participating with others in the learning with TD, S4 said the following:

S4: *We became more open to share knowledge with other students, and that was what was very positive and very good because nobody was hiding anything and sharing SAVOGOs knowledge with each other was done so in such a positive, friendly manner and an open way, which for me was very beneficial, because it made me think more positively in aid of learning.*

S1 added that:

S1: *I can say that the relationship amongst students is positive, so learning with TD will be a success and efficient.*

To the same question, S5 commented that:

S5: *So, it helped me to work in a team, it helped me to understand them (students and lecturers) better, and it also helped me to understand my fellow students better and the lecturer (participant) better. That was because of the collaboration.*

The open and positive culture was also enhanced and encouraged by the non-threatening and non-judgemental approach of the lecturer in most of the learning process with TD. This further encouraged students to give their best and engage more easily in collaboration and participation in learning with TDs. S6 commented and said:

S6: *Everybody is involved, lecturers are involved, and students are involved and that forces HoDs also to become more involved in the lecture room of the lecturer without feeling threatened by the HoD, and that is also something that came out from this TD process. I did not feel threatened by the researcher.*

On this, S5 went further to say:

S5: *It was non-threatening, because normally a lecturer will come into your lecture room for instructions, but here the lecturer was one of us, and I think on that note it brought in a positive experience because we students got to share our experiences afterwards as well. S3 agreed with S5 and said:*

S3: *Yes, indeed, I felt like we were the same when coming to knowledge, all at the same level, all students were at the same level, so I did not fear (non-threatening) there is a lecturer and there is a student. In this TD learning process, there was no difference; we were all the same.*

All six students, that is 100%, referred to the concept of the positive relationship which developed between the students and the lecturer in one way or another. All of them also referred to the fact that learning with TD provided a great platform for students

and lecturers to participate with one another. The six students referred to this concept 24 times.

As far as further comments are concerned, it is interesting to note that S5 experienced the entire learning with TD as Ubuntu, considering the openness it inculcated. S5 concluded in his comment that:

S5: *Learning with TD has a lot of community of practice in it. Ubuntu.*

S6 added and concluded: *It was a positive learning atmosphere for all students. All positive! As each session takes place, learning becomes increasingly articulated.*
The results can be indicated as follows in a table format.

Table 5.9: Promotion of problem-solving skills through collaboration and participation

Learning with TD and ChatGPT-4 led to healthy discussions between students	17.17%
TD and ChatGPT-4 encouraged the sharing of ideas and knowledge amongst students, lecturers, and between HODs	13.18%
TD encouraged openness between students and lecturers	21.23%
Learning with TD brought about trust and respect amongst students and between students and lecturers through the process of collaborative learning	21.18%
Open culture of learning developed through learning with TD and encouraged positive relationships between lecturers and students	27.24%

According to Table 5.9 above, the aspects of positive relationships, openness, trust, and respect scored quite high, with positive relationships scoring the highest (27, 24%). This clearly shows that students found TD to be a collaborative and problem-solving approach to teaching and learning, which resulted in a positive atmosphere. The visibility of the lecturers within this process assists in this outcome. The aspects of openness, trust, and respect also contribute to fostering this positivity, as these elements are deeply interdependent. This is supported by existing literature, which will be elaborated upon in the discussion of Chapter 6.

5.8 Personal fulfilment and happiness, as well as improvement and empowerment of students

The power of working collaboratively and engaging with students led to increased participation, which not only boosted their confidence but also enhanced their motivation. Students have mentioned that this has resulted in overall improvement and that they feel more empowered than ever before. This growth stems from their increased confidence and self-esteem in mathematics, particularly in the topic of space, shape, and orientation, as well as their personal development. Students have also revealed that they now feel more motivated towards the subject in general. Theme 4 is divided into two subthemes: (i) empowerment of students to increase their confidence and motivation, and (ii) empowerment of students in decision-making regarding educational technology.

5.8.1 Empowerment of students to increase their confidence and motivation

Working collaboratively and participating in a team, such as learning with TD, boosts confidence and self-esteem because each student in the lecture room has a chance to give input, and no idea is far-fetched or ignored. Hence, this motivates students in a lecture room to do better, and this eventually empowers them.

In relation to the above, the researcher asked the following questions.

R: *In which way did the sharing of ideas and knowledge in the learning with TD increase your confidence, and how did it motivate and change your attitude?*

S3 responded that:

S3: *I cannot explain in what way, but I think I'm kind of motivated and have a positive attitude towards mathematics. I'm kind of motivated, and I am more confident now in the mathematics subject. And this learning with a TD helped me in mastering SAVOGOs, yes. Well, it motivated me in the sense that when I have anything in which I am struggling, I should know what to do, especially operating the TD.*

S4 has the same view and mentioned in addition that it also boosted his confidence participating in learning with TD and gained a more positive attitude. He, for example, states that:

S4: *Yes definitely, I can start by saying learning with TD did motivate me and my confidence has also increased as well so it is all positive and what motivated me is when we shared our knowledge and experience after learning took place, before the debriefing with the fellow students and the lecturer there was also an informal debriefing with each other as well which I found to be motivating…… It also boosted our confidence as students who wanted to improve performance and gained more positive attitude as well.*

In return, S1 mentioned that learning with a TD increased her confidence and motivated her; it also increased confidence and self-esteem for other students as well.

For example, S1 continued and said:

S1: *But what I did pick up was the fact that so many students, like I said the confidence and self-esteem of students increased …. And for myself it did motivate me and confidence, yah, confidence maybe in reading students better and I think in that sense to try something new, a new approach of TD but, yah, and it was just the fact that students can still enjoy. Lecturers must just put in a different approach, but I don't think confidence in the sense of how I will necessarily learn that because something that I'm pretty sure the topic SAVOGOs that I'm confident with.*

The above student's view was also corroborated by what participants reported in the interviews conducted by the researcher. Although the words "confidence," "motivation," and "positive attitude" were used frequently, the students' responses below can clearly illustrate these qualities. They demonstrated improved skills in calculating perimeter and area through learning with TD, and some students reported increased motivation and a positive attitude towards doing better. When students were

asked, “What can you do now (or do better) that you could not do before?”, the following participants, who clearly exhibited confidence, self-esteem, and a positive attitude:

S2 echoed: Make mistakes Ma’am, don’t be frightened to make mistakes

S3 confidently said: Don’t be afraid to ask for help and be proactive.

S5 courageously said: Calculating areas and volumes of a pyramid is now better than previously.

S1, S2, S3 and S4 clearly show a sign of motivation and a positive attitude when learning SAVOGOs with TD.

S1 with a bright face said: Go over your work through a TD every day just for an hour or so.

S2 added with a positive attitude that: Practice SAVOGOs and the use of mathematical videos, as well as animations.

S3 also agreed with S2 and said: Engaging with others (fellow students) will assist in understanding SAVOGOs’ content and improve performance.

S4 concluded with confidence: And try to memorise all these formulas for different pyramids.

The following student response reflects a positive attitude and demonstrates how this study has inspired the student to become more motivated toward this new approach to learning with a TD.

S5: Students will be motivated *to solve the SAVOGOs’ questions, as learning with TD is a new and beneficial approach for them.*

S6 cited an increase in motivation and positive attitude not only in her but also noticed the increase in motivation in her peers as well. For example, she mentions that:

S6: *We had good students in the lecture room, students who know what they're doing, and they were enthusiastic. They became motivated, and their attitude also improved in the learning of SAVOGOs through TD.*

S4 expressed the same view as the previous students but added that he found the debriefing stage motivated him and instilled confidence. He states that:

S4: *Yes, definitely, I can start by saying TD process did motivate me and my confidence has also increased as well so it is all positive attitude and what motivated me is when we shared our experiences and knowledge after the learning with TD took place, before the debriefing with the researcher there was also an informal debriefing with each other as well which I found to be motivating.*

S2, as a more knowledgeable participant, mentioned that he is already confident as a student learning SAVOGOs and that learning with a TD has impacted him in being a confident student already. He mentioned that:

S2: *I am confident. Okay. Yes, so it did impact me positively. You can learn and engage, and that makes you a little bit more confident in a sense when you look at the way mathematical videos were pouring information to us.*

S1 mentioned that the two low-performing students in the lecture room were quiet at the beginning, but later in the learning with TD, their confidence and self-esteem, as well as their attitude towards SAVOGOs, really improved. She points out that:

S1: *(referring to the low-performing students). Their understanding was very low. At the beginning, they were very, very quiet; afterwards, they came into the rhythm of participating. I think they still have sort of the feeling that they must learn from the more experienced and knowledgeable students. But I mean, they had very valuable input to give themselves, and their confidence also improved.*

On the above aspect of the low performing students being quieter and not giving as much input in the SAVOGOs discussions than the other two, the researcher also observed this behaviour and commented as follows:

R: *I observed and noticed that some students were passive in the discussion until the researcher prompted a few reactions from them.*

Two of the students, who were initially very quiet and not participating fully, were now also making valuable comments and providing their input to the discussions and towards the learning with TD.

Students who were quiet were now participating more eagerly in the discussions and also giving input, suggestions and contributions. They were now showing more confidence and a positive attitude in the learning SAVOGOs than before.

The researcher further asked the following question to probe a bit further into the *inclusion of the lecturer in the learning process with TD.*

R: *In which way and to what extent did the lecturer, in a participative capacity, contribute towards building confidence in you and empower you through the learning process with a TD? S2 responded that:*

S2: *I must say, the inclusion and involvement of the lecturer, it raised my confidence. I viewed the lecturer as a member of the team who was leading and supportive, rather than the traditional "I know it all" kind of approach that certain lecturers apply. It raises our confidence, we managed to talk and discuss on the same level as if the lecturer's presence was not there, and there was no differentiation between students and the lecturers. Her involvement gave me confidence.*

Five of the six students, that is 84%, mentioned that TD empowered them in terms of raising their confidence and becoming motivated through the learning process. One student mentioned that he did not become more confident as he felt he was already confident and confident enough. This at least showed honesty on his part and came as a surprise. From the above, it appears that most students became empowered through TD as far as confidence, motivation and positive attitude are concerned, and roughly this concept was referred to 20 times by the students.

Furthermore, on the issue of confidence, motivation and positive attitude, the following student commented.

S1: *Students are confident in their approach, and everyone was contributing.*

I also commented on the issue of confidence, motivation and positive attitude.

R: *Students are more confident and focused and contributed in a valuable manner to the discussions of SAVOGOs' questions.*

5.8.2 Empowerment of students in decision-making about educational technology

One of the aspects of learning SAVOGOs with TD is to empower students to make decisions freely during the learning process. This creates a strong platform where decisions need to be made, and the ability to make those decisions should not be stifled in any way. For learning mathematics with TD to be successful, there should be

some form of a bottom-up approach that aids decision-making. For the most part, students mentioned that they felt free to make decisions and that their decision-making skills improved, which was also empowering for them.

In connection with this, the researcher asked the following important question related to the freedom to make decisions in the TD process:

R: *In which way did learning with the TD process within the lecture room in the participative process of collaboration empower you to make decisions freely?*

To this question S3 mentioned that:

S3: *Now I feel free to go to a fellow student, in other words, to be assisted. Yes. Yes, previously I didn't. There is also freedom to approach the lecturer. I feel free to go to other students to share ideas, an open approach to working together.*

S3 further mentioned how important it is for TVET management to realise that students also need to be free to make decisions in their learning to empower them:

S3: *The participative and collaborative approach in learning did not put you under a prescription nor was it prescriptive or restricted. I was free to be open in the learning process. I could also make decisions. It was flexible, and I could come up with my own ideas, and nobody said that's not a good idea. And lecturers should also learn that students also need to make decisions freely.*

S2 revealed that he was empowered because of the lecturer's involvement and because decisions were made freely, agreements and consensus could be reached quickly. He said that:

S2: *You know, like I said, you (the lecturer) were very professional in your approach and very nice and respectful. So, in that sense, you empowered us. We ventured to express ourselves, and you gave us freedom as well to express if anything was wrong, like we could just debate it. So that was a very mature approach.*

S2 went further to point out that:

S2: *It empowered me to make decisions. We discussed, and we came to an agreement. There were no arguments, maybe more consensus on the things, and to clarify things. So that made it more likely for students to participate, to bring*

challenging ideas and students showing respect for one another and for another student's knowledge and so on.

S1 echoed what was mentioned before and put it this way:

S1: *Participation encourages free collective decision-making. Yeah, this relationship with my peers in any case (through the TD process), I don't want to make the decisions by myself. I can still learn after all these years. I mean, yah, we know more, we've been through the mills, but I mean we can still contribute something new, and no one is going to shut it down because times change and things become modern and technological. So, decisions are freely made. Uhm, so now I don't feel that I was restricted like before. No, I would not say I was restricting myself, and I could make decisions freely in the learning with the TD process and in participation.*

S4 agreed that the student has the same view. He stated that:

S4: *Ok, in the lecture room, I would say that the way it took place did empower us to make decisions freely, which was restricted in a sense before.*

All six students mentioned that the TD process in the format in which it was done in this study, where the lecturer was present in a collaborative and participative manner, empowered students to make decisions freely in the process and thereafter. Hence, it appears that the TD process is very favourable in terms of encouraging students to make decisions freely. The issue of being able to make decisions freely was mentioned roughly 17 times by students.

The researcher observed and commented on students being free to make contributions.

Students were enthusiastic and passionate about their field of study. They were eager and free to share their experience and knowledge.

The above results can be illustrated in a pie chart as follows:

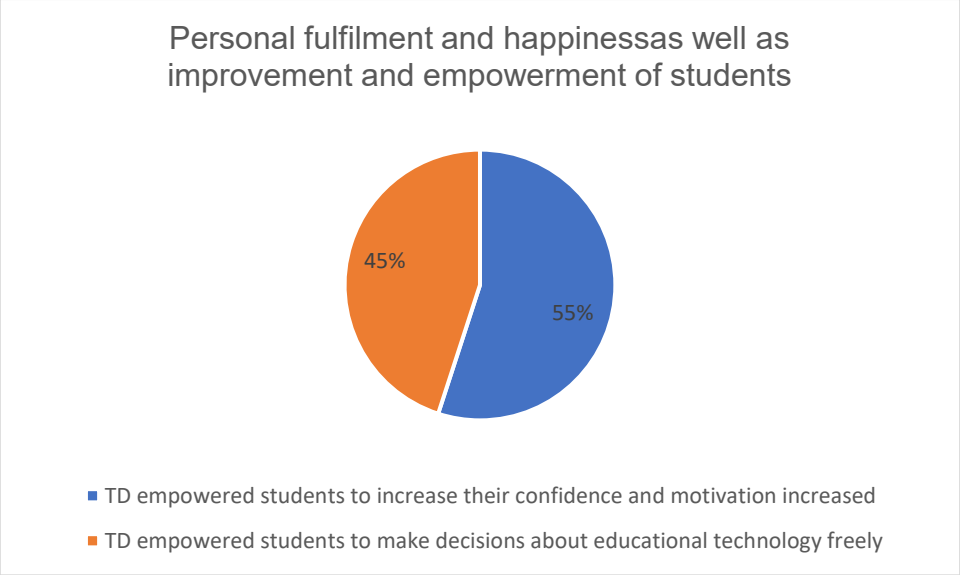

Figure 5.7: Personal fulfilment and happiness, as well as improvement and empowerment of students

As illustrated in Figure 5.7 above, students found that learning with TD was an empowering process that enhanced both their confidence and motivation. It also afforded them greater freedom in decision-making, while fostering an improved culture of participation and collaboration.

5.9 Students' role, contributions and participation in the use of TD at TVET colleges

As mentioned before, at schools and TVET college campuses, lecturers and students are seldom involved in learning with TD. They only use technology for their personal interests. On many occasions of assisting students in learning, HoDs are also not fully involved in the entire process of the LS. Many activities are run with lecturers giving a workshop on learning with TD and instructions to the students to learn SAVOGOs with TD. In this study, the lecturer was involved throughout the entire TD process, and his role as facilitator, guide and advisor, amongst others, became crucial and was also revealed to be an important element in seeing the successful completion of the process. This theme is divided into three subthemes: (i) improved participation and collaborative culture at TVET colleges, (ii) lecturers' contribution through their involvement, participation and collaboration in learning with TD, and (iii) improved performance in mathematics.

5.9.1 Improved participation and collaborative culture at TVET colleges

Students were asked what role managers played in the learning process with TD by posing the following question in the following way.

R: *What role did the lecturers play in learning with TD sessions, which you were a part of recently, and what do you think a lecturer's role should be in the learning process with TD?*

Participants answered in various ways, and different aspects were touched on. For example, S4 mentioned that the lecturers shared the students' experiences in the lecture room and brought them to the same level as the students. He mentioned that:

S4: *In the TD situation, we got to associate with each other on the same level and I think that was quite nice because it was informative also to have the lecturer present, to actually share experiences with the lecturers and I also realised that, although they are called the lecturers they actually do share and understand the experiences we have within the lecturer room,*

On the same aspect, S4 continued and stated that:

S4: *It was non-threatening, because normally a lecturer will come to the lecture room for teaching and giving SAVOGOs' information, but here the lecturer was one of us, and I would say from the facilitation point of view, like, from their point of view, it was quite good to work with them on the same level in participation and collaboratively.*

When the researcher further asked how the participation and collaboration in a group of students helped in bringing about closeness, S4 further said:

S4: *In the TD process, I got to interact more with my lecturer, which I never did before, and this brought about great closeness between lecturers teaching at different levels, and this was a great new and positive development brought about by participating in the learning with the TD process and the collaboration.*

On the bottom-up approach, which TD brought forth, the following student focuses on the value of the bottom-up approach and mentions that it was due to the participation and the collaboration aspects of TD, which were never possible under normal circumstances. S1 pointed out that:

S1: *I think students could just see you (researcher) as a colleague in that sense that you are at the same level as all the others, and we did not see you as a lecturer in terms of learning with TD, which teaches lecturers to have a more bottom-up rather than a top- down approach. I think we all appreciated it. I think so, we all felt like that.*

S4 agreed and said:

S4: *What's nice about learning with TD is that the lecturer and us were at the same level and I think that also contributed with the confidence of the process and I would say it was a bottom-up approach for me that provided confidence because I could communicate on a level we do not get every day, for example, although my lecturer is like that, we can communicate at that level. The focus of students is different, and for the lecturers to participate in the classroom through TD helps students not to become obsolete in the way of thinking because it's no use as they are lecturers, but he is not in touch with what is happening in terms of technology, the lecture room and the subject. This provides students the opportunity to remain updated and get to terms with what is happening in the current time.*

S3 also referred to the teamwork that comes about because of participation and collaboration. He mentions that:

S3: *So, it helped me to work in a team, it helped me to understand them (students and lecturers) better, and it also helped me to understand my fellow students better and the lecturers (participants) better. That was because of the collaboration and participation.*

S3 went on to further state that:

S3: *If you work with other students, they might have a different way of doing things than what you have, but it doesn't mean yours is out of order. If we collaborate and participate, we can make them interpret it better through the learning approach in a collaborative approach through learning with TD. So now if we work together, we will know who's strong in what. So, the lecturer being part of it will also know who is strong and who is weak. So, then we can develop a structure and strategy of helping each other. So, if we do that through collaboration and working together, we can learn from each other. And the TVET College management can take that and implement it.*

Five of the six students (84%) mentioned the improvement of the participative and collaborative culture in various ways, such as the bottom-up approach to decision-making, teamwork, and the closeness in the learning of SAVOGOs with TD. Most of them were positive about the improvement of the participative and collaborative culture of TVET colleges. This aspect was mentioned 26 times by the students.

The following points were also mentioned by students as they continued studying:

S4 echoed the enjoyability of learning with TD and said***:*** *This session of learning with TD was enjoyable. Always a learning curve.*

S2 also emphasised what S4 had said***:*** *I enjoyed it, very interactive. There was constructive engagement between students and between students and lecturers.*

S3 added that***:*** *Working collaboratively was good, and the purpose of learning with TD was reminded.*

S4 agreed and said: *Planning our learning collaboratively helps us to understand SAVOGOs' content much better.*

The researcher also mentioned the following:

R: *The beautiful part of this collaboration and participation is that everyone was very helpful to one another, and students were very willing to offer their part in bringing the learning with TD together. A real positive and open culture of learning has been developed.*

5.9.2 Lecturers' contribution through their involvement, participation and collaboration in learning with TD

It has been found through what students have revealed that the involvement and participation of lecturers in the TD process enable them to contribute quite powerfully and positively by fulfilling their roles as guides as well as support for the TD process. This has been shown to be the case in the TD process itself and must continue in all future instructional deliveries at colleges so that students can become visible in classes to improve results. The following student revealed that lecturers' involvement has guided the process of TD and that the presence and visibility of the lecturer supported the process.

