Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool

by

Nicole Cunningham

Submitted in fulfilment of the requirements for the degree of

MAGISTER EDUCATIONIS

in the Faculty of Education

at the

UNIVERSITY OF PRETORIA

Supervisor: Dr RD Sekao

October 2024

Declaration

I, Nicole Cunningham, U17126844, declare that the dissertation titled: “**Grade 6 mathematics teachers’ use of Inquiry-Based Learning as a pedagogical tool**”, which I hereby submit for the degree in Magister Educationist at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

____

October 2024

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Ethical Clearance Certificate

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Make today matter
www.up.ac.za

FACULTY OF EDUCATION
Ethics Committee

RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	CLEARANCE NUMBER: **EDU115/23**
DEGREE AND PROJECT	MEd Grade 6 mathematics teachers' use of inquiry-based learning as a pedagogical tool
INVESTIGATOR	Miss Nicole Cunningham
DEPARTMENT	Science Mathematics and Technology Education
APPROVAL TO COMMENCE STUDY	28 July 2023
DATE OF CLEARANCE CERTIFICATE	13 August 2024

CHAIRPERSON OF ETHICS COMMITTEE: Prof Funke Omidire

Mr Simon Jiane
Dr David Sekao

This Ethics Clearance Certificate should be read in conjunction with the Integrated Declaration Form (D08) which specifies details regarding:

- Compliance with approved research protocol,
- No significant changes,
- Informed consent/assent,
- Adverse experience or undue risk,
- Registered title, and
- Data storage requirements.

Fakuiteit Opvoedkunde
Lefapha la Thuto

Ethics Statement

The author, whose name appears on the title page of this dissertation, has obtained the applicable research ethics approval for the research described in this work. The author has observed the ethical standards required in the University of Pretoria's Code of Ethics for Researchers and the Policy guidelines for responsible research.

Signature:
Student name: Nicole Cunningham
Month, Year: September 2024

Dedication

To my parents, Frank and Bianca Cunningham, thank you for your boundless love, patience, and unwavering support throughout this journey. Your belief in my abilities has been my constant source of strength. Thank you for the sacrifices you have made and the IOUs, both fulfilled and forgotten, that have paved the way to this moment.

To Brandon, you have been by my side for nearly a decade, but these last two years have been extraordinary. You stood with me through every struggle, listened to my worries, and never let me give up. Your encouragement carried me through the toughest moments, and I am forever grateful. I look forward to supporting you with the same dedication as you pursue your dreams.

To my Oumi, Professor Monica Jacobs, I never imagined I would be here today with three degrees, distinctions, and a dissertation. The only thing missing is you. The more I worked, the more I admired your accomplishments. As a professor in education, what an honour it would have been to learn from you and be guided and mentored by you. However, dementia took you away and, with it, the vast knowledge you carried. One day, I hope you will know I did this with you in my heart, mind, and soul. Life truly is unfair sometimes.

To God, thank you for guiding me through this journey. In moments of doubt, you provided me with strength and direction. Your presence reminded me I was never alone, even in my hardest moments.

Acknowledgements

To Dr. RD Sekao, my lecturer, mentor, and constant guide, thank you for your tireless dedication and support. Your passion for education and your commitment to my success have been remarkable. I am endlessly grateful for the time you invested in me, and I will forever cherish the knowledge and wisdom you shared.

To the teachers and schools that graciously participated in my study, thank you for your time, cooperation, and willingness to participate. Your involvement was instrumental in making this study possible.

Thank you to the University of Pretoria for providing an exceptional academic environment and for the opportunities and support you offered throughout my postgraduate journey. Special thanks to the merit bursaries and the postgraduate programme that helped me achieve my dreams.

To my colleagues, your understanding and flexibility allowed me to balance the demands of work and research. Your support in managing responsibilities and checking my progress made all the difference. I am deeply grateful for your encouragement throughout this process.

My friends, thank you for your patience, understanding, and unwavering support. You allowed me to rain check on plans when I needed to work, and your check-ins, along with the coffee and chocolate deliveries, sustained me during difficult times. I truly appreciate your kindness and care.

Abstract

In this study, I explored the incorporation and utilisation of Inquiry-Based Learning (IBL) by Grade 6 mathematics teachers, focusing on their instructional practices when teaching the area concept. Guided by the 5E Instructional Model (Bybee, 1997), I explored teachers' instructional activities that promote competence, autonomy, and relatedness. Three conveniently selected schools participated in my study to answer the main question: How do Grade 6 mathematics teachers use IBL as a pedagogical tool to teach the concept of *area*? Situated within the interpretivist paradigm, this qualitative case study employed multiple data collection methods, including document analysis, observation and semi-structured interviews. Through these multiple data collection methods, I gained insights into the teachers' instructional practices and the challenges they face when using IBL in mathematics. The findings revealed significant challenges in implementing IBL despite its prominence as a recommended pedagogical approach in the South African mathematics curriculum.

The findings revealed that teachers struggled with the practical application of IBL, particularly in fostering deep conceptual understanding and learner autonomy in teaching the concept of area. This study highlights the crucial role IBL plays in promoting critical thinking, problem-solving, and active learner participation, which are key to successful mathematics education. However, the findings emphasise that without proper teacher training and resources, the potential of IBL remains underutilised. The study underscores the need for comprehensive teacher support and professional development to bridge the gap between curriculum expectations and classroom practices, ensuring IBL is more effectively integrated into lessons to promote meaningful and engaged learning.

Keywords: Inquiry-Based Learning, 5E model, learner autonomy, learner competence, learner relatedness.

Language Editor

Busy Bee EDITING
Brenda van Rensburg
Hugo Chandler
BA Psychology and Drama (UCT)
Struisbaai, Western Cape, South Africa, 7285
Tel: +27 (0)72 244 4363
Email: info@busybeeediting.co.za / brendavanrensburg2@gmail.com / Website: www.busybeeediting.co.za

PROOFREADING AND EDITING CERTIFICATE

With an unwavering commitment to precision, Busy Bee Editing has diligently completed the proofreading and editing tasks. This comprehensive process, which includes ensuring consistency in spelling, hyphenation, numerals, fonts, and capitalisation; maintaining internal consistency; correcting spelling, grammar, punctuation, and syntax; altering sentence structure; creating a cohesive flow; ensuring appropriate paraphrasing; and verifying that formatting and layout are correct and checking existing references to the best of their ability, has been applied to the Master's Dissertation titled: **Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool**, by **Nicole Cunningham**, submitted in fulfilment of the requirement for the degree of Master of Education in the Faculty of Education at the University of Pretoria.

It is important to note that Busy Bee Editing's role concludes upon delivering this Master's Dissertation to **Nicole Cunningham** or his/her Supervisor, **Dr. RD Sekao**. Any spelling and grammar mistakes, amendments, or alterations made after delivery are not the responsibility of Busy Bee Editing. This proofreading and editing certificate does not cover these errors, spelling and grammar mistakes, amendments, or alterations. As the author, **Nicole Cunningham** holds the sole discretion to accept or decline any amendments made by Busy Bee Editing. It is **Nicole Cunningham's** responsibility to thoroughly review the proposed changes and their potential impact on the Master's Dissertation, thereby maintaining complete control over the final version of the Master's Dissertation. **Nicole Cunningham** is responsible for always confirming the accuracy and originality of the completed Master's Dissertation to his/her Supervisor, **Dr. RD Sekao**.

Hugo Chandler - BA Psychology and Drama (UCT)
Proofreader and Editor at Busy Bee Editing

Brenda van Rensburg
Proofreader and Editor at Busy Bee Editing

Date of Completion: 14 September 2024, marking the finality and closure of Busy Bee Editing's involvement in the proofreading and editing process of the Master's Dissertation.

List of Abbreviations

ANA	Annual National Assessment
ATP	Annual Teaching Plan
CAPS	Curriculum and Assessment Policy Statement
DBE	Department of Basic Education
GDE	Gauteng Department of Education
IBIM	Inquiry-Based Instructional Model
IBL	Inquiry-Based Learning
IBL-M	Inquiry-Based Learning in Mathematics
NCS	National Curriculum Statement
SACE	South African Council for Educators
SDT	Self-Determination Theory
SGB	School Governing Body
SRQ	Secondary Research Question
STEM	Science, Technology, Engineering and Mathematics
TA	Thematic Analysis
TIMSS	Trends in International Mathematics and Science Study

Description of Key Terms

Learner: According to the South African Schools Act 84 of 1996, a learner is defined as any person who is registered at a school and receives education in terms of this Act (South African Schools Act, 1996). In South Africa, the term "learner" is used, whereas other countries may use terms such as "pupil" or "student." This distinction aligns with the country's educational framework and legal terminology.

Inquiry-Based Learning (IBL): Inquiry-based learning is an educational approach in which learners actively explore and investigate questions, problems, or scenarios to build their understanding and knowledge. It emphasises learner-driven exploration, critical thinking, and problem-solving rather than passive reception of information (Şen et al., 2021; van Graan, 2020).

Self-Determination Theory (SDT): Self-Determination Theory is a psychological framework focusing on the intrinsic and extrinsic factors influencing motivation. It highlights the importance of three fundamental psychological needs—competence, relatedness, and autonomy—in fostering intrinsic motivation and enhancing learning experiences (Wang et al., 2019; Ryan & Deci, 2000).

5E Instructional Model: The 5E Instructional Model is a framework used in science and mathematics education that includes five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. Each phase specifically facilitates IBL and promotes a deeper understanding of concepts (Laursen et al., 2011).

Curriculum and Assessment Policy Statement (CAPS): This framework is used in South Africa to outline the curriculum and assessment standards for various subjects and grades. It provides guidelines for teachers on what content to teach and how to assess learners' learning (Department of Basic Education, 2011).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: GENERAL ORIENTATION OF THE STUDY

1.0. INTRODUCTION

As stated in the National Curriculum Statement (NCS) in South Africa, mathematics is a human activity that necessitates active participation from learners to build their understanding of the subject (DBE, 2011). The role of learners in the learning process is crucial, and how the curriculum content is delivered is a key factor in furthering a learner's progress in mathematics (van Graan, 2020). In recent years, there has been extensive discussion on the use of active involvement in learning mathematics, which has become the accepted alternative to traditional methods of teaching, which prioritise passive learning (Li & Schoenfeld, 2019).

Contemporary teaching methods are interactive and engaging. This allows learners to relate abstract concepts and theories to practical observations (Noreen & Rana, 2019). Traditional teaching methods are teacher-directed, whereby learners are taught in a manner conducive to sitting and listening (Tularam & Machisella, 2018). This approach tends to impact learners negatively as they are not constructors of knowledge but instead assume the position of a spectator, as they are fed knowledge and are expected to understand it (Tularam & Machisella, 2018) without autonomy (Deci & Ryan, 2012).

Contemporary teaching methods, such as IBL, aim to empower learners to take ownership of their learning and encourage active investigation and experimentation. The NCS for mathematics, Grade 4-6, emphasises this personally constructed nature of mathematical knowledge: Mathematics involves observing, representing, and investigating patterns and relationships in social and physical phenomena and between mathematical objects (DBE, 2011, p. 8). Furthermore, contemporary teaching and learning methods like IBL follow a learner-centred instructional practice driven by learners' questions and innate curiosity, using meaningful tasks such as investigations (Gholam, 2019) to situate learning. Sibanda and Rambuda (2021) defined an investigation as a formal task to determine rules or concepts and connections of patterns, arrive at conclusions, and identify patterns. The IBL approach and investigations echo the idea that mathematics is a human process by encouraging learners to actively engage, question, and explore mathematical concepts, thereby fostering more profound understanding and problem-solving skills. In this study, I aim to highlight the potential benefits of the IBL approach, inspiring and motivating teachers to adopt this method in their classrooms.

1.1. PROBLEM STATEMENT AND RATIONALE

The newly introduced mathematics teaching framework in South Africa (DBE, 2018) acknowledged the need to change the pedagogical outlook on mathematics. It emphasised the importance of teachers adopting a revised perspective on teaching aligned with the curriculum to enhance mathematics education in schools (DBE, 2018). Thus, traditional teaching methods, where the teacher is the central figure, need to make way for more contemporary teaching and learning approaches which are more learner-centred and develop learners' curiosity in mathematics (DBE, 2011).

The traditional teaching method negatively affects learners as they are not encouraged to work independently or use skills such as discovering, investigating, problem-solving and decision-making (Mabena et al., 2021). Despite the NCS advocating for the use of learning through inquiry in mathematics during the Intermediate Phase (Grades 4-6) in South Africa (DBE, 2011), the reality is that teachers often neglect to adopt this approach consistently. Instead, teachers tend to incorporate an IBL approach only during Term 2, as mandated by the CAPS document, when they (the teachers) are required to assess learners through an investigation task. Consequently, using an IBL approach tends to be limited to a single instance rather than being integrated consistently throughout the curriculum.

These questions need to be explored, lest IBL become elusive. Therefore, the concern is how teachers utilise IBL in mathematics classes to adequately prepare learners for completing an investigation, which is one of the assessment forms prescribed in the Curriculum and Assessment Policy Statement (CAPS). If teaching is not synchronised with assessment, learners will be less likely to acquire and demonstrate the intended skills, i.e. exposing learners to a mathematical investigation without incorporating IBL creates discord in knowledge and skills. Despite the emphasis placed by CAPS on an active and critical learning approach in the classroom (DBE, 2011), many South African teachers still predominantly rely on traditional methods, resulting in a teacher-centred approach (Motsoeneng et al., 2021). This disregard for a learner-based approach could make learners feel that their questions and contributions in class are undervalued. An IBL approach, for instance, has been shown to make abstract mathematical concepts more tangible and relatable, stimulating and sustaining learners' interest in mathematics and enhancing academic performance (van Graan, 2020). This approach fosters a more comprehensive and multidimensional method of teaching mathematics in South African schools, resulting in improved overall educational outcomes.

1.2. PURPOSE OF THE STUDY

My study aims to explore Grade 6 mathematics teachers' use of IBL when teaching the concept of *area,* as prescribed in the mathematics curriculum in South Africa. I intend to accomplish this by exploring how mathematics teachers design learning activities promoting the STD attributes (competence, autonomy, and relatedness), secondly, by determining the extent to which the attributes of IBL, namely Engagement, Exploration, Explanation, Elaboration, and Evaluation, feature in teachers' lesson plans and overall instructional practice and thirdly, to observe how teachers facilitate inquiry-based lessons when teaching the area concept.

1.3. RESEARCH QUESTIONS

The research questions presented in this paragraph are extracted from and aligned with the purpose of my study in paragraph 1.3. Through the study, I intend to answer the following primary research question: How do Grade 6 mathematics teachers use IBL as a pedagogical tool to teach the concept of *area*? To answer this question, I will be guided by and will respond to the following secondary research questions (SRQs):

SRQ1: How do mathematics teachers design learning activities that promote autonomy, competence, and relatedness when teaching the concept of *area*?

SRQ2: To what extent do mathematics teachers incorporate the attributes of the 5Es of IBL when teaching the concept of *area*?

SRQ3: How do mathematics teachers facilitate an inquiry-based lesson, and, if any, what related challenges do they experience when teaching the concept of *area*?

Table 1.1 below presents the alignment between the research questions, the theoretical framework, and data collection strategies.

Table 1.1.

The alignment between the research questions, theoretical framework and data collection strategies

Secondary Research Questions	Purpose of the Research Questions	Theoretical Framework	Data Collection Methods
SRQ1	This research question explores the degree to which mathematics teachers incorporate activities that promote learners' autonomy, competence, and relatedness in their lesson plans.	Self-determination theory (SDT)	- Document analysis - Semi-structured interviews
SRQ2	This question explores how mathematics teachers include and use the 5Es of IBL in their lessons.	The 5Es of IBL	- Semi-structured interviews - Observation
SRQ3	This question explores how mathematics teachers actively teach through IBL and the challenges, if any, they experience while teaching the concept of *area through inquiry*.	The 5Es of IBL	- Observation - Semi-structured interview

1.4. LITERATURE REVIEW

This literature review chapter explores the concept of IBL and its significance within the South African educational context. It examines scholarly articles, studies, and sources, identifying areas for future research and development. The chapter addresses three sub-questions: understanding IBL, curriculum policy perspectives in South Africa, and applying inquiry-based learning in mathematics classrooms. It concludes with a discussion of the study's theoretical framework, which is discussed in more detail in Chapter 2.

1.4.1. Understanding inquiry-based learning

Contemporary education aims to equip learners with essential life skills such as critical thinking, effective communication, technological proficiency, adaptability, innovation, and responsibility (Joynes et al., 2019). These skills should develop throughout the educational journey and are evidenced by academic accomplishments (Suto, 2013). Dewey (1938) emphasised the importance of active engagement, inquiry, and critical evaluation in learning (Santrock, 2017), thereby influencing the development of IBL, which promotes curiosity, critical thinking, and problem-solving (Gholam, 2019). IBL aligns with constructivist theories, encouraging learners to build on prior knowledge and experiences (Brau, 2020). While initially prevalent in science education, IBL is gaining traction in mathematics education by emphasising active engagement and exploration (Ramnarain & Hlatswayo, 2018). This learner-centred approach, supported by autonomous, supportive teachers, enhances competence, interest, and satisfaction in learning (Hui & Tsang, 2012). This topic will be discussed further in Chapter 2.

1.4.2. Curriculum policy perspectives on inquiry-based learning in South Africa

In South Africa, CAPS guides the teaching and learning from lesson plans to learning outcomes. Sections 1 and 2 of CAPS highlight specific aims and skills that learners should attain (DBE, 2011). These include developing a curiosity and a love for mathematics, learning to investigate and interpret information, encouraging an active and critical approach to learning, and solving problems using critical and creative thinking. While CAPS does not explicitly stipulate pedagogical tools for each mathematics content area, it implicitly supports IBL. For example, CAPS emphasises investigation, a core tenet of IBL. For example, in Grade 6, learners are encouraged to investigate why the area of a rectangle can be stated as its length multiplied by its width without merely memorising the formula (DBE, 2011, p. 285). IBL aligns with CAPS's goal of promoting meaningful and long-lasting learning experiences by encouraging learners to pose and answer their own questions. This fosters critical thinking and problem-solving skills, thus allowing learners to understand the subject. Thus, there is a strong connection between CAPS and the IBL approach, with IBL characteristics used to achieve academic outcomes.

In conclusion, although CAPS does not explicitly use the term IBL, its emphasis on investigation suggests a strong reliance on this approach. Teachers are encouraged to facilitate exploration, explanation, and engagement with content (Bybee & Landes, 1990). CAPS advocates the development of critical thinking, problem-solving, and other valuable skills that are the hallmarks of IBL, integrating them throughout the curriculum to enhance the overall learning experience for learners. This is discussed in more detail in Chapter 2.

1.4.3. Inquiry-based learning in mathematics classrooms

IBL-M involves various activities such as questioning, experimenting, exploring, reasoning, arguing, investigating, and proving (Artigue et al., 2012). Through these activities, inquiry-based mathematics education enables learners to develop competencies in each area (Gholam, 2019).

In South Africa, CAPS incorporates the principles of IBL and the 5Es while teaching the concept of *area* in mathematics education. CAPS encourages explorations and engagements that align with the characteristics of IBL. For instance, learners are prompted to investigate the relationship between the perimeter and area of rectangles and squares (DBE, 2011). Learners are guided to develop an understanding of square units by finding areas of regular and irregular shapes by counting squares on grids (DBE, 2011). By engaging in these activities, learners actively explore and experiment with mathematical concepts, promoting a deeper understanding of the subject. CAPS further emphasises the importance of developing rules for calculating the areas of squares and rectangles (DBE, 2011). This process encourages learners to engage in reasoning, arguing, and proving, which are key components of IBL. By engaging in these mathematical inquiries, learners develop competencies associated with each activity, such as critical reflection, creativity, and reasoning (Artigue et al., 2012). Moreover, the CAPS curriculum encourages learners to view mathematics as a human endeavour and an integral part of society, aligning with the broader goals of IBL (DBE, 2011).

IBL in Mathematics (IBL-M) education in South Africa encompasses various problems derived from real-world contexts and within the realm of mathematics itself (Artigue et al., 2012). Through the process of inquiry, these problems are transformed into mathematical questions using modelling techniques, whether conceptual or physical (Harlen, 2013). Rather than relying on direct observation or manipulation of the real-world, mathematical solutions are validated through logical arguments, which aligns with the inherent nature of mathematics as a discipline (Harlen, 2013). By incorporating the principles and aspects of IBL into the concept of area mathematics, teachers in South Africa strive to cultivate a more profound comprehension of mathematics, stimulate critical thinking and problem-solving abilities, and inspire learners to participate actively in the learning process.

1.4.4. Theoretical framework

SDT and the 5Es of IBL provides two complementary lenses for understanding and enhancing learner engagement and motivation in the classroom. SDT emphasises self-motivation, autonomy, and the role of self-determined motivation in shaping educational experiences (Deci & Ryan, 2000). It posits that learners are active agents who grow and integrate experiences into a coherent identity (Deci & Ryan, 2000). According to Hoffman (2016), highly motivated learners with positive attitudes tend to engage deeply with tasks and seek additional information. SDT is widely applied in educational contexts to explain how meeting learners' needs for competence, autonomy, and relatedness fosters active participation (Wang et al., 2019). Creating a supportive environment that addresses these needs enhances motivation and engagement (Niemiec et al., 2009).

The 5Es of the Inquiry-Based Instructional Model (IBIM)—Engagement, Exploration, Explanation, Elaboration, and Evaluation—offer a practical framework for applying SDT principles in teaching (Bybee & Landes, 1990). Each phase of the 5Es model supports active learning and self-regulation, aligning with SDT's emphasis on autonomy and competence. For example, the engagement phase connects new content with learners' prior knowledge, fostering relatedness (Thangjai & Worapun, 2022). The exploration phase promotes autonomy by encouraging independent investigation (Thangjai & Worapun, 2022). The explanation phase supports autonomy and relatedness through feedback and interaction (Thangjai & Worapun, 2022). The Elaboration and Evaluation phases reinforce SDT by encouraging knowledge application and self-assessment (Thangjai & Worapun, 2022). Together, SDT and the 5Es of IBIM provide a comprehensive approach to implementing IBL in the classroom. They emphasise the importance of active learning, engagement, and a learner-centred approach, which can significantly benefit mathematics teachers and enhance the learning experience. Chapter 2 will provide a more detailed discussion of these two lenses.

1.5. RESEARCH METHODOLOGY

1.5.1. Research paradigm and assumptions

The research paradigm for this study is grounded in the interpretivist perspective, which seeks to understand participants' perspectives and the intricate nature of phenomena by examining their subjective views (Creswell, 2018; Maree, 2007; Thanh & Thanh, 2015). This paradigm recognises multiple realities and emphasises the importance of participants' beliefs, attitudes, opinions, and practices (Hamilton & Corbett-Whitter, 2013). The study employs multiple data collection methods, such as interviews, observations, and document analysis, to gain comprehensive insights

(Creswell & Poth, 2017). This paradigm and its implications will be discussed in more detail in Chapter 3.

1.5.2. Research approach

A qualitative research approach is employed to explore, interpret, and generate an understanding of social interactions and individual experiences (O'Brien et al., 2014; Maree, 2016). This approach thoroughly examines how IBL is implemented in teaching the concept of area in a Grade 6 mathematics classroom. Grounded in the interpretivist paradigm, the qualitative approach values subjective human interpretation while acknowledging objectivity (Crabtree & Miller, 1999; Creswell & Poth, 2017). This approach will be discussed in more detail in Chapter 3.

1.5.3. Research design

The study uses an exploratory case study design to focus on three mathematics teachers, exploring how they incorporate IBL and SDT in teaching the concept of area (Hamilton & Corbett-Whittier, 2013). This design allows for detailed data collection through lesson plans, instructional practices analysis, and direct observations and interviews. While effective for investigating complex issues, it has limitations in terms of generalisability (Louw, 2015; Mills et al., 2017; Creswell & Poth, 2017). This design will be discussed in more detail in Chapter 3.

1.5.4. Sampling

Purposive and convenient sampling methods are used to select three Grade 6 teachers from different schools in the Tshwane West district, Gauteng province, South Africa (Patton, 2015). Convenience sampling is based on the proximity of schools to the researcher's location, while purposive sampling intentionally selects teachers currently teaching the concept of *area* during Term 3. This approach ensures rich and meaningful data collection from participants with relevant expertise and experience. The sampling methods and criteria will be discussed in more detail in Chapter 3.

1.5.5. Data collection

The data collection process will involve semi-structured interviews, document analysis, and lesson observations with three teachers to understand their use of the 5Es of IBL and the promotion of learner autonomy, competence, and relatedness.

Semi-Structured Interviews

Interviews will provide insights into how teachers implement IBL and promote learner autonomy, competence, and relatedness (Maree, 2016). These interviews will be 30 to 45 minutes long, with enough flexibility to accommodate participants' needs. The audio recordings will be transcribed for thorough analysis.

Document Analysis

Teachers' lesson plans will be analysed to understand the incorporation of the 5Es of IBL and promote learner autonomy, competence, and relatedness (Maree, 2016; Creswell, 2018). This will examine IBL elements, open-ended questions, learner inquiry opportunities, and hands-on activities.

Observations

Classroom observations will be conducted to see how teachers implement IBL and support learner autonomy, competence, and relatedness during their lessons on the concept of area (Maree, 2016; Creswell, 2018). The observations will be video-recorded and transcribed for detailed analysis. This multi-method approach aligns with the interpretivist paradigm, allowing for a comprehensive understanding of the research topic from different perspectives (Baxter & Jack, 2008; Louw, 2015). The data collection methods will be discussed in more detail in Chapter 3.

1.5.6. Data analysis

In my study, data analysis will be guided by the interpretivist philosophy, which acknowledges that reality is constructed through individuals' subjective experiences of the external world (Levers, 2013). As Maree (2016) suggested, the analysis of qualitative research commences from the early stages of data collection. During the analysis process, the investigation will examine teachers' implementation and utilisation of the 5Es of IBL and their efforts to foster autonomy, competence, and relatedness. Rather than solely focusing on participants' experiences, perceptions, and viewpoints (McMillan & Schumacher, 2010), my study will emphasise integrating and appreciating these insights as vital elements in comprehensively understanding the investigated phenomenon.

I will be guided by Braun and Clarke's (2006) six-stage thematic analysis in conducting the analysis.

- The first stage involves familiarising myself with the data by reading the transcripts multiple times. In this way, I will gain a better understanding of the content.
- The second stage involves generating initial ideas. In this stage, I will identify and label patterns or interesting features in the data. I will organise the data and facilitate the identification of potential themes.
- In the third stage, I will examine and organise the ideas into themes. The data will be segmented and deconstructed through winnowing, allowing me to focus on some parts of the data while disregarding others.
- The themes will be reviewed in the fourth stage to ensure that they accurately reflect the data.
- The fifth stage will involve naming and explaining the themes that have been identified.
- In the final stage, the themes will be incorporated into the overall narrative of the study to produce the final report.

After incorporating the identified themes into the overall narrative of the study, the final report will culminate with a comprehensive summary. By employing a systematic approach to data analysis, I aim to enhance my research study's reliability, comprehensiveness, and validity. To ensure accuracy and thoroughness, the audio recordings from the interviews, classroom observations, and document analysis will be diligently transcribed. This transcription process will provide a detailed and reliable source of information for further analysis and interpretation of the collected data. This will be discussed in more detail in Chapter 3.

1.6. QUALITY CRITERIA

In qualitative research, trustworthiness ensures confidence in data collection, interpretation, and analysis processes (Connelly, 2016). This is achieved through credibility, dependability, transferability, and confirmability.

Credibility

Credibility refers to the trustworthiness of research findings (Graneheim & Lundman, 2004). Triangulation will enhance credibility, involving multiple data collection methods such as interviews, document analysis, and observations. This multi-method strategy captures diverse perspectives and comprehensively summarises the research topic.

Dependability

Dependability ensures the consistency and stability of data (Connelly, 2016). Strategies to enhance dependability include selecting insightful participants, maintaining detailed field notes, using direct quotes to reduce bias, and seeking peer feedback.

Transferability

Transferability refers to the applicability of findings to other settings (Graneheim & Lundman, 2004). It will be enhanced by providing a detailed description of the research context, participants, and methodology, thereby allowing readers to assess the relevance of the findings to their own settings.

Confirmability

Confirmability ensures objectivity in research (Connelly, 2016). This will be achieved through triangulation, using multiple data collection methods to uncover consistent patterns and themes. Video recordings and transparency with the supervisor will further enhance confirmability. These quality criteria will be discussed in more detail in Chapter 3.

1.7. ETHICAL CONSIDERATION

Interacting with human beings in research raises various ethical issues. As a qualitative researcher, I must adhere to ethical guidelines. Ethical consideration is important because it demonstrates that the research complies with established ethical standards and safeguards the participants from harm or exploitation (Diener & Crandall, 1978). This study will not commence until written approvals are obtained from the University of Pretoria Ethics Committee, the Gauteng Department of Education (Annexure A), the relevant district (Annexure B), and the (Annexure C).

Informed Consent

I will disclose the study's purpose and data collection methods to each participant upon receiving approval. Participants will be informed of the voluntary nature of their involvement and their right to terminate participation or request a time-out during the data collection process. Teachers, learners, and parents who agree to participate will sign consent forms (Annexures D, E, and F).

Confidentiality and Anonymity

The identities of the research site and participants will remain confidential. All participants' faces will be blurred in any visuals, school logos will be removed from the material, and no learners' names will appear on collected data or worksheets. Schools will not be named, and teachers will be referred to as Teacher 1, Teacher 2, and Teacher 3 to ensure anonymity (Patton, 2015). The information gathered will not be disclosed to anyone not directly involved in the study.

Caring and Fairness

Caring and fairness will be maintained throughout the study through open discussions and negotiations with participants, thereby ensuring an ethical research environment.

Further details on these ethical considerations will be discussed in Chapter 3.

1.8. CHAPTER OUTLINE

CHAPTER 1: GENERAL ORIENTATION OF THE STUDY

This chapter introduces the research topic, providing context and background. It then outlines the research problem and rationale, highlighting the significance of the study. The chapter also states the purpose of the research, lists the primary and secondary research questions, and gives a brief overview of the relevant literature. Finally, it describes the research methodology, quality criteria, and ethical considerations.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

This chapter presents a comprehensive literature review and a detailed explanation of the theoretical frameworks guiding the study. It covers understanding IBL, its application in mathematics education, and its inclusion in the South African curriculum (CAPS). The chapter discusses the evolution of education in South Africa, the roles, forms, and challenges of IBL in mathematics teaching, and teachers' perspectives on utilising and implementing IBL. It also elaborates on the theoretical framework, by explaining the selected theories and concepts underpinning the research.

CHAPTER 3: RESEARCH METHODOLOGY

This chapter describes the research methodology used in the study. It explains the research paradigm, assumptions, qualitative approach, and design. The chapter details the sampling methods and data collection instruments, including document analysis, observation, and interviews. It outlines the research procedure and Clarke and Braun's (2006) six-step data analysis process. The chapter concludes with a discussion on quality criteria, ensuring research credibility, dependability, transferability, and confirmability, and addresses ethical considerations related to informed consent, confidentiality, anonymity, caring, and fairness.

CHAPTER 4: PRESENTATION OF FINDINGS

This chapter presents the findings of my study, focusing on how Grade 6 mathematics teachers design learning activities fostering autonomy, competency, and relatedness. It provides insights from three teachers on designing learning activities that promote these elements. The chapter highlights discrepancies between teachers' practices, discussing the observed differences and the implications for IBL in Mathematics education.

CHAPTER 5: DISCUSSIONS AND RECOMMENDATIONS

This chapter synthesises the findings from my comprehensive study and discusses the theoretical framework and existing literature. It highlights the challenges and implications of implementing IBL in Grade 6 mathematics classrooms. Key findings are analysed, focusing on insights from teachers' experiences and practices, and discrepancies identified among teachers are explored. The chapter evaluates the utility of the theoretical framework, discusses study limitations, and offers practical recommendations for teachers and policymakers. Reflexivity is considered, reflecting on the researcher's positionality and potential biases. The chapter summarises the main findings, their implications, and my study's overall contribution to mathematics education. This includes sections on the utility of the theoretical framework, limitations, recommendations, reflexivity, and the conclusion.

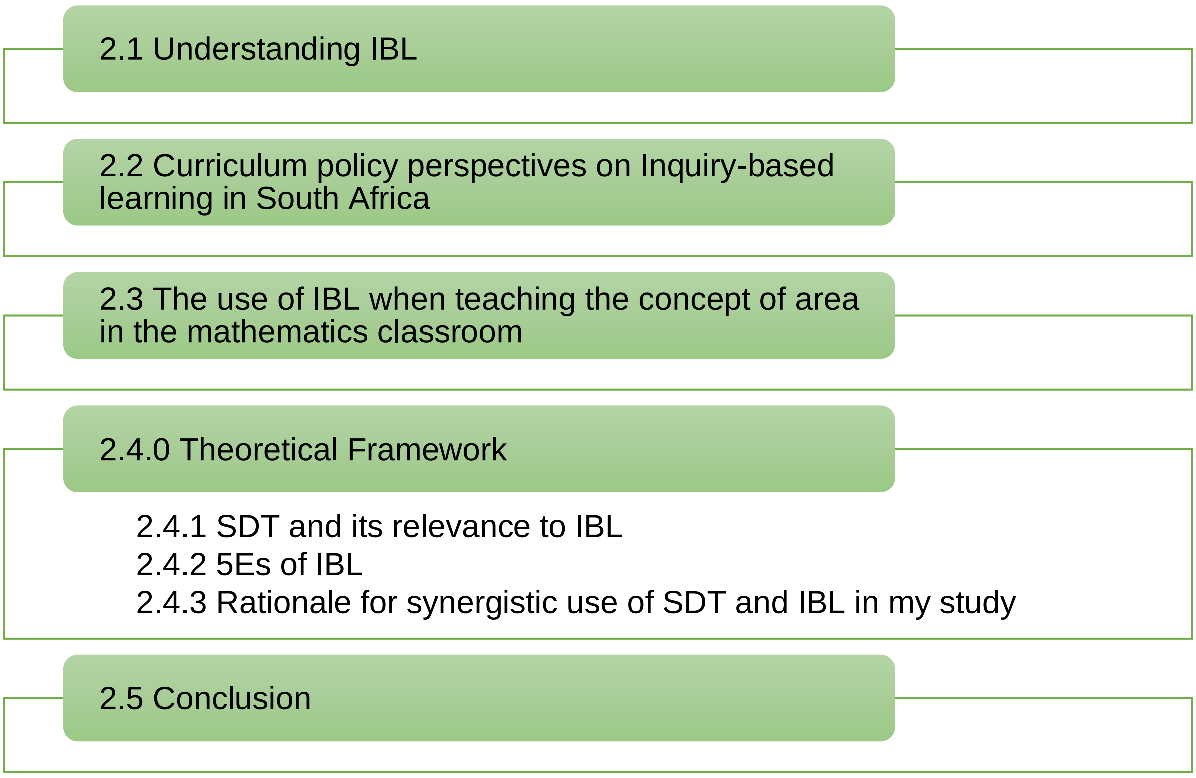
CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.0. INTRODUCTION

A literature review examines scholarly articles, books, and other sources related to a specific issue, research area, or theory. It provides a description, a summary, and a critical evaluation of these works. A literature review aims to overview the sources explored during research on a particular topic and show how the research contributes to the broader field of study (Ramdhani et al., 2014). Thus, this literature review aims to explore the concept of IBL and its significance within the South African educational context by examining scholarly articles, studies, and sources and identifying future research and development areas. This chapter was structured around three sub-questions: understanding what IBL is, the curriculum policy perspectives on IBL in South Africa, and the application of inquiry-based learning in mathematics classrooms. Figure 2.1 below demonstrates the flow of the chapter, illustrating how each section is interconnected and contributes to the overall understanding of IBL. The chapter ends with a discussion of the theoretical framework underpinning my study.

Figure 2.1.

Structure and flow of chapter 2



2.1. UNDERSTANDING INQUIRY-BASED LEARNING

Contemporary education's primary objective is to equip learners with essential life skills necessary for success in the global community. These skills encompass critical thinking, effective communication, technological proficiency, adaptability, innovation, and responsibility (Joynes et al., 2019). These skills naturally develop as learners progress through their educational journey and are evidenced by their academic accomplishments (Suto, 2013).

Dewey (1938), a prominent American scholar and advocate of experiential learning and inquiry-based education, emphasised the importance of learners' active engagement, continuous inquiry, and critical evaluation of evidence (Santrock, 2017). Dewey (1938) strongly believed that learners must be reflective problem solvers (Santrock, 2017). His philosophy underscores the role of inquiry in connecting our perception of the world with ideas, highlighting learning as an adaptable process driven by experience (Artigue & Blomhøj, 2013). Consequently, organising learners' experiences and nurturing their inquisitive tendencies is crucial for developing critical thinking skills in the classroom (Artigue & Blomhøj, 2013). Dewey's (1938) insights have significantly influenced the development of IBL, a pedagogical approach that strongly emphasises learners' thinking processes (Gholam, 2019).

Jerome Bruner, a contributor to constructivism, believed that education should be relevant to learners' needs at each stage. This could be accomplished by allowing learners to actively participate in learning (Roblyer & Doering, 2010). His theory of discovery learning, a form of IBL, posited that learners are more likely to understand and remember concepts they discover while interacting with the environment (Roblyer & Doering, 2010). Lev Vygotsky, known for his social constructivism theory, explains that social interaction and critical thinking are two main ingredients of the learning process (Liu & Matthews, 2005). He describes IBL as an 'integral part of creating... a social constructivist classroom' (Powell & Kalina, 2009, p. 244).

IBL is an educational approach where learners play an active role in seeking solutions. At the same time, teachers guide them through various stages such as observation, question formulation, investigation planning, experimentation, data analysis, and sharing findings (Simpson, 2015). This approach aims to cultivate learners' ability to ask questions, systematically investigate, think critically, and independently solve problems (Ibrahim, 2007; Philips, 2023). By actively engaging learners in the learning process and fostering their curiosity and analytical skills, IBL empowers them to become self-directed lifelong learners capable of navigating complex challenges in the 21st century (Joynes et al., 2019).

IBL aligns seamlessly with Piagetian constructivist pedagogical theory, wherein learners actively construct new ideas or concepts based on their prior knowledge and experiences (Brau, 2020). IBL encourages learners to be curious and engaged, moving away from traditional teaching methods, and reducing learner boredom (Willingham & Riley, 2020). While IBL has long been prevalent in science education, it is now gaining popularity in math education (Ramnarain & Hlatswayo, 2018). This approach highlights active engagement, critical thinking, problem-solving, and exploration among learners. IBL is based on the belief that people naturally want to discover things for themselves (Joynes et al., 2019). Inquiry and curiosity are innate traits children possess and should be nurtured and stimulated in educational contexts to enhance learning outcomes.

Gholam (2019) states that IBL prioritises active and learner-centred learning. Instead of merely receiving information from a teacher, learners are encouraged to take an active role in their learning, engaging in critical thinking, problem-solving, and exploration (Verma et al., 2023). This approach can take many forms, including mathematics investigations where learners develop important skills such as critical thinking and research (Minner et al., 2010; Verma et al., 2023). Additionally, IBL fosters a love of learning and a sense of independence and empowerment as learners take ownership of their education and are more likely to retain what they have learnt and apply it meaningfully (Gholam, 2019).

Researchers such as Caswell and LaBrie (2017) and Calleja and Buhagiar (2022) perceive IBL as an autonomous approach that places learners at the centre of the learning process, allowing them to pose and answer their own questions and move beyond basic curiosity into the realms of critical thinking and understanding. Calleja and Buhagiar (2022, p.128) maintain that “learning through inquiry offers possibly life-changing transformative opportunities” for learners. The attributes advocated by IBL, such as autonomous learning and critical thinking (Hui & Tsang, 2012), are also supported by the SDT (Rosli et al., 2022). However, to self-motivate, Hui and Tsang (2012) argue that one must first reach a level of self-determination—thinking for oneself and making conscious choices and decisions.

Hui and Tsang (2012) further argue that reaching a level of self-determination necessitates meeting basic needs such as competence, relatedness, and autonomy. Research indicates a strong correlation between academic success and fulfilling these psychological needs (Gagné et al., 2022). Once these fundamental needs are met, learners tend to achieve greater academic success and experience increased satisfaction in their academic and personal lives (Hui & Tsang, 2012; Gagné et al., 2022).

Learners' autonomy in learning does not start and end in the classroom. It can be inculcated in their lives at home, too. Autonomous-supportive parents can cultivate self-determination in learners by allowing them to make decisions according to their interests and values (Hui & Tsang, 2012). This can be achieved by expressing genuine interest in the children's views and concerns, allowing them to develop decisive agency by their views (Gagné et al., 2022). Without autonomous-supportive parents, self-determined autonomy within learners can be initiated in the classroom through autonomous-supportive teachers using IBL (McCombs, 2015; Deci & Ryan, 2000). By assuming the role of an autonomous-supportive teacher, teachers offer choices, provide rationale, empathise with learners' perspectives, and minimise the use of controlling language in the classroom (Hui & Tsang, 2012). This approach implies that knowledge is not simply delivered by a teacher but developed through active collaboration between teacher and learner and among learners (McCombs, 2015). As a result, an autonomous-supportive teaching and learning environment can enhance learners' competence, interests, and enjoyment, leading to greater life and school satisfaction (Hui & Tsang, 2012).