When students were asked,

R*: Which ways can you suggest the learning with TD be modified to include more software programmes in a bigger way to make learning with TD more effective and transform colleges?* S1 answered that:

S1: *As a student, because then you most likely learn through the process, I think you need to build a good relationship with your fellow students. I mean, if you are a student who is learning SAVOGOs, you need to guide the team, you know.*

The fact that the lecturers need to be a guide who needs to be non-prescriptive and non-threatening, which was mentioned before, was also mentioned by the same student. The lecturer is also there to keep the TD process on track, which is something lecturers need to take note of. S1 further reiterated that:

S1: *I think the lecturer's role is a guide who gives guidance and then also an observer, maybe a participant observer when it is needed, when it is asked to give the group guidance, but not be prescriptive, but rather to observe, guide and listen. As I said before, I think it's important to keep the students on track, to guide them to make sure that learning is not done haphazardly and is done thoroughly.*

S4 mentioned that the role of the lecturer in the process of learning with TD was to govern, organise, guide and support. He points out that:

S4: *The involvement role and governing role of lecturers are very important. He is the organiser, coordinator, guide and support. The lecturer was governing the whole learning process with TD. The lecturer made sure that the student was following what needed to be done within a specific time, and I think that it was planned very well and prepared very well because we had the opportunity to edit and go back to the activity.*

S3 corroborated with the previous student but added that the lecturers also have a coordinating role, and the lecturer participating with students makes any enquiries immediate.

For example, S3 mentioned that:

S3: *Lecturers have a dual role. Firstly, lecturers should give guidance to the process in terms of structure around LS; overall must give structure to the process, which means lecturers and students must be informed about TD. Secondly, as an observer as well as giving input, not calling the shots, but also learning from students*

(participants) and what is taking place from his observations, what the lecturers are saying (about content). He/she must also have the skill to pull it off and pull all of the elements together, which is a learning skill. Coordinator coordinating the process.

S3's sentiments were corroborated by the following students:

S2: *The first thing I can say is that the role of the lecturer is to build the quality of learning through the provision of curricular guidelines and curricula interpretations where necessary or where it is needed, and where students need clarity, the lecturer will be there to assist and to use his/her experience to guide the students immediately.*

All six students mentioned that the role of the lecturer is to guide, support, and coordinate. It was mentioned 15 times by the participants.

The following was mentioned by the students.

S1: *The session was structured and to the point due to the lecturer's guidance.*

S2 agreed and said that the researcher handled the group well and explained the research question and goal well. There was great learning with TD.

S2 further added that:

S2: *The researcher's planning of the TD was excellent, and the direction was good.*

S3 supported the idea confidently and said:

S3: *The session went very well, and all students were certain of what was expected of them in the learning of SAVOGOs with TD.*

S4 also commented with a positive attitude and said:

S4: *The learning of SAVOGOs with TD was better than the previous one.*

5.9.3 Improved performance in mathematics

Students were also queried about how TD can impact the improvement of results, as the researcher wanted to ascertain how and to what extent the ideas and processes of learning with TDs could be utilised to enhance performance in learning SAVOGOs with TD. The following question was therefore posed, and many students expressed a positive belief that it could significantly impact performance improvement.

R: *How and to what extent can learning with TD impact improved performance, and how can it assist students in looking differently at the approach of answering SAVOGOs' questions?*

For example, S2 mentioned that because of the presence of the lecturer in learning with TD, it is very practical. He mentioned that:

S2: *It will impact (the performance) and this is actually good because you have the grassroots students grappling with learning content with SAVOGOs and so on and then feeding into those students who master the application of TD and so on and make it more pragmatic or practical yeah and saying like listen, we have now sat and collaborated in TD and we found this and that you know, these are the problems we are having because we also identified the problems related to it (through TD) and feed it through to the various students that are responsible (for improved performance).*

The same student also highlighted how lecturers can also become involved in feeding findings from TD processes into improved performance by focusing on stumbling blocks with regard to the mathematics performance at their respective campuses. He mentioned that:

S2: *This is like you say, we can always like look at the way we learned SAVOGOs previously and inform our lecturer about the problems that we are having from discussions. What are the stumbling blocks towards improving our standards at college? What are the stumbling blocks? Why are they not able to improve performance? So, they can look at a variety of things.*

S1 also mentioned that it is good that lecturers are involved in the learning of SAVOGOs with TD, as it is the responsibility of lecturers to implement a better learning method, namely, TD. This way, the lecturers can see first-hand where students' gaps are.

S1: *I would say, for instance, improved performance through TDs is more a lecturer's forte for implementing learning with TD, etc., but through the learning process, especially now with SAVOGOs, just focusing on it because that is what we have decided on. Yeah, I think it can because the learning process will be able to identify the gaps. Yeah. I mean, maybe for improved performance, you must set time aside to address the gaps before you deal with the more complicated issues. So, I think it will*

influence performance, yes, unequivocally, it will influence students' performance in a positive way.

She further raised an important point, noting that TD can play a significant role in advising lecturers that an opportune time to address improved performance is at hand, particularly as the college seeks to improve its throughput rate across various subjects. S1 went on to say that:

S1: *Maybe at our discussion groups, we can say we have done this learning of SAVOGOs with TD and the way it is in the textbook, it is not how it's supposed to be, because the students felt differently about it and stuff like that, and we think now it should maybe change to be learned with TD. So, I think it can, and it will influence the improved performance if you are going to change your learning method.*

On the question of how the TD can assist students to look differently at SAVOGOs, S3 said that the presence of mathematical videos and animations is important and had the following to say:

S3: *Students should consider how mathematical videos and animations are implemented and used. Lecturers should also encourage the implementation of TD and the use of mathematical videos in the classroom situation, and this will help them to amend certain sections based on the outcomes that they see in the classroom situation or when we collaborate between students and lecturers, as we have done in the learning with TD.*

S3 further added the aspect of resources and mentioned that lecturers also need to know what resources are needed and how a certain subject links with other subjects at the same level. He mentions that:

S3: *Because, as it stands for now, this is the content, it must be delivered irrespective of whether you have the resources? Maybe you don't have or how will this link to a certain subject, like students who are doing science, so I am doing the Mathematics Level 3, and does it link with the subject Engineering Science? So how does it link? Yeah, I think those things will help students and lecturers to look at the mathematics content, maybe differently, when they are analysing the impact of TD on improved results.*

Since this study focused on misunderstandings in the topic of SAVOGOs in Mathematics Level 3, the S3 further highlights that the gaps identified through learning with TD, concerning the misunderstandings noted, should be used to improve performance. However, S3 concluded that this can only occur when the lecturer is involved and aware of the issues, and it requires a bottom-up approach. He mentions that:

S3: *Whatever we find has a misunderstanding, that's what the curriculum needs to highlight because the focus, the emphasis of the improved performance must be based on what the students understand. Some of the misunderstandings may be based on the misinterpreted content and method of learning. So, it opens a gap, and it widens a gap, but now the lecturers based in this study can be able now take in the form of a bottom-up approach to change the learning and teaching method instead of a bureaucratic top-down approach.*

With regards to improved performance in S4, due to his participation in learning with TD and his collaboration with other students and lecturers, he came to realise that the current method of learning can be very assumptive, often ignoring the social aspects and backgrounds of students and being dictatorial in its implementation. He echoes the views of previous students by mentioning that:

S4: *From my experiences, the previous method of learning does not take into account the social context (background) of students and the method of teaching and learning was a sense of dictatorship, we had to follow the SAVOGOs content as is, and we have; there is no way we can leave certain things out or/and add something that is not part of the content, we have to follow the content to the tee. If you look at SAVOGOs' content, the assumption of pre-knowledge is there. It assumes that the student knows the pre-knowledge.*

S4 added that the lecturer can play a big role in influencing performance if he is involved with the learning with TD. He adds that:

S4: *And from a student point of view, uhm, they can also, through TD, get the opportunity to see where the problems are within the SAVOGOs content and within the teaching and learning process and maybe lecturers can also be involved in developing these exercises since they have the experience.*

All four students commented that learning SAVOGOs with TD can significantly impact performance. It appears that all the students who spoke on the subject felt very strongly about its potential. This aspect of improved performance as a role for students was mentioned 23 times.

The results are illustrated in the following pie chart:

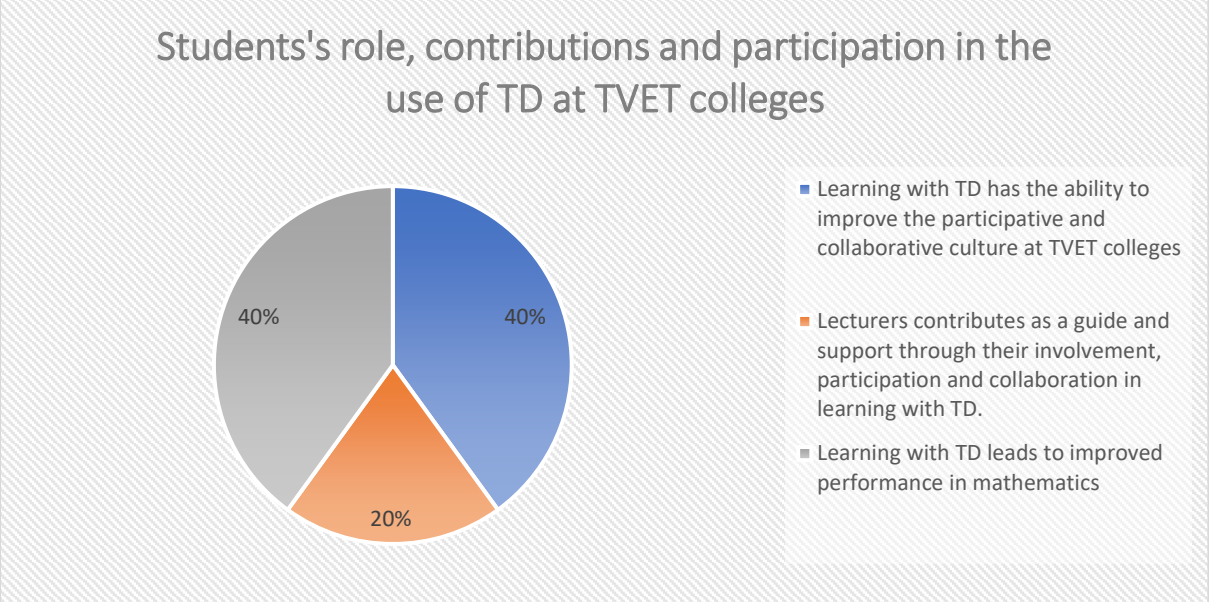

Figure 5.8: Chart showing the role of students contributing to improved performance through participation in learning with TD

Figure 5.8 shows that, in this study, students' roles in learning with TD fostered an improved participative and collaborative culture at TVET colleges. Additionally, learning with TD led to improved performance in mathematics, which proved to be a greater benefit than aspects such as the lecturer's contribution in guiding and supporting students through their involvement, participation, and collaboration in learning with TD. Further interpretation and discussion of these aspects will be conducted in Chapter 6.

5.10 Challenges students are likely to encounter when learning SAVOGOs with TD at TVET colleges

The process of learning with TD is not without challenges. Some of the challenges revealed in this study were time, lack of resources, attitude and resistance from

students, and lecturers' skills and conceptual knowledge. Time was one of the biggest challenges in most literature cited in studies relating to learning with TD, and it was no different in this study. This theme is discussed under (i) Time and time constraints in learning SAVOGOs with TD, (ii) attitude and resistance in learning with TD, (iii) Students', lecturers', and managers' skills and knowledge in learning with TD, (iv) Lack of resources and training, and (v) Solutions to challenges for college management in the TD implementation.

5.10.1 Time and time constraints in learning SAVOGOs with TD

When students were asked about the obstacles, negatives, or challenges they encountered, as well as what lecturers and college management need to be aware of during the TD process, most students referred to time as a scarce commodity in short supply.

The researcher asked the following question to the students.

R: *What negatives and challenges were there for you, if any, in the experiences in the learning process with TD, and what must lecturers and college management be aware of?*

S1 mentioned that:

S1: *The only negative that I can think of is the time issue. It was very informative but in reality, we won't have I don't know how many hours? Eight hours to spend on a fifty-minute lesson, unfortunately. So, that's why maybe if we do one lesson at a time, until we understand. Doing one lesson at a time collaboratively will assist in performance improvement. Taking two or three lessons per trimester or per semester over a few years, you've covered the whole syllabus on those areas that are giving problems.* S3 agreed and said:

S3: *So, the issue was time because we have deadlines. We have a lot of things to do. So, we must sacrifice for the benefit of this because this is not about you, but it's about implementing a new learning strategy that will help everybody, so we had to sacrifice the usual time. No, other negatives, I think everything was fine. That was the only thing for me, time constraints and putting TD at a safer place and making sure they are charged and ready for the next use, yes, that was tough for me.*

S4 links the issue of time to teaching and learning and specifically refers to the student-centred and problem-solving approach, and he mentioned that:

S4: *Uhm, I would not say there was anything negative necessarily, but if you look at the context, if I look at my own context in the lecture room sometimes time is a factor when it comes to a student-centred and problem-solving approach. The problem-solving approach depends on our ability to learn independently or in a peer relationship with his students. It does depend on the calibre of the students, and most students are not ready for problem-solving yet.*

S4 went further to say that:

S4: *Timetable for learning with TD in the college timetable… but make it voluntary, not forced. Furthermore, do not use the admin period. For myself if it was timetabled, I would say it should not be timetabled like often, like maybe once a week like we have done it (in this study) and it should not be in place of a free/admin period because students might feel that is their time to do their admin, for example, because we have to acknowledge that this learning with TD and activity is an add on to our current workload of making sure we learn all the subjects to improve the college's throughput rate.*

S4 also mentioned that time can be a problem for lecturers:

S4: *Lecturers do teach but the major challenge I can mention already is time.*

S1 proceeded to say that we can start with the more challenging parts of the syllabus to save time.

S1: *To start, maybe we can look at SAVOGOs like we have done now (with these TD) because it's always been a challenge, but Level 3 Paper 1 maybe not as much.*

When asked how she would implement learning with TD at this college, S1 emphasised the importance of time, advising lecturers to deliberately set aside dedicated time for TD-assisted learning, failing which, the experience would prove unproductive. Specifically, she advised that:

S1: *Oh, I think firstly is the time, putting the time aside, scheduling the time for that specific TD purpose. I mean, you cannot just put time aside; it has to be for and with a purpose. It must be put down for this TD, and it must be scheduled, it must be*

structured. You know that you've got a goal that you need to work towards, and then sharing, I would say, within the college management, with, like we said before, the departments and then maybe with other neighbouring colleges. And I think that is where the college management will come in because you'll be the driver of the process.

S2 also talks about time being a problem, but also mentions that it needs to be structured within the timetable. He noted that this is something that college management and lecturers can improve on. For example, he points out that:

S2: *Yes. We spoke about that. Time can be a problem. If it is not structured within your timetable, it can be a problem. So, there must be time for that (TD). There should be like a specific time allocated for lessons to be learned, like SAVOGOs within the timetable. I love that, so we can suggest like an hour for and it is your lesson study. Uhm negatives? I don't see lots of negatives, I must tell you.*

All the student participants (100%) mentioned that time is a challenge for them. It appears that all the students who commented on this issue agreed that it posed a challenge for them in one way or another. The issue of time was mentioned by the students 10 times.

The issue of time was also highlighted by S1 as follows:

S1: *Students need to focus on exams, revision, and preparation for the June exams. Their focus may be somewhere else. Time is an issue at this moment. Good input was provided, but we feel a bit rushed.*

S4 added and said:

S4: *Time is essential.*

The researcher also observed that time became a problem for the students and noted the following at a time when students were stressed in preparing for exams, audits, etc., which implies that lecturers and college management need to plan correctly when it comes to the implementation of TD-assisted learning.

Students are experiencing challenges and feeling pressure from college stress. Energy levels are low, and enthusiasm is low.

5.10.2 Attitude and resistance in learning with TD

Resistance from students can be a challenge both before the learning with TD begins and during the TD learning process. Prior to the commencement of learning with TD, some students may withdraw, or some lecturers may leave for better opportunities, which can disrupt plans, as occurred in this study. At other times, attitudes and resistance can pose challenges during the learning with TD, particularly when students have too much to do or are occupied elsewhere. In this study, the main resistance was related to adjusting to the learning with TD and the mathematical video programme. The following student refers to the resistance lecturers might experience when conducting TD lessons, which is related to the current culture prevalent at the college.

This student was then further probed on this issue as follows:

R: *In which way do you suggest resistance can be a challenge?*

S3 explained as follows:

S3: *The current culture of how we do things will determine how much of an obstacle TD is. Timeframes, schedules of lecturers, etc. In terms of how much admin students and lecturers do. It might be caught with some resistance from students in terms of how collaboration must happen throughout. Might short step it and not apply the full process of learning.*

On the same issue, S3 explained further by saying that the collaboration was something new to him, and he himself had to adjust. He mentioned that:

S3: *The first obstacle was myself (laughs) because it took a bit of a paradigm shift and I had to get over how I think, how I process and analyse because we can benefit from collaboration, it's not only my way it's all of our way it's not only my space, somebody else is entering my space in the lecture room during learning, for instance. In fact, that was a big paradigm shift. We are sometimes our worst enemies, because we are sometimes resistant to change, we don't want to, plus it is not my learning method, it is our learning method. So, what lecturers must learn is that when introducing learning with TD, explain to all students that they need to change their attitude or paradigm.*

Although only three of the six participants, or 50%, mentioned attitude and resistance as a challenge in the TD process, it might go unreported. It appears that attitudes such as resistance to the learning process with TD were not a major challenge in this study.

It was only mentioned five times.

5.10.3 Students, lecturers and managers' skills and knowledge in learning with TD

Some students also referred to the skills of lecturers involved in the TD process as important for making learning with TD a success. The following student, for example, mentioned that:

S2: *If TD was implemented, we must make sure that the lecturers, HoDs and all managers understand this. The negatives might be unskilled lecturers and HoDs. If a manager or a lecturer is not knowledgeable about the method of learning, education principles and so on might become a serious problem. So, what lecturers and managers must learn is that, when introducing TD, the process of learning must be explained to all participants involved so that they change their attitude.*

Only one participant from the four participating students, that is 25%, referred to this aspect, and it appears that the skills and knowledge of managers when conducting the TD process were not an issue for the other three students. The issue of skills and knowledge of managers was mentioned five times by this student.

5.10.4 Lack of resources and training

Other challenges that can be a challenge at many TVET colleges are a lack of resources and training. This study has also revealed that both resources and training are in short supply. Another point highlighted by some students is that if the student is involved with TD, the lecturers will be aware of it. For example, S3 said:

S3: *I think the resources, because we can't say, okay, this is what I have to show, but I basically have, I'm not equipped on that, for instance, the issue of operating TD. I'm not equipped with the software package used in Mathematics Level 3. So that can give lecturers an idea, look, students don't know the operation of TD, so the college management must arrange for training for them.*

S3 continued to put the emphasis on hard resources. He mentions that:

S3: *Because as much as I don't have a TD and not well conversant with the operation of it, which is I am not in control of the management side in buying the device for us, so that we can learn those spaces and shapes, because I might have a picture in mind, but there is no way the students can have the picture because they have a different picture in their mind, a different picture altogether. But if lecturers display the picture to us, it means now we are in the same boat. So, infrastructure and then now material, like in the case of mine. I can't even have a scientific calculator, like when I must calculate something now, I need to use my judgement and impaired knowledge, I am struggling with that side.*

S2 shared the same view about resources as the previous student and echoed the previous student's words when he mentioned that:

S2: *Check if there are enough resources for the SAVOGOs topic we must study. It's good that the manager is there facilitating because people can say Yeah, but we don't have this. Why don't you see that we have this resource in the class? This is the problem that we are involved with.*

Only three of the six participants mentioned resources and training as far as TD is concerned, and it appears that two participants were very vocal about it, something that lecturers need to take note of for the smooth running of the TD process and beyond. The lack of resources was referred to 10 times by student participants.

5.10.5 Solutions to challenges for college management in the implementation of TD-assisted learning

S4 provided a solution as far as the lack of time is concerned for students to attend TD sessions or meetings, debriefs and lesson learning. He mentioned that:
S4: *A good idea is to have LS, but assistant lecturers can take the LS participants' classes, and that idea makes sense because it won't add to the time of the lecturer. Classes can still go on, and the students won't lose out, and their time will also not be wasted.*

In connection with the above, S3 also provided some solutions to the lecturer to make the entire TD process smoother with the use of technology and beyond TD. He added that:

S3: *Uhm, in terms of time constraints, the solution could probably be to make use of the technology in terms of emailing and probably inventing some discussion forums while the TD process is going on. Emails, text messages, some comments, opening commentary boxes, and the like. I think that will greatly assist in solving part of the time constraints.*

S1 added that:

S1: *Create a forum for texting or emailing SAVOGOs' ideas to one another if there are any ideas participants have after learning, like a discussion forum, something we possibly missed, post-meeting discussion, etc. Every participant must be on the same page as far as the research lesson is concerned. Google Sheets can also be used for this.*

Five of the six students, or 84%, felt the need to provide solutions to the challenges mentioned by the lecturers and were quite enthusiastic when these solutions were proposed. It seems that they felt strongly about their suggestions for lecturers to consider when implementing TD at the campus and the college of the researcher. The need to offer solutions to these challenges was mentioned seven times by participants.

The above can be illustrated in a table as follows:

Table 5.10: Challenges of learning with TD at TVET colleges

Challenges of learning with TD at TVET colleges				
Time constraints	Attitude and resistance of students	College Management, Lecturers, HODs and Students' skills and knowledge	Lack of resources	Solutions to challenges
28,5	12,5	12,5	28,5	18

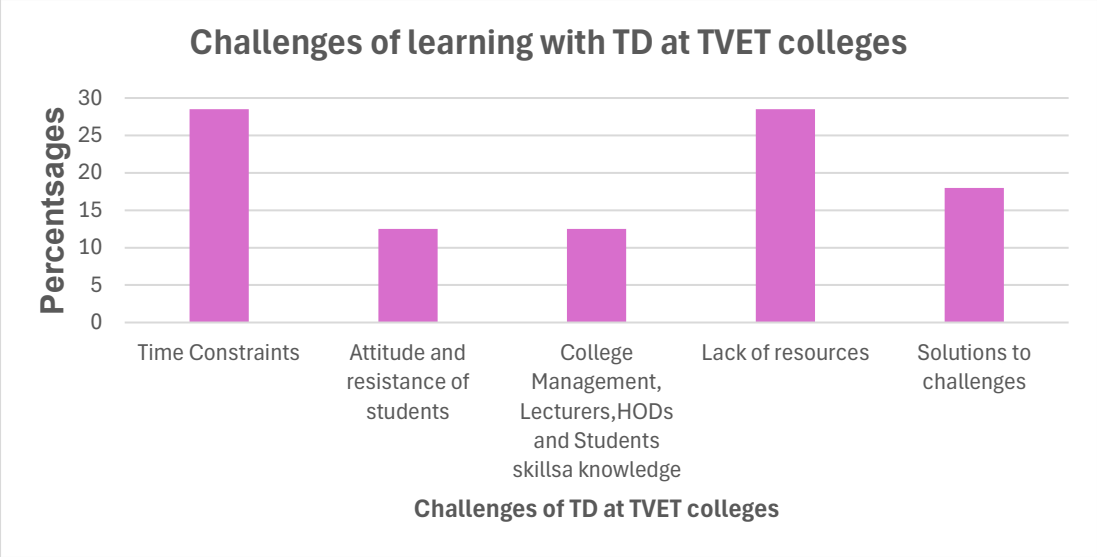

Figure 5.9: Challenges of learning with TD at TVET colleges

Figure 5.9 and Table 5.10 highlight time constraints and a lack of resources as challenges of learning SAVOGOs with TD more than the others. Further interpretation and discussion regarding this aspect are done in Chapter 6.

5.11 The future of TD in the TVET sectors when learning SAVOGOs

Learning with TD could focus our attention and reflection on various issues, ranging from SAVOGOs content to the role of college management, as well as the challenges faced and how these can be addressed by students and lecturers, particularly college managers. It also enhances social interaction and empowers students by boosting their confidence and motivation. Therefore, there is a future for learning SAVOGOs with TD at TVET colleges, with students taking on a participative role, as revealed in this study.

5.11.1 Students as champions for learning with TD at TVET colleges

Since students learning SAVOGOs with TD in this study have experienced and acquired skills in learning with technology, many of them have indicated that it can be a great benefit for TVET colleges, provided that it is implemented gradually, starting with campuses and involving students as champions, alongside lecturers, HoDs, and college management, before escalating to colleges and then to the entire TVET sector.

When students were asked how they would start the implementation of learning with TD at their campus in the future, given that they have now successfully participated in it, some students responded that they would first need to involve lecturers by gaining their buy-in.

In view of the above, students were asked the following question.

R: *Now that you were part of the group learning SAVOGOs with TD, how would you start the implementation of learning mathematics with TD at TVET colleges, and how will you get lecturers involved in the process?*

S3 stated that:

S3: *Well, I think firstly is to ask our lecturers to approach the College management after considering the benefits which the students will enjoy in the learning process, as well as improved performance. So, we need the buy-in of the lecturers, and it is basically to identify the benefits of learning with TD to the institution so that they will be the highlight, and the bottom line.*

A further question was then put to the participants.

R: *What suggestions would you make to lecturers to effectively implement learning with TD at this college and the whole TVET sector?*

All six participants were in agreement that they needed to get lecturers' buy-in. They answered as follows:

S4: *I would request our lecturer to start off with an information session, introducing the topic to students with TD in the presence of college managers and lecturers and explain to them the benefits of learning with TD. For example, the main benefit is having students working collaboratively, emailing and probably inventing some discussion forums. I would also request our lecturer to motivate the process of learning with TD to managers by asking one of the students to share his/her experience of learning with a TD, for example, getting to learn conceptual knowledge and ideas from TD, mathematical videos, as well as communicating with other students through discussion forums.*

S3 emphasised that:

S3: *Well, as a group, we need to basically inform the Student Representative Council (SRC), lecturers, HoDs and College management that when we work together, it's easy to overcome some SAVOGOs challenges. Secondly, we need to inform them that this topic on SAVOGOs is quite challenging; therefore, I think some collaboration is needed. Well, I will suggest and recommend that this kind of learning be implemented in our colleges, because it has improved our performance and attitude in SAVOGOs.*

S4 added on S3's view and said:

S4: *I would say it will be better to group ourselves and prepare a presentation and maybe take it to the lecturer, HoDs and College management, and convince them based on the benefits of learning SAVOGOs with TD and the experiences of students and that the researcher also has the experience of lecturing with a TD. Once we have that confidence, our presentation will be more powerful, and we will take it further to get first lecturers and management buy-in, and once we have their buy-in, it will be easier to be implemented at the College.*

S2 also added the same sentiments and said:

S2: *Look, I would say it should come first from the buy-in must first be from the lecturers who were involved with the study and then the HoDs, finally the College managers. We need to follow the protocol to avoid obstacles.*

S2 further noted that exposing students to SAVOGOs using TD across various campuses and colleges would lead to improved results, both in SAVOGOs specifically and in Mathematics Level 3 overall. He added that the value of learning with TD should be clearly visible and significant.

S2: *You know, always with new things, you have difficulties like convincing people. Everything should be structured in a way that it could be accepted by all, and the value of learning with TD should be seen, and nobody can dispute its value because there is, and it should be emphasised that this can raise performance in your marks at your college. Similarly, the marks will also improve because students will understand better. Those resources will be available because you look at what resources can be used.*

S1 noted that even if the TD cannot be used in its entirety, given its reliance on Wi-Fi and internet connectivity, partial use of the TD, or an adapted approach to working with it, can still be highly effective. She mentioned that:

S1: *So, basically, what I am saying is sometimes you cannot learn with TD the whole time, but maybe you can take some sections from that, like observation, like you can maybe just come together one day and learn together on a certain topic that may be giving you problems or giving the cohort of students problems. Yes, and you can also ask the lecturers to come and be observers in your discussions and to sit with students, then maybe one day it will be your turn to observe how other students are using mathematical videos and search engines in another class discussion.*

S5 highlighted the seriousness of learning with TD as a tool to improve Mathematics Level 3 at TVET colleges by suggesting that separate institutions should be started just for learning with TD, or a unit at TVET colleges dedicated only to the implementation of learning with TD. He stated that:

S5: *Somebody must start a separate institution that just works on learning with TD and do it for this college, and then for all the TVET colleges, like they are doing in other countries, like China. You come in and say, OK, like we are going to look at learning with TD, and this is what we do.*

He continued and commented:

S5: *Yes, starting like a special dedicated unit for the introduction of learning with TD. That only looked at the implementation of TD at a college and then transfer that knowledge to other TVET colleges and invest in the learning with TD plus maybe personal development and training, different learning approaches, and so investing in students. And the focus should be on investing in the students. This study is actually investing in the students' learning if learning with TD is being done and implemented properly.*

S6 commented on the platform TD--assisted learning created.

S6: *Learning with TD created the platform for us to converse with each other in an open and trustworthy way and I would say definitely that this should be a process that can be implemented within the TVET sector because for me I would say on an academic level, where they would say two heads are better than one and perfectly*

suits the function of learning with TD. I would recommend something like this to the TVET sector.

S1 agreed with S6 and said:

S1: *I would say it is better to start learning with TD within the college before, and then maybe with other colleges and then the TVET sector.*

S3 suggested the survey and said:

S3: *I think it is better to make a survey running of what topic students think we should start with, and in Mathematics Level 3, timetable it, and then roll it out on a big scale. It must start like that on a small scale in a real context, not the Chinese context, not the American context, but for SA and then specifically for the TVET sector, so that we can also have our data for TVET colleges. Schools, because it has so many districts and sectors, TVET colleges may be more successful in learning with TD.*

From the above comments and responses, it appears that all students feel strongly about taking learning with TD further at their own campuses for their subjects and others, as well as for their own college and the TVET sector. All of them also felt strongly about becoming champions for learning with TD at their own campus and college. This aspect of learning with TD was referred to by students 12 times.

The following was noted by the researcher regarding learning with TD being a benefit for the college and its future.

When a senior manager was overhearing the proceedings of learning with TD that the students were conducting, the Manager was blown away by the concept of learning with TD and the benefits it can hold for TVET colleges, lecturers, and students, but also for managers like her. She further mentioned in an education specialist meeting the powerful tool TD holds for all NCV fundamental subjects and referred to what the researcher is doing in mathematics, encouraging all other education specialists to attempt it in their subjects as well.

S2 also referred to the comments above in his interview with the researcher when he was asked what suggestions he would make to lecturers to effectively implement TD at this college and the whole TVET sector. He mentions that:

S2: *It happened that one of our mathematics senior lecturers walked into the room where the learning was taking place unannounced, and she was blown away. She saw the value immediately. She's raving about it to everybody, so, yes, the College management will see the value of it, but also you must have the entire College knowledgeable about learning with TD to implement it.*

5.11.2: The benefits of learning with TD for the TVET sector

Learning with TD has huge benefits for the TVET sector in terms of collaborating and assisting the colleges to work together on issues of improved performance in SAVOGOs and other topics in Mathematics Level 3. When learning with TD starts at a college, the various campus successes that are achieved can be exported to other colleges. This has huge benefits for students' performances, lecturers' abilities, and the transformation of the TVET college sector.

R: *In your opinion, what do you think will be the benefits of implementing learning with TD where the education specialist is a member of the team, throughout your college?*

The following participants mentioned that:

S6: *Yes, there are many benefits, one of which is teamwork, and its basic core focus is teamwork. And it is important for lecturers to encourage students to reflect on their learning of SAVOGOs with TD, maybe in a collaborative way. I think that is one of the big benefits. So, I think the colleges can benefit, and the college sector can benefit in that sense.*

S5: *It is a benefit for TVET colleges because learning with TD is different from the norm, meaning that the norm is the lecturer being inside lecturer in the classroom. So, I would say that learning with TD is a benefit for the entire TVET sector, because students of different levels in mathematics get to share their experiences with each other across the TVET sector. Also, students can email and probably invent some discussion forums through tablet devices.*

S1: *I wish we could do this more often and that this could be done across all programmes, subjects and levels. A good idea for future implementation.*

Five of the six students referred to the benefits of learning with TD for the TVET sector, and it appears that all five of them mentioned it very enthusiastically and positively. This aspect was mentioned by students eight times.

The results are illustrated by the following column chart as follows:

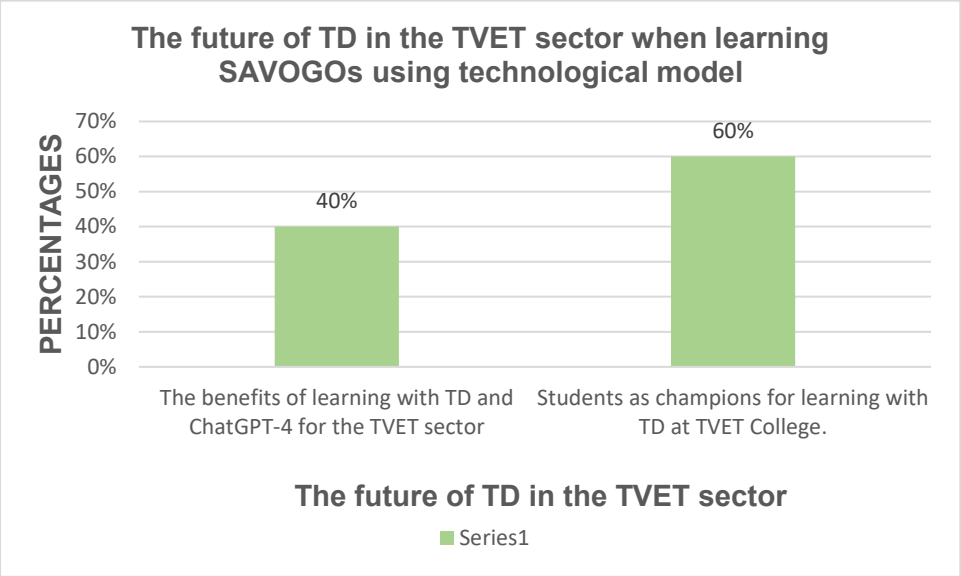

Figure 5.10: The future of TD in the TVET sector

From Figure 5.10 above, it is indicated that students would be keen to become champions in learning with TD at their TVET colleges before extending this method of learning to other TVET colleges. The chart also suggests that there could be immense benefits for the TVET sector in implementing learning with TD. Further interpretation and discussion of this aspect will be provided in Chapter 6.

5.12 THE NEED FOR THE PARTICIPATION AND INVOLVEMENT OF COLLEGE LECTURERS AT TVET COLLEGE WHEN STUDENTS ARE LEARNING WITH TD

In this study, the researcher was involved in every stage of learning SAVOGOs with TD and participated in all TD-mediated learning phases, including lessons conducted and student debriefings. Many students in this section and previous sections have indicated the advantages and benefits of having the lecturers involved in the learning process with TD. This involvement has also been foundational for maximising performance in the learning of the SAVOGOs with the TD model proposed by the researcher in this study.

Some students have expressed strongly that learning with TD should not occur without the lecturers' involvement. The benefits of lecturers' participation in the TD learning method include increased awareness of what occurs in the lecture room, enhanced thoroughness, improved structure to the process, better relationships, closeness between students, and greater visibility of the lecturers.

5.12.1 Need for lecturers' involvement when students learn with TD

Students were asked whether the lecturers should be part of learning with TD by posing the following question.

R: *So, what is your view in terms of whether a lecturer should be part of the process of learning with TD or not? Please explain?*

S4 answered in the following way:

S4: *I would say definitely a lecturer should be part of the TD process and be involved during the TD process, I am not sure to what extent but they should definitely be involved, maybe not fully involved but they should be made aware of the learning process that is taking place, the group method that is taking place and maybe they can sit during group discussion as well to gain insight on what's happening because they have to know about activities done inside the lecture rooms, and in fact, I think they should actually be the ones to initiate the TD process of learning if it is to be part of a college system. The fact that the lecturer was involved in the whole process, I would say, is a bonus, and it should not be done without the lecturers' involvement.*

S1 added that having the lecturer as part of the TD process brings about more thoroughness to learning.

S1: *I think it was done more thoroughly with the researcher (lecturer) being a part of it, because I think we're, in that sense, very similar to students. You know, the way you only do up until a certain point and then you stop, so I think with a researcher (lecturer) being present, it's almost as if just analysing it more…and I don't think it would have necessarily been done that thoroughly without the lecturer.*

S1 continued by saying that the presence of lecturers in the process of learning with TD has brought structure and form to the process:

S1: *And the lecturers are needed because like I said, I think the driving force is that students do need a push. Yes, as soon as you don't have anybody setting targets or submission date or deadlines or whatever, then there is no structure. And learning with TD will fall flat. I think it is important for the lecturer to be present and visible, just to make sure that things happen, and use the full time allocated for TD group discussions. Visibility of the lecturer brings effectiveness to the TD process.*

S3 agreed and added his voice. He mentioned that:

S3: *I will say it will help lecturers to be part of any project that is being done. Okay, because they will know what is happening on the students' side of the story, and also great benefit to have the lecturer as part of the TD process of learning. A better understanding of the lecturer and can be approached. It changed my perception of lecturers. Relationship with lecturers improved dramatically. There are great benefits to having the lecturer on the TD process of learning.*

S2 mentioned that the involvement of lecturers in the TD method of learning brought about great closeness between lecturers and students:

S2: *There was this great closeness between students and lecturers, which was good, and this also resulted in students respecting one another more. So, you learn to value peers. You will also see that my relationship with my fellow students also improved, and with you (researcher), it also improved.*

S2 further mentioned that the lecturers should guide, but he can also delegate, but he must be present and visible. He mentioned that:

S2: *Yes, they (lecturers) should be there, should be part of it. But like I said, they don't essentially have to take the lead all the time; they can just facilitate and guide, give exercises, delegate group leaders, for instance, but must be there and visible and keep order during learning. Yes, lecturers will have to be more visible, and the relationship will improve, and it has improved also, but like I said, and I want to also emphasise that learning with TD can't be introduced if there's no buy-in from the campus management.*

All students, representing 100%, referred to the necessity of lecturer involvement in the TD process. It appears that most of them were extremely favourable towards this involvement, citing reasons such as the need for lecturers to be aware of what occurs

in the lecture room, increasing lecturers' visibility, bringing structure and thoroughness to the process, and improving relationships between lecturers and students. The aspect of lecturers' involvement was mentioned 26 times.

From S2's point of view, the following was recorded:

S2: *Lecturers should encourage students at colleges to learn with TD to see the benefits of this learning process – that is, all lecturers, including the College management.*

5.12.2 Learning with TD, a bottom-up approach

The aspect of the bottom-up approach present during the learning with TD was already mentioned before in previous themes, and it was also revealed under this subtheme. The positive and open approach and the freedom to make decisions due to the varied input, which resulted from collaboration and participation, afforded members the opportunity to make decisions that are bottom-up rather than top-down. The bottom-up approach becomes even quicker if lecturers are involved for guidance as part of the collaboration and are part of the decisions.

When students were asked how and to what extent it would be beneficial for a lecturer to be part of the process instead of not being part of the process and facilitating the learning process, S6 stated the following:

S6: *Learning with TD teaches lecturers to have a more bottom-up rather than a top-down approach. I think we all appreciated it*. S5 added by saying*:*

S5: *Be part, so, I am saying for a lecturer to be part during the learning with TD is more of a bottom- up approach than a top-down approach. They can learn that from the process of learning with TD because learning with TD is a participative process.*

S4 agreed with all the above comments and said:

S4: *Learning with TD allows for a bottom-up approach to college lecturers as well. I would say it was a bottom-up approach for me that provided confidence because I could communicate on a level (same level as a lecturer) where we do not get every day, for example.*

S5 is of the opinion that most lecturers instruct students on the strategy to be followed, but are absent when it must be executed. Hence, he explains that:

S5: *Most lecturers are there for the strategy, but absent for the execution, so during the learning with TD the complete line is followed where the lecturer puts in the strategy but is present to see and experience the execution (like in this study). Even as the observer, the lecturer as research leader diminished as that of an observer, but the ability of the lecturer not to stay as the lecturer but come down to the level of a student and become part of the whole learning process.*

S5 further added that:

S5: *Even though the intention of the lecturer is not to police in this learning process, the presence of the lecturer in the process ups the learning because of the authority the lecturer has in the learning process. It encourages students to give their best. It encourages that. It brings a level up because of the involvement of lecturers in the learning process. For the lecturers to be involved in the learning process, it becomes bottom- up and top- down. The visibility of the lecturer overall also improved the performance in SAVOGOs.*

All four participants commented on the bottom-up approach to learning with TD, noting the lecturer's involvement in the learning process. It appears that all felt very strongly that the bottom-up approach is the correct form of decision-making. This aspect of the bottom-up approach was mentioned 15 times during the interview.