Two key components pivotal to learning in an IBL mathematics classroom are deep mental engagement with mathematics and peer-to-peer collaboration. These elements are so intertwined that they are often dubbed the "twin pillars" of IBL instruction (Laursen et al., 2011, p. 160). Learners who engage deeply with mathematics independently come to class well-equipped to contribute meaningfully to group work (Alfieri et al., 2011). In communicating their ideas and listening to others, they deepen and crystallise their knowledge. Learner interviews revealed that deep mental engagement and peer-to-peer collaboration are central to learning in an IBL mathematics classroom. These two ideas were so common and intertwined that they were referred to as “twin pillars” of IBL instruction: neither alone is sufficient to explain the learning outcomes, but together, they account for much of what learners found beneficial about their IBL experience (Laursen et al., 2011, p. 160). Learners saw both engagement and collaboration as integral to the IBL approach.

In IBL, learners actively engage in the learning process, exploring and understanding the world around them. Verma et al. (2023) assert that IBL allows learners to interact with materials, manipulate variables, and apply principles, fostering a more profound understanding by uncovering patterns and causal relationships.

Embracing IBL not only engages learners but also maximises learning outcomes. Learners in IBL tasks tackle relevant, meaningful, and authentic challenges, going beyond mere facts to contemplate concepts, patterns, and generalisations (Ulker & Ali, 2023). This approach encourages more profound understanding and personal growth, empowering learners to apply their learning to real-life situations.

Webb et al. (2014) observed that learners who actively engaged with mathematics independently were better equipped to participate effectively in group activities. By sharing thoughts and listening to others, they reinforced their comprehension. One learner remarked, "When you go away, and you think about it with your peers and stuff, then you’re able to like pull it apart and really see what the teacher means. And that’s where you claim it for yourself" (Laursen et al., 2011, p.137). Similarly, another learner pointed out, "One thing that I’ve learnt if I wanna understand something, I just need to spend some time alone with it, you know. So, I think that that’s something that I’ve just realised through IBL. And I think that once you spend some time alone with it, then talking to other people really helps solidify it" (Laursen et al., 2011, p.137).

These experiences contributed to personal and professional growth in multiple areas: comprehension and integration of mathematical concepts, enhancement of critical thinking skills, gaining insights into the nature of mathematics and effective learning strategies, enjoyment and increased confidence in mathematical abilities, and improvement in communication skills (Laursen et al., 2011). While learners emphasised intellectual benefits, they also acknowledged the significance of other aspects of learning. The interconnected nature of these benefits was evident as learners linked their newfound understanding of mathematical concepts and learning experiences to their enjoyment, confidence, and interest (Verma et al., 2023).

IBL typically involves more learner autonomy and active participation, which create challenges for classroom management. Large class sizes and varying levels of learner's motivation make it difficult for teachers to manage an IBL approach effectively, especially when learners work in groups or engage in hands-on tasks. Chan (2010) found that one of the reasons teachers were reluctant to implement IBL was the difficulty of maintaining control over learners' behaviour, particularly when learners were allowed to design their own experiments or explore concepts independently. Additionally, Saad and BouJaoude (2012) also found that large class sizes and varied learner engagement levels undermine the success of IBL, making it difficult for teachers to monitor and support all students effectively.

2.2. CURRICULUM POLICY PERSPECTIVE ON INQUIRY-BASED LEARNING IN SOUTH AFRICA

The CAPS policy document is umbilically connected to the South African education curriculum. Since its implementation in 2012, it has acted as a comprehensive policy document, replacing the previous subject and learning area statements and the learning and assessment guidelines for all subjects listed in the NCS from Grade R to 12 (DBE, 2011).

CAPS aimed not only to reform education as it was but also to edify teachers in how they assess and teach learners. Sections 1 and 2 in CAPS highlight specific aims and skills that learners should attain (DBE, 2011).

Some of the aims and skills that the DBE (2011, p. 8) identified in CAPS are:

- Develop a spirit of curiosity and a love for mathematics.
- Learn to investigate, analyse, represent, and interpret information.
- Encourage an active and critical approach to learning rather than rote and uncritical.

- Identify and solve problems and make decisions using critical and creative thinking.

Although the pedagogical tools for each mathematics content area are not explicitly stipulated in CAPS, a critical analysis of how content is expressed clearly indicates the pedagogical tools to be employed. For instance, although IBL is not explicitly mentioned in CAPS, developing "a spirit of curiosity…" and the skill of "[learning] to investigate…" (DBE, 2011, p. 8) lend themselves to IBL. In addition, it is also stated in CAPS (DBE, 2011, p. 285) that: "In Grade 6, they should investigate why the area of a rectangle can be stated as its length multiplied by its width. They are not required to know this formula off by heart, nor are they required to apply this formula in area calculations."

The investigative aspect CAPS advocates is an integral tenet of IBL because it aligns with the goal of learner-centred education, promoting critical thinking and problem-solving skills. By actively engaging in activities, learners develop a deeper understanding of the subject matter, which aligns with CAPS' objective of promoting meaningful and long-lasting learning experiences.

The investigative aspect purported by IBL encourages learners to establish themselves as respected and authoritative through self-reasoning by posing their questions and then analysing them to produce an answer. Thus, an umbilical connection exists between CAPS and the IBL approach, whereby the characteristics of IBL are utilised in CAPS to achieve academic outcomes.

IBL was not commonly used as a teaching approach in traditional mathematics education. However, since implementing the CAPS curriculum, IBL has become more integrated with mathematics projects and investigations (Ramnarain & Hlatswayo, 2018). Teachers must now use mathematics investigations in Term 2 and mathematics projects in Term 3 as assessment forms (DBE, 2011). These requirements highlight the ongoing improvements in mathematics education since adopting CAPS and the correlation between the current curriculum and the use of IBL.

Including IBL terminology in the curriculum further reflects the growing understanding that mathematics and science education are interconnected (Ramnarain & Hlatswayo, 2018). Despite its distinctiveness, mathematics is recognised is not purely deductive but includes an experimental aspect like the natural and life sciences (Artigue & Blomhøj, 2013). The introduction of IBL terminology aligns with decades of evolving research and teaching methods aimed at improving mathematics learning and teaching. In South Africa, further evidence of the incorporation of IBL is evident in the CAPS curriculum's approach within the Intermediate Phase for mathematics. Although the term "inquiry" is not explicitly used, in the CAPS curriculum for the Intermediate Phase for mathematics, the curriculum emphasises IBL characteristics through synonymous words like 'explore' (mentioned four times), 'investigate' (mentioned 42 times), 'explain' (mentioned 24 times), 'analyse' (mentioned 25 times), and 'examine' (mentioned seven times) (DBE, 2011). These words are not used by chance but rather to express and entrench a paradigm shift in South Africa's approach to education, which aligns with the objectives sought by utilising IBL in education. By adopting IBL, South Africa can cultivate critical thinkers and problem solvers essential for the country's global competitiveness.

However, many teachers lack adequate training on how to implement an IBL approach effectively. Even when they understand the concept of IBL, they may not know how to design IBL activities, assess learners' progress, or facilitate inquiry in a way that promotes deep learning. Crawford (2014) highlights that teachers often feel underprepared for an IBL approach, as traditional teacher preparation programs tend to focus more on direct instruction than on inquiry-based methodologies. This lack of pedagogical training can leave teachers feeling uncomfortable or uncertain about how to guide learners through inquiry. Additionally, Trautmann, MaKinster, and Avery (2004) reveal that teachers often do not have access to professional development opportunities that would equip them with the skills needed to manage inquiry-based classrooms, leading to inconsistent implementation.

Furthermore, Wallace and Kang (2004) discuss the challenges of assessment in inquiry-based classrooms, particularly in contexts where standardized tests and exams are the primary means of evaluation. Teachers may struggle to measure learners' progress and achievement in ways that align with traditional assessments, given the open-ended nature of inquiry. Saad and BouJaoude (2012) emphasize that assessing learners in inquiry-based classrooms, where the focus is on the process of learning rather than the final product, can be challenging. This approach stands in stark contrast to traditional assessment models, which prioritise memorisation and rote learning.

2.3. THE USE OF IBL WHEN TEACHING THE CONCEPT OF AREA IN MATHEMATICS CLASSROOM

In South Africa, teaching the concept of area is a crucial component of the Grade 6 mathematics curriculum, as outlined in the CAPS document (DBE, 2011). According to research (Umugiraneza et al., 2018), area refers to the measure of the total surface covered by a region. However, there is often an overemphasis on the memorisation and application of the area formula (Length (L) × Breadth (B) = Area (A)), which can lead to a superficial understanding of the concept and hinder learners' ability to grasp its significance fully (Boaler, 2016; Schoenfeld, 2016). This formulaic approach neglects the deeper conceptual understanding required for meaningful learning. Without effective lesson planning, this issue can be exacerbated, as teachers might rely heavily on procedural teaching rather than engaging learners in exploring the concept.

The CAPS curriculum emphasises the importance of developing a comprehensive understanding of area through practical activities, such as counting squares on grids and calculating the areas of squares and rectangles. IBL offers a practical approach involving learners in exploration and discovery (Artigue et al., 2012). Through IBL, learners engage with mathematical problems by posing questions, exploring various solutions, and deriving conclusions based on evidence. For instance, using grid paper or physical tiles to cover different shapes allows learners to count square units and compare their findings, fostering a deeper understanding of area beyond mere formula application (Wake, 2011). Initiating learning in an inquiry-based mathematics classroom involves posing problems or questions related to areas for learners to investigate (Artigue et al., 2012). This inquiry acts as a catalyst for designing and implementing procedures and drawing conclusions from evidence (Ndlovu, 2015). For example, exploring how different tile arrangements cover the same area or investigating changes in areas with varying dimensions helps learners understand area as a measure of surface, not just a formulaic concept. Mathematical tools, such as grid paper or digital apps, play a crucial role in this process, enabling learners to substantiate their findings (Wake, 2011). Despite the benefits of IBL, effective implementation can be challenging due to variations in teacher interpretation, policy, time constraints, and classroom context (Dobber et al., 2017). Teachers must adapt their strategies to meet learning objectives and address learners' needs, making detailed lesson planning essential. Without it, lessons may lack structure and fail to address the conceptual depth required for a robust understanding of the area.

A key challenge in implementing IBL lies in the alignment of teachers' beliefs with the inquiry-based approach itself. While many teachers recognize the value of IBL, their traditional views on teaching and learning obstruct its adoption. For instance, many teachers still adhere to a more teacher-centered approach, where the teacher is the primary source of knowledge and learners are seen as passive recipients (Chan, 2010; Saad & BouJaoude, 2012). This belief in the effectiveness of direct instruction can make it difficult for teachers to embrace the more learner-centered and participatory nature of IBL. As Binns and Popp (2013) argue, teachers' beliefs about teaching and knowledge acquisition significantly influence their willingness to adopt inquiry-based methods. Teachers with traditional beliefs often find it hard to relinquish control over the learning process, which is a core tenet of IBL, and may be reluctant to allow learners more autonomy in their learning.

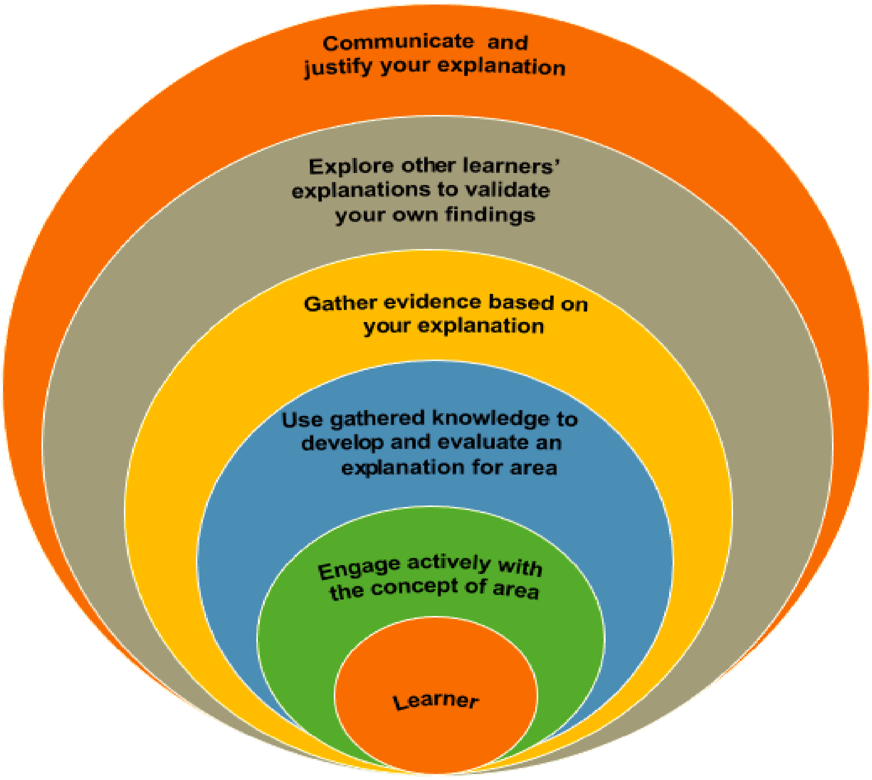
A common issue, particularly in rural or underfunded schools, is the lack of resources necessary for effective inquiry-based teaching. IBL typically requires access to a variety of materials and equipment for hands-on exploration, but many teachers in resource-constrained environments face significant barriers in this regard. Crawford (2014) points out that inadequate resources—ranging from laboratory materials to basic classroom supplies—pose substantial obstacles to implementing IBL in both science and mathematics classrooms. Teachers in such contexts often struggle to design and facilitate inquiry-based activities because of the lack of essential resources. Similarly, Saad and BouJaoude (2012) highlight that in resource-limited settings, teachers find it difficult to engage learners in meaningful inquiry, especially when materials such as scientific apparatus or math manipulatives are unavailable.

Moreover, teachers often face pressure from strict curriculum timelines, which require covering a broad range of content within a limited time frame. This can lead teachers to prioritize more traditional, time-efficient methods of instruction, such as direct teaching, over the time-consuming nature of inquiry-based activities. As noted by Ramnarain, Nampota, and Schuster (2016), the pressure to "cover" the curriculum within a set timeframe is especially prevalent in overcrowded South African classrooms, where teachers frequently resort to teacher-centered methods to expedite content delivery. This pressure is further compounded by the time required for IBL activities, such as formulating research questions, conducting open-ended investigations, and engaging in in-depth exploration, all of which can conflict with the demands of completing the curriculum (Wallace & Kang, 2004).

In summary, the core focus of IBL in Mathematics (IBL-M) is the active involvement of learners in their learning process. Essential components of an IBL-M classroom include engaging learners with mathematically oriented questions, prioritising evidence to develop and evaluate explanations, and formulating and justifying these explanations based on their investigations (Minner et al., 2010). Figure 2.2 below illustrates the core components of IBL-M, adapted from van Graan's framework originally designed for science education. This adaptation highlights the centrality of learner engagement and active participation in the inquiry-based process of learning about the area (van Graan, 2020; Şen et al., 2021).

Figure 2.2.

The centrality of learner's engagement in IBL



Effective IBL-M extends beyond hands-on activities. It allows learners to explore, investigate, and reflect on mathematical concepts, share their ideas in groups, and discuss their findings in class (Şen et al., 2021; van Graan, 2020). This collaborative approach helps learners address and correct misconceptions. For example, learners may initially believe that shapes with the same perimeter have the same area. However, through inquiry-based activities, they can explore and understand that this is not necessarily the case, as shapes with identical perimeters can have different areas (Van de Walle et al., 2014).

Despite its benefits, implementing IBL-M can be challenging due to variations in teacher interpretation, policy, time constraints, and classroom context (Dobber et al., 2017). Teachers must adapt their strategies based on learning objectives and the specific needs of their learners (Pedaste et al., 2015). The National Research Council (NRC) provides a framework outlining key components of IBL-M, including:

- engaging learners with meaningful questions, facilitating active mathematical thinking, and

- supporting the development and communication of explanations (Laursen et al., 2011).

This framework emphasises the importance of integrating IBL principles into existing curricula, adjusting teaching methods to meet diverse educational contexts, and promoting a comprehensive understanding of the area (Şen et al., 2021). By effectively incorporating IBL into the teaching of area, South African educators can enhance learners' understanding of this fundamental concept, stimulate critical thinking and problem-solving skills, and align with the broader goals of the CAPS curriculum. This approach addresses common misconceptions and fosters a deeper, more meaningful engagement with the area concept.

2.4. THEORETICAL FRAMEWORK

A theoretical framework serves as a foundational structure that guides the research process by offering a lens through which the phenomenon under study is understood and interpreted (Luft et al., 2022). Additionally, it articulates the researcher's assumptions and orientations concerning the topic, providing a coherent basis for explaining and analysing the data (Collins & Stockton, 2018). A theoretical framework reveals the researcher's subjectivities, including their values, social experiences, and viewpoints, influencing the study. While the framework itself does not justify the necessity of the research, it illuminates the study's focus, challenges existing knowledge, and extends understanding within its defined scope (Collins & Stockton, 2018). For this study, I employed two theoretical lenses: SDT to explore motivational factors and the 5E's IBIM to examine IBL processes. Integrating these lenses provide a nuanced understanding of the educational phenomenon, highlighting both motivational and instructional aspects which are crucial for effective teaching and learning.

2.4.1. SDT and its relevance to IBL

SDT emphasises self-motivation and autonomy and the impact of self-determined motivation on experiences (Deci & Ryan, 2000). The theory posited that humans are active organisms who grow, overcome challenges, and integrate experiences into a coherent identity (Deci & Ryan, 2000). SDT underscores the significance of intrinsic motivation, where individuals engage in activities for inherent satisfaction and interest, promoting deep learning and creativity (Deci & Ryan, 2000).

In contrast, extrinsic motivation involves participating in activities for external rewards or to avoid punishment, which, although sometimes necessary, may not sustain long-term engagement or foster meaningful learning experiences (Deci & Ryan, 2000). The theory suggests that perceptions and cognition predict outcomes based on self-motivation and autonomy. Hoffman (2016) supports this, noting that highly motivated learners with positive attitudes are more eager to perform tasks and seek additional information related to the subject content.

SDT has been extensively applied in educational contexts to explain learners' willingness to participate and engage in their education actively (Wang et al., 2019). Learners are more likely to engage in learning activities when the classroom context supports their needs for competence, autonomy, and relatedness (Wang et al., 2019). In educational settings, SDT highlights three fundamental psychological needs crucial for fostering self-driven learners: competence, relatedness, and autonomy (Wang et al., 2019).

Competence

Competence involves learners' ability to master a skill or understand content within a discipline. IBL activities can be designed to gradually increase in complexity, helping learners build confidence and competence. While open inquiry can be intellectually challenging and sometimes overwhelm lower-ability learners (Wu & Krajcik, 2006; Gormally et al., 2009; Zhao et al., 2021), structured and guided inquiry can provide the necessary scaffolding. In the context of the teaching area, teachers can start with simpler tasks that ensure early success and build learners' confidence, gradually introducing more complex problems as their competence grows. Constructive feedback focusing on effort and improvement, rather than just outcomes, can further enhance learners' sense of competence (Deci & Ryan, 2000; Zhao et al., 2021).

Relatedness

Relatedness refers to learners feeling supported, valued, and connected with others (Deci & Ryan, 2012; Niemiec et al., 2009). IBL can foster this by creating a collaborative classroom environment where learners work in groups to solve problems and explore concepts. Teachers play a crucial role in establishing this environment by encouraging peer support, showing genuine interest in learners' progress, and being approachable for help (Zhao et al., 2021). Group activities where learners measure and compare different areas can promote a sense of community and shared learning experiences when teaching the area concept. Ensuring learners feel comfortable asking questions and making mistakes is also vital for meeting their need for relatedness (Furrer & Skinner, 2003; Zhao et al., 2021).

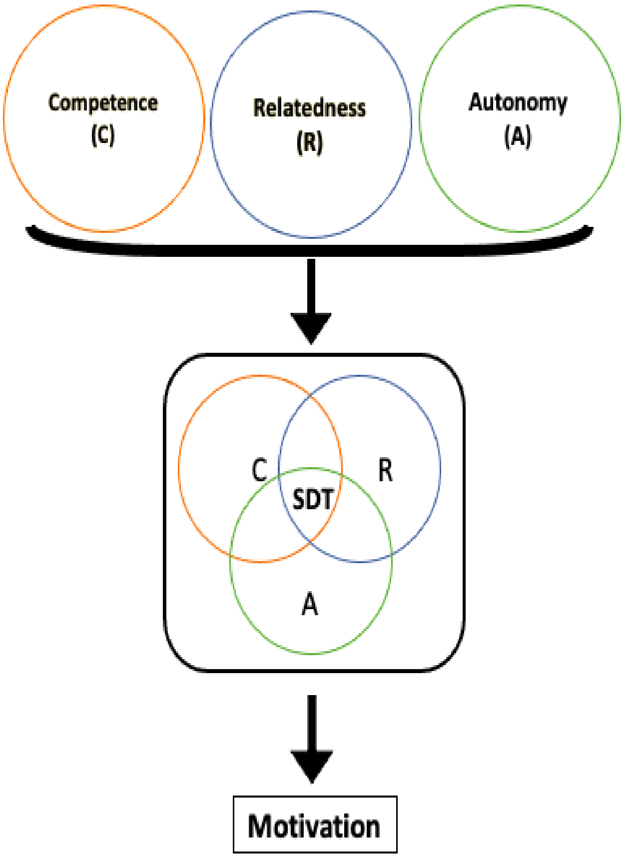
Autonomy

In an educational context, autonomy refers to learners' perception of having a choice and voice in the learning activity (Deci & Ryan, 2012; Niemiec et al., 2009). IBL, particularly guided and open inquiry, supports this need by allowing learners to take more control over their learning process. Learners who are given opportunities to explore mathematical concepts such as area through inquiry-based activities are likelier to feel a sense of ownership and engagement (Zhao et al., 2021; Gholam, 2019). This autonomy can increase intrinsic motivation and a deeper understanding of the material. For example, learners might be free to choose different shapes and objects to measure and calculate the area, aligning the activity with their interests and promoting self-initiated exploration.

In conclusion, incorporating SDT into IBL practices can enhance the teaching and learning of mathematical concepts, such as in a Grade 6 classroom. By providing learners with autonomy, ensuring they build competence through structured support, and fostering a sense of relatedness, teachers can create a motivating and effective learning environment that aligns with SDT and IBL (Zhao et al., 2021). This holistic approach addresses learners' cognitive and affective needs, promoting academic success and personal growth. Further, by aligning IBL activities with the three psychological needs of SDT, teachers can create a learning environment that not only supports academic achievement but also nurtures intrinsic motivation and a love for learning. Figure 2.3 below visually represents how fulfilling the psychological needs of (competence, autonomy, and relatedness) leads to intrinsic motivation, fostering self-determined learners (Muir, 2020).

Figure 2.*3.*

The psychological needs of competence, autonomy, and relatedness

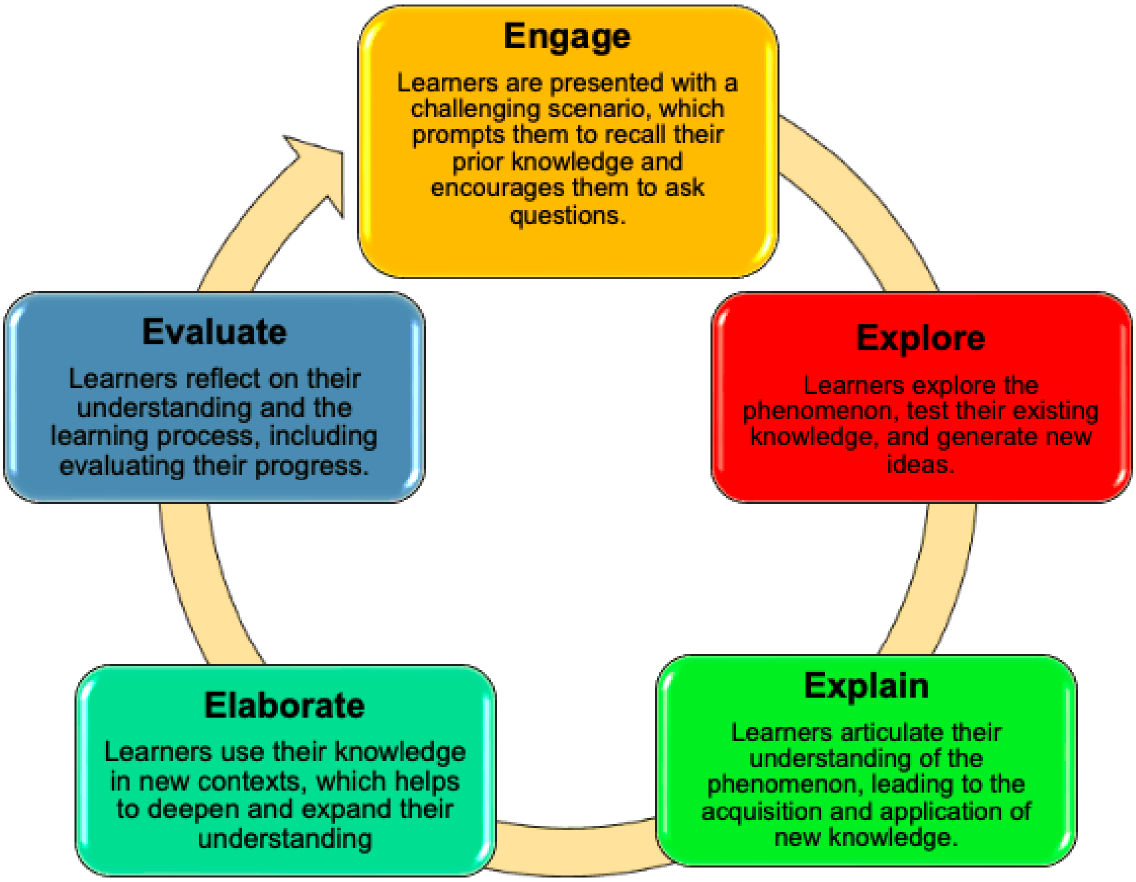


2.4.2. The 5Es of Inquiry-based learning

According to Bybee and Landes (1990), the 5E's of the IBIM is grounded in cognitive psychology, constructivist learning theory, and Science, Technology, Engineering and Mathematics (STEM) instruction (Thangjai & Worapun, 2022). The five stages—Engagement, Exploration, Explanation, Elaboration, and Evaluation—provide a structured framework for implementing IBL in the classroom. While IBL and IBIM are used interchangeably throughout this study, they refer specifically to the structured model of the 5E's (Bybee, 2009), as illustrated in Figure 2.4. Each phase is designed to support effective teaching and cultivate desirable learning behaviours.

Figure 2.4.

The 5E's of inquiry-based learning



Engagement

The engagement phase involves a quasi-ontological learning process where learners integrate past experiential knowledge with the current task. This integration is designed to captivate their interest and encourage them to seek solutions to the presented problems (Darling-Hammond et al., 2023). By linking new data with existing knowledge, learners are motivated to explore further (Thangjai & Worapun, 2022). This phase often includes intriguing questions, thought-provoking demonstrations, or real-world scenarios that make the learning relevant and engaging. For example, a teacher might begin a lesson by showing learners a picture of an irregular shaped garden, and ask the learners “How can we determine how much grass seed we need to cover this space?” This question prompts learners to recall their prior knowledge of area and shapes, sparking curiosity and motivating them to engage in problem solving. Teachers might use multimedia resources, storytelling, or other creative techniques to stimulate curiosity and prompt learners to ask questions that guide their inquiry (Van Uum et al., 2016)

Exploration

In the exploration phase, learners conduct an internal inquiry process, connecting new data with their existing knowledge to build new connections and assimilate information (Darling-Hammond et al., 2023). This phase emphasises hands-on activities that allow learners to engage directly with materials, fostering the generation of new ideas and preliminary investigations (Thangjai & Worapun, 2022). Learners often work collaboratively during exploration, engaging in discussions and problem-solving tasks that encourage diverse perspectives and deeper understanding. Teachers act as facilitators, guiding learners and providing support as needed. The goal is to create a rich learning environment where learners can experiment, take risks, and learn from their experiences (Van Uum et al., 2016).

Explanation

In the explanation phase, teachers guide learners in organising their findings and connecting them to established frameworks, which helps to contextualise the new information within their existing knowledge base (Darling-Hammond et al., 2023). For example, after measuring shapes, learners might be guided to discuss why the same perimeter can enclose different areas, or how area measurements differ from regular versus irregular shapes. The explanation phase is pivotal for transitioning from exploration to a deeper conceptual understanding. During this phase, teachers provide structured feedback and correct any misconceptions learners may have developed during their exploration. This process involves formalising and consolidating knowledge through clear definitions, notes, and labels (Bybee, 2009). Teachers facilitate this by addressing the procedures necessary for clear and accurate articulation of concepts, such as formulating precise research questions that provide direction in an investigation (Van Uum et al., 2016).

Elaboration

The Elaboration phase is essential for deepening learners' understanding by encouraging them to apply their newly acquired knowledge and skills to various activities, such as investigations and projects (Thangjai & Worapun, 2022). For example, learners could be asked with designing a floor plan for a classroom using grid paper, ensuring that the total area foes not exceed a specified limit while incorporating specific shapes. This phase promotes deeper learning and the ability to transfer knowledge to new contexts. During this stage, learners engage in more complex tasks that require them to synthesise information and solve problems using their expanded understanding (Darling-Hammond et al., 2023). Teachers facilitate this process by providing opportunities for learners to extend their thinking, encouraging them to explore additional questions, and guiding them to apply their knowledge in real-world situations (Van Uum et al., 2016).

Evaluation

The evaluation phase is critical for assessing learners' understanding and progress. This phase includes using assessments to gauge learning achievements and provide feedback (Thangjai & Worapun, 2022). For examples, learners might be asked to create a poster explaining the steps for calculating the area and perimeter of a complex shape, complete with diagrams and real-life application. This activity assesses their comprehension while allowing for creativity and self-expression. This phase also encourages self-assessment and peer evaluation, thereby allowing learners to reflect on their learning journey and provide constructive feedback to their peers (Wang et al., 2019). The results of these assessments, often involving the analysis of collected data, guide future instruction, and can highlight areas for further inquiry or improvement (Darling-Hammond et al., 2023). Teachers use this phase to make recommendations for learners' next steps, thus ensuring a continuous cycle of learning and growth (Van Uum et al., 2016).

2.4.3. The rationale for synergistic use of SDT and IBL in my study

Incorporating the SDT framework alongside the 5Es of IBL is essential for fostering self-driven and self-determined learners (Zhao et al., 2021). Integrating these frameworks creates a well-rounded educational environment that meets cognitive and psychological needs, while ensuring that learners remain engaged, motivated, and empowered to direct their learning experiences (Muir, 2020). The 5Es framework supports the principles of SDT by encouraging intrinsically motivating activities (Zhao et al., 2021). When learners' needs for competence, autonomy, and relatedness are addressed, their intrinsic motivation increases, leading to enhanced engagement and persistence in their educational pursuits (Bybee, 2009; Deci & Ryan, 2000). To achieve a successful integration of SDT with the 5Es of IBL, the alignment between these lenses is discussed below:

***Engagement*:** This phase aims to captivate learners' attention and interest by linking new teaching content with their existing knowledge and experiences (Thangjai & Worapun, 2022). Engaging activities stimulate curiosity and motivate learners to explore further.

- Fostering Autonomy: By connecting new concepts to learners' prior knowledge, teachers help them to see the relevance of their learning, thus fostering a sense of autonomy and ownership (Muir, 2020).
- Enhancing Competence: By engaging with material that is appropriately challenging but still accessible, learners experience early successes that enhance their competence and motivation to tackle more complex problems (Gormally et al., 2009; Wu & Krajcik, 2006).
- Enhancing Relatedness: Activities often involve collaborative discussions, promoting a sense of relatedness among peers (Muir, 2020).

Exploration: Learners engage in hands-on activities to build on their prior knowledge, generate new ideas, and conduct preliminary investigations. This phase is crucial for nurturing deep understanding (Duran & Duran, 2004).

- Fostering Autonomy: Learners take responsibility for their learning by actively participating in the exploration process, thereby promoting self-determined behaviour (Zhao et al., 2021).
- Enhancing Competence: Hands-on activities allow learners to experiment and discover, enhancing their competence as they solve problems and uncover solutions (Thangjai & Worapun, 2022).
- Enhancing Relatedness: Learners work together on hands-on activities and investigations, inherently promoting relatedness. By collaborating on tasks such as measuring and comparing different areas, learners build a sense of community and shared experience. This collaborative environment helps

learners to feel supported and valued, as they rely on each other's ideas and feedback to solve problems (Zhao et al., 2021).

Explanation: Teachers provide feedback and correct misconceptions after learners have actively explored concepts (Bybee, 2009; Duran & Duran, 2004). This phase involves formalising knowledge through definitions, notes, and labels.

- Enhancing Competence: Providing clear explanations and feedback helps learners solidify their understanding, thereby boosting their competence (Thangjai & Worapun, 2022).
- Enhancing Relatedness: Teachers' active involvement in this phase fosters a sense of connection and support, enhancing relatedness (Muir, 2020).

Elaboration: Learners apply their new knowledge and skills in various activities, such as investigations and projects (Thangjai & Worapun, 2022). This phase promotes deeper learning and the ability to transfer knowledge to new contexts.

- Fostering Autonomy: Engaging in self-directed investigation assignments allows learners to pursue their interests, thus fostering autonomy (Muir, 2020).
- Enhancing Competence: Applying knowledge in different contexts helps learners to master concepts, thereby increasing their competence (Zhao et al., 2021).
- Enhancing Relatedness: Through collaborative efforts and shared learning experiences learners learn how to work with others on group projects or investigations. In that way, they continue to build connections with their peers and feel part of a learning community. Engaging in collaborative tasks during this phase helps learners to support each other, share ideas, and build a sense of camaraderie.

Evaluation: Learners assess their learning achievements and receive feedback (Thangjai & Worapun, 2022). This phase includes both formative and summative assessments to gauge understanding and progress.

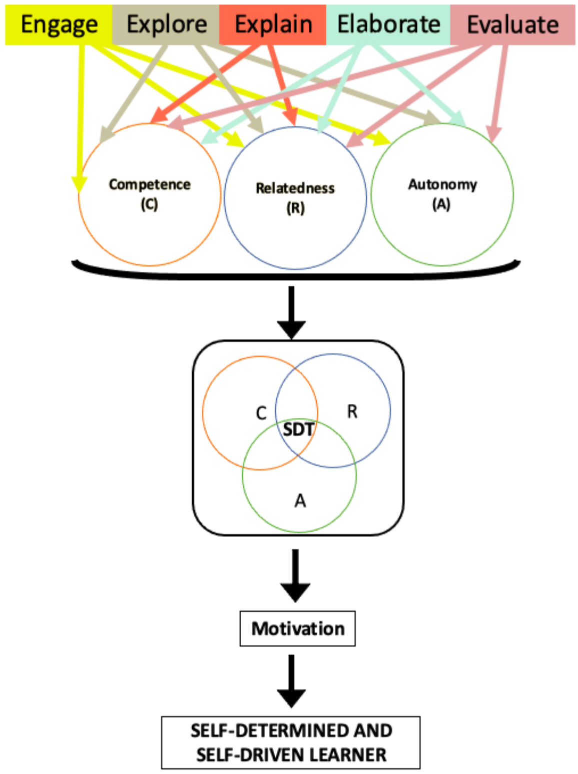
- Fostering Autonomy: Self-assessment and reflection give learners control over their learning, thus promoting autonomy (Thangjai & Worapun, 2022).

- Enhancing Competence: Learners receive constructive feedback that highlights their strengths and areas for improvement. That then contributes to their sense of competence by helping them to understand where they stand and how they can improve (Ryan & Deci, 2000; Zhao et al., 2021).
- Enhancing Relatedness: Varied assessment methods, including collaborative discussion, build a sense of relatedness to the subject matter and peers (Thangjai & Worapun, 2022).

Figure 2.5 below demonstrates the synergy between the 5Es and SDT. Together, these frameworks emphasise the importance of promoting engagement and achievement through active learning, thereby providing significant benefits for mathematics teachers in facilitating subject content. By encouraging learners to seek knowledge through inquiry, critical thinking, and problem-solving, the 5Es and SDT facilitate a learner-centred approach that enhances active engagement (Zhao et al., 2021). Consequently, these frameworks are integral for implementing IBL into the classroom, thus helping mathematics teachers to create more effective and engaging learning experiences.

Figure 2.5.

The synergy between SDT and the 5Es of IBL



2.5. CONCLUSION

In conclusion, this chapter highlights the significance of IBL in fostering deeper mathematical understanding and developing essential skills in learners. By emphasising critical thinking, problem-solving, and engagement, IBL aligns with the core objectives of contemporary education as outlined in Dewey's experiential learning theory. This approach encourages learners to participate actively in their education, thus transforming traditional teaching methods to cultivate autonomous, lifelong learners.

While the CAPS curriculum in South Africa does not explicitly use the term IBL, it supports many of its principles by encouraging learner exploration, investigation, and critical analysis. As mandated by CAPS, teaching mathematical concepts such as area allows teachers to incorporate IBL methodologies, which, when applied effectively, can move beyond rote learning and formulaic understanding to deeper conceptual engagement. However, challenges remain in fully integrating IBL into the classroom, particularly in teaching the area concept. The findings underscore that teachers often overemphasise formula memorisation, impose strict time constraints in lessons, and fail to apply real-world contexts, all of which hinders IBL's potential to promote meaningful learning. These limitations highlight the need for teachers to adopt more flexible, inquiry-driven approaches that allow learners to explore mathematical concepts on a deeper level.

Furthermore, the literature review emphasises that successful IBL implementation depends on aligning teaching strategies with curriculum goals and learner needs. Teacher preparation is critical, as variations in IBL practices are often linked to differences in how teachers understand and interpret IBL principles. This reinforces the importance of professional development, hence ensuring that teachers are equipped with the necessary skills, resources, and knowledge to facilitate IBL effectively in diverse classroom contexts.

The author suggests that to realise the full benefits of IBL, teachers must receive proper support and training to implement these methodologies effectively. By addressing the challenges highlighted in this study and fostering a more inquiry-driven learning environment, teachers can better equip learners with the skills necessary for success in an increasingly complex and interconnected world. Additionally, integrating SDT into the application of IBL emphasises the importance of promoting learner autonomy, competence, and relatedness, thus ensuring that inquiry-based activities enhance cognitive understanding and nurture learners' intrinsic motivation and positive attitudes toward learning.

CHAPTER 3: RESEARCH METHODOLOGY

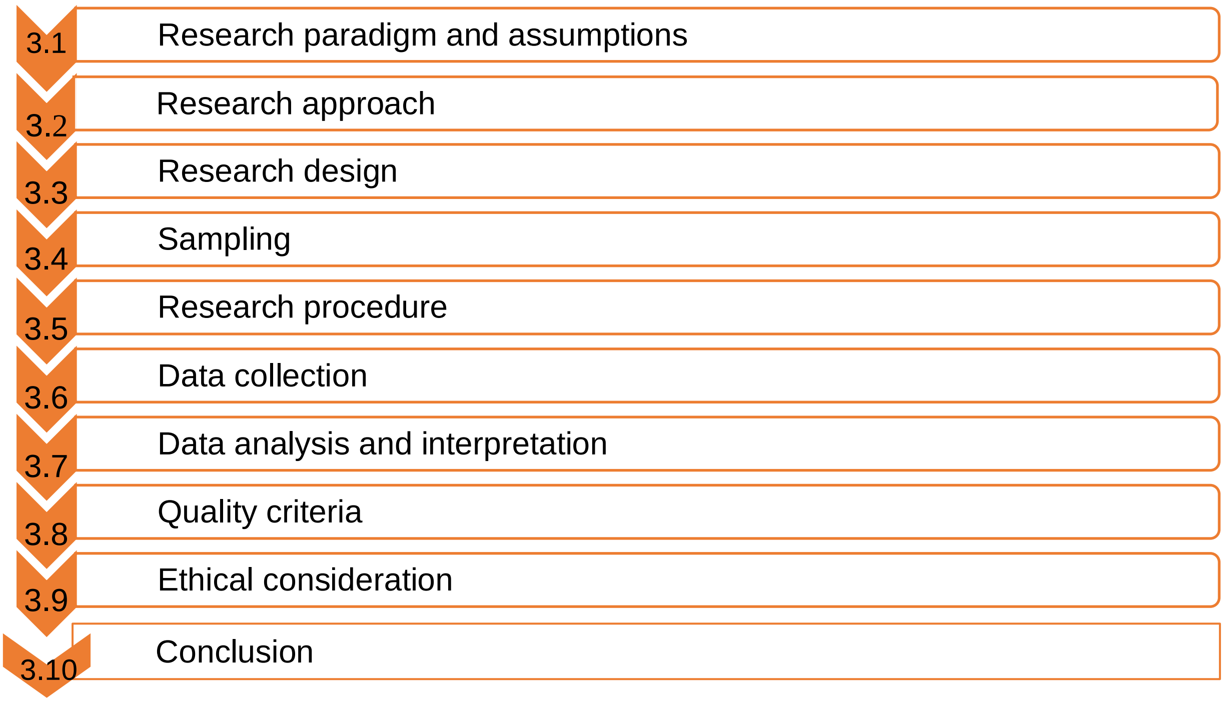
3.0. INTRODUCTION

The focus of my study was on the utilisation of IBL as a pedagogical tool employed by mathematics teachers in Grade 6 classrooms. The primary objective was to examine how teachers facilitate the aspects and characteristics of IBL when constructing mathematics knowledge in Grade 6 classes.