The results are illustrated in the following pie chart.

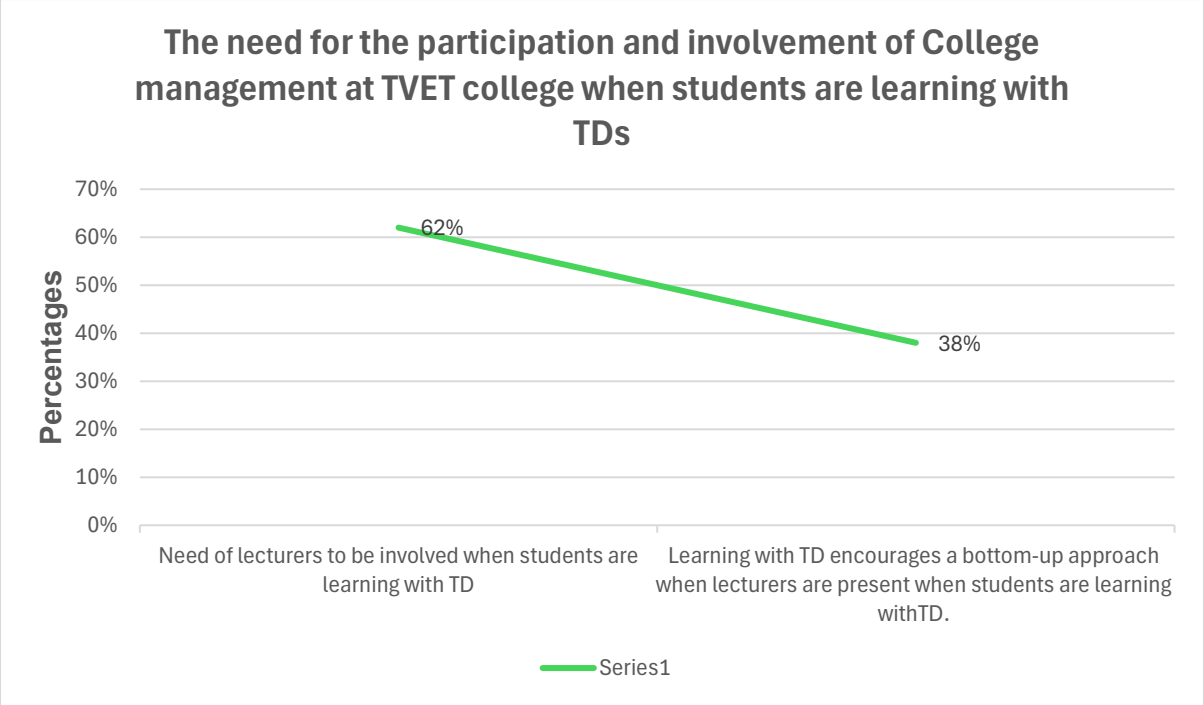

Figure 5.11: Need for lecturers to be involved when students are learning with TD

From the above graph, students feel more strongly about the need for lecturers to be involved in the learning process with TD and with students in classes than the bottom-up approach in decision-making, although the bottom-up approach in decision-making also features in the learning with the TD process as an aspect a manager should take cognisance of. The interpretation and discussion of the need for lecturers to be involved with students are further discussed in Chapter 6.

5.13 SUMMARY OF THE MAIN ASPECTS THAT WERE COVERED

Chapter 5 is about the findings of the study, which started by giving an overview of the classroom setting in which the research was taking place. This was followed by a data presentation process which included results, findings and benefits of the pilot study. Afterwards, the main study data presentation was reported under eight formulated themes together with their sub-themes. Extracts were also included to beef up the chapter, and finally, inferential analysis of variance was explored to indicate the final findings of the study.

5.7 CONCLUSION

In this chapter, I report the findings of a mixed-method study that consisted of both qualitative and quantitative data collection methods. The quantitative study was presented as scripts of the pre- and post-test that students wrote, along with the percentages obtained. The qualitative method involved semi-structured interviews with six participants, conducted before and after learning with TD, which included two cycles. The researcher also reported on ATMI with six students before and after each of the two cycles. Furthermore, students' comments, as well as the researcher's own observations and field notes, were documented to corroborate the interviewees' comments. The researcher's comments were also recorded after all the students' debriefing sessions. The discussion of the themes and subthemes will be addressed in Chapter 6.

CHAPTER 6

DISCUSSION OF THE RESEARCH FINDINGS

6.1 INTRODUCTION

In the previous chapter, I presented the data collected. After following the reduction process from codes to categories, eight themes were identified, which guided the findings of the study. In this chapter, the results are discussed by interpreting what was said and found, thereby providing meaning to the data. The significance of the findings is also highlighted by discussing the results under each major theme.

6.2 DISCUSSION

The purpose of this research study was to answer the question, “What is the impact of using tablets on TVET Level 3 students’ performance and attitude in calculating SAVOGOs?” To answer this question, the study’s objectives were to:

- Establish how Level 3 students’ performance compares with using tablet devices as opposed to the traditional textbook method of learning.
- Investigate how Level 3 students’ attitudes compare with using tablet devices as opposed to the old traditional textbook method of learning.
- Determine challenges experienced by Level 3 students when learning SAVOGOs using tablet devices.
- Determine the benefits of learning SAVOGOs with tablet devices.
- Suggest a model maximising performance in mathematics at TVET colleges using mobile devices.

The discussion is centred around eight major themes, namely i) enhanced contingencies that improved students’ performance and attitude in learning SAVOGOs, ii) reflections on determining the best method in learning and attempting SAVOGOs questions, iii) promotion of problem-solving skills through collaboration, iv) personal fulfilment and happiness as well as improvement and empowerment of students, v) students’ role, contributions and participation in the use of TD at TVET colleges, vi) challenges students are likely to encounter when learning SAVOGOs with

TD at TVET colleges, vii) the future of TD in the TVET sectors when learning SAVOGOs using the model to maximise performance, and viii) the need for the participation and involvement of college lecturers at TVET colleges when students are learning SAVOGOs with TDs.

6.3 DISCUSSION ON THE THEMES

A review of the related literature in Chapter 2, specifically Sections 2.3, 2.4, and 2.5, has indicated the importance of integrating technological development (TD) into Level 3 TVET college students' performance and attitudes when calculating SAVOGOs in mathematics. Integrating TD in the study of mathematics involves incorporating mathematical videos, search engines, animation systems, and familiar technological practices into the learning process. This approach ensures that learning and instruction resonate with learners' everyday experiences and technological backgrounds (Coughlan et al., 2025; Dias & Deodalo, 2025). This section discusses the findings of the study based on the main themes highlighted in Chapter 5, Table 5.1, and Section 5.3.

6.3.1 Enhanced contingencies that improved students' performance and attitude in learning SAVOGOs

Through interaction with SAVOGOs' content and participation in the learning process, the devices provided students with a great deal of mental nourishment in reflecting on their own learning. Furthermore, the devices encouraged improved implementation in their classes and designed their learning approach to effectively deal with the areas that are found challenging. Data presented revealed that learning with TD and the application of mathematical videos and animations enabled students to broaden their content knowledge, develop new instructional techniques, and reflect on their actions to determine what works best for them, as presented in Section 5.2.3 on page 43. Furthermore, the process of using TD allowed students to work together and collaborate. This is an uncommon practice at TVET institutions since, in the past, each student believed that their tablet was their personal space and territory and, as a result, did not permit other students to use it. There was also evidence that using TD forced students to improve their content knowledge through working collaboratively with

others and enhanced the skill of learning with TD. This is evident from the data presented in Chapter 5, Section 5.5. Observations of how the researcher and students operated TD, as well as reflections and debriefing about the best methods to be used in future, were also conducted. It was also observed that using TD revitalised a renewed focus on student-centred learning and teaching, as well as an introduction to the problem-solving approach. Furthermore, the use of TD brought about a renewed reflection on the learning method and on the aspect of anticipated student responses, and this was totally new to students.

Although it appears that it was mostly the high-performing students who referred to learning with TD in a collaborative format, the data presented reveal that they felt strongly about being removed from desolation, which also shows their eagerness to learn. This concurs with Fister and McCarthy (2021), who note that one student also referred to the fact that when he learned mathematics using the textbook method, he felt even more alone and lonely. Removing students from desolation due to learning with TDs, being collaborative and participative, also steered the sharing of ideas and knowledge, which is discussed in more detail in the next theme.

Although the use of TD focuses mostly on students and their learning of SAVOGOs, this study also revealed how it gave lecturers the opportunity to view and reflect on how colleagues deliver a lesson and, through reflection, adjust and amend their own lecturing. The fear of the dreaded examination with the invigilators present in the entire examination room was also reduced. Data presented on TD also provided an opportunity for the students to view things in a different way. Furthermore, the data presented reveals experience and improvement gained by students through engaging with the SAVOGOs' content through the operation of TDs. Students' challenges in the learning of SAVOGOs in calculations of different shapes displayed in Extract 5.1 did not indicate correctly which formula was for triangular, square, or hexagonal pyramids. In that extract, it was also observed that all the labelling for Question 1.1 was incorrect. Question 1.2 was also attempted, but the formula for the surface area of a hemisphere was incorrectly written. In that formula, (i) the base area was incorrectly written, and this indicated a lack of interpretation of the hemisphere as half of a circle. Additionally, the incorrect (ii) area of the hemisphere was written without the correct units, and (iii) the substitution for the radius in the formula for calculating the volume and surface

area of the solid cone was noticed. This also indicates the student's misunderstanding of concepts and uncertainty in the choice of formulae and the writing of correct units. These disputed findings by Engelbrecht and Borba (2024), who assert that multiple representations of space, shapes, and measurement support students in learning and identifying different formulae, proved to give those students a stronger chance of comprehension.

It was observed from Extract 5.2 that S6 had the highest score of all the students who participated in this study before the intervention. One could realise that the student scored 35%, which was not a good percentage, even though it is recognised as a pass percentage according to the Department of Higher Education and Training. Upon attempting Question 1.1, S6 managed to match the square pyramid correctly, but was unable to match the hexagonal and triangular pyramids correctly. This is evidence that the understanding of SAVOGOs was unsatisfactory, and it might be that the student was guessing the matching of the square pyramid. In attempting 1.2, the formula for the area of the hemisphere was incorrectly written as "$A = \pi r^2 + \frac{1}{2}(2\pi r^2)$" instead of "A = $\pi r^2 + \frac{1}{2}(4\pi r^2)$" and this is also classified as a misunderstanding of contents and concepts. Instead of writing $4\pi r^2$, the student wrote $2\pi r^2$ for the area of a sphere. The formula for the volume was also incorrectly written as V = $\frac{1}{2}(\pi r^2)$ instead of V=$\frac{1}{2}(\frac{4}{3}\pi r^3)$ and miscalculated, even the units were mistakenly written as cm instead of cm^3. Mostly, students were uncertain about the correct method and formulae to be used. This can be aligned to Mohammed and Termini (2010), who assert that a negative correlation exists between mathematics uncertainty, anxiety and performance, and that anxiety due to the inability to identify formulae has a significant impact on performance.

In Extract 5.6, which is S6's attempt, it can be observed that the formula for the volume of a hexagonal pyramid was incorrectly written as $V = \frac{1}{3}(\frac{\sqrt{3}}{2})l^2h_{\perp}$ instead of $V = \frac{1}{3}(\frac{3\sqrt{3}}{2}l^2)h_{\perp}$. The difference in the two formulae is that the three (3) next to the square root of 3 in the correct formula was omitted in the students' attempt, and that impacted the final answer negatively. This is evidence that the student did not have a full conceptual understanding of the volume of a hexagonal pyramid and how to use the

formula thereof. Also, one could notice that the perpendicular height ($h_\perp$) was not calculated, indicating another misunderstanding. When looking at the attempt, S6 did not realise the need to go through the formula $h_s^2 = h_\perp^2 + \frac{3}{4}l^2$ for her to calculate the perpendicular height using the given information. This is another lack of conceptual understanding of SAVOGOs' formulae. The area was written without the correct unit cm^2. This also indicated a lack of conceptualisation of the hexagonal pyramid when the traditional textbook method (TTBM) of learning was used.

When the researcher asked participants if they could differentiate between a square and a rectangular pyramid, the answer depicted confusion, as it did not answer the question. To show that S6 lacked conceptual understanding of SAVOGOs, and that underperformance in the written test was worrying her, she immediately switched to the challenges about hexagonal pyramids. Evidence of S6's interpretation of volume for hexagonal pyramids is in Extract 5.4, where she could not write the formula for the volume of hexagonal pyramids correctly. There was an omission of three in the formula, which caused the answer to be incorrect. Omission of some numbers or variables when writing formulae during assessments was one factor indicating uncertainty and misunderstanding when learning SAVOGOs traditionally. It could be observed again from Extract 5.4 that the final response about the area and volume was written without the correct units cm^2 and cm^3. This indicates uncertainty about the correct unit to be written. Students sometimes write the unit for area as cm instead of cm^2 when calculating the area and that one of volume also as cm instead of cm^3. This clearly indicates a serious misunderstanding which need to be corrected to inform students about the correct way of using and writing units.

In Extract 5.5, S4 attempted the area incorrectly, and the variable *h* in the calculation indicates that the perpendicular height ($h_\perp$) was not calculated before the area was calculated. This may be possible if the student was able to answer Question 1.1, where she was expected to identify the relationship between the slant heights(h_s), perpendicular height$(h_\perp)$ and the base edge $(l)$for square, triangular and hexagonal pyramids. Additionally, the question about the volume of the hexagonal pyramid, which requires the formula $V = \frac{1}{3}bh_\perp$ was not attempted.

Moreover, S4 did not attempt Question 2 on calculating the volume of the sphere and the total surface area of the square pyramid. It is evident that S4 lacked conceptual understanding of when to use the formulae $V = \frac{2}{3}bh$ for calculating the volume of a sphere and $A = b + \frac{1}{2}ph_s$ for calculating the surface area of a square pyramid. It was observed that the students attempted the question as if it were about differentiating a square from a rectangle, only to realise that they misunderstood the question, which was asking about a square and a rectangular pyramid.

The misunderstanding indicated in Extract 5.7 from S5's response was that he did not substitute for the height (h) as he was not sure if it was a perpendicular height $(h_{\perp})or\ a$ slant height (h_s). This also shows that S5 was uncertain about differentiating between the $(h_{\perp})\ and\ (h_s)$. For Question 1, a table summarising the relations between the slant height (h_s), perpendicular height $\boldsymbol{(h_{\perp})}$ and the base edge (l) for triangular, square and hexagonal pyramids was given. Students were expected to label the figure by indicating which formula is for triangular, square and hexagonal pyramids. This is associated with Dennis (2025), who associates misunderstanding with mathematics anxiety, which leads to a feeling of tension, helplessness and distress that impede the ability to concentrate and consequently affect the learning of mathematics. Dennis (2025) contends that students experience tension, helplessness, distress, and confusion during the Mathematics Paper 2 examination, all of which adversely affect their performance. Alex (2021) also echoes that mathematics anxiety is believed to have an impact on attitude and motivation to learn mathematics, and consequently on students' performance in mathematics. Findings reveal that students' performance after using the TTBM of learning was unsatisfactory due to the following groups of reasons.

(i) General misunderstanding by students,
(ii) Students struggle with the identification of correct formulae, and
(iii) Students' lack of conceptual understanding.

Figure 5.2 clearly indicates that in this study, the biggest misunderstanding was the uncertainty in calculating the area and volume of pyramids. This uncertainty arose from a limited number of examples and a lack of understanding, as well as difficulties in communicating with other students electronically. This aligns with Alex (2021), who defines mathematics anxiety as an emotional response towards mathematics, where

students experience negative reactions to studying mathematical concepts and testing. Students' unsatisfactory performance in this study appeared to stem from a lack of mathematical knowledge when dealing with SAVOGOs in the following areas:

(i) Finalising area and volume with correct units (for example, cm^2 for square and cm^3 for Volume),
(ii) Content, terminologies, language and word usage,
(iii) Identification and writing the correct formula for square, rectangular, hexagonal pyramid and regular cone,
(iv) Incorrect application of formulae, and
(v) Lack of concept understanding.

This concurs with Prensky (2018), who defines mathematics anxiety and uncertainty as negatively correlated to metacognitive knowledge, which is the ability to reflect, understand content areas and the volume of pyramids, as well as control over one's learning. For example, in this study, the more anxious and uncertain students were, the less metacognitive knowledge they had, and this ultimately hampered their performance in the subject. What appears to have caused students' anxiety and lack of conceptual understanding in this study is content, terminology, language, and word usage in Mathematics Level 3 Paper 2, which is usually about the interpretation of the correct formulae for pyramids. This concurs with Mohammed and Termini (2010), whose study in higher education institutions revealed a negative correlation between mathematics uncertainty, anxiety, and performance, and that incorrect application of formulae has a significant impact on performance.

From Figure 5.3, it is evident that when students use formulae, they apply them incorrectly by matching the pyramid in question with the incorrect formulae or omitting variables and numbers when writing a formula, as well as incorrect substitution of values. Additionally, it was also noticed in this study that content, terminology, and words like tetrahedron, pyramids, sphere, hemisphere, and regular cones used to formulate questions had an influence on the way students interpreted and calculated their answers. Moreover, it was discovered that the usage of slant height (h_s), perpendicular height $(\boldsymbol{h_\perp})$ and the base edge (l) for triangular, square and hexagonal

pyramids was also a major misunderstanding, which caused uncertainty in answering that question. The student also grappled with:

i. Identification of missing dimensions of geometrical objects,
ii. Finding different shapes contributing to the combination of geometrical objects, and
iii. Understanding that $'b'$ in the formulae $V = \frac{1}{3}b\boldsymbol{h}_{\perp}\ and\ A = b + \frac{1}{2}ph_s$ required them to calculate the base area of the given pyramid and $'p'$, the perimeter of the given pyramid.

Some students in this study showed challenges in the interpretation of base area and perimeter when calculating the volume and surface area of pyramids. This study showed that, when given a square, rectangle, triangle, hexagon, and regular cone, students could not realise that they should calculate the base area and perimeter of the square, rectangle, triangle, hexagon, and circle according to the given pyramid. This misunderstanding and uncertainty led to incomplete responses, unattempted questions, and omission of variables in the formulae, hence unsatisfactory performance. This concurs with Walberg's theory, which analyses students' performance and provides reasons why students are not reaching their full potential, as well as why students' grades do not match their capabilities.

The interpretation of the ATMI in this study revealed students' attitudes towards the learning of mathematics. Mathematics is often perceived as a difficult subject by students, parents, and lecturers alike, and this usually serves as a source of anxiety that interferes with the mathematics itself. Yet, difficulties with mathematics are most often attributed to cognitive reasons, lack of ability, preparedness, practice, and conceptual knowledge. Mazana (2024) from the ABC Attitude Model describes this as the emotional component consisting of feelings and emotions that are associated with attitudes towards an object. In this study, this refers to calculating the surface area and volume of geometrical objects in mathematics. This agrees with Masoabi and Alexander (2021), who described the behaviour as the action component consisting of predispositions to act in a particular way towards the mathematics object attitude in this study. Alexander and Masoabi (2021) further defined cognition as a mental

component that consists of beliefs and perceptions students hold about their attitude towards mathematics.

The study found that all sixty students strongly disagreed with the statement "SAVOGOs are a very important and necessary topic to learn," indicating a negative attitude towards learning mathematics. Only eight students wanted to improve their skills in learning SAVOGOs after using the textbook method, while nineteen students did not want to improve their skills due to a lack of understanding. No student was happy or interested in solving SAVOGOs problems after learning with the textbook method, and none felt SAVOGOs problems helped grow their minds or teach them to think. The statement "SAVOGOs are important in everyday life" was also negative, with nineteen students disagreeing and forty-one remaining neutral. The statement "Learning SAVOGOs will be helpful in any job I want to get when I am older" received negative responses, with 58 students not seeing a possibility of applying mathematics in their desired job. From this data, it can be concluded that students cannot think of many ways to use mathematics outside of college. The low performance displayed by students in the pre-test and the negative attitude towards mathematics after learning traditionally motivated the researcher to conduct an intervention aimed at improving students' performance in mathematics.