Rather than attempting to control or influence the teachers' behaviour, this research aims to investigate events as they naturally occurred within the classroom setting. In this chapter, I presented a detailed account of the methodological foundations of my study. I also provided a detailed account of collecting, processing, and analysing relevant data gleaned through specified data collection strategies and informed by sound philosophical persuasions. The framing of this chapter is illustrated in Figure 3.1 below.

Figure 3.1.

Structure and flow of chapter 2



3.1. RESEARCH PARADIGM AND ASSUMPTIONS

My study was grounded within the interpretivist paradigm, shaping how researchers approach their inquiries. This paradigm served as a guiding framework, encompassing beliefs about the nature of reality (ontological assumption), the nature of knowledge (epistemological assumption), and the methods used to acquire knowledge (methodological assumption) (Creswell, 2018). These assumptions align closely with the interpretivist paradigm that asserts reality is socially constructed and knowledge is inherently subjective (Denzin & Lincoln, 2000).

Within the interpretivist paradigm, the ontological assumption holds that no ideal version of reality exists regarding the phenomenon under investigation. Instead, the understanding of the phenomenon is shaped by individual perspectives. For my study, the phenomenon under investigation involved comprehending and analysing the utilisation and facilitation of IBL by Grade 6 mathematics teachers. Researchers within the interpretivist paradigm recognise the challenge of maintaining complete neutrality regarding impartiality and objectivity because individual perspectives inevitably influence researchers' perceptions and understanding of the world (Cohen et al., 2011).

Additionally, I outlined the paradigmatic assumptions that underpin my study, encompassing fundamental beliefs about the research environment (Creswell, 2018). These assumptions guided my research approach and included ontological, epistemological, and methodological assumptions. Within the interpretivist paradigm, I aimed to examine how participants carry out and support IBL, probing the complex aspects of these phenomena from their viewpoints (Maree, 2016). I emphasised the significance of comprehending how individuals subjectively perceived the world, encompassing their beliefs, attitudes, opinions, and practices (Hamilton & Corbett-Whittier, 2013). This alignment informed the foundation of my research, and I welcomed the opportunity to discuss it further.

As Creswell (2018) emphasises, interpretivism, at its core, involves conducting a qualitative study that recognises the existence of multiple realities. In my study, my objective was to unveil the varied approaches employed by each teacher and gain valuable insights into their unique methods of incorporating IBL. By embracing the subjective viewpoints of Grade 6 teachers, this research aims to uncover how teachers facilitate and use IBL principles when teaching the concept of 'area.' This approach enabled an appreciation of the unique contexts in which IBL unfolded and a thorough exploration of the factors that influenced its successful incorporation.

In alignment with the ontological and epistemological assumptions of the interpretivist paradigm, a diverse array of data collection methods employed, including document analysis, observations, and semi-structured interviews (Creswell, 2018). These methods complement each other seamlessly, with document analysis shedding light on the extent to which IBL principles are integrated into teachers' instructional practices and lesson plans, observations providing a first-hand view of IBL in action within real classroom settings, and semi-structured interviews allowing for an in-depth exploration of teachers' IBL practices. This multifaceted approach to data collection was designed to provide a comprehensive understanding of the studied context. Further details on the data collection techniques and associated instruments are provided in subsequent sections.

The ontological assumption within the interpretivist paradigm revolves around how society perceives and comprehends reality, positing that the human mind plays a pivotal role in shaping the meaning ascribed to reality (Nieuwenhuis, 2016). Whitehead (2009) defined ontological assumptions as perspectives on the fundamental nature of existence. This perspective encompasses how individuals formulate their thoughts regarding themselves and their immediate environment, encapsulating their values, norms, and the dynamics of interpersonal interactions. Similarly, Moalusi (2020) characterised the ontological assumption as the presumptions people make about the essence of reality and what they believe exists. Within this context, reality can be understood as a collection of socially constructed concepts influenced by internal dynamics. This constructivist viewpoint aligns with the interpretivist paradigm I selected for my study, positing that reality is socially moulded by influential forces within societies (Denzin & Lincoln, 2000).

The ontological assumption is closely tied to my study on mathematics teachers' incorporating IBL aspects and characteristics and considering SDT principles. It provided the foundation for understanding how teachers construct their teaching realities. By delving into the teacher’s lesson plans and classroom practices, I aimed to uncover the ontological underpinnings that shaped their approach to fostering IBL environments in mathematics education. I approached epistemological assumption from a qualitative perspective. As described by Moalusi (2020), the epistemological assumption examines the assumptions people hold about the nature of knowledge and encompasses how people perceive and make sense of the world. Nieuwenhuis (2016) emphasised that epistemological assumptions address how knowledge should be acquired, while Scotland (2012) emphasised its role in seeking to understand reality and acquire knowledge, as noted by Crotty (1998) and Morgan and Henning (2011).

In my study, the epistemological assumption held a significant role as it influenced how I approached and perceived knowledge, particularly in understanding how mathematics teachers incorporated aspects of IBL into their classrooms when teaching the concept of area. As I analysed the teacher's lesson plans, engaged in direct observations of teachers, and witnessed their interactions with learners, I discovered that epistemological assumptions were central to my research process. Epistemological assumptions, in this context, enabled me to critically evaluate the information acquired through direct observations and semi-structured interviews with teachers; enhancing my study's insights into how teachers facilitate and utilise IBL aspects within their mathematics classrooms.

3.2. RESEARCH APPROACH

A research approach serves as the blueprint that outlines the key aspects of a study (Maree, 2016). Researchers typically opt for one of three main approaches when designing their research: (i) quantitative, (ii) qualitative, or (iii) mixed methods approaches. Quantitative research deals with quantifying and analysing variables to obtain results, employing numerical data and statistical techniques to address questions about who, how much, what, where, when, how many, and how events happen (McCusker & Gunaydin, 2014). This approach is often grounded in the positivist paradigm. On the other hand, a qualitative research approach seeks to understand how things are done and the meaning they hold in individuals' lives (Teherani et al., 2015) delving deep into issues, revealing thoughts and opinions, and offering in-depth exploration (Berkwits & Inui, 1998). Qualitative studies often align with an interpretivist paradigm.

As the name suggests, the mixed methods approach combines elements of both qualitative and quantitative research approaches, aiming to achieve a comprehensive understanding through breadth and depth of investigation and corroboration (Schoonenboom & Johnson, 2017). This approach typically falls under the pragmatic paradigm. I adopted a qualitative research approach for my study, which was ideal for addressing my primary and secondary research questions (Cohen et al., 2011). This approach allowed for a comprehensive exploration of how Grade 6 mathematics teachers used aspects of IBL when teaching the concept of *area*. This alignment was essential to gain insight into their teaching practices, understand the IBL elements, and focus on the subjective aspects of teaching and learning. Qualitative research is a deliberate endeavour to explore, interpret, and fathom the depths of social interactions and individual experiences in their natural settings (O'Briens et al., 2014). It revolves around a personalised, immersive examination of phenomena to unravel the meaning and significance attributed to these experiences. Significantly, it veers away from numerical data and statistical analysis, opting for a more human-centric understanding of the subject matter (Maree, 2016). The qualitative approach I chose promises a profound and intricate examination, which is invaluable when embarking on an in-depth study.

The qualitative research approach is grounded in an interpretivist paradigm, a philosophical foundation that highlights the role of subjective human interpretation while simultaneously embracing elements of objectivity (Crabtree & Miller, 1999). It provides a pathway to delve deeply into the rich context of specific cases, thus fostering a comprehensive grasp of the precise issue under scrutiny (Ponelis, 2015). By adopting this approach, I ventured into the heart of Grade 6 mathematics classrooms to intimately observe, interview, and engage with teachers as they implemented the approach. I facilitated aspects of IBL into their mathematics classroom.

This immersive research journey was perfectly attuned to both the interpretivist paradigm and the qualitative approach, thereby emphasising the importance of understanding how individuals, in their unique contexts, engage with and interpret the educational phenomena of IBL.

The qualitative research approach is the instrument of choice when it comes to interpreting phenomena through the lens of the meaning's individuals ascribe to them (Punch, 2013). It not only unlocks the depths of understanding but also unravels the intricate tapestry of the subject matter (Henning et al., 2009; Cohen et al., 2011). Through this immersive approach, I have gained profound insights into the practical application of IBL by Grade 6 mathematics teachers when teaching the concept of area.

Moreover, the qualitative approach allows for the versatile use of multiple data collection and analysis techniques (Johnson & Christensen, 2011). A multifaceted approach ensures that no stone is left unturned when attempting to unearth the phenomenon's essence and significance to those involved (Johnson & Christensen, 2011). This comprehensive approach meant observing and interviewing teachers and meticulously analysing teachers' materials and documents. This methodological richness further deepens the data generated, thereby offering a substantial foundation for advocating changes and improvements in IBL practices among mathematics teachers. The interpretation of the collected data revealed significant insights into how to address the research questions posed in my study, as indicated in Table 3.1 below.

Table 3.1.

Summary of the methodology of the study

APPROACH	DESCRIPTION
Research approach	Qualitative
Research design	Case Study
Primary research question	How do Grade 6 mathematics teachers use an IBL as a pedagogical tool to teach the concept of area?
Secondary question	SRQ 1: How do mathematics teachers design learning activities that promote autonomy, competence, and relatedness when teaching the concept of area? SRQ2: To what extent do mathematics teachers incorporate the attributes of the 5Es of IBL when teaching the concept of area? SRQ3 How do mathematics teachers facilitate an inquiry-based lesson, and, if any, what related challenges do they experience when teaching the concept of area?
Participants	Three Grade 6 mathematics teachers are teaching the concept of area
Data collection method	- Document analysis - Classroom observation - Semi-structured interviews

3.3. RESEARCH DESIGN

The case study design proved to be a valuable approach, facilitating in-depth investigations of specific situations in their natural settings, with a primary focus on comprehending the perspectives of the involved participants (Crowe et al., 2011). This approach was particularly advantageous when my research encompassed more variables of interest than available data points, necessitating the collection of evidence from various sources, often guided by theoretical propositions (Yin, 2003).

In the context of my study, the aim was to shed light on specific decisions, their underlying rationale, implementation, and resulting outcomes within the framework of a case study (Ebneyamini & Sadeghi Moghadam, 2018). As Yin (2003) elucidated, a case study entails an empirical exploration of a contemporary phenomenon in-depth and within its real-life context, particularly when the boundaries between the phenomenon and its are context blurred. This approach proved particularly suitable for unravelling complex social phenomena and real-life events, such as organisational and managerial processes.

Yin (2003) further highlighted the multifaceted applications of case studies, ranging from explaining intricate causal relationships in real-life interventions to describing the contextual backdrop against which interventions unfold, detailing the intervention itself, and exploring situations characterised by ambiguous outcomes. The case study design seamlessly aligned with the defining characteristics articulated by Stake (1995), thereby emphasising its holistic, empirical, interpretive, and empathic nature. As Merriam (1998) described, case studies offered an intensive, holistic exploration of bounded phenomena, yielding rich, descriptive accounts that significantly enhanced my comprehension of the subject under scrutiny. This design facilitated a close examination of data within specific contexts, often focusing on a small geographic area or a limited group of individuals. By wholeheartedly embracing the essence of the case study design, I wielded a potent tool for an in-depth exploration and investigation of contemporary real-life phenomena, augmenting my understanding through meticulous contextual analysis (Yazan, 2015).

Transitioning to case selection, Yin (2003) delved into the debate surrounding single and multiple case studies, underscoring the importance of selecting the most suitable approach to understand the phenomenon under scrutiny comprehensively. This decision engendered a spectrum of perspectives within the research community. Yin (2003) expounded on the merits of the multiple case study approach, emphasising its capacity to facilitate an analysis of data within specific situations and across various situations, thus providing a broader perspective compared to a single case study. In the context of a multiple case study, researchers delve into multiple cases to unearth their similarities and differences. This approach empowers the researcher to glean valuable insights from a diversity of variations and commonalities, as suggested by Vannoni (2014). Notably, a multiple case study emerged as a requisite when my study encompassed more than one case.

Eisenhardt (1991) emphasised that the choice of the number of cases should hinge on the existing knowledge base and the potential contributions of the selected cases. Regarding generating new insights. Baxter and Jack (2008) underscored the robustness and reliability of evidence generated through a multiple case study. Yin (2003) underlined the value of multiple case studies when results either corroborated similar findings across studies or revealed contrasting outcomes for expected reasons. Eisenhardt (1991) contended that multiple case studies allowed for assessing the significance of findings and fostered a comprehensive exploration of theoretical development and research questions.

In the context of my study, I embraced a qualitative research approach and opted for a multiple case design. This choice allowed for a detailed examination of specific aspects, one at a time, without overwhelming the study with overly broad research inquiries (Yin, 2003). My research focused on unravelling how teachers incorporated various aspects and characteristics of IBL into their lesson planning and teaching, particularly emphasising the area concept.

To accomplish this, I diligently scrutinised their documents to illuminate their intentions to integrate these aspects into their teaching. Classroom observations gave me an invaluable opportunity to witness how these identified aspects were implemented during the teaching process. This comprehensive approach placed within a qualitative framework, seamlessly aligned with the holistic, interpretive, and empirical essence of case study research, thus enabling a more profound exploration of the subject matter (Yazan, 2015). Furthermore, it offered a unique opportunity to conduct an in-depth investigation into one situation that served as a representative microcosm of the broader population to which it belonged (Basit, 2003).

3.4. SAMPLING

The sample size was intentionally limited to three schools within a single district, to enable an in-depth qualitative analysis, as qualitative research prioritises depth over breadth (Creswell, 2018). The schools were selected for their geographic proximity, ensuring practical feasibility. However, this focus on a single district presents a limitation in terms of generalisability to schools outside similar contexts, a constraint that is acknowledged in this study.

The three participants (Teacher 1, Teacher 2, and Teacher 3) in my study are employed in three public primary schools within one education district in the Gauteng province of South Africa. As per Yin (2003), this constitutes a multiple case study where each teacher's experiences in their particular school served as an individual case. To recruit these participants, I first contacted the Gauteng Department of Education (GDE) (Annexure A) and then the relevant district (Annexure B). I provided them with a thorough explanation of my study's purpose and objectives (see paragraph 3.6 for ethical considerations). Subsequently, I approached the principals of the schools (Annexure C). Each principal identified a teacher who volunteered for my study. After explaining my study's purpose and objectives to these teachers, I obtained consent from the teachers (Annexure D), parents (Annexure E), and learners (Annexure F). I received approval from their respective school authorities. Maintaining the utmost confidentiality and anonymity was of the utmost importance for safeguarding the privacy of both the participants and their respective schools throughout the study.

The participants were Grade 6 mathematics teachers. During my visit to each school, I first analysed each teacher's lesson plans and other relevant documentation before presentation of the lesson. Afterwards, I observed each teacher while they taught the area concept to Grade 6 learners. Lastly, I interviewed them to gain more insight into how they utilised and incorporated aspects of IBL into their lesson plans and teaching.

Johnson and Christensen (2011) stated that a sample is a small portion of the target population selected by a researcher. The participant selection process for my study employed a combination of purposive sampling and convenient sampling methods to ensure the representation of relevant and accessible participants. These approaches were sequentially employed to capture data from participants who could contribute to the research objective.

Purposive sampling is a deliberate and focused approach, and it was employed to select participants who possessed a high degree of relevance to the study's central theme (Etikan et al., 2016). The targets group consisted of Grade 6 mathematics teachers responsible for teaching the concept of *area* during Term 3. This purposive selection was informed by the desire to gather in-depth insights from teachers directly engaged with the specific topic and timeframe of interest, thereby enhancing the study's credibility. Within the purposive sampling framework, a specific technique known as criterion purposeful sampling (Maree, 2016) was used to select the three participants, namely, three teachers from three different schools within the same district. This technique is a subset of purposive sampling and involves identifying and selecting cases that meet predefined criteria (Etikan et al., 2016).

In my study, the criteria were three-fold: (i) the participants had to be Grade 6 mathematics teachers in public primary schools, (ii) they had to teach the concept of *area* during Term 3, as outlined in the Department of Basic Education's Annual Teaching Plan (ATP), and (iii) they had to be teachers registered with the South African Council for Educators (SACE). This rigorous criteria-based case sampling approach facilitated the identification of participants who possessed direct and relevant experience in line with the study's focus, thereby enhancing the depth and precision of the gathered data.

Convenience sampling, on the other hand, was integral to ensuring the practical accessibility of the chosen participants (Liaga, 2019). The schools' proximity to my residence and workplace played a significant role in this aspect of sampling. All three selected schools were located within the same education district in the Gauteng province of South Africa. This strategic choice not only streamlined the logistical aspects of data collection but also optimised resource utilisation, aligning with the principles of efficient research design. By thoughtfully intertwining purposive and convenient sampling techniques, my study provided well-rounded and insightful information regarding Grade 6 mathematics teachers' facilitation and use of IBL aspects, to teach the concept of *area*.

3.5. DATA COLLECTION INSTRUMENTS

When employing a qualitative study, it becomes possible to develop a comprehensive understanding of the research topic, as diverse sources of information contribute to various opinions and findings (Creswell, 2018). Using multiple data collection techniques aligns with the interpretivist paradigm, which emphasises the existence of multiple realities rather than a singular reality (Baxter & Jack, 2008). In addition, using multiple data collection has the added benefit of triangulating the data.

Triangulation is validating data by employing various approaches, data sources, or even different researchers (Lincoln & Guba, 2007). In simpler terms, triangulation is a process whereby researchers combine multiple sets of data of the same type that are relevant to a specific context. Triangulation is a pivotal strategy for enriching my exploration of the facilitation and utilisation of aspects and characteristics of IBL within the Grade 6 mathematics classroom, particularly when approached from a qualitative perspective. Triangulation involves integrating various qualitative data sources to provide a more comprehensive understanding of the phenomenon under investigation, hence aligning closely with the interpretivist philosophy's emphasis on exploring multifaceted perspectives (Tobin & Begley, 2004).

In practical terms, my study exclusively relied on qualitative approaches, eschewing quantitative data. I applied triangulation by integrating various data collection instruments, such as document analysis, semi-structured interviews, and lesson observations, to substantiate and extend my insights within the specific context of IBL facilitation and utilisation. The fusion of qualitative approaches enabled me to uncover the nuanced and contextually embedded aspects of teachers' facilitation and utilisation of IBL aspects in their practices, staying true to the interpretivist commitment to exploring the depth and complexity of human experiences (Tobin & Begley, 2004). This allowed the study to be reflected on from different perspectives (Louw, 2015). As Creswell (2018) outlined, multiple sources of information may encompass document analysis, observations, and interviews.

3.5.1. Document analysis

The initial phase of my data collection process requires document analysis. This valuable research technique thoroughly examines and interprets written materials or artefacts, such as lesson plans. As Maree (2016) outlined, this method gathers insightful information that is directly relevant to my research topic. Creswell (2018) further emphasised that document analysis focuses on scrutinising documents related to the phenomenon under investigation.

I utilised document analysis as the first stage to explore incorporating and utilising aspects and characteristics of IBL into the lesson plans and preparations according to the area concept. By reviewing the lesson plans created by the participating teachers, I intended to identify how these IBL aspects were brought into each teacher's lesson plans and lesson preparations. The specific aspects under analysis include references to IBL aspects, the presence of open-ended questions, opportunities for learner inquiry, and the inclusion of hands-on activities that are designed to promote critical thinking and problem-solving skills (for further details, refer to Annexure G). It is important to note that document analysis is the initial step in a comprehensive data collection process, combining document analysis, observation, and semi-structured interviews. This holistic approach is designed to provide a thorough understanding of how aspects of IBL are integrated into teachers' lesson plans.

3.5.2. Observation

In the second phase of data collection, I conducted observation of lessons. I employed an instrument described by Maree (2016) as a systematic recording of the behaviours of participants, objects, and occurrences without engaging in questioning or direct communication. Creswell (2018) stated that effective observation requires the identification of participants' potential and the establishment of a positive rapport. My focus during classroom observation was on examining how teachers implemented aspects and characteristics of IBL to teach mathematics, specifically the concept of *area*, based on the insights gained during the document analysis phase.

To collect data for the study, I observed the lessons in which each participating teacher taught the topic of the *area*. During these observations, I made field notes on my observation sheet and recorded the lessons on video—the recorded lessons served as valuable materials for accurate data analysis (McMillan & Schumacher, 2010). One of the key advantages of using recorded video was that it allowed me to review classroom episodes and occurrences multiple times, providing an in-depth understanding of the events. In other words, through repeated reviews of the recordings, I could conduct a thorough analysis, ensuring that no important details from the lessons were overlooked. Furthermore, I have attached the proposed observation protocol Annexure H to facilitate systematic data collection.

3.5.3. Interviews

Following the completion of document analysis and lesson observations, I engaged in interviews with each teacher. Interviews were a crucial component of my study because relying solely on document analysis and observations would not have sufficed to ensure the quality and depth of the research. As Patton (2015) explained, "We interview people to find out from them those things we cannot directly observe and to understand what we have observed. We cannot observe feelings, thoughts, intentions, and behaviour" (p. 426).

There are two different types of interviews: (i) unstructured interviews and (ii) structured interviews with semi-structured and fully structured interviews, which fall under the heading Mueller & Segal, 2015).

(i) Unstructured interviews involve open and spontaneous conversations between the interviewer and the participants (Maree, 2016). These interviews lack predefined guidelines regarding specific discussion topics and the depth of conversation (Mueller & Segal, 2015). The unstructured approach offers ample flexibility for gathering participant information (Mueller & Segal, 2015).

(ii) Structured interviews, on the other hand, adhere to a predetermined set of questions, which may include follow-up queries (Mueller & Segal, 2015). They follow a uniform questioning sequence and systematically evaluate participants' responses (Mueller & Segal, 2015). Structured interviews can be categorised into two types: (a) fully structured and (b) semi-structured. In a fully structured interview, questions are presented exactly as written to the participant in a predetermined order (Mueller & Segal, 2015). The wording of any follow-up questions is predetermined, and interviewers must adhere strictly to this format without deviation (Mueller & Segal, 2015). In contrast, semi-structured interviews start with predetermined questions (Jamshed, 2023) typically asked verbatim to the participant. However, interviewers have significant flexibility in probing and following up on responses (Mueller & Segal, 2015). I can adapt and add personalised and context-specific questions to gather data more accurately. Semi-structured interviews often complement information obtained from other sources (Maree, 2016). These qualitative interviews aim to gain an in-depth understanding of participants' perspectives, offering valuable insights if conducted effectively (Maree, 2016).

In my study, I opted for semi-structured interviews (See Annexure I) as the data collection instrument of choice to understand how teachers effectively facilitated and implemented aspects of IBL in teaching the concept of *area* to Grade 6 learners. The choice of semi-structured interviews was particularly relevant for several reasons. Firstly, semi-structured interviews allowed for a balanced approach to data collection (Creswell & Poth, 2017). By employing predetermined questions as a foundation for the interview, I was able to guide the conversation in a structured manner, ensuring that I covered essential topics related to IBL in Mathematics instruction. Secondly, using semi-structured interviews allowed me to formulate additional questions as the interview process unfolded. This adaptability is crucial because it enables me to delve deeper into the participants' responses (Mueller & Segal, 2015).

By tailoring follow-up questions to the specific insights I gathered from each participant, I explored emerging themes or unique practices related to IBL in teaching the concept of *area* (Mueller & Segal, 2015). This adaptability ensured that the data collection process remained responsive to the participants and allowed for a more nuanced and comprehensive understanding (Creswell & Poth, 2017). Furthermore, the semi-structured interviews were positioned within a broader research methodology, including document analysis and lesson observations (Mueller & Segal, 2015).

This triangulation of data sources was a powerful approach to validate and cross-reference findings (Lincoln & Guba, 2007). The interviews were vital to the triangulation process, helping corroborate or refine insights gathered from the document analysis and lesson observations. Lastly, the predetermined questions used in the interviews were specifically designed to focus on how the participants facilitated, utilised and incorporated IBL aspects into their teaching planning and preparations and their mathematics classroom when teaching.

This targeted approach ensured that the interviews homed in on the core objectives of my study, aligning with the research questions and objectives. In summary, my study's choice of semi-structured interviews was deliberate and highly relevant. It offered a balanced approach, combining structure with flexibility, to collect rich and comprehensive data on the facilitation, utilisation and implementation of IBL in Grade 6 mathematics education. These interviews were critical in a triangulated data collection approach, ensuring that my study's objectives were met and facilitating a deep exploration of the participants' experiences and practices.

3.6. THE RESEARCH PROCEDURE

A research procedure can be defined as a structured and systematic sequence of activities and tasks essential for the successful execution of a research study (Singh & Singh, 2021). These activities typically encompass the identification of a research problem, conducting a comprehensive literature review, designing the research methodology, specifying the sampling approach, gathering empirical data, implementing the research plan, performing data analysis, drawing general conclusions, interpreting findings, and ultimately, presenting the research results in a formal report or presentation format (Singh & Singh, 2021).

The research procedure for my study commenced with document analysis. In this initial phase, I analysed various documents related to teaching the concept of the area by the Grade 6 mathematics teacher. I requested it prior to the lesson observations and interviews.

This included a thorough analysis of teachers' lesson plans, worksheets, and any other relevant artefacts used by the teacher to prepare for their *area* lesson. The goal was to understand how aspects and characteristics of IBL were incorporated and facilitated into the *area* lessons before the lesson was presented. This analysis allowed me to assess whether the teachers considered IBL aspects and characteristics during their lesson planning phase.

Subsequently, I moved on to the phase of lesson observation. Here, my approach was multifaceted, focusing not only on the teachers’ teaching methods and content delivery but also on the learners' engagement and involvement during the lessons. I observed the teachers’ presentation style, teaching methodology, and learners' interaction with materials and content.

Additionally, I evaluated the learners’ ability to apply their new knowledge to new and practical situations. I also analysed the visual presentation of information on the whiteboard or blackboard and textbook activities.

Following the comprehensive lesson observations, I concluded my data collection process with semi-structured interviews with each teacher. The interviews with Teacher 1 lasted 18 minutes, Teacher 2 lasted 8 minutes, and Teacher 3 lasted 9 minutes. These interviews provided me with an invaluable opportunity to delve deeper into the nuances of the teachers’ approaches to planning and executing the integration of aspects and characteristics of IBL into their lessons.

The interview questions were thoughtfully designed to elicit detailed information regarding the aspects of IBL incorporated into their lesson plans, classroom presentations, and broader teaching practices. Through these semi-structured interviews, I understood how IBL was embraced and practically executed within the teachers’ classrooms.

The meticulous progression from document analysis to lesson observation and semi-structured interviews, as illustrated in Figure 3.2 below, allowed for a holistic view of the teachers’ adoption of IBL aspects and characteristics. This layered approach showcased their conceptual understanding evolving into practical application in the classroom. As depicted in the figure, the combination of these methodologies culminated in a comprehensive exploration of the intricacies of IBL practices within the context of Grade 6 mathematics education.

Figure 3.2.

My research procedure

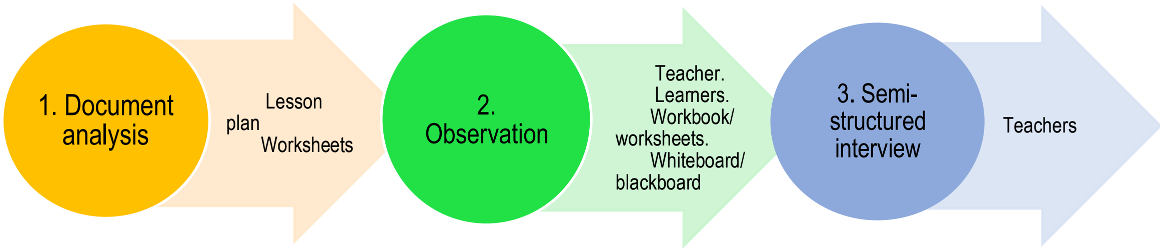


Table 3.2 below offers a visual representation of the specific dates and the precise area concepts observed, facilitating a clear temporal and thematic mapping of the observations.

Table 3.2.

The dates and duration of data collection

Grade 6	Date	Duration of Document Analysis	Duration of Observation	Duration of Interview	Teacher's Name	Concept Being Taught
Lesson 1	12/09/2023	10 minutes	53 minutes	18 minutes	Teacher 1	*Area* with rectangles and squares.
Lesson 2	20/09/2023	20 minutes	35 minutes	8 minutes	Teacher 2	*Area* with rectangles, squares, and irregular 2D shapes.
Lesson 3	27/09/2023	10 minutes	19 minutes	9 minutes	Teacher 3	*Area* with various 2D shapes (trapezium, triangle, square, etc.).

3.7. DATA ANALYSIS AND INTERPRETATION

Data analysis entails manipulation through coding, index sorting, and retrieval (van Graan, 2019). As Maree (2016) suggested, qualitative research analysis commences during the early stages of data collection. Throughout this analysis process, careful attention was given to participants' experiences and practices (McMillan & Schumacher, 2010), with their insights as essential components for a comprehensive understanding of the investigated phenomenon. Guided by Braun and Clarke's (2006) six-stage thematic analysis, my approach followed the process illustrated in Figure 3.3 below.

Figure 3.3.

Six stages of thematic analysis by Braun and Clarke 2006

Thematic analysis (TA) identifies, analyses, and reports patterns within qualitative data (Braun & Clarke, 2006). Its primary aim is to uncover valuable themes (patterns) within the data and then use them to analyse research findings, thus aiding in the interpretation and comprehension of a study (Maguire & Delahunt, 2017). In qualitative research, vast amounts of data are typically collected, necessitating effective data management strategies to prevent overwhelming the researcher (Nieuwenhuis, 2016).

I explored the integration of IBL aspects into a Grade 6 *area* lesson. Diverse data sources such as documents, lesson observations, teacher interviews, photographs, and video and audio recordings required comprehensive data management. As Dey (1995) and Nieuwenhuis (2016) recommended, the coding process proved highly effective in organising this varied data. Coding systematically categorised data into coherent and detailed themes or categories, facilitating nuanced analysis (Creswell, 2018).

Before my research, I identified relevant categories or themes for my study. This aligned with Stemler's (2001) concept of categorising data before and during research, providing a focused approach to data collection. Throughout the research process, I often encountered data that did not immediately align with a predefined code. In such instances, a critical examination became necessary to determine whether the data should be coded or discarded, following the guidance of Braun and Clarke (2006) and Nieuwenhuis (2016). Irrelevant data was thoughtfully discarded, thereby maintaining the study's comprehensiveness and alignment with the research purpose.

In qualitative research, two levels of coding are prominent: semantic and latent. Semantic analysis means analysing codes to identify common themes and meaningful patterns, making it inductive (Maguire & Delahunt, 2017). This approach is concerned with the explicit content of the data. In contrast, latent analysis, in line with the framework proposed by Maguire and Delahunt (2017), delves into the subtext and underlying assumptions and ideologies shaping the semantic content of data. It seeks to identify hidden ideas and beliefs.

These two levels of coding allow for a holistic understanding of the data, aligning with the principles of qualitative analysis (Creswell, 2018; Maguire & Delahunt, 2017; Braun & Clarke, 2006). To facilitate TA in my study, I adhered to the six steps formulated by Braun and Clarke (2006). These steps guided the systematic exploration and interpretation of my data, ensuring rigour and comprehensiveness.

Stage 1: Familiarisation

The initial stage of the research process entailed approaching the data with an open and non-judgmental mindset, thereby aligning with Huckin's recommendation (2004). Stressing the significance of this phase, Babbie and Mouton (2000) and Braun and Clarke (2006) underscored the importance of enabling the researcher to become well-acquainted with the collected data and facilitating the potential generation of pertinent codes.

I started with document analysis, focusing on the teachers' lesson plans and preparations before they taught the lesson. This approach allowed me to determine whether the teachers' incorporated aspects of IBL into the planning and preparation stage and considered the basic principles of SDT. By analysing these documents, I could identify initial evidence of an IBL approach and the fostering of SDT principles.

Next, I observed the teachers while they taught the Grade 6 lesson on the concept of area. During these observations, I analysed whether the teachers included the elements from their planning and how they interacted with the learners. I paid particular attention to how the teachers facilitated and utilised IBL aspects in their lessons. This step was crucial in understanding the practical application of IBL and SDT principles in a real classroom setting.

Following the observation, I interviewed the teachers. During the interview, I reviewed the 5E Instructional Model and asked the teachers how they incorporated or tried to incorporate these aspects into their lessons. Additionally, I explored how the teachers fostered learners' autonomy, competence, and relatedness, which are key components of SDT. To further enrich my understanding, I took photographs of various elements related to the lesson, including learners' work, the classroom setup, the teachers' lesson plans, resources used during the lesson, and the work displayed on the board.

These visual data points provided additional context and helped to triangulate my findings. Rather than constantly searching for direct answers to my research inquiries, I aimed to understand how IBL elements were incorporated within all forms of resources. This familiarisation process afforded me a holistic perspective of the data, fostering deeper engagement and a heightened grasp of my dataset.

Stage 2: Coding

In the second stage, the collected data are organised and analysed systematically through coding. Coding involves assigning specific labels to parts of the data to describe their content (Maree, 2016). This process enables the researcher to create a condensed summary that captures the data's key themes and recurring elements. Importantly, there are no strict limitations on the number of codes one can employ during this phase, as researchers are encouraged to use as many codes as necessary, provided that they are relevant to the study's focus (Braun & Clarke, 2006). Furthermore, the same data can be linked to multiple codes, allowing for a nuanced analysis (Braun & Clarke, 2006).

My study aimed to assess whether the teachers incorporated IBL elements into their lessons. To achieve this, I developed interview questions aligned with the 5E's instructional model—Engagement, Exploration, Explanation, Elaboration, and Evaluation—which provided a structured data coding framework. I framed specific questions for each phase of the 5Es to ensure that the responses from teachers would directly reflect their use of IBL. These questions were designed to align with the secondary research questions guiding my study, particularly the one investigating how mathematics teachers facilitate inquiry-based lessons when teaching the concept of area. For each phase, I posed the following questions to the teachers:

1. Engagement: "How do you ensure that learners are engaged during your lessons and activities?" - "What strategies do you use to capture learners' attention at the beginning of the lesson?"

2. Exploration: "How do you provide learners with opportunities to explore new ideas and phenomena?" - "Can you describe an activity where learners investigated a concept independently?"

3. Explanation: "How do you create opportunities for learners to explain their understanding?" - "Do you allow learners to present their reasoning to the class?"

4. Elaboration: "How do you ensure learners apply their knowledge in new situations?" - "Can you share an example of how learners used what they learnt in a real-world context?"

5. Evaluation: How do you assess learners' understanding of the content?" - "Do learners have opportunities to reflect on what they have learnt?"

These questions were designed to explore how teachers incorporated each phase of the 5E model, providing insight into the extent to which IBL was employed during lessons. The resulting codes were applied to the teachers' lesson plans and observations of how these phases were implemented in the classroom. By integrating the 5E model with SDT principles, I could systematically assess the lessons' planning and execution. This dual approach ensured a thorough analysis of how IBL and SDT principles were embedded and facilitated in the teaching process.

Stage 3: Generating Themes

In this stage, the coded data from Stage 2 was meticulously aligned with the primary and secondary research questions. This alignment was the cornerstone for structuring themes that guided subsequent data analysis, especially when discernible patterns emerged from the coded data. Developing themes is an integral part of TA, as themes often comprise a combination of codes and are hierarchically organised. At this point, a key consideration was ensuring that no data were discarded prematurely, as doing so could potentially overlook valuable insights that might contribute to a more nuanced understanding of the research (Braun & Clarke, 2006). This step is critical as it allows for a systematic approach to addressing the research questions by ensuring that the themes generated are deeply rooted in the data (Maree, 2016). It is crucial to recognise that the themes initially developed at this stage are not fixed; they are subject to further revision and refinement during the ongoing data analysis process.

This flexibility allowed me to continuously adapt the themes as my understanding of the research findings deepened (Braun & Clarke, 2006). Moreover, this iterative approach was essential in ensuring that the themes reflected the complex and multifaceted nature of the data, particularly concerning teaching mathematics through IBL and applying SDT principles in the classroom. From the coded data, I derived themes that aligned with my secondary research questions, particularly SRQ3, which focused on teachers' facilitation of and challenges experienced in inquiry-based lessons. Two prominent themes emerged about the autonomy, competence, and relatedness of learners during the lessons:

1. *Autonomy in Learning*: Teacher 1 encouraged learners to ask questions and engage in discussion. However, it was observed that certain learners received more attention than others, limiting the remaining learners' autonomy. Time constraints also significantly impacted learner autonomy, as Teacher 1 imposed strict time limits (ranging from 5 to 20 seconds) for learners to respond to questions. This limited the learners' opportunities for independent exploration and critical thinking. Teacher 2, in contrast, allowed for more learner participation, giving them space to explore new ideas through hands-on activities. However, this exploration was still heavily guided by the teacher, which prevented learners from fully exercising their autonomy in the learning process.

2. *Development of Competence*: Teacher 1's strict time limits diminished learner autonomy and impacted their sense of competence. Many learners appeared hesitant to participate, suggesting a lack of confidence in their abilities, further exacerbated by the rushed pace of the lessons. Teacher 3, while encouraging deeper exploration of concepts, heavily guided the process, which, although supportive, restricted learners' development of independent problem-solving skills. The tension between providing

guidance and fostering competence was evident, as learners were not given adequate space to independently apply their knowledge and skills.

The emergence of these themes provided insight into the varying levels of autonomy and competence promoted in the classroom and how these factors influenced the overall facilitation of IBL.

Stage 4: Reviewing Themes

At this stage, I carefully reviewed the identified themes to ensure that they were effectively interrelated with the various codes and demonstrated coherence and alignment with the research questions (Maree, 2016). It was essential to verify that each theme was sufficiently supported by data and maintained the dataset's original conceptual coherence, as Braun and Clarke (2006) suggested. This review process is critical for establishing the robustness of the TA, ensuring that the themes truly reflect the complexities of the data and are not superficial or arbitrary.

During this phase, I thoroughly re-examined all the coded data to verify the accuracy and completeness of the themes. I also consolidated codes with similar meanings to avoid duplication and ensure a more streamlined analysis. This process enabled me to identify gaps and inconsistencies within the themes. Where such gaps or discrepancies were observed, I sought to understand possible reasons by drawing on multiple data sources, including interviews, classroom observations, and documents. For example, one significant gap I identified was the minimal emphasis placed on the ‘Engagement’ and ‘Exploration’ phases of the 5E’s model across the observed teachers. Teachers 1 and 2 predominantly focused on the ‘Explanation’ phase, where teacher-directed instruction took precedence, leaving limited opportunities for learners to engage deeply with the material. Teacher 3 incorporated the ‘exploration’ phase more effectively but limited learner autonomy due to excessive guidance.

Additionally, Teacher 1’s strict time constraints and lack of active learner participation significantly hindered the effective incorporation of IBL principles. These gaps in facilitating inquiry-based lessons were noteworthy, as they underscored teachers' challenges in fully implementing IBL in the classroom.

Stage 5: Defining and Naming Themes

In this stage, researchers must delve deeper into the essence of each theme, considering how they interconnect to form a cohesive narrative about the data (Maree, 2016). Braun and Clarke (2006) emphasised the importance of clearly defining and naming themes to maintain the coherence and integrity of the TA. This step involves refining the themes to ensure that they encapsulate the central message of the data by aligning closely with the research questions and the overarching narrative of the study.

During this phase, I refined the themes identified in Stage 3 and ensured that they encapsulated the core aspects of the data. This process involved revisiting the research questions, particularly the secondary research questions (SRQ1, SRQ2, and SRQ3), to ensure that the themes addressed the key issues related to the design and facilitation of IBL in the classroom. For example, the theme of ‘autonomy in learning’ was not only relevant to SRQ3 (How do mathematics teachers facilitate an inquiry-based lesson and, if any, what related challenges do they experience when teaching the concept of area?) but also addressed SRQ1 (How do mathematics teachers design learning activities that promote autonomy, competence, and relatedness when teaching the concept of area?). By refining the themes in this manner, I was able to create a coherent and nuanced narrative that connected the various aspects of the study.

Stage 6: Producing the Report

The final stage of TA involves compiling a comprehensive report that presents the findings coherently and compellingly. This report should clearly articulate the relationship between the themes and the research questions, thereby providing a detailed account of how the themes were derived and how they contributed to answering the research questions (Maree, 2016). Braun and Clarke (2006) stated that the report should present a clear narrative that integrates the themes into a cohesive argument about the data. In this stage, I ensured that the themes were presented logically, starting with a detailed explanation of each theme and how it related to the research questions. The report also highlighted teachers' challenges in implementing IBL, particularly in promoting learner autonomy and competence.