The findings of this study indicate the approach to the learning of SAVOGOs before TD and how participants had improved. Participants mentioned that they improved from the traditional textbook method (TTBM) of learning to the student-centred learning approach they learned from the use of the TD process. For example, S5 mentioned that adaptive and personalised learning through TD assisted her in finding the questions in the assessment approachable, and that those platforms leverage algorithms that analyse student performance through quizzes, assignments, and interactive exercises. Based on this study, the TD platform dynamically adjusts the difficulty level for the student, identifies misunderstandings and areas needing reinforcement, and recommends relevant resources. This is indicated by S5's comments in Chapter 5. This also concurs with Williams et al. (2022), who assert that the condition in which learning takes place is another fundamental element to consider when evaluating a student's performance in mathematics, like other types of environments, such as the library (mass media) or the home, technology, and peer

groups (Engelbrecht & Borba, 2024). This is because those spaces can also affect performance in understanding mathematics and demonstrating what students have understood, while also building their understanding of the subject. For example, students are likely to underperform academically if there are no gadgets, like tablets, to practice mathematics exercises or to explore new topics.

The data presented revealed that all students improved their attitude towards the learning of mathematics. The researcher, in her interaction with students, realised that TDs and the mathematical programmes in videos, animations, and mathematics manipulatives used to help visualise mathematics concepts, both in mobile learning environments and computer-based environments, brought about efficiency and convenience in the learning of SAVOGOs. The TDs offered the convenience of learning anytime and anywhere. The researcher also observed that students could (i) find online lectures in abundance for different sub-topics in SAVOGOs, (ii) access resources and study materials through their TDs, making it easier to fit the learning of SAVOGOs into their mathematical schedules, and (iii) improve engagement and collaboration after intervention. This concurs with Masoabi and Alexander (2021), who assert that TDs also help with reciprocated collaboration and engagement of students with lecturers, as students connected with lecturers worldwide remotely.

TDs provided students with mathematical videos, which offered immediate feedback on assignments and tests. Students could watch videos, animations, and mathematics manipulatives used to help visualise mathematics concepts, both in mobile learning environments and computer-based environments. Furthermore, students used online tools to calculate SAVOGOs, learn, and practise online. It helped students identify areas for improvement and allowed for timely intervention to address learning gaps. Finally, the researcher made students aware that familiarity with search engines and TDs is increasingly valuable in today's job market. Using search engines, mathematical videos, and animations for learning SAVOGOs at the same time equipped students with digital literacy skills and prepared them for the technology-driven workplace of the future. This concurs with Gerber (2023), who asserts that learning mathematics with TDs allows greater interaction and more feedback between students and the lecturer in almost all cases. This is also aligned with Alex (2021), who notes that in new technology such as TDs, it is easier for students to watch videos

and create an improved mathematics learning environment. This aligns with Mullis and Kelly (2022), who found that online mathematics classes became a popular concept in schools when the pandemic struck the world. In this COVID era, tablets have been changing the way lecturers and students work and live. Both lecturers and students were seeking to embrace tablet methods and applications with the rising use of EduTech.

There was also evidence that being part of the TD team and collaboratively learning and teaching lessons provoked a new sense of emphasis on the student-centred approach as a form of learning. This could be used by HoDs to encourage lecturers in Mathematics Level 3, and other subjects, to implement it in their lecture rooms at TVET colleges in a more structured way through the vehicle of learning with TD. Through the use of TD and mathematical videos, adaptive learning was also discovered. This is a technology-oriented approach that adjusts to individual student needs. A healthy student-centred learning environment where students feel comfortable taking risks, trying new things in SAVOGOs, and being themselves was established. This learning environment allowed students to be more engaged in their education and take ownership of their learning. This agrees with Dennis (2025), who asserts that DHET incorporated the use of new educational devices like teaching and adaptive learning using tablets to avoid boredom and weariness while improving performance and attitude in mathematics for students at NW TVET colleges.

From Extract 5.8, S1's work after the intervention indicated positive progress, confidence and ability to solve problems. This also indicated that with tablet device usage and the watching of mathematical videos, S1 was able to show the relationship between the slant height (h_s), perpendicular height ($h_\perp$), and the base edge (l) for square, triangular and hexagonal pyramids. This concurs with Prensky (2018), who asserts that self-confidence in mathematics refers to a student's perceptions of self as a mathematics learner and includes beliefs about one's own ability to learn and perform well in mathematics. In this study, students perceived themselves as those who were unable to learn and perform well in mathematics before the intervention. Hanalei and Amidala (2004) explain self-confidence as an important factor that influences students' learning and improves their performance in mathematics.

In Extract 5.9, the base of a circle for Question 1.3 was correctly written as πr^2, but later S4 cancelled the two, indicating a square for r in the formula πr^2. This cancellation of two indicates an uncertainty in S4's response. Even though the calculation was incorrect, the improvement was noticed because the formulae in 1.3 were partly correct as compared to the first attempt before intervention. The radius was correctly calculated and substituted. One could notice a cancellation for the substitution of the slant height h_s which was supposed to be 75 and was now written as 70 with a cancellation. This indicated the experiences and improvement gained by students through engaging with the SAVOGOs' content through the operation of TDs.

6.3.2 Reflections on determining the best method in learning and attempting SAVOGOs questions

This chapter has demonstrated that learning with the aim of long-term retention while utilising TD is the most effective method for learning in general, as opposed to cramming. Additionally, students discovered that making a study plan with clear objectives gave them a roadmap to follow and made them feel more prepared. Students were also taught how to be proactive in recognising SAVOGOs areas in which they required support and promptly seeking that support. Eventually, students realised that studying with others allows them to question each other, explain the content to each other, and create a network that they can rely on for the remainder of the semester and beyond. When studying using TD, students recommended practising the following steps: (i) Reviewing their prior knowledge of the subject and their learning objectives before beginning a new chapter or attending a lecture. (ii) Making extra notes as they read or listen to new information, such as themes the content reminds them of or possible links to other courses. (iii) Making a note of any queries they had, and (iv) Compiling their knowledge and looking for answers to any queries they still had.

This is emphasised by Dennis (2025), who posits that the brain can only process a certain amount of information at a time and hence the need for rest. That rest enables our brain to compress and consolidate memories of the material students have practised. The author also emphasised that students should make sure they allow enough time to relax and sleep in between study sessions so that their brains can be refreshed and ready to accept new information. Dennis (2025) further emphasised

that where one studies can be important. When students study with TD, they should find a space that is free of distractions and has all the materials and supplies they need at hand.

This view is shared by Dennis (2025), in which it was found that content knowledge was increased among student participants, and students' practice changed, having a positive effect on students' mathematical performance and attitude. This is also revealed in Figure 5.6, where students' reflections on determining the best method of learning benefited more from the stage of observation in the TD process than any other, although reflecting on the anticipated responses and reflecting and debriefing on learning after the intervention method was administered scored the same. All these concepts were also new for students, and they received more attention from them.

In this study, data revealed that learning SAVOGOs with TD provided an excellent opportunity for all students, including lecturers, to have healthy communication, discussions, debates, and critical thinking in a mature setting. This resulted in good sharing of TD knowledge expertise, both concerning content and knowledge about SAVOGOs and answering question papers during assessments. At the same time, learning with TD also provided a glimpse to the college manager of how TD and mathematical videos could be used as a platform to encourage healthy discussions between students and their peers, as well as lecturers and HoDs, in a positive atmosphere. This concurs with Masoabi and Alexander (2021), who assert that the use of tablets increased the interaction between the lecturer and the students, rendering the class more dynamic and tailored in real time to the students' needs in mathematics. In addition, Alexander and Masoabi (2021) demonstrated that mathematics students were more engaged in tablet classes and maintained their concentration until the end of the lessons.

Extract 5.14 demonstrates S4's successful attempt to calculate the volume and surface area of a hexagonal pyramid. The student correctly wrote the formula and partially substituted the base area, omitting Part 3 in the formula. The student also correctly wrote the formula, converting 100m into 10cm, demonstrating significant improvement after the intervention. Aligning with Borba et al. (2025), who contend that TD significantly enhance learning accessibility, the findings of this study demonstrate access at the observation stage of learning with TDs. During observations, low-

performing students were identified. The use of TD brought a totally new dimension to teaching and learning in the lecture rooms of the TVET college where this study took place. It has also put an important focus on instruction as well as an opportunity, which allowed lecturers and students to observe in action in the lecture rooms of TVET colleges. This is also revealed when most participants viewed this stage of observation, an irreplaceable part of learning with TD, as *'a novel idea'* and an '*eye-opener'* and a stage of learning with TD which they thoroughly enjoyed and want more of.

Notably, the research revealed that the observation stage shifted lecturers' focus toward the student, reinforcing the fundamental notion of TD as a pedagogy that places the student under the spotlight. Furthermore, it was also noteworthy that some students exemplified the fact that the observation stage made them reflect on their own learning methods by observing other students learning SAVOGOs and how they can improve their own learning methods in the future. This corresponds with a study by Engelbrecht and Borba (2024), who state that students learn best from and improve their practice by seeing other students learning. This happened in a very professional atmosphere and a professional sharing of knowledge among students in terms of peer learning and observations. It also allowed lecturers to adjust their perception towards the concept of student learning in future class discussions and observations. This concurs with Dennis (2025), who proposed three measures of behaviour, which include observable actions performed by the subjects recorded by an investigator, individual commitment to perform the behaviours, and self-reported behaviour. However, Sundrani (2025) note that the last two measures can only be considered if it becomes difficult to make direct observations of the noticeable behaviours.

In this study, observable action is an observational method that involves observing students' attitudes in and outside the classroom when learning SAVOGOs. During this observable action, the lecturer served as the observer as he taught and collected data. Data collected in this study emphasise students' reflections on TDs, mathematical videos, and animations. It was reported that it is crucial to use TDs, mathematical videos, and animations when learning SAVOGOs to improve the learning style. Students further reported that with TDs, mathematical videos, and animations, they

can debrief to address and resolve misunderstandings they encountered during the learning process. Students felt that it was about preparing, reading, and going through the topic before the lesson and checking with mathematical videos, which would help them during the delivery of the lesson by the lecturer. Furthermore, findings revealed that a student-centred approach in the classroom, where active engagement and experiential learning take precedence over traditional lecture-based instruction, is crucial to encourage the skills of collaboration, critical thinking, and problem-solving. Students were encouraged to explore, question, and innovate, and this laid a foundation for lifelong learning and adaptability. This, as Creswell and Clark (2023) refer to it, is equilibration, which allows students to find a balance between applying their existing knowledge and adapting their behaviour to new information.

In this study, data revealed that five of the six students, or 84% of them, referred to the student-centred and problem-solving approach used in this TD, and all of them had very positive experiences and attitudes towards the learning of SAVOGOs. One student mentioned that he enjoyed the engagement between students and the lecturer. One mentioned the independence and confidence it increased in students, while the other referred to student-centeredness and problem-solving as a good challenge for students as well as for lecturers. The concept of student-centeredness and problem-solving was mentioned at least 10 times by these students. This supports Higgins' (2025) definition of engagement in mathematics learning, whereby active participation strengthens and expands students' neural connections.. Interaction, communication, and collaboration are just some of the ways to engage mathematics students.

In Extract 5.12, it was noticed that the incomplete Question 2.2, which was not done before the intervention, may be due to time constraints. Also, one could notice students’ examination anxiety and uncertainty from the incorrect numbering of the questions. Because S6 managed to write the correct formulae, this is evidence that this student did understand what was needed in the learning of SAVOGOs when using tablet devices. Identification of correct formulae was key in answering the question, and it indicates that correct mathematical concepts in mathematics indicated that TD provided a new focus on student-centeredness and problem-solving skills. Students mentioned that they liked the student-centred approach as they were actively involved.

This agrees with the second element of motivation, which, according to Simon et al. (2025), includes the intention of each student to conduct activities, solve problems, and get actively involved in their classes. To emphasise the findings, TD does take on a problem-solving approach as well as a student-centred approach, which gives the students the opportunity to have learning in their own hands, thus giving them the responsibility for their own learning.

This skill set should be facilitated through innovative educational technology, which encourages collaboration, communication, and problem-solving to navigate SAVOGOs' complex challenges. Mathematical videos (MVs) enhance personalised learning experiences for students, providing each student with a unique learning experience tailored to their exact needs, hence a positive attitude towards mathematics. Through MV-powered tools embedded in TD and animations, lecturers can tailor educational content to cater to the diverse requirements of each student. The use of educational technology improved students' attitudes towards mathematics and facilitated improved student engagement, personalised feedback, and enhanced learning outcomes. Participants strongly agreed that mathematics is a product of everyday activities and experiences. This agrees with the assertion by Higgins (2025), who considers mathematics as a technological process, which is contrary to the traditional dominant view of mathematics. The traditional view is that mathematics is both textbook-oriented and face-to-face in the lecture room (Limi, 2025; Sundrani, 2025) of the literature review. This traditional dominant view has a negative impact on the learning of mathematics at TVET colleges.

Findings about focus on anticipated students' responses indicate that only two students passed the pre-test, whereas in the post-test results, a total of 11 students passed the post-test. This is indicated in Table 5.8, which shows a percentage increase of 19% in the pass rate of the post-test as compared to the 4% pass rate of the pre-test. A 15% increase in the pass percentage is noted, indicating that learning SAVOGOs with TD improved students' performance and attitude. This is supported by Giri (2021), who asserts that multiple studies back the idea that a positive attitude directly affects performance positively, while a negative attitude lowers performance in all ways. Another finding is shown in Figure 5.5, where it was noted that students' scores improved throughout, as the graph of the post-test remained above that of the

pre-test. The findings concluded that there is improved performance after learning mathematics with TD. The findings also indicated that anticipated students' responses when learning made them more proactive in their thinking.

Within a structure that facilitates the transmission, formation, reformation, and reflection of learning methods and lecturers' instructional practices through collaboration (Williams et al., 2022; Coughlan et al., 2025), it was found that learners' reflection on learning methods can be crucial for revising methods of learning to create revised acceptable learning methods. This concurs with Novita and Herman (2021), who assert that cognitive learning equips students with the skills they need to learn effectively and thereby enables them to develop the problem-solving skills needed to apply in solving challenging tasks. In this study, through experiential learning, students were able to recycle and use the same learning methods that worked previously. This helped them learn new things much faster, as they already knew what worked for them when obtaining new knowledge.

Another aspect that was highlighted rather strongly through the findings was the debriefing sessions after the delivery of the research lessons. This was taken seriously by students in this study, and it was viewed in a positive light as something new, as it was not usually done by students when learning traditionally. Since it was reflected upon by a group of students participating in collaboration with one another and by giving their views and input in the lesson, it made it even more powerful. The debriefing sessions allowed for reflection on learning methods, which corresponds with studies conducted by Dias and Deodalo (2025) regarding TD providing students with unique opportunities to observe fellow students' activities in a constructed lesson for interpretation and reflection. This also assisted students and the lecturers in terms of what could be changed and revised in the future concerning the learning of SAVOGOs.

It was also found that the debriefing session was an optimal utilisation of time and a beneficial investment of time, as reported, *'will make more effective use of your time'.* This was also seen as a powerful learning development because after the debriefing and reflection stage, strategies could be immediately put in motion, unlike the traditional TBML, where there is no follow-up. This is consistent with findings by

Brooke et al. (2022), Dias and Deodalo (2025), and Prensky (2018), which declare that the traditional TBM of learning is no longer effective as there is no immediate feedback. In fact, all the stages of the TD process in this study became a powerful way for learning. It was also worthwhile to note that the debriefing session was seen as a sound encouragement for lecturers to encourage students to always reflect on the learning methods of Mathematics Level 3 in a collaborative way, and for lecturers to become involved in lecture rooms. This is consistent with Alex (2021) and Adams (2025), who are of the view that lecturers must become involved with students in their lecture rooms and thereby become more visible in the eyes of the students.

This finding is important for lecturers as it shows that the involvement of lecturers in lecturers' rooms could improve the performance of students in mathematics. Also, it improves the ability of students to look at and reflect more deeply on their learning in view of what was found in the debriefings. With students engaging in collaboration with TDs, their view of learning also changed insofar as the learning methods are concerned. Student-centred teaching and learning with a problem-solving approach took on a new meaning for certain lecturers. Student-centred learning and problem-solving also brought about positive expressions from students as they enjoyed the teamwork that it afforded, as well as the engagement with fellow students and especially with the lecturer.

This is consistent with Eshetu and Wakuma (2024) and Dennis (2025), who note that student-centeredness and problem-solving approaches enhanced both lecturers' and students' performance. However, one student felt that students are not yet ready for the problem-solving approach at TVET colleges. Another area that provided a great learning curve to participants in this study was that the researcher started to think more deeply in terms of what they can expect students to do, what misunderstandings can be expected, and how to gear future learning methods towards highlighting these areas. This aspect of TD placed a totally different angle on teaching method plans to the extent of starting to think critically when preparing to learn SAVOGOs. This concurs with Mullis and Kelly (2022) and Kulik and Fletcher (2020), who note that lecturers improved their knowledge and focus on students' anticipated responses as an inclusion when designing lessons.

6.3.3 Promotion of problem-solving skills through collaboration and participation

Students were prepared to be open and learn from lecturers, and individually and collectively implement problem-solving skills promoted through learning with TD. Usually, the presence of a lecturer creates a threatening atmosphere and fosters a perception in students that the lecturer is there to check for mistakes. Findings from this study revealed that learning SAVOGOs with TD led to an open, non-threatening, and non-judgemental approach, which resulted in the freedom to make decisions, and this led to improved performance. The power of subordinates for free decision-making in a non-threatening and non-judgemental atmosphere and environment is fundamental in a participative and collaborative relationship, such as learning using TD. When this occurs in a supportive and positive atmosphere, it results in improved performance and a positive attitude in learning SAVOGOs. Working together in a group of students learning the same subject, with a lecturer present, could enhance the participative and collaborative culture of learning mathematics at a TVET college. This is possible if students in study groups see the lecturer as someone who is there to guide.

The students' ability to learn SAVOGOs was also transformed, because instead of instructions being top-down, a learning atmosphere in which decisions and instructional offerings are also bottom-up was created. This was because decisions were made in collaboration and participation. Through learning SAVOGOs with group discussions as teams, these findings have revealed that all the aspects that make a TVET college effective include healthy discussions, openness, trust and respect, positive relationships, and sharing ideas, which were also experienced by students in this study. This concurs with Coughlan et al. (2025), who assert that peer learning of SAVOGOs in TVET colleges prevails, and that performance and positive attitudes improve. Coughlan et al. (2025) further state that the promotion of a positive learning environment affects students' performance in SAVOGOs and students' attitudes in the learning of SAVOGOs. In this study, learning with TD showed that, through the collaboration and participation of students, a positive culture of learning was created in the college, resulting in improved performance and attitude in the learning of SAVOGOs. Students further revealed that, through healthy mathematical discussions,

learning SAVOGOs with TD placed renewed focus on critical thinking and fostered discussions on mathematical content. What was fascinating was that students experienced this before and after the TD learning process ended. This was revealed by students' statements like, 'using mathematical videos and animations as well as discussions between students is *now done more regularly; previously, I only looked at my fellow students and never interacted or engaged with them in this way.'* Also, Coughlan et al. (2025) see the tablet as more than digital textbooks for students to refer to, but also as an interactive, engaging device to enhance students' learning experiences. This sharing of knowledge assisted students in discovering effective learning methods, sharing common experiences between them and the lecturers, and being an asset not only for this TVET college but also for the integrated TVET sector. This supports Thurm and Barzel (2022), who proposed that a shared knowledge base can be used by students to share ideas, knowledge, and skills, thereby building a shared knowledge base which can be used by all; in this case, by all TVET colleges.

In this study, the sharing of mathematical knowledge was achieved because the collaborative approach collectively brought together new SAVOGOs ideas through the input of students who embraced learning with TD. When studying together, one learns from peers, which includes the perception of co-learning and self-directed learning (SDL). This concurs with Voss et al. (2023), who assert that SDL is the process of learning in which students take the initiative for their learning and hold themselves responsible for it. During this process, students were responsible for organising and managing their own learning activities and needs. Voss et al. (2023) further emphasised that SDL encourages students to become responsible for their own learning, identify gaps in their knowledge, and critically appraise new information.

Furthermore, this study has also demonstrated very strongly that sharing knowledge generally, and specifically regarding mathematical content, has brought about an open relationship among students as well as between students and the lecturers. This transpired because the participation and collaboration provided an equal opportunity to share participants' experiences and their ideas regarding SAVOGOs' content. This agrees with Gerber (2023), who suggests that working together promotes self-directed learning (SDL), participatory learning (PL), as well as social interaction (SI) through peer learning and co-learning. SDL discovered during the learning with TD

encouraged students to become responsible for their own learning, identify gaps in their knowledge, and critically appraise new information. This concurs with Prensky (2012), who shows that sharing the responsibilities with hands-on students produces more effective and efficient practices. A state of closeness was observed between students and the lecturers through co-learning, interaction, and sharing ideas.

The stage of observation during learning with TD revealed a great degree of reflection among students, as well as a culture of openness and improvement in students, in a very friendly way. This openness led to a culture of trustworthiness, friendliness, and interactive, constructive learning engagement, which is also logical with a theory by Audi (2023). This study furthermore revealed that collaborative learning enforced trust and respect among students and lecturers. This agrees with Kulik and Fletcher (2020) and Dias and Deodalo (2025), who found that collaborative interaction often results in the exchange of thoughts with trust and respect among students and their lecturers.

In this study, students reported that the lecturers must also be open-minded, professional, engaging, and non-restrictive in their approach when teaching with TD. This suggestion concurs with Richardson (2022), who asserts that lecturers must know what students are thinking or were thinking when they make mistakes and find ways to identify the common misunderstandings.

6.3.4 Personal fulfilment and happiness, as well as improvement and empowerment of students

Data presented in the previous chapter revealed that lecturers' collaboration with students in the learning of SAVOGOs with TDs resulted in empowering students personally and ensuring that their confidence improved. This motivated them to enhance their method of learning mathematics and to improve their performance and attitude towards the subject. This was evident from the students' improved performance in the SAVOGOs post-test. This concurs with Richardson (2022), who asserts that students believed their SAVOGOs content knowledge was positively influenced in the areas of deeper understanding, which led to an increase in self-confidence. This aligns with Arvanitaki and Zaranis (2020), who found that students experienced intensive satisfaction and a strong relationship when learning using

tablets and sought to investigate the effect tablets had on school mathematics performance.

Students also gained confidence from working collaboratively with peers during the process of learning SAVOGOs with TD. These fascinating results concur with Simsek and Can (2020), who found that collaboration resulted in positive attitudes, motivation, and confidence in various learning methods, especially when learning with TD. This study revealed that most students who participated in learning with TD became empowered, confident, and motivated regarding educational technology. Specifically, students felt more empowered to make sound decisions about the method of learning SAVOGOs. Their confidence was boosted as they developed a positive attitude towards learning mathematics, and their enthusiasm and self-esteem improved.

This improved performance occurred because, when studying SAVOGOs with TD, they could freely provide input, irrespective of whether it was correct or incorrect. Hence, an atmosphere of democratic decision-making was created and experienced by participating students. The findings concur with McMillan and Jones (2022), who note that collaborative opportunities involving multiple representations allow students to see the same mathematical expressions or relationships presented in more than one form. For this to be successful, active collective engagement and participation from all participants in the process of learning with TD are necessary, as highlighted by Masoabi and Alexander (2021).

The inclusion of lecturers was seen as a contributing factor towards raising confidence and motivation in this study, as the participating students mentioned that the presence of the lecturers during the learning with TD also boosted their confidence. This inclusion fostered visibility and teamwork between students and lecturers, as found by Voss et al. (2023). Comments about the inclusion and involvement of lecturers, as mentioned by the students themselves, were a significant discovery in this study and contrasted with what was anticipated. This was also noted in the study, as the participating students expressed that making mathematical decisions was empowering and that their decision-making abilities improved; an open approach was developed between peer students and the lecturers, allowing for quick agreements and consensus during learning. This aligns with Kulik and Fletcher (2020), who assert

that student collaboration and decision-making with lecturers through participative learning practices have the potential to develop and improve performance in educational institutions. This same model can be transplanted to TVET colleges with student collaboration.

6.3.5 Students' role, contributions and participation in the use of TD at TVET colleges

Results of this study identify student use of TD as playing a role in student motivation to learn. Patterns associated with student use reveal that students who readily employed the tablet and its related features were more likely to indicate that they use learning strategies that aid in mastery of mathematics and application of formulae related to SAVOGOs. The use of TD allowed for student engagement with the learning of mathematics. Animation and search engine features facilitated students' organisation of SAVOGOs' content, but also allowed students to elaborate on the information being presented by the lecturers. Students used the stylus to create diagrams and mark notes on the PowerPoint slides generated by the lecturers during class.

Students had the opportunity to question the information to see if they understood or needed further clarification in relation to the material being presented as they jotted down notes on the computer screen. The use of the TD also allowed students to study on their own, with students indicating that they used the TD to access online resources that aided in their understanding of mathematics material. Across lecture rooms and the mathematics department, mathematics students reported that they were most likely to use the software OneNote to collaborate with peers using their TD. Providing feedback and sharing notes allowed for a critical exchange of information to take place and provided another venue for students to think about and make sense of course content.

Many students at TVET colleges found that having lecturers in the learning process brought them and their peers to the same level. This interaction led to increased closeness between lecturers teaching at different levels. The lecturers' roles as guides, mentors, supporters, advisers, and facilitators were emphasised, as

collaboration and participation helped blur the line between subordination and superiority. Participation and peer tutoring are generally feared by students, but participation when learning with TD in this SAVOGOs study also resulted in creating a non-threatening learning atmosphere with the lecturers being present.

This study found that self-efficacy positively predicted students' perceived ease of use and perceived usefulness of TD in the lecture room settings. This finding is consistent with most of the previous research by Mullis and Kelly (2022). Students who see themselves as more capable of using TD are more inclined to find TD useful for their study and easy to use. In addition, students in the study highlighted the lecturers' roles as facilitators in the learning process with TD. Students' interviews also revealed that collaboration between students and lecturers enhanced the lecturers' guidance and support, aligning with Dennis (2025), who emphasises the lecturers' significant role in guiding students and maintaining their learning progress when learning with TD.

The study further emphasises the importance of lecturer support for students learning with TD. Lecturers need to guide, mentor, and coordinate to enhance the learning process. Badenhorst and Rammile (2023) underscore the significance of continuous lecturer support for successful TD learning, involving collaboration with students. Lecturers' involvement raised questions about SAVOGOs’ content, aligning with TD's student-embedded nature. Bara (2023) asserts that TD learning is contextualised within the lecture room and is subject to change. Lecturers play a crucial role in reviewing the mathematics curriculum to meet TVET market standards. Spending more time in lecture rooms can make lecturers more visible and effective.

In this study, students further emphasised how lecturers can impact the mathematics curriculum through participation and collaboration, identifying gaps and informing improvements. By involving lecturers in the process of learning with TD, they gained insight into practical implementation before official implementation. This hands-on approach allows for feedback on what works and what doesn't, facilitating adjustments and improvements. Students further emphasised the importance of obtaining first-hand knowledge of how the curriculum plays out at grassroots levels to inform higher-level decision-making. Students mentioned that involving lecturers in discussions at discussion group meetings helps bridge the theory-practice gap and address resource

shortages in the mathematics curriculum. The findings also highlighted the value of lecturer involvement during learning with TD to provide immediate feedback and facilitate changes to enhance the mathematics curriculum.

Students finally emphasised that learning with TD in a team setting has prompted a fresh perspective on the mathematics curriculum, offering immediate feedback on learning, pinpointing misconceptions, and suggesting improvements. In the learning process, students communicated directly with lecturers and curriculum developers through emails to address challenges. This aligns with Bara's (2023) notion of a cyclical learning process within the lecturer's room. Recommendations for curriculum implementation and resource needs are addressed, potentially influencing broader educational programmes. This approach diminishes authoritative implementation of the curriculum, enhancing collaboration and adaptability. Grounded in TD action learning principles, the process weaves together planning, research, and reflective learning into a cohesive cycle.

6.3.6 Challenges students are likely to encounter when learning SAVOGOs with TD at TVET colleges

Key challenges included time limitations, student resistance, formulaic identification difficulties, lecturer skill deficiencies, and resource inadequacies, alongside the strategies employed to address them. In this study, as far as time was concerned, it was a learning curve because students' various other assignments, examination commitments and deadlines meant they had to juggle their time between classes, administrative periods, and examination preparation to be present during TD learning sessions. This also increased learning stresses and pressures, as was evident from what the participants revealed. This also meant many sacrifices had to be made by students and lecturers. It also had timetable implications and impacted other non-participating students affected by the process of learning with TD.

The issue of time was a concern in all the stages of the learning process with TD, and it influenced classroom time, planning time, as well as learning preparations, and the meeting to debrief the research lessons, as it consumed much time. This also concurs with the challenges of time as mentioned by Aldossry (2023) and Novita and Herman

(2021). This has implications for future planning of TD at TVET colleges, and something lecturers must prepare for going forward in terms of wise planning and scheduling, and to improve learning with TD at TVET colleges.

The study found that students often struggle with interpreting base area and perimeter to calculate the volume and surface area of pyramids, leading to incomplete answers and unsatisfactory performance. The Chinese version of the ATMI is a reliable, valid, and compact instrument for measuring students' attitudes towards mathematics and was used in this study. It was found that mathematics is often perceived as a difficult subject, causing anxiety and hindering learning. However, difficulties are often due to cognitive reasons, lack of ability, preparedness, practice, and conceptual knowledge. In this study, a student attempted multiple questions incorrectly, including incorrect formulas for triangular, square, and hexagonal pyramids, incorrect hemisphere surface area, and incorrect substitutions for radius, indicating misunderstandings and uncertainty in formula choice and units. Students were uncertain about the correct method and formulae. Extract 5.4 shows that students' final answers for area and volume were written without correct units, indicating a misunderstanding. They sometimes wrote the area and volume in cm instead of cm^2 for the area and the volume as cm^3. The area was incorrectly attempted, and the variable *h* was not calculated before the area.

Additionally, the student did not attempt questions about the volume of a hexagonal pyramid or the surface area of a square pyramid, indicating a lack of understanding. Students misunderstood a question about differentiating a square from a rectangular pyramid, focusing on ordinary squares and rectangles. They did not substitute for height (h) and were uncertain about differentiating between perpendicular and slant heights. Additionally, they did not attempt Question 1 and omitted variables in formulae for the table summarising relations between slant height, perpendicular height, and base edge for triangular, square, and hexagonal pyramids. From the above findings, which included students' pre-test analysis, interviews conducted, and comments by the researcher, it was confirmed that students' performance after using the TTBM of learning was unsatisfactory due to the following groups of reasons.

i) General misunderstanding by students,

ii) Students struggle with the identification of correct formulae, and
iii) Students' lack of conceptual understanding.

This concurs with Simon et al. (2025), who assert that mathematics students were hesitant to use tablets, believing that using tablets would take too much time and increase the risk of misunderstanding mathematical concepts. Figure 5.2 clearly indicated that the biggest misunderstanding was the uncertainty in calculating the area and volume of pyramids, with uncertainty arising from a few examples and a lack of understanding, as well as the ability to communicate with other students electronically. This is aligned with Alexander and Masoabi (2021), who found that in higher education institutions, a negative correlation between mathematics uncertainty, anxiety, and performance has a significant impact on performance. It was also found through this study that students' unsatisfactory performance was due to a lack of mathematical knowledge when dealing with SAVOGOs in the following areas:

i) Finalising area and volume with correct units (for example, cm^2 for square and cm^3 for Volume),
ii) Content, terminologies, language and word usage,
iii) Identification and writing the correct formula for square, rectangular, hexagonal pyramid and regular cone,
iv) Incorrect application of formulae, and
v) Lack of concept understanding.

From Figure 5.3, it is evident that when students use formulae in this study, they apply it incorrectly by matching the pyramid in question with the incorrect formulae, or omit variables and numbers when writing formulae, as well as incorrect substitution of values. Additionally, it was also perceived in this study that content, terminologies and words like tetrahedron, pyramids, sphere, hemisphere, and regular cones used to formulate questions influence the way students interpret and calculate their answers. Moreover, it was discovered that the usage of slant height (h_s), perpendicular height ($\boldsymbol{h_{\perp}}$) and the base edge (l) for triangular, square and hexagonal pyramids was also the major misunderstanding, which caused uncertainty in answering the question. The student also grappled with the following:

i) Identifying missing dimensions of geometrical objects,

ii) Finding different shapes contributing to the combination of geometrical objects, and

iii) Grappling to understand that $'b'$ in the formulae $V = \frac{1}{3}b\boldsymbol{h_{\perp}}\ and\ A = b + \frac{1}{2}ph_s$ means calculate the base area of the given pyramid, and $'p'$ means the perimeter of the given pyramid.

This concurs with Mullis and Kelly (2022), who highlight challenges students grappled with in mathematics as resistance and attitude students experience when learning with TD, particularly in the statement "SAVOGOs are a very important and necessary topic to learn." All 60 students strongly disagree with this statement, indicating a serious attitude and resistance. This highlights the need for lecturers to consider this when teaching with TD in TVET colleges and how Level 3 students' attitudes differ when using tablet devices compared to traditional textbook methods.

6.3.7 The future of TD in the TVET sector when learning SAVOGOs using the model to maximise performance

Through interaction with SAVOGOs' content and participating in the learning process of TD, the device provided students with a great deal of mental nourishment in reflecting on their own learning. Furthermore, the device encouraged an improved implementation of TD in their lecture room and helped them design their learning approach to effectively deal with the areas that are found challenging in mathematics. This concurs with Simsek and Can (2020), who assert that through learning with TD and the application of mathematical videos and animations, students received an opportunity to broaden their content knowledge, develop new instructional techniques, and reflect on their actions to determine what works best for them. Furthermore, it was found that the process of learning with TD allowed students of TVET colleges to work together and collaborate, something which is not usually done at TVET colleges. Engelbrecht and Borba (2024) emphasised that this is because each student felt that his/her tablet is their domain and territory and hence did not allow other students into their space. Learning with TD also forced students to improve their content knowledge

through working collaboratively with others, and developed the skill of operating TD. Observation of how the researcher and students operated TD, as well as reflection and debriefing about the best methods to be used in future, was also conducted. The operation of TD also revitalised a renewed focus on student-centred learning and teaching, as well as an introduction to the problem-solving approach. Furthermore, TD also brought about a renewed reflection on the learning method and on the aspect of anticipated student responses, which was something totally new to students. Removing students from desolation due to learning with TD, being collaborative and participative, also resulted in the sharing of ideas and knowledge, which is revealed in more detail in the previous themes.

There can also be immense benefits for improving students and lecturers in the process of learning and teaching with TD and beyond. This study has demonstrated that TD-assisted learning has improved participant students to the point where they can now advocate for the use and manipulation of TD at both their own educational institutions and other TVET colleges. This is advantageous for the TVET sector since it will ultimately be the students, together with lecturers, who must decide what issues to focus on, as postulated by Coughlan et al. (2025).

Furthermore, this study showed that participant students reported that the approach they would take would include getting lecturers' buy-in in the process of learning with TD by involving both lecturers and students and by showing them the mathematical benefits for the TVET college, as well as for the students, lecturers, and managers. What stood out in this study is that most students mentioned the importance of lecturers' buy-in in the learning process with TD, without which it cannot work. This is also supported by the study by Williams et al. (2022), who refer to lecturers' buy-in. This must be done by explaining to lecturers the benefits of learning with TD found in this study by participant students, such as the input of the participation, collaboration and group work, sharing study group experiences and ideas, the ease with which challenges can be overcome by working in collaboration, and how this collaboration closes the gap between lecturers and students.

What also surfaced as encouraging in this study was the idea proposed by certain students to establish online learning institutions where students and lecturers utilise TDs. This concurs with Engelbrecht and Borba (2024), who mentioned that online

learning is fun and is a method of education that uses electronic devices and the internet to deliver instruction and interaction to students who are separated from the lecturer or lecturers. In this study, one student mentioned that she liked online learning because it can be synchronous, where students and lecturers are online at the same time, or asynchronous, where students and lecturers are online at different times, thereby allowing them to invest in their learning by starting flexibly at their own pace and from different geographical areas.

Among the benefits participants mentioned that can assist the TVET sector when students learn SAVOGOs using TD were teamwork during learning, collaborative reflection on learning methods, and sharing mathematical knowledge and ideas across the entire TVET sector. The study:

- Highlighted students' misunderstandings and errors,
- Provided a platform for closeness among students and lecturers, sharing knowledge and expertise,
- Placed emphasis on students' anticipated responses and re-focused attention on the method of learning by reflecting,
- Embedded TD reflection and follow-up were done within a lecture room context,
- Made mathematics students the central focus,
- Empowered students and lecturers through improved performance, attitude, confidence and motivation,
- Focused lecturers' attention on shortcomings in the lecture room and the TVET college, and
- Created a positive and open TVET college culture to maximise efficiency and performance.

Some of the benefits above correspond with what was found by Prensky (2018), Sundrani (2025), and Gerber (2023). What was a surprising result from this study was that many students reported that the involvement of a lecturer assisted in their freedom to make decisions, a result of the non-threatening and non-judgmental approach of the process of learning with TD. This is consistent with the Conceptual Model of Participatory Engagement Within E-learning Community, maximising performance. According to Alex (2021) and Masoabi and Alexander (2021), in the e-learning community, collaborative learning causes a variety of interaction activities that contribute to participatory engagement: i) interactions of learners; ii) interaction of educators and learners; iii) interaction with content; iv) self-reflection; and v) collaborative learning in the e-learning community. Furthermore, this freedom to make decisions also resulted in a bottom-up approach to decision-making, which is quicker when it comes to reviewing the mathematics curriculum.

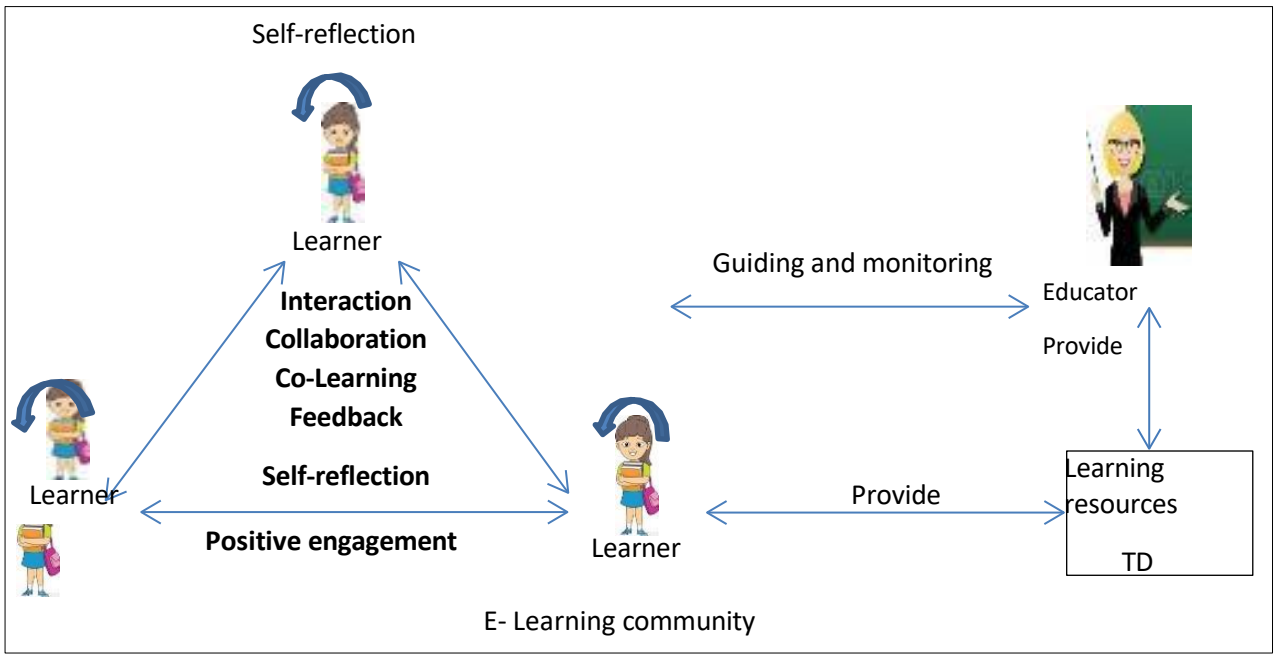

Fig 6.1: Conceptual model of participatory engagement within e-learning community maximising performance

The findings in this section also help in answering the following research questions: *What benefits do Level 3 students experience when learning SAVOGOs using tablet devices?*

6.3.8 The need for college lecturers to be involved when students are learning with TD

In this study, the lecturer as researcher was part of the process when students were learning SAVOGOs with TD. The advantages of having lecturers involved and being part of the students' learning with TD have already been mentioned above. Students mentioned in this study that there is a need for the lecturer (researcher) to be involved in the process of learning with TD, and this was emphasised very strongly by all participants. It was also mentioned by some participants that even if college management is not fully involved, there must be some kind of management involvement. Most students agreed that there should be involvement, and it cannot be done without the involvement of college management, even if some parts of it can be delegated, as some students mentioned.