In this stage, the coded data from Stage 2 should align with the primary and secondary research questions. This alignment was the foundation for structuring themes that guided the subsequent data analysis, particularly when discernible patterns emerged from the previously created codes. It is worth noting that themes often comprise a combination of codes and are organised hierarchically. Data should not be discarded at this juncture, as it may hold valuable insights (Braun & Clarke, 2006). This step is important as it enables me to address the research questions effectively (Maree, 2016). It is crucial to recognise that these initially developed themes were not set in stone; they could be adjusted or even completely revised during data analysis, thereby allowing for a more refined understanding of the research findings (Braun & Clarke, 2006).

I presented the findings in a structured manner, clearly outlining the identified themes and their relevance to the research questions. I provided evidence from the data, including direct quotes from interviews, observations, and document analysis, to support each theme. This detailed reporting ensured transparency and rigour in presenting my research findings.

TA offers several advantages, particularly for novice researchers who may not be well-versed in more complex qualitative analysis methods. Unlike other analytical approaches that require specific theoretical frameworks or epistemologies, TA allows researchers to apply them alongside any theory or methodology they prefer (Dawadi, 2020).

This flexibility allows for creating comprehensive and intricate data descriptions (Braun & Clarke, 2013; Braun & Clarke, 2006). This method of data analysis proved highly relevant to the study as it facilitated the development of themes from my data, ultimately helping me discern the objectives and purposes of these themes.

3.8. QUALITY CRITERIA

In a qualitative study, trustworthiness refers to confidence in the techniques employed throughout the data collection, interpretation, and analysis processes and the methods used to ensure high-quality data (Connelly, 2016). Connelly stated that achieving trustworthiness relies on several criteria, namely credibility, dependability, confirmability, and transferability, which are further discussed below.

3.8.1. Credibility

Credibility, in the context of a qualitative study, refers to the confidence and trustworthiness placed in the research findings (Graneheim & Lundman, 2004). Triangulation is a key approach to enhance credibility, as Maree proposed (2016). Triangulation involves utilising multiple sources of data collection to validate and corroborate the findings (Hadi & Class, 2016). By employing a multi-method strategy, such as interviews, document analysis, and observation, I intended to incorporate diverse perspectives and multiple realities (McMillan & Schumacher, 2010).

This approach allowed for a comprehensive exploration of the research topic from various angles, increasing the credibility and richness of my study's findings. By considering different data sources, my study captured a more nuanced understanding of the phenomenon under investigation.

3.8.2. Dependability

Dependability in qualitative research refers to the consistency and stability of collected data (Connelly, 2016). To ensure dependability in my study, I employed several strategies. Firstly, I selected participants who could provide rich and insightful information, promoting reliability. Detailed field notes were maintained, documenting study details for transparency. Direct quotes from participants were used to support key points, thereby

reducing personal bias. Open communication with participants and seeking feedback from superiors or colleagues enhanced dependability.

3.8.3. Transferability

As defined by Graneheim and Lundman (2004), transferability refers to the extent to which the research findings can be applied to other settings. While generalizability is not typically pursued in qualitative studies, researchers still strive for transferability (Connelly, 2016). My study enhanced transferability by providing a comprehensive and detailed description of the research context, participants, and methodology (Maree, 2016). By offering this level of transparency, readers can gain a deeper understanding of the study’s parameters. Hence, they were better equipped to assess the relevance and applicability of the findings to their respective settings.

3.8.4. Confirmability

Confirmability, as discussed by Connelly (2016), refers to consistency and objectivity in a study. Confirmability was achieved through triangulation. Three participants and data collection techniques were used to uncover similar patterns and themes. Video recordings provided tangible evidence, which was shared with the supervisor for transparency and verification. Triangulation was implemented to enhance the quality of my study by using multiple methods to validate the findings (Maree, 2016). Data was triangulated by combining interviews and observations to ensure consistency and bolster credibility, transferability, dependability, and confirmability.

3.9. ETHICAL CONSIDERATION

Ethical considerations are fundamental to conducting research, especially when interacting with human participants in their natural environments. Research ethics ensure that participants are treated with respect, dignity, and confidentiality and that their rights and welfare are protected throughout the research process (Creswell, 2018). As a qualitative researcher, I am acutely aware of the ethical obligations that must be adhered to, particularly in studies involving learners and teachers in an educational setting. Before commencing my study, obtaining written approvals from the University of Pretoria Ethics Committee, the Gauteng Department of Education, and the principals of the schools where the research was conducted was imperative. Ethical approval ensures that the research adheres to legal and moral standards, thereby minimising harm and addressing issues such as informed consent, confidentiality, and the right to withdraw (Maree, 2016).

3.9.1. Informed consent

Informed consent is a crucial ethical principle in research, ensuring that participants fully understand the nature of the study, their role, and their rights before they agree to participate (Maree, 2016). Protecting participants from harm and safeguarding their autonomy by providing sufficient information to make a voluntary and informed decision is essential. Informed consent also involves clearly communicating the study's purpose, procedures, potential risks, and benefits (Creswell, 2018). Participants must be made aware of their right to withdraw from the study at any point without facing any consequences. after receiving approval from the relevant authorities, including the University of Pretoria Ethics Committee, the Gauteng

Department of Education, and the school principals, I ensured that all participants were fully informed about the purpose and nature of the research. I disclosed how I would collect data, including interviews, observations, and document analysis, and explained the voluntary nature of participation.

Participants were informed that they could terminate their involvement at any point or request a break (time-out) during the data collection process without any negative repercussions. To formalise this, I provided consent forms to the teachers, learners, and parents, outlining the details of the study and their rights. These forms required signatures from the participants, indicating that they had been fully informed and had agreed to participate voluntarily. This process ensured that all participants were aware of their roles and the research processes, thereby aligning the study with ethical standards in qualitative research (Sanjari et al., 2014).

3.9.2. Confidentiality and anonymity

Confidentiality and anonymity are fundamental ethical considerations in research that protect participants' privacy and safeguard their identities. Confidentiality refers to the researcher's responsibility to keep personal information shared during the study private, thereby ensuring that no unauthorised individuals could access participants' data (Creswell & Poth, 2018). In contrast, anonymity ensured that participants' identities were not disclosed, even to the researcher, or were kept undisclosed in the research reporting (Babbie, 2021). While both concepts aim to protect participants, confidentiality focuses on safeguarding the information, while anonymity ensures that no identifying information is connected to the participants.

I ensured both confidentiality and anonymity. To protect the identities of the research site and participants, the names of the schools were not disclosed, and the identities of the teachers, learners, and parents were anonymised. Specifically, the teachers were referred to as Teacher 1, Teacher 2, and Teacher 3 to protect their anonymity, thereby ensuring that their real names were not used or disclosed in the data analysis and reporting process. To anonymise the learners, I blurred their faces in any visual data and removed all identifying features, such as names or school logos, from materials. No identifying information that could be traced back to the learners or their families was included in the study. This ensured that both learners' and parents' identities remained confidential throughout the research. Furthermore, I ensured that all data collected remained confidential and accessible only to those directly involved in the study. No information was shared with individuals or entities that were not part of the research. Thus, I strictly adhered to both principles of privacy, ensuring that all participants were protected and that their personal information was kept confidential and anonymous as per the ethical guidelines of qualitative research (Maree, 2016).

3.9.3. Care and fairness

Care and fairness are critical ethical principles in research, focusing on participants' well-being and equitable treatment. Care involves the researcher's responsibility to ensure participants' physical and emotional well-being while demonstrating empathy and respect throughout the study (Guillemin & Gillam, 2004). Fairness refers to treating all participants equitably, ensuring that the research process did not exploit or disadvantage any participant group and that their contributions are acknowledged and valued (Beauchamp & Childress, 2013).

Care was reflected in ensuring that all participants felt comfortable and respected throughout the research process. I prioritised open communication and actively listened to participants' concerns while adjusting the study protocol to address their needs and preferences. For instance, I allowed participants to choose convenient times for data collection and provided options for pausing or withdrawing from the study if they felt uncomfortable at any point. Fairness was upheld by ensuring that all participants were treated equitably. I applied fair practices in selecting participants, avoiding biases favouring certain individuals. I also ensured that all participants had equal access to information about the study, including their right to withdraw or ask questions. In reporting findings, I carefully anonymised all data to prevent individuals from being unfairly represented or identified. Additionally, I ensured that the benefits and risks of participation were communicated and that no participant was disadvantaged or exploited due to their involvement in the study. By adhering to these principles of care and fairness, I aimed to foster a research environment that respected and valued each participant, aligned with ethical standards and enhanced the integrity of my study (Beauchamp & Childress, 2013; Guillemin & Gillam, 2004).

3.9.4. Safety

Ensuring the safety of participants is a critical aspect of conducting ethical research. Safety encompasses physical and psychological aspects, ensuring that participants are not exposed to harm or distress throughout the research process (Creswell & Poth, 2018). In my study, I considered the following measures to ensure the safety of participants:

Physical Safety: The study was conducted in a controlled environment where all activities and interactions were planned to minimise physical risks. For example, during classroom observations, I ensured that all activities were conducted according to the school's safety protocols and that no physical harm could come to the learners or the researchers.

Emotional and Psychological Safety: Creating an environment where participants felt secure and supported was crucial. This involved maintaining a nonjudgmental approach during interviews and observations, and reassuring participants that their responses would be treated confidentially and respectfully. I also ensured that participants were aware they could withdraw from the study without any repercussions, reducing potential stress or discomfort.

By implementing these safety measures, the study aimed to protect participants from harm and ensure a supportive and respectful research environment (Creswell & Poth, 2018).

3.10. CONCLUSION

This chapter delved into the methodology guiding my study, encompassing paradigm perspectives, research design and approach, data analysis and interpretation, validity and trustworthiness, and ethical considerations. The interpretivist paradigm underpinned the research, seeking to comprehend contextual complexities for an in-depth exploration of participants' engagement with IBL and the inclusion and consideration of learners' autonomy, competence, and relatedness.

Adhering to Clarke and Braun's TA stages, the study adopted a qualitative research approach. This approach enabled the exploration and interpretation of data collected through observation, semi-structured interviews, and document analysis. The chapter outlined the processes involved in this qualitative study and how validity and trustworthiness were ensured. Ethical considerations were also highlighted, emphasising the significance of informed consent, confidentiality, and anonymity for participants while they were on the research site, while promoting a relationship built on care and fairness between participants and the researcher.

CHAPTER 4: PRESENTATION OF FINDINGS

4.0. INTRODUCTION

Chapter 4, often called the 'Findings' or 'Results' chapter, is crucial in any research study. The primary function is to present the data collected during the research in a structured and systematic way. This chapter displays the research results without discussion, utilising various formats such as tables, figures, and text to provide a clear overview of the study's discoveries (Creswell & Creswell, 2018). This chapter describes the data, and key findings are outlined, including patterns, trends, and relationships that were identified through the research.

Additionally, the findings are organised according to themes or categories that were relevant to the research questions or hypotheses. This systematic organisation facilitates a clearer understanding of how the data addresses the research objectives (Braun & Clarke, 2006). Ultimately, the findings presented in this chapter serve as the basis for the discussion and interpretation in Chapter 5.

I have adopted an integrated approach towards exhibiting the application, in practice, of three different Grade 6 mathematics teachers:

SRQ1: How do mathematics teachers design learning activities that promote autonomy, competence, and relatedness when teaching the concept of *area*?

SRQ2: To what extent do mathematics teachers incorporate the attributes of the 5E's of IBL when teaching the concept of area?

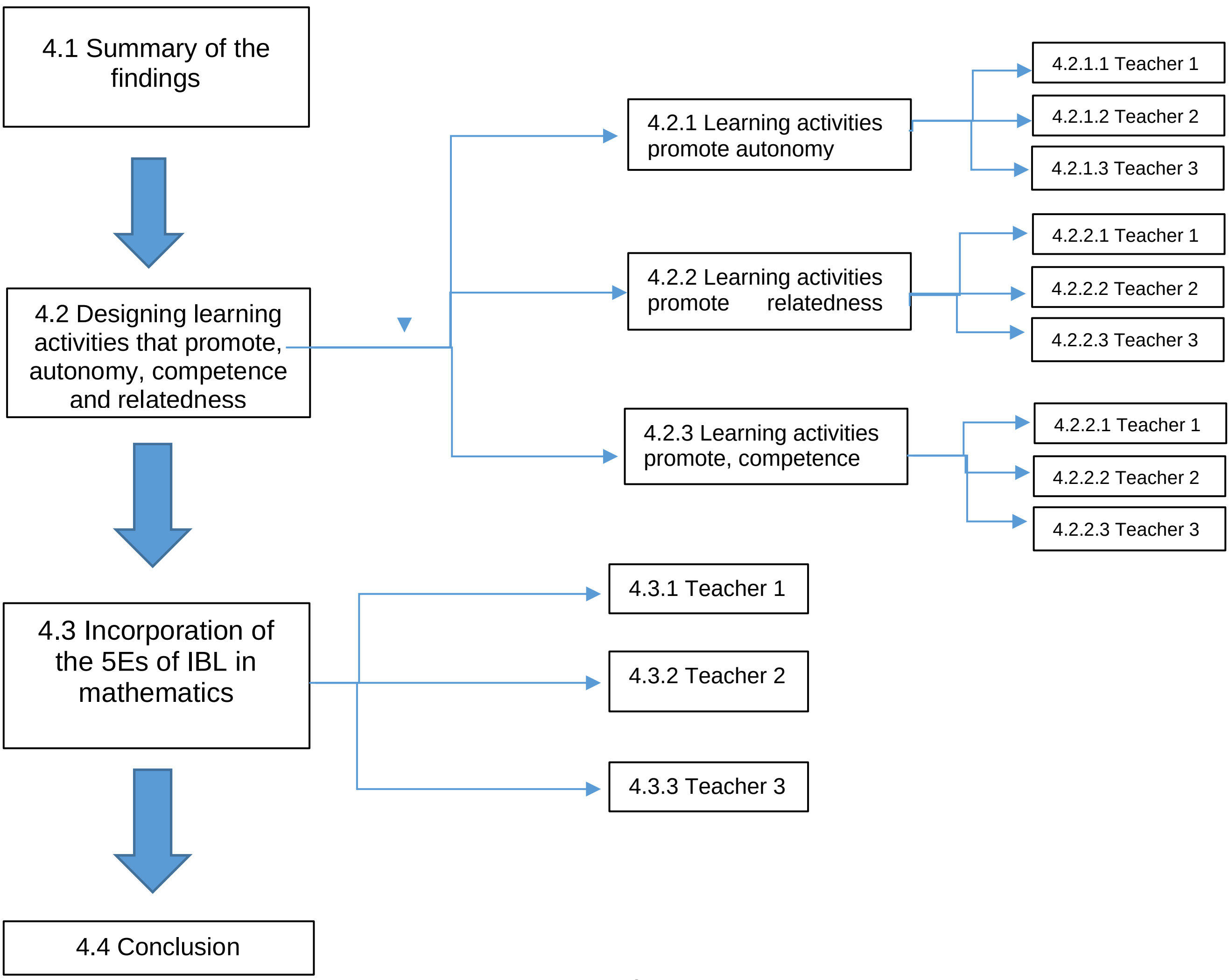
SRQ3: How do mathematics teachers facilitate an inquiry-based lesson, and, if any, what related challenges do they experience when teaching the concept of area?

To maintain confidentiality and anonymity in this study, I assigned pseudonyms to the three Grade 6 mathematics teachers, each representing a different school. Throughout this dissertation, they are referred to as Teacher 1 (associated with School 1), Teacher 2 (associated with School 2), and Teacher 3 (associated with School 3). As indicated in par. 3.10 of Chapter 3, this approach of anonymisation ensured that the identities of the participants and their respective schools were concealed. At the same time, I, as the researcher, could establish a clear association between each teacher and their respective school.

In structuring my findings, I deemed it essential to adhere to a consistent organising format aligned to the research questions. Accordingly, the main subheadings correspond to and are informed by their respective research questions, although I have rephrased the research questions into statements/headings. For example, RSQ 1, 'How do mathematics teachers design and facilitate learning activities that promote autonomy, competence, and relatedness?' has been restructured as heading 4.1, 'Designing and facilitating learning activities fostering, autonomy, competence and relatedness.'

Figure 4.1.

Structure and flow of chapter 4



Furthermore, it is important to note that the teacher's responses are quoted verbatim. As a result, grammatical errors have not been corrected to preserve the authenticity of their original statements.

4.1. SUMMARY OF THE FINDINGS

Approximately 30-35 learners were present across the research sites in each class. The medium of instruction was English at two schools and Afrikaans at one. The learners were generally seated in pairs, except in one school, where small individual tables were used. The tables were arranged in rows facing the board, offering limiting space for movement and interaction.

The findings revealed varied implementations of the IBL model and SDT principles across the observed classrooms. Teacher 1's lessons highlighted a structured approach but lacked in-depth engagement and exploration phases, often emphasising a more teacher-centred method, despite attempts to incorporate IBL. Teacher 2 demonstrated a more balanced integration of the 5E but has struggled to effectively facilitate the elaboration and evaluation stages, often reverting to traditional methods.

Teacher 3, while adopting an engaging and interactive approach, faced challenges in maintaining a consistent focus on the autonomy and competence aspects of SDT, sometimes leading to limited learner involvement. Overall, the observations underscore a gap between the intended IBL practices and the actual classroom dynamics, reflecting a need for further development in aligning instructional strategies with IBL and SDT principles.

4.2. DESIGNING LEARNING ACTIVITIES THAT PROMOTE AUTONOMY, COMPETENCE AND RELATEDNESS

In mathematics education, lesson planning and preparations and integrating the five phases of IBL can positively impact learners' autonomy, competence, and relatedness within their learning environment (Rosli et al., 2022). Autonomy flourishes through learner choice and self-directed learning (Hui & Tsang, 2012), while competence ensures learners feel capable in handling tasks (Deci & Ryan, 2000). Relatedness is achieved when learners feel connected to peers and teachers (Deci et al., 2018).

4.2.1. Learning activities fostering autonomy

4.2.1.1. Teacher 1

In this section, I share my findings from Teacher 1's document analysis, observations and interview. Despite attempts at analysing Teacher 1's document, no lesson plans were completed for teaching the concept of *area*, only "other documents", as Teacher 1 referred to them (See Annexure J and Annexure K). Additionally, Teacher 1 expressed that "preparing a lesson is time-consuming."

Moreover, you can make resources, make PowerPoint presentations, and get your interactive videos. it is very time-consuming, and you do not always have the time to plan.'' In other words, despite informing Teacher 1 that I would require her to share her lesson plan, she did not have any.

However, when conducting the interviews, I asked Teacher 1 to share her obstacles or difficulties when designing interactive and captivating lessons and elaborate on such challenges. Teacher 1's response is captured below:

> *At the beginning of every term, I like to construct dates, calendars, with homework page. I will set out the dates of the weeks and the different concepts that need to be taught from the ATP, so I use my ATP a lot. I think that is your basic framework of the concept that you need to teach so use your ATP. Your week has already been set out, so I usually make a calendar with the textbook pages because I use the textbook and the DBE pages, and I set it out and then I've got a full framework. So, setting out your assessment tasks on the calendar, a date list and your ATP together, works for me.*

However, despite Teacher 1's emphasis on using an ATP for her lesson planning and preparations, she could not provide me with an ATP upon request. Only a Grade 6 mathematics homework paper (Appendix J) was given to me as part of Teacher 1's lesson plan for the *area*.

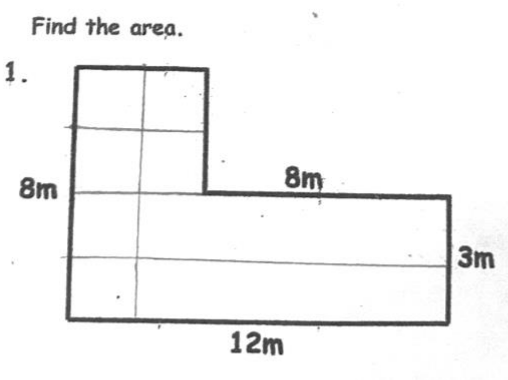
Additionally, during the interview with Teacher 1, I had to find out how she was designing activities that fostered her learner's autonomy. I asked Teacher 1 if she promotes an independent work environment, and she responded thus:

It's quite challenging to get them [learners] to work individually on their own, taking responsibility for their own work. In the class we have dividers, so if I have a formal or a smaller informal assessment, I usually make sure that there is a divider on the table so that they are not joining books. So, everybody's got their own stationery, own book, own textbook, own worksheet on their side of the table that's number one. So, the organisation so that they can have their own things - that's quite important. And yeah, I try to motivate them by walking through my class, seeing if they struggle and if they can go on their own, and I always make sure that there's more questions of similar sort on the worksheet or in the textbook, so that if they are fine and they can work on their own and they understand the concept that they can go on their own with the same type of questions. So, the first three questions are the example and then there's ten more questions. The learners, that's faster that understood the work can go on with number 11, 12 up to 15, so there's always an extra worksheet or some extra stuff that they can keep themselves busy with if they do understand the concept.