It was found in this study that the involvement of lecturers brought about thoroughness to the process, structure, manager's presence and visibility, change of perception of the manager, improved relationships, and closeness. TDs are gaining popularity for TVET colleges' instruction because they can facilitate more personalised content interactions for students and enable lecturers to monitor learning in real time. TDs' size and functionality can provide a mobile yet fully functional solution for students and lecturers, both in and outside of the lecture room. Yet, using tablets in the lecture room requires thoughtful planning to ensure that the technology improves the teaching and learning process.

In this study, students mentioned that working with lecturers in real time using TD was a lifesaver for them, as they received immediate, direct feedback that was effective and saved a lot of time in communication. Furthermore, from interviews, it was a pleasure to notice students' individual differences reflected in their processing input; one student mentioned, "it was as if we were sitting next to each other in a physical classroom." The study recommends that lecturers incorporate more tablet-assisted learning activities in their teaching to encourage students' acceptance of tablets as a learning tool. In addition, lecturers should regularly monitor these activities to ensure they are completed effectively and on time.

6.4 SUMMARY OF THE MAIN ASPECTS THAT WERE COVERED

Chapter 6 covered the discussion of the research findings and concentrated on eight themes namely i) enhanced contingencies that improved students' performance and attitude in learning SAVOGOs, ii) reflections on determining the best method in learning and attempting SAVOGOs questions, iii) promotion of problem-solving skills through collaboration, iv) personal fulfilment and happiness as well as improvement and empowerment of students, v) students' role, contributions and participation in the use of TD at TVET colleges, vi) challenges students are likely to encounter when learning SAVOGOs with TD at TVET colleges, vii) the future of TD in the TVET sectors when learning SAVOGOs using the model to maximise performance, and viii) the need for the participation and involvement of college lecturers at TVET colleges when students are learning SAVOGOs with TDs.

6.5 CONCLUSION

This chapter further discussed, explained, and interpreted the findings presented in Chapter 5 by first providing the key findings of this study, followed by discussing and interpreting the findings of every theme together with its sub-themes and comparing them with previous literature as to where they correspond, where agreement was found, and where they differ. It also mentioned that what was found in this study could be added to the research. In the next chapter, the researcher outlines the conclusions of this study by answering the main research question, reflecting on the study, highlighting the limitations, and making recommendations and suggesting ideas for further research.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

This is the last chapter of this study. In this chapter, I present a summary of the chapters, a summary of the literature reviewed, findings, limitations of this study, recommendations for further research, and final reflections, as well as a conclusion. The recommendations are meant for the Mathematics Department in TVET colleges, while the conclusions and final reflections are meant to guide the integration of TDs in the teaching and learning of SAVOGOs in TVET colleges.

7.2 SUMMARY OF LITERATURE REVIEWED

The review was organised into numerous sections to create an outline to support the research purpose within this study. The review began with the use of technology in the mathematics lecture room, which further explored the importance and integration of tablets in students' learning of mathematics during the COVID-19 era in mathematics lecture rooms. The use of tablets in mathematics learning, creativity and hands-on learning with tablets, together with students' peer learning, students' feedback on peer learning, the use of the tablet PC in tutorials, the use of the tablet PC in one-to-one mathematics consultation learning, and students' comments on learning with tablet devices were explored. This was followed by tablets for anytime, anywhere education and then literature on studies that used tablets for mathematics learning.

The effectiveness of tablets on learning mathematics, followed by the benefits of tablet use, which highlighted the enhancement of learning, heightened adaptability, increased engagement, and maximised efficiency and performance, was also explored. The review continued to include factors that negatively influence tablet integration, such as cost, concerns about misuse, training needed for integration, and the reliability of new technologies. The chapter then concluded by exploring students' attitudes towards learning mathematics.

7.3 SUMMARISED FINDINGS OF THE STUDY

The main research question addressed how TD can improve performance and attitude in the learning of SAVOGOs in Mathematics Level 3 at TVET colleges. The answers are presented in a structured discussion under the following headings: (1) Lecturers' involvement with students when learning SAVOGOs with TD, (2) Challenges experienced by Level 3 students when learning SAVOGOs using TD, (3) Students' benefits when learning SAVOGOs with TD, (4) Students' empowerment in learning mathematics with TD, (5) A renewed look at the implementation of TD and the role of lecturers, and (6) Model used in maximising performance in mathematics at TVET colleges using mobile devices.

7.3.1 Lecturers' involvement with students when learning SAVOGOs with TD

The involvement of lecturers with students when learning SAVOGOs with TD resulted in improved teaching and learning aspects, which then improved student performance and attitude. The results also indicated that there was a renewed focus on the content of Mathematics Level 3, reflection, student-centred learning, and problem-solving, together with students' anticipated responses. The power of collaboration and participation when students learned SAVOGOs with TD was clearly visible and was revealed as participants grappled with Mathematics Level 3 content guided by the lecturers. Participants began to reflect on SAVOGOs' learning as they picked up issues that would have gone unnoticed and came to learn, know, and apply the concept of anticipated students' responses on which the TD lessons were based. The contribution this study made to the result-driven and immediate focus on learning mathematics with TD positively, through the bottom-up approach, improved performance and attitude towards Mathematics Level 3.

7.3.2 Challenges experienced by Level 3 students when learning SAVOGOs using TD

Some of the challenges revealed in this study were associated with time, lack of resources, attitudes and resistance from students, together with lecturers' skills and conceptual knowledge in learning with TD. Students' learning of SAVOGOs using the TTBM of learning was a major challenge. In addition, misunderstandings

in SAVOGOs, lack of mathematical knowledge, as well as the calculation of SAVOGOs traditionally and identifying missing dimensions of geometrical objects, were also highlighted in students' work. Challenges experienced by Level 3 students when learning SAVOGOs using TD were overcome when students became champions in learning with TD.

7.3.3 Students' benefits when learning SAVOGOs with TD

TDs removed students' desolation and provided a new focus on student-centeredness and problem-solving skills. An open culture of learning developed through learning with TD and encouraged positive relationships between lecturers and students. Additionally, collaborative learning, enforcing trust and respect amongst students and lecturers, was noticed when learning with TD. Furthermore, learning with TD incorporated at TVET colleges placed lecturers in a crucial role of influencing teaching, personal, and learning outcomes. Through the TD stage of learning and observation, immense information was gathered about students' misunderstandings in SAVOGOs. These include being learning-oriented students, having effective problem-solving techniques, sharing knowledge and expertise with other students, and being a vehicle through learning with TD to empower other students.

7.3.4 Students' empowerment in learning mathematics with TD

It was observed that students became more confident and motivated, emerging from desolation as they learned SAVOGOs with TD. This enhancement led to improved performance and a positive attitude towards learning Mathematics Level 3, as well as fostering an open culture at the TVET College through the collaboration and participation of students and lecturers. The openness, improved performance, and positive attitude in learning SAVOGOs allowed participants to make independent decisions. Additionally, these attributes were further intensified through bottom-up decision-making that prevailed throughout the learning of mathematics with TD. Furthermore, students realised that their approach to the entire learning process, from TD to debriefing and reflection, changed their attitude towards mathematics, as shown in this study. This transformation was evident through powerful new ways of learning, observing, anticipating students'

responses, debriefing, and reflection that had not previously taken place in TTBM learning.

The remarkable contributions included the removal of barriers that usually exist and are perceived between students and lecturers after the post-test and ATMI when learning mathematics with TD. Contrary to the belief that the presence of a lecturer brings tension and fear between lecturers and students, this study has shown that an open and positive atmosphere developed between them. This occurred due to the involvement of lecturers in the entire process of learning SAVOGOs with TD. Learning with TD paved the way for greater openness and positivity between lecturers and students. It also demonstrated that an improved open college culture can result from the empowerment of students to learn with TD, as it built more confidence and motivation. This was a result of the free, democratic decision-making that learning mathematics with TD provided.

7.3.4 Model used in maximising performance in mathematics at TVET colleges using mobile devices

The emergent model proposed is the conceptual model of participatory engagement within the e-learning community, which, according to this study, maximises performance in mathematics learning. The critical part of this model is the involvement of the lecturers when students learn mathematics with TD. Through participative engagement with TD and collaboration among students, the positive outcomes of this participatory engagement model can be achieved.

7.3.5 A renewed look at the implementation of TD and the role of lecturers

In this study, a renewed look was also placed on the implementation of TD at TVET colleges. The relevance of lecturers' future roles as participants in all facets of mathematics at TVET colleges was emphasised because of their function as guides, support, and coordinators of the SAVOGOs learning process with TD. Consequently, the aforementioned has demonstrated that almost all the research questions finally confirmed the importance of implementing TD in TVET colleges for teaching and learning.

7.4 LIMITATIONS OF THE STUDY

The current study has certain limitations, even though it produced some insightful research findings. However, these limitations do not render the study ineffective; rather, they should be used as a tool to recognise and evaluate the study's shortcomings. The following is a summary of the limitations of this study.
The study faced several limitations, including a one-group pre-test post-test design, a limited sample size, and the subjectivity of the coding process. The one-group pre-test post-test design allowed for a single group of participants to assess the dependent variable before and after a treatment, which may have enabled a more detailed analysis of errors and misunderstandings. The study was limited to a single TVET college campus, which restricts its generalisability. The sample size was small, and the research problem was only studied at one level, Level 3. The study's focus on SAVOGOs during a curriculum period could have affected students' performance and attitude, as well as the overall quality of the findings. Some participants were unable to attend certain lessons with TD due to other obligations, which could have resulted in insufficient feedback.

Additional limitations included scheduling the study during a curriculum period when Level 3 students were preoccupied with SAVOGOs and the subjectivity of the coding process. The pre-and post-test questions could be modified to accommodate students' understanding, performance, and attitude towards mathematics, and implementing focus group interviews could strengthen collaboration and encourage open communication.

7.5 RECOMMENDATIONS FOR FURTHER RESEARCH

Recommendations for further research stemming from this study are:

- To test the utility value of the TD approach, a more comprehensive field test of the model that emerged from this study is required.
- This study suggests that other studies focusing on specific elements of the TD learning model, analysing how lecturer involvement can improve or influence specific outcomes, could potentially use this as an area of research.
- The identical methods employed in this study can be applied to another topic of

Mathematics Level 3, in place of SAVOGOs.

- Teams' use of virtual learning also brought attention to the need for more research on how some TD-assisted learning components can be integrated into virtual learning, particularly in difficult geometric subjects with a lot of diagrams that require orientation to grasp.
- It would be prudent to carry out a study of this kind at multiple campuses and TVET colleges concurrently rather than just one. This would increase The impact of learning SAVOGOs with TD and, thus, the sample size.
- Future research should prioritise rigorous longitudinal studies to assess the sustained impact of tablet integration on Mathematics L3 learning outcomes. Additionally, evidence-based evaluation of tablet applications within specific Mathematics L3 sub-disciplines is warranted. Equally critical is the development of targeted strategies to support lecturers in strengthening both their pedagogical adoption of tablet technology and their broader technological fluency.

7.6 FINAL REFLECTIONS

The researcher realised that learning with TD is a powerful technique that can and should be applied at all educational institutions to increase performance in at-risk subjects. The researcher also had the chance to see a teaching approach first-hand at one of the campuses of a TVET college in South Africa as part of this study. The study also helped the researcher realise that learning with TD is a method that can help change the entire TVET sector for better results. Over a year, this study gave the researcher, as a lecturer, the chance to observe the personal growth of 60 participating students as they learned mathematics with TD. It also gave the researcher herself a valuable developmental experience using a comprehensive, holistic teaching approach.

During learning with TD, the researcher gained new insight into Mathematics Level 3, the lecturer's classroom practice, as well as the realities which this teaching had to face. The researcher also gained insight into the contributions that she should be making as a lecturer in enhancing the subject of mathematics at a college, and it helped her to reflect on her own lecturing skills. The researcher also came to understand how crucial

it is to be present in the lecture room and be visible to students.

Finally, the researcher learned and experienced a great deal by conducting a literature review, studying the underlying theories in education and learning methods, as well as conducting research on TD itself. This was a worthwhile five-year journey that included a multi-disciplinary study encompassing Mathematics Level 3, aspects of college management, and testing a relatively new teaching and learning model called the Conceptual Model of Participatory Engagement within an e-learning Community. My goal is for this study to spread throughout educational institutions, particularly TVET colleges, in order to improve not only the performance and attitude of students and lecturers but also that of Department of Higher Education and Training (DHET) officials, as students and lecturers do not cover half of the aspects that are required by TD at TVET colleges.

7.7 SUMMARY OF THE MAIN ASPECTS THAT WERE COVERED

This chapter explored a summary of chapters, literature review and summarised findings of the study by including the lecturer's involvement with students as well as challenges experienced by Mathematics Level 3 students when learning SAVOGOs. In addition, students' benefit, empowerment and models used in maximising performance in mathematics at TVET colleges using mobile devices were also explored. Furthermore, a renewed look at the implementation of TD and the role of lecturers when students learned mathematics with TD was thoroughly dealt with. Finally, the limitations of the study, recommendations for further research, and final reflections were also explored in this chapter.

7.8 CONCLUSION

This final chapter discusses the summary of findings, limitations, recommendations for further research, recommendations because of this study, and contributions of this research. Learning with TD provided promising strategies for effecting changes that would empower students to create that change and for lecturers to drive the process of learning mathematics with TD by becoming involved during learning. The literature review of this study referred extensively to what previous researchers have written on the topic. The global perspective, African perspective, South African perspective and

North West Province perspective were explored to intensify the study. The theoretical lens for this study is the Affective, Behavioural, and Cognitive (ABC) Model of Albert Ellis (1955). This theoretical framework provided a lens for the L3 mathematics students' attitudes and performance, while the three Cognitive Learning Strategies (Learner-centred strategy, Meaningful Experiences strategy and Learning Through Discovery strategy) provided a roadmap in terms of teaching, learning and assessment methodologies under discussion.

The analysis was supported by Table 4.1, indicating scores for attitude towards mathematics. The table was used to calculate Cronbach's reliability range.
Data with a Cronbach's alpha of 0.914 indicates that the items in the scale are strongly correlated, suggesting that they measure a cohesive construct. This level of internal consistency is generally considered acceptable for this academic research, allowing the researcher to confidently use the scale for drawing conclusions. Interpretation of the grouped tests according to categories was done, and with $|t| \approx 3{,}27, the\ p-value\ for\ df \approx 3-6 < 0.05 \rightarrow statistically\ significant$.This implies that the test instrument was reliable, and the tablet has a positive impact on the learning of pyramids.
The directional hypothesis was supported. Groups of TVET L3 students calculating SAVOGOs using tablet devices improved performance and attitude. For a one-tailed test at $\alpha = 0.05$ and $df = 59$: $t_{0.05,59} \approx 1.671$. The computed $t = 2.037 > 1.671$, so we are in the rejection region. We are rejecting the null hypothesis "There is no variation in performance and attitude when a cohort of TVET L3 students calculate SAVOGOs using a tablet device as opposed to the traditional textbook method". The rejection region highlights the significance of the observed sample mean relative to the hypothesis population mean. Then the directional hypothesis "Group of TVET L3 students calculating SAVOGOs using tablet devices improved performance and attitude as opposed to the traditional textbook method." This indicates statistical significance: we reject H_0 in favour of the alternative hypothesis $H_1 : \mu > 10.52$

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APPENDICES

APPENDIX A: SAVOGOS QUESTION PAPER

Duration: 1h30

INSTRUCTIONS:

Answer **ALL** the questions.

Show **ALL** calculations

Choose **ONE** answer from the given options

Answers should be rounded to **TWO** decimal places

QUESTION 1

1.1) The table below summarises the relations between the slant height(h_s), perpendicular height($h_\perp$), and the base edge (l) for triangular, square and hexagonal pyramids. Label by indicating which is triangular, square and hexagonal pyramids.

OBJECT		
A	**B**	**C**
$h_s^2 = h_\perp^2 + \frac{1}{4}l^2$	$h_s^2 = h_\perp^2 + \frac{1}{12}l^2$	$h_s^2 = h_\perp^2 + \frac{3}{4}l^2$

A: Triangular Pyramid Square Pyramid Hexagonal Pyramid

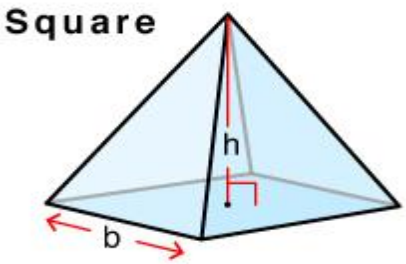
B: Square Pyramid Hexagonal Pyramid Triangular Pyramid

C: Triangular Pyramid Hexagonal Pyramid Square Pyramid

PTO

SMALLER SQUARE PYRAMIDS

1.2 Suppose you have a square pyramid below with the following measurements. Calculate:



- Base side $l = 3$ cm
- Slant height $h_s = \sqrt{18{,}25}$
- Vertical height $h_\perp = 4$ cm

1.2.1 The surface area and

$A: 41{,}00\ cm^2$ $B: 34{,}63\ cm^2$ $C: 40{,}00\ cm^2$

1.2.2 The volume of the square pyramid.

$A: 12{,}00\ cm^3$ $B: 15{,}00\ cm^3$ $C: 20{,}00\ cm^3$

1.3 Given $base\ l = 4\ cm\ and\ h_\perp = 5\ cm$ of a square pyramid.

1.3.1 Calculate the surface area and

$A: 59{,}08\ cm^2$ $B: 68{,}25\ cm^2$ $C: 98\ cm^2$

1.3.2 The volume of the square pyramid.

$A: 26{,}67\ cm^3$ $B: 36{,}67\ cm^3$ $C: 40{,}00\ cm^3$

1.4 Calculate the

1.4.1 volume and **PTO**

$A: 4.00\ cm^3$ $B: 8.00\ cm^3$ $C: 6.00\ cm^3$

1.4.2 surface area of a square pyramid with a base edge of $2\ cm$ and slant height of $\sqrt{10}$ cm.

$A: 18{,}46\ cm^2$ $B: 22{,}97\ cm^2$ $C: 22{,}97\ cm$

1.5 Given: $h_\perp$ = $4\ cm$ and h_s = $\sqrt{21}$ of a square pyramid calculate the:

1.5.1 volume and

$A: 33.33 cm^3$ $B: 33{,}33\ m^3$ $C: 33{,}33 cm^2$

1.5.2 surface area

$A: 70{,}83\ cm^2$ $B: 81{,}10\ cm^2$ $C: 77{,}70\ cm^2$

QUESTION 2: BIGGER SQUARE PYRAMIDS

2.1 Given volume of a square pyramid = $120\ cm^3$and $h_\perp$= $10\ cm$:

2.1.1 Calculate the base side of a square pyramid.

$A: 6\ cm$ $B: 5\ cm$ $C: 3\ cm$

2.1.2 Calculate the surface area of a square pyramid.

$A: 161{,}28\ cm^2$ $B: 180{,}98\ cm^2$ $C: 120{,}00\ cm^2$

2.2 Calculate the volume and surface area of a square pyramid if $h_\perp = 12\ cm$ and base side $l = 8\ cm$

$A: V = 256{,}00\ cm^3\ \&\ SA = 266{,}39\ cm^2$ $B: V = 156{,}00\ \&\ SA = 166\ cm^2$ $C: 12\ cm^3$

2.3 The volume of a square pyramid is $147{,}00\ cm^3$ and the base side $l = 7\ cm$.

2.3.1 Calculate the perpendicular height $h_\perp$

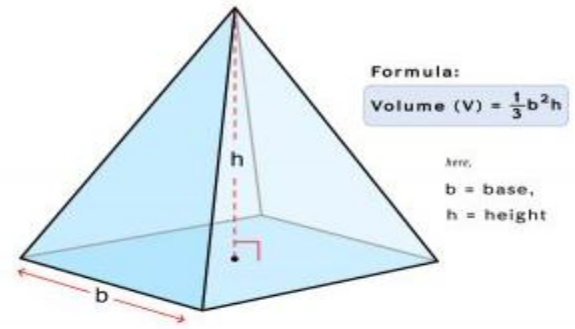
$A: 9\ cm$ $B: 12\ cm$ $C: 19\ cm$

PTO

2.3.2 Calculate the surface area of a square pyramid.

$A: 184{,}19\ cm^2$ $B: 221{,}77\ cm^2$ $C: 223{,}19\ cm^2$

2.4



2.4.1 Calculate the surface area and volume of the above square pyramid with the following measurements $h_{\perp} = 15\ cm\ and\ base\ side\ l = 9\ cm$.

$A: SA = 362{,}89\ cm^2\ \&\ V = 405{,}00\ cm^3$ $B: SA = 16\ cm^2\ \&\ V = 40\ cm^3$

$C: SA = 263{,}98\ cm^3\ \&\ V = 450\ cm$

APPENDIX B

SAVOGOs DETAILED MARKING GUIDELINE

QUESTION 1

1.1

A= Square Pyramid

B= Triangular Pyramid

C= Hexagonal Pyramid

SMALLER SQUARE PYRAMIDS

1.2 $h_s^2 = h_\perp^2 + \frac{1}{4}l^2$

$= 16 + \frac{9}{4}$

$h_s = \sqrt{18{,}25}\ cm$

1.2.1

$A = b + \frac{1}{2}ph_s$

$= l^2 + \frac{1}{2}(4l)\sqrt{18{,}25}$

$= 9 + (6\sqrt{18{,}25})$

$= 34{,}63\ cm^2$

1.2.2

$V = \frac{1}{3}bh_\perp$

$= \frac{1}{3}l^2h_\perp$

$= \frac{1}{3}(9)(4)$

$= 12\ cm^3$

PTO

1.3 $h_s^2 = h_\perp^2 + \frac{1}{4}l^2$

$= 25 + 4$

$h_s = \sqrt{29}\ cm$

1.3.1

$A = b + \frac{1}{2}ph_s$

$= l^2 + \frac{1}{2}(4l)\sqrt{29}$

$= 16 + (8\sqrt{29})$

$= 59{,}08\ cm^2$

1.3.2

$V = \frac{1}{3}bh_\perp$

$= \frac{1}{3}l^2h_\perp$

$= \frac{1}{3}(16)(5)$

$= 26{,}67\ cm^3$

1.4 $h_s^2 = h_\perp^2 + \frac{1}{4}l^2$

$(\sqrt{10})^2 = h_\perp^2 + \frac{1}{4}(4)$

$10 = h_{\perp}^2 + 1$

$\sqrt{9} = h_{\perp}$

$h_{\perp} = 3\ cm$

1.4.1

$V = \frac{1}{3}bh_{\perp}$

$= \frac{1}{3}l^2 h_{\perp}$

$= \frac{1}{3}(4)(3)$

$= 4{,}00\ cm^3$

PTO

1.4.2

$A = b + \frac{1}{2}ph_s$

$= l^2 + \frac{1}{2}(4l)\sqrt{10}$

$= 4 + (6\sqrt{10})$

$= 22{,}97\ cm^2$

1.5 $h_s^2 = h_{\perp}^2 + \frac{1}{4}l^2$

$(\sqrt{21})^2 = (4)^2 + \frac{1}{4}(l^2)$

$21 = 16 + \frac{1}{4}l^2$

$5(4) = l^2$

$\sqrt{20} = l$

$l = 5\ cm$

1.5.1

$V = \frac{1}{3}bh_{\perp}$

$= \frac{1}{3}l^2h_\perp$

$= \frac{1}{3}(25)(4)$

$= 33{,}33\ cm^3$

1.5.2

$A = b + \frac{1}{2}ph_s$

$= l^2 + \frac{1}{2}(4l)\sqrt{21}$

$= 25 + (10\sqrt{21})$

$= 70{,}83\ cm^2$

QUESTION 2: BIGGER SQUARE PYRAMIDS

2.1.1

$V = \frac{1}{3}bh_\perp$

$120 = \frac{1}{3}l^2(10)$

$36 = (l^2)$

$l = 6\ cm$

2.1.2

$A = b + \frac{1}{2}ph_s$

$= l^2 + \frac{1}{2}(4l)\sqrt{109}$

$= 36 + (12\sqrt{21})$

$= 161{,}28\ cm^2$

2.2 $h_s^2 = h_\perp^2 + \frac{1}{4}l^2$

$h_s^2 = 144 + \frac{1}{4}(64)$

$h_s = \sqrt{144 + 16}$

$h_s = \sqrt{160}$

$V = \frac{1}{3}bh_\perp$

$= \frac{1}{3}l^2 h_\perp$

$= \frac{1}{3}(64)(12)$

$= 256.00\ cm^3$

$A = b + \frac{1}{2}ph_s$

$= l^2 + \frac{1}{2}(4l)\sqrt{109}$

PTO

$= 64 + (16\sqrt{160})$

$= 266{,}39\ cm^2$

2.3 $h_s^2 = h_\perp^2 + \frac{1}{4}l^2$

$h_s^2 = 81 + \frac{1}{4}(49)$

$h_s = \frac{\sqrt{373}}{2}$

2.3 .1

$V = \frac{1}{3}bh_{\perp}$

$V = \frac{1}{3}l^2h_{\perp}$

$147 = \frac{1}{3}(49)\ h_{\perp}$

$h_{\perp} = 9\ cm$

2.3.2

$A = b + \frac{1}{2}ph_s$

$= l^2 + \frac{1}{2}(4.7)\frac{\sqrt{373}}{2}$

$= 49 + 7\sqrt{373}$

$= 184{,}19\ cm^2$

2.4 $h_s^2 = h_{\perp}^2 + \frac{1}{4}l^2$

$h_s^2 = 225 + \frac{1}{4}(81)$

$h_s = \frac{\sqrt{981}}{2}$

2.4.1 $A = b + \frac{1}{2}ph_s$

$= l^2 + \frac{1}{2}(4.9)\frac{\sqrt{981}}{2}$

$= 81 + 9\sqrt{981}$

$= 362{,}89\ cm^2$

2.4.2

$$V = \frac{1}{3}bh_{\perp}$$

$$= \frac{1}{3}l^2h_{\perp}$$

$$= \frac{1}{3}(81)(15)$$

$$= 405.00$$

MULTIPLE CHOICE MARKING GUIDELINE

QUESTION 1

1.1

A = Square Pyramid

B= Triangular Pyramid

C= Hexagonal Pyramid

1.2

1.2.1 B

1.2.2 A

1.3

1.3.1 A

1.3.2 A

1.4

1.4.1 A

1.4.2 8

1.5

1.5.1 A

1.5.2 A

QUESTION 2

2.1.1 A

2.1.2 A

2.2 A

2.3

2.3.1 A

2.3.2 A

2.4.1 A

END OF SECTION

APPENDIX C
T-TEST USING VOLUME WITH CATEGORIES

t-test using surface area and volume of smaller and bigger square pyramids					
Square Pyramids	**Base Side (l cm)**	**Slant Height (hs)**	**Perpendicular Height (h⊥)**	**Surface Area (cm)^2**	**Volume (cm)^3**
SP1	3	$\sqrt{18,25}$	4	34,63	12.00
SP2	4	$\sqrt{29}$	5	59,08	26,67
SP3	2	$\sqrt{10}$	3	22,97	4.00
SP4	5	$\sqrt{21}$	4	70,83	33,33
BP1	6	$\sqrt{109}$	10	161,28	120.00
BP2	8	$\sqrt{160}$	12	266,39	256.00
BP3	7	$\sqrt{373}/2$	9	184,19	147.00
BP4	9	$\sqrt{981}/2$	15	362,89	405.00
SP=Smaller Pyramids			**Vsp=Volume of Smaller Pyramids**		
BP=Bigger Pyramids			**Vbp=Volume of Bigger Pyramids**		
A two t-test to compare SP group vs BP group for volumes					
Vsp	**Vsp -$\bar{V}$sp**	**(Vsp-$\bar{V}$sp)^2**	**Vbp**	**Vbp -$\bar{V}$bp**	**(Vbp - $\bar{V}$bp)^2**
12	-7	49	120	-112	12544
26.67	7,67	58,83	256	24	576
4	-15	225	147	-85	7225
33,33	14,33	205,35	405	173	2993
TOTAL		**538,18**			**50274**
Mean= 19=	$\bar{V}$sp		$\bar{V}$bp=232		

Computing Standard Deviation (s)

$$S_{sp} = \sqrt{\frac{\sum(Vsp - \bar{V}sp)^2}{n-1}}$$

$$= \sqrt{\frac{538,18}{3}}$$

$$= 13.39$$

$$S_{bp} = \sqrt{\frac{\sum(Vbp - \bar{V}bp)^2}{n-1}}$$

$$= \sqrt{\frac{538{,}18}{3}}$$

$$= 129.45$$

Computing t-Statistics

$$t = \frac{\bar{V}_{sp} - \bar{V}_{bp}}{\sqrt{\frac{S_{sp}^2}{n_{sp}} + \frac{S_{bp}^2}{n_{bp}}}}$$

$$t = \frac{19-232}{\sqrt{\frac{(13{,}39)^2}{4} + \frac{(129{,}45)^2}{4}}}$$

$$t = \frac{-213}{\sqrt{44{,}82 + 4189{,}33}}$$

$$t = \frac{-213}{\sqrt{4234{,}15}}$$

$$t = -3{,}27$$

Degrees of freedom can be approximated with the Wetch-Satterthwaite equation since variances are unequal.

Also, For Two-Sample t-Test (independent Sample)

$$df = n_{sp} + n_{bp} - 2$$

$$= 4 + 4 - 2$$

$$= 6$$

Interpretation

With $|t| \approx 3{,}27, the\ p - value\ for\ df \approx 3 - 6 < 0.05 \rightarrow statistically\ significant$

NB: The test instrument was reliable, and the tablet has an impact on the learning of pyramids.

The directional hypothesis was supported. Groups of TVET L3 students calculating SAVOGOs using tablet devices improved performance and attitude.

Appendix D

Table 4.4: A Summary table of codes, categories, subthemes and major themes

Abbreviated Codes	**Matching Categories**	**Subthemes Summarised**	**Themes**
Uncer, Misu, Disa, trad, *Term*, basa, per, *Conf - und sat-perf*, Unsa-perf, dept, inac, know *Fexam*, Unit. Pve, Guew, Dims, Atude, Min, Fer, Nve,	Uncertain, Content Underperformance Few Examples, Units Formulae, Dimensions Concepts understanding, Base Area, Perimeter, Omission, Negative and Positive attitude, Mind & Fear.	• Students' challenges in learning SAVOGOs for calculations of different shapes. • Experiences and improvements gained by students through the operation of TDs.	1) Enhanced contingencies that improved students' performance and attitude in learning SAVOGOs.
TD, Chat-4, CHAL, SHA, CURR, TRU, RESP, IDEA, POS, CONF, DISC, GROUP, OPE, COLL, PART, SUPP, GUI, LEVEL, FREE, EMP, MOT, OBSE, DEBR, TI, REFL,	desolation Reflections Observation Students' centeredness Students' responses	• TD removed students' desolation • Reflecting focus, TD placed on observing students. • Students' reflections on TDs, mathematical videos and animations.	2) Reflections on determining the best method in learning and attempting SAVOGOs questions.

DESOL, LECT & HOD, T/T, BI, KNOW, BEN, T+L, AR, CHANG, PSOL, VAL, CLOSE, DELE, NJUDG, NAPR, PROF, FEDBAC, ENGA, NT, INPU, U-B, PD, ST-SC, SKILS, TRAIN, MISU, GOAL, **RESOU** CL PURP, TM, PRO/A, CORD, COMM, VIEW, NPUN, **TVET**, POWER, FLEX, GAPS, SUBJ, VIBE, ENTH, DRI, STRUC, EXP, IMP, CRIT, PEER, FELLWST, DEV, ORG, OPIN, CONS, CRTH, STR, LEARN, TD, AUTH, INSL, DICT, LCURVE, ANA,W+S, IMAGE, RES,		• TD provided a new focus on student-centeredness and problem-solving skills. • Focus on anticipated Students' responses	
	Sharing of ideas, Discussions Open Culture Openness Trust & Respec	• TD using mathematical videos and animations, and discussions between students. • Sharing of ideas and knowledge. • Open culture of learning development between students and lecturers. • Collaborative learning enforcing of trust and respect amongst students and lecturers. • Positive relationship developed between lecturers and students	3) Promotion of problem-solving skills through collaboration and participation

MAT-V, TD, ANIM, SEAENG.	Confidence Empowerment Collaboration Participation College Management Guide and support	• Empowerment of students to increase their confidence and motivation. • Empowerment of students in decision-making about educational technology. • Improved participation and collaborative culture at TVET colleges. • Lecturers' contribution through involvement, participation and collaboration in learning with TD. • Improved performance in mathematics.	4) Personal fulfilment and happiness, as well as improvement and empowerment of students. 5) Students' role, contributions and participation in the use of TD at Colleges.
	Time constraints Attitude Management Skills **Resources**	• Time and time constraints in learning SAVOGOs with TD. • Attitude and resistance in learning with TD.	6) Challenges students are likely to encounter when learning SAVOGOs with TD at

		• Students, Lecturers and Managers' skills and knowledge in learning with TD. • Lack of resources and training. • Solutions to challenges for college management in the TD implementation.	TVET Colleges.
	TVET Benefit in Level 3 Mathematics Competent students in performance (Champions)	• Students as champions for learning with TD at TVET Colleges. • Benefits of learning with TD for the TVET sector	7) The future of TD in the TVET sectors when learning SAVOGOs.
		• Need for lecturers' involvement when students learn with TD. • Learning with TD, a bottom-up approach.	8) The need for involvement of lecturers at TVET College when students learn with TD.

APPENDIX E

A LETTER REQUESTING ASSENT FROM LEARNERS IN A TVET COLLEGE TO PARTICIPATE IN A RESEARCH PROJECT

Dear Learners, Date: 2023/04/13

I am doing a study on PhD Mathematics Education as part of my studies at the University of South Africa. Your Campus Manager and HOD Fundamental has given me permission to do this study in your school. I would like to invite you to be a very special part of my study. I am doing this study so that I can find ways that your lecturers can use to improve and perform better. This may help you and many other learners of your age in different TVET Colleges.

This letter is to explain what I would like you to do. There may be some words you do not know in this letter. You may ask me or any other adult to explain any of these words that you do not know or understand. You may take a copy of this letter home to think about my invitation and talk to your parents about this before you decide if you want to be in this study.

I would like to ask you to:

- Take part in a semi-structured interviews where the interviewer does not rigorously follow a formalised classification of questions. Instead, more open-ended questions will be asked, allowing conversation with the interviewee comparatively than direct question and answer pattern. The interview will take place in their lecture room after writing the Pre-test & Post-test and it will be approximately 30 minutes. The Attitudes Toward Mathematics Inventory (ATMI), created by Tapia and Marsh (2004) will be used. Then statistical analysis programs will be used to analyse data, which will yield results to be published.
- Complete a test: Pre-test and post-test will be completed in their lecture room after learning using the traditional method, and afterwards using a tablet device. It will be a 1 h 30 test.
- Other: The Attitudes Toward Mathematics Inventory (ATMI), created by Tapia and Marsh (2004), will also be used to check the attitude of students towards

mathematics before and after the intervention. A video recording during the interview will be used for future reference.

I will write a report on the study, but I will not use your name in the report or say anything that will let other people know who you are. Participation is voluntary, and you do not have to be part of this study if you don't want to take part. If you choose to be in the study, you may stop taking part at any time without penalty. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you. When I am finished with my study, I shall return to your school to give a short talk about some of the helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

The benefits of this study are to come up with a rigorous and robust intervention strategy for excellent performance in mathematics. This study will contribute to the development of improved educational policies, which will recommend the use of tablets in educational institutions. The policy will emphasise that lecturers and students should have regular access to technological tools, support and advance mathematics sense making, reasoning, problem solving, and communication. The policy will also recommend that effective lecturers optimise the potential of technology to develop students' understanding, stimulate their interest, increase their proficiency in learning SAVOGOs and provide greater access to mathematics for all students. Therefore, this study intends to improve SAVOGOs understanding by using technological devices and also to benefit students, lecturers, managements, all stakeholders in NW TVET Colleges, communities, South Africans and different countries at large.

For this study, there is no risk involved in terms of time management. The students will be taught by their lecturer during their allocated period. The year plan, assessment schedule and timetable will be followed as planned. The researcher will only request question papers and results of the test written on SAVOGOs after and before the intervention.

You will not be reimbursed or receive any incentives for your participation in the research.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can

have your parent or another adult call me at 014 597 5645. Do not sign the form until you have all your questions answered and understand what I would like you to do.

Researcher: Mrs Rakhudu Phone number: 014 597 5645. Do not sign the written assent form if you have any questions. Ask your questions first and ensure that someone answers those questions.

APPENDIX F

WRITTEN ASSENT

I have read this letter, which asks me to be part of a study at my school. I have understood the information about my study, and I know what I will be asked to do. I am willing to be in the study.

_____	_____	_____
Learner's name (print):	Learner's signature:	Date:
_____	_____	_____
Witness's name (print)	Witness's signature	Date:

(The witness is under 18 years old and present when signed.)

_____	_____	_____
Parent/guardian's name (print)	Parent/guardian's signature:	Date:
_____	_____	_____
Researcher's name (print)	Researcher's signature:	Date:

APPENDIX G

CONSENT/ASSENT TO PARTICIPATE IN THIS STUDY (Return slip)

I, _____ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation. I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified. I agree to the recording of the Pre-test, post-test, semi-structured interviews and The Attitudes Toward Mathematics Inventory (ATMI), created by Tapia and Marsh (2004).

I have received a signed copy of the informed consent agreement.

Participant Name & Surname (please print) _____

_____ _____

Participant Signature Date

Researcher's Name & Surname (please print) Ms N.F. RAKHUDU

_____ _____

Researcher's signature Date

APPENDIX H

B. SEMI-STRUCTURED INTERVIEWS

Student No. _____

Researcher: “Mention the challenges experienced when calculating surface area and volume of geometrical objects (SAVOGOs)?”
Student: _____

Researcher: “Are there any other challenges except from the one you mentioned?”
Student: _____

Researcher: Is the textbook helpful enough in learning SAVOGOs?
Student: _____

Researcher: “Tell me more about the prescribed textbook you used
Student: _____

Researcher: Can you differentiate between a square and a rectangle?
Student: _____

Researcher: Can you identify a square pyramid?
Student: _____

Researcher: Can you calculate the surface area and volume of a square pyramid
Student: _____
Researcher: Give the overall comment about the test you wrote.
Students: _____

I: Attitude Towards Mathematics Inventory (ATMI) Questions

ATTITUDE TOWARDS LEARNING SURFACE AREA AND VOLUME OF GEOMETRICAL OBJECTS (SAVOGOS).

Indicate the block that describes your opinion on each question:

A. AVOGOs are a very important and necessary topic to learn.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

B. I want my skills in learning SAVOGOs to grow.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

C. I get happy when I solve a (SAVOGOs) problem.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

D. SAVOGOs problems helps to grow my mind and teaches me to think.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strognly Disagree

E. SAVOGOs problems are important in everyday life.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

F. SAVOGOs are one of the most important topic to study.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

G. Learning SAVOGOs will be helpful in any job I want to get after completing my studies.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

H. I can think of many ways to use mathematics outside of school.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

I. Mathematics is my most feared subject.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

J. My mind goes blank and I am unable to think clearly when I am doing mathematics.

1: Strongly Agree 2: Agree 3: Neutral 4: Disagree 5: Strongly Disagree

APPENDIX I

ETHICS APPROVAL

UNISA

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2023/04/12

Ref: **2023/04/12/49047884/05/AM**
Name: Mrs NF Rakhudu
Student No.:49047884

Dear Mrs NF Rakhudu

Decision: Ethics Approval from 2023/04/12 to 2028/04/12

Researcher(s): Name: Mrs NF Rakhudu
E-mail address: nrakhudu@orbitcollege.co.za
Telephone: 072 229 9012

Supervisor(s): Name: Prof ZMM Jojo
E-mail address: jojozmm@unisa.ac.za
Telephone: 073 488 2211

Title of research:

The impact of using tablets on students' performance and attitude in calculating Surface Area and Volume of Geometrical Objects (SAVOGOs).

Qualification: PhD Mathematics Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2023/04/12 to 2028/04/12.

*The **medium risk** application was reviewed by the Ethics Review Committee on 2023/04/12 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

University of South Africa
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www.unisa.ac.za

APPENDIX J

EDITORIAL CERTIFICATE

EDITORIAL

CERTIFICATE

Author: Nnane Franscina Rakhudu

Document title: TABLETS' IMPACT ON NORTH WEST TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING LEVEL 3 STUDENTS' PERFORMANCE AND ATTITUDE IN GEOMETRY

Date issued: 08/04/2026

This document certifies that the above thesis was proofread and edited by Prof Gift Mheta (PhD, Linguistics).

The document was edited for proper English language, grammar, punctuation, spelling, and overall style. The editor endeavoured to ensure that the author's intended meaning was not altered during the review. All amendments were tracked with the Microsoft Word "Track Changes" feature. Therefore, the author had the option to reject or accept each change individually.

Signed:

Prof Gift Mheta (Cell: 073 954 8913)

APPENDIX K

TURNITIN REPORT

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