Teacher 1 referred to numbers 11, 12, and 15 as indicators of additional questions that the fast-working learners in her class could complete on a worksheet while waiting for the other learners to finish numbers 1 to 10 of the worksheet. Furthermore, during my observation of Teacher 1's lesson, it became apparent that a frequent practice was imposition of approximately 20-seconds that Teacher 1 used while teaching the concept of *area* to show learners how to apply what they knew to calculate the answer.

Figure 4.2.

Problem-solving question



Below is an extract capturing the instructions given to the learners by Teacher 1; explaining to them how to complete the question above:

All right now take your ruler and go cut it. Cut your shape there; go cut it. Cut off the shape, so you're going to take your pencil, ruler, put it down, cut, cut, cut that shape. Now please go and inside the shape write down A and B. Look I'm writing B in the middle because this is one shape. That's A, that's B. Now, you're going to work out the area of A and area of B. I'm giving you 20 seconds.

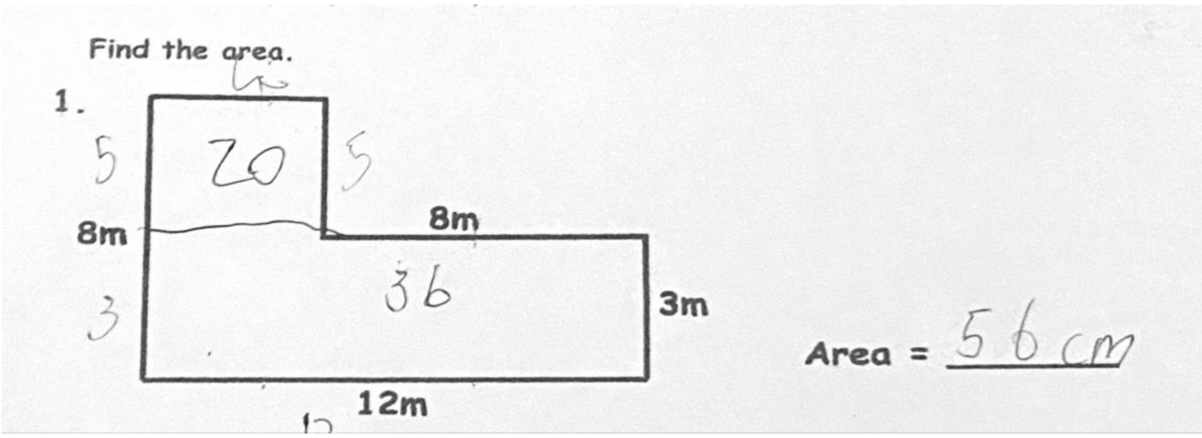
After approximately 20 seconds again, Teacher 1 further instructed:

Guys don't change anything. This is not a length activity; okay, don't convert if it's centimetres, keep to centimetres, okay? So, it's 12 pieces, multiply times three.

I walked around the class to examine learners' calculations, based on Teacher 1's instructions. Figure 4.3 captured how a learner incorrectly completed question 1 despite Teacher 1 providing the learners with the verbal instructions shown above.

Figure 4.3.

Certain learners' calculations



During the interview session with Teacher 1, I inquired about the overall level of independence among her learners**,** to which she had the following response:

Uh, they definitely still rely on me. We try to motivate them, and we try to give them that confidence and building relationships in the classes that they have that self-motivation to work on their own, to be confident, to try a new concept on their own. And to work on their own and go on. But it does not always work that well. You do have the learners that are so dependent on the teacher, and they just need you the whole time. They struggle to go on their own. Yeah, they don't have that ability, so we try to teach them to work on their own and be confident enough to ask questions *and continue with the worksheet and figure it out and try it, but yeah, we definitely still need some time to work on that so that they can be confident to work on their own. I do have maybe 15% of my class that can work confidently on their own.*

Teacher 1 mentioned many strategies to help their learners gain independence, confidence, and motivation. However, I did not encounter any of the above strategies during my lesson observation. Due to the strict no-talking policy that Teacher 1 implemented in her class, the learners did not engage or appear confident enough to ask for assistance.

4.2.1.2. Teacher 2

Teacher 2's lesson was conducted in Afrikaans, and the following analysis was translated into English. In this section, I present my findings regarding how Teacher 2 designed and facilitated learning activities aimed at fostering her learner autonomy. Despite Teacher 2 providing me with her lesson plan (Annexure L) on the topic (onderwerp) of *area* (copperplate), prior to teaching the concept, the document did not include crucial elements necessary for autonomy, such as promoting the learner's agency. Teacher 2's primary focus on her lesson plan revolved around resources such as the textbook (handboek), worksheets (werkkaarte), and PowerPoint slides.

During the interview, I asked Teacher 2 about her approach to promoting an independent work environment, and she responded thus:

Usually, when I'm in a class situation, and especially when it comes to word problem-solving, children will tell you that they are struggling, and then I will tell them "I want you to read through the question again, and I want you to think a little bit" so I will allow them to struggle a little. Not just because I don't want to help them but because I want them to grow and give them the opportunity to think for themselves. And usually, I will tell them in the class it's not that I don't want to help you at that moment. I want you to grow. I want you to think outside of the box. Because what happens during the exam? When you [learner] have a question, and you can't answer it? I'm not there to guide you and help you, so you need to learn to solve things by yourself, to think outside of the box by yourself. And then when a learner really struggles after a few minutes, or so, then I will go and just give them some guidance and then allow them to try again, you know.

Despite Teacher 2's response about allowing learners to think "outside the box" and "giving learners an opportunity to think for themselves," the classroom observation proved otherwise. For instance, immediately after Teacher 2 handed out the worksheet to her learners, Figure 4.4 shows their reliance on Teacher 2, as they immediately raised their hands. The first question on the worksheet asked, '*Define area' (gee die definisie van oppervlakte).*

Figure 4.4.

Learners needing assistance with question 1

While walking through the class to understand what exactly the learners asked Teacher 2, and what they needed assistance with, I noted that the learners asked, "Teacher, must we only write length times by breadth" *(Juffrou, moet ons lengte maal breedte skryf?)* and "Do we write the formula?" *(moet ons die formule skryf?)* and "must this be written in words?" *(moet hierdie in woorde geskryf word?)*.

Furthermore, during the interview with Teacher 2, I asked her to estimate the number of learners who can work independently, and she responded thus:

> *I think if 50%, I don't know if 50% will be correct. But I think less than 50% they can really, really, really work independently. Most of the learners will ask questions, and then some of the learners won't. But you know they are struggling. So, I think that is the problem with our generation. The generations that we have now. They have so much help. They have so much technology and the parents that are always protecting them and stuff. That they struggle to think for themselves, they struggle to do group work. They struggle to work independently and it's like they want that guidance, the whole time – if I can explain it like that.*

At first, Teacher 2 thought that 50% of her learners could work independently. However, towards the end of her response, she highlighted the challenge of learners' autonomy, as she expressed that "*less than 50%*" of her learners were reportedly capable of working independently.

4.2.1.3. Teacher 3

In this section, I share my findings from Teacher 3 on how she designed activities to foster her learner's autonomy. I asked Teacher 3 to provide me with the lesson plan for teaching the concept of *the area prior to the lesson presentation.* However, this was unsuccessful as Teacher 3 did not have a lesson plan prepared nor any other resources available. During the lesson observation, I noticed that Teacher 3's lesson about *area* was taught verbally and kinaesthetically through instructions she gave and learners executing tasks in small groups of 2 to 3 learners. The learners did not work individually in this lesson, and worksheets were not utilised; instead, learners created shapes using square-shaped floor tiles, based on area measurements given by Teacher 3 (see Figure 4.5).

Figure 4.5.

Learner's completing class work in groups

During the interview with Teacher 3, I sought to understand exactly how learners' autonomy was facilitated and how Teacher 3 promoted an independent work environment. Teacher three responded by explaining as follows:

> *I found that difficult in math because we can work independently, but I find it difficult for children to work independently because the (a) classes is too big, the learners in the class are too big and the classroom is too small. So, there's really no space for children to work individually, what I found it's better for children especially in math's to work two-two together. I have a buddy system in my class, so if learner A struggling, I will get learner B to come and assist the learner in the class, it's more relatable with one learner teaches another learner, than sometimes me standing and teaching them.*

When asked about the percentile estimation of the class learners who were capable of working independently, Teacher 3 estimated it at 50%. This prompted me to inquire further, as I wanted to understand how Teacher 3 managed to equip her learners with the skill to work independently, despite my observations suggesting otherwise. I noted that Teacher 3 frequently moved around the classroom, providing instructions to the learners. However, she never left them alone to complete activities independently within their groups not even for a few minutes. Instead, she revisited each group approximately every 30 seconds to check on their progress. If they completed the instructions incorrectly, she would comment, "*I said a triangle with an area of 3 square units."* I then asked Teacher 3 how she managed to get more than 50% of her learners to work independently. She explained:

> *So, I have a very strict classroom policy discipline. If we can say it like that. So, I would usually type the learners that I can see doesn't want to participate today, what I do then is, after I've walked around in my classroom, I will walk around and then I will give the marker to someone that I can see doesn't really want to participate today. I will give them the marker and say, "OK. It's your turn to go and explain to the class." What I have as well is if I have these ice cream sticks with numbers on them, so every child knows their class number in the class. So, I will pick up the stick and "Say, okay, number 20 is Rea, and Rea must answer me." So, I force them to participate in the class.*

Teacher 3 consistently moved from group to group, closely observing and following up on their work. If learners struggled or completed the activity incorrectly, she repeated the instructions or encouraged them to “think.”

4.2.2. Learning activities promote relatedness

Relatedness in the classroom refers to creating an environment where learners feel connected, respected and valued by their teacher and peers. Learners who feel connected tend to be more motivated to engage in classroom activities (Ryan & Deci, 2000). Strategies such as showing warmth and empathy can nurture this sense of relatedness (Muir, 2020).

4.2.2.1. Teacher 1

As previously mentioned, my efforts to analyse Teacher 1’s documents were unsuccessful due to the absence of lesson plans or preparations related to teaching the concept of area. While observing Teacher 1’s lesson, I first noted that she was a strict teacher who disliked an ill-disciplined classroom environment. Before the lesson started, Teacher 1 allowed me to introduce myself to the class, and I explained that I was there for observation purposes. Afterwards, Teacher 1 asked the learners to be on their best behaviour, or that they might land at the “tiny table”. Teacher 1 explained to me in front of the class that learners would “sit at the tiny table” at the front if they were caught talking during her lesson. The “tiny table” was small in front of Teacher 1’s desk, approximately the size of a Grade 1 table and chair, which is notably small and uncomfortable for Grade 6 learners. Furthermore, I noted that the learners were afraid to speak during Teacher 1’s lesson as they rarely raised their hands to ask questions. Instead, the learners often resorted to seeking help covertly from their peers or attempted tasks independently, even if it meant making errors, rather than seeking guidance from Teacher 1. During my interview with Teacher 1, I inquired about the strategies she employed to encourage learners to feel comfortable engaging and participate in her lessons, to which she responded:

> Dividers [placed] on the learners’ tables” to ensure that they [the learners] are not joining books and [that] everybody's got their own stationery, own book, own textbook, own worksheet.

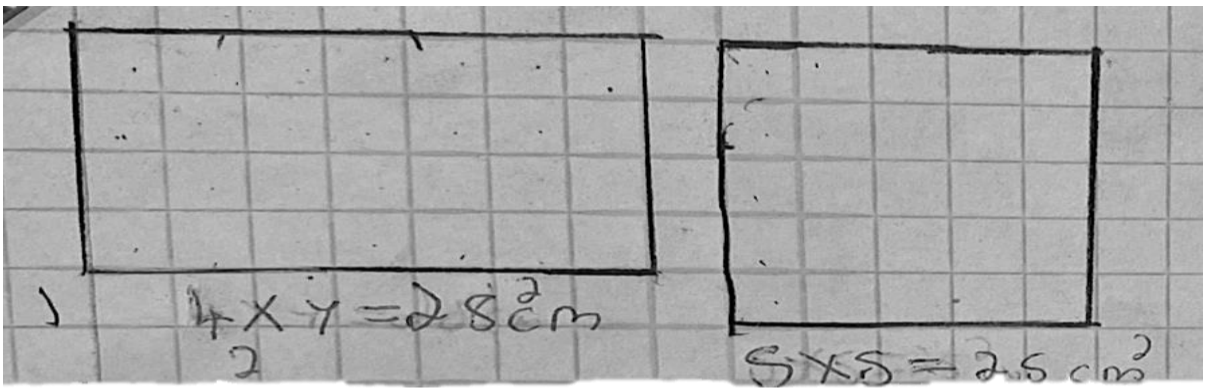
This prompted me to try to find out how Teacher 1 gained an understanding of her learners' interests if the interactions during her lessons were kept to a minimum. I asked Teacher 1 to explain what she did to allow her learners to feel connected to the content she taught, to which she responded:

> *[I] Get something that they [the learners] are really interested in and use that to get them involved. Then, they will definitely pay more attention in class. For example, with their investigation, they [the learners] had to determine who stole the sandwich from the fridge by completing a mathematical equation or word problems or questions and finding the name of the person [criminal] at the end.*

As seen above, Teacher 1 briefly explained the investigation her learners completed during Term 2, demonstrating how she incorporated concepts for learners to relate to. I noted that Teacher 1 prioritised individual work and did not encourage collaboration among learners nor did she practice empathy and warmth. Furthermore, Teacher 1 started the lesson by verbally instructing a learner to draw a rectangle of "4 by 7"; which I assumed was the length and width of a rectangle, which learners had to draw. Afterwards, Teacher 1 asked a particular learner to answer the previous question, and then she moved on to the next question. Teacher 1 then asked the learners to draw a square of "5 by 5". Teacher 1 did not mention square units or areas when instructing learners to draw the shape above. Instead, she assumed that the learners knew what to do. Figure 4.6 below illustrates how a certain learner completed their calculation and accidentally squared '28' instead of 'cm', but Teacher 1 was unaware of this, and the learner's misconception was not corrected.

Figure 4.6.

Misconception of square



Due to the strict classroom setup, the learners did not address their misconceptions. Teacher 1 did not move around the class, encouraging discussions among her learners in order to understand their struggles.

4.2.2.2. Teacher 2

As previously mentioned, Teacher 2’s lesson plan covered the basic aspects of a lesson, such as the topic, resources, and activities that would be used during the lesson. However, Teacher 2’s lesson plan, used to teach the *area* concept, did not specify the incorporation, facilitation, and utilisation of relatedness.

I observed Teacher 2’s lesson, in which she taught the concept of *area* to her learners. Teacher 2 used a projector which displayed a PowerPoint presentation in Afrikaans. However, in the PowerPoint slides, as seen in Figure 4.7 and Figure 4.8, I noted that the slides contained examples that had already been completed. Hence, the answers and calculations were visible. Consequently, the learners did not engage or discuss any examples on the PowerPoint slides, as all the answers and calculations were provided.

Teacher 2 read through each slide with the learners; I noted that the examples presented relied heavily on a formula (formule) to calculate the area (oppervlakte), which is not required. Additionally, I noticed that Teacher 2 only used one square (vierkante), one rectangle (reghoek) and one irregular shape (onreelmatige vorm), when covering the concept of *area.*

Teacher 2 did not use any other 2D shapes, despite the curriculum requirements for teaching *area* to Grade 6 learners stating that learners should be able to calculate the *area* of:

- regular shapes where the sides are all the same length with straight sides,
- irregular shapes where the sides are not all the same length with straight sides and,
- shapes with curved sides (DBE,2011).

Furthermore, I noticed the absence of real-life situations and examples within Teacher 2’s PowerPoint presentation.

Figure 4.7.

A PowerPoint slide used by teacher 2

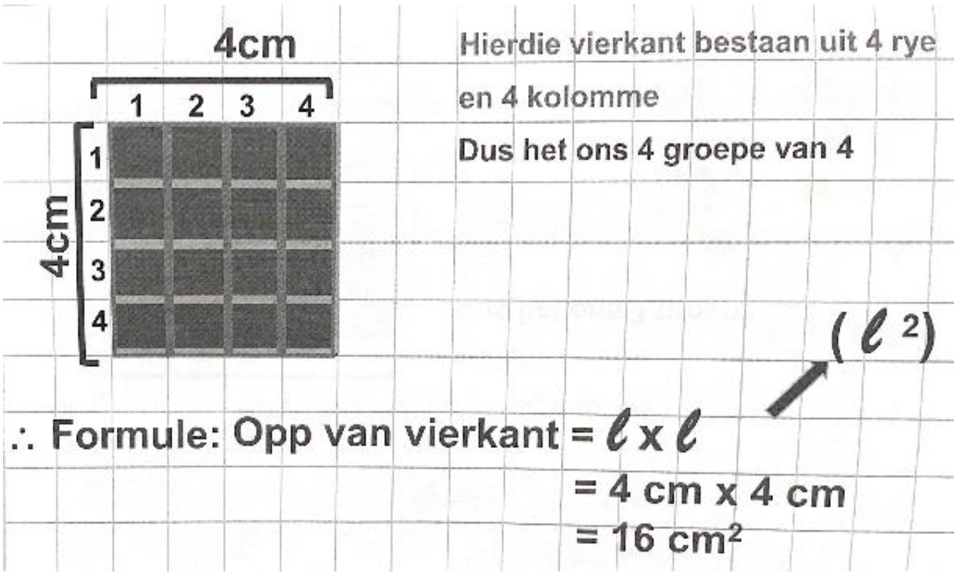
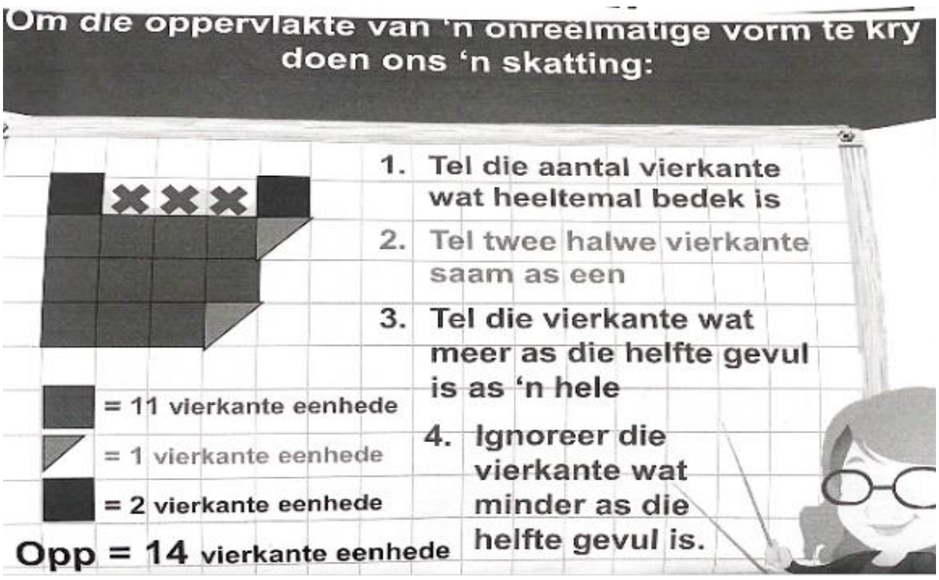


Figure 4.8.

One example of an irregular shape



During my interview with Teacher 2, I asked Teacher 2 how she created a classroom environment that allowed her learners to feel connected to the content that she taught, Teacher 2 responded by saying:

> *[I] put up posters so that they [the learners] can see examples. I will use examples in daily lives, in our daily lives, that they can relate to. That relates to the content or theme I am teaching them.*

Figure 4.9.

Teacher 2's posters

After my interview with Teacher 2, I examined the posters to find out how they helped the learners in Teacher 2's classroom to feel connected to the content being taught – *area*. However, I noticed that the posters did not specifically address the concept of *area,* and that there was an absence of real-life situations on all posters, as seen in Figure 4.9.

4.2.2.3. Teacher 3

Despite the absence of lesson plans for Teacher 3's lesson on *area,* she cultivated a sense of relatedness in her classroom as she divided learners into groups of 2 to 3, handed each group some string, and instructed them to use the classroom floor tiles (Figure 4.10) to complete the verbal instructions, which she provided them with.

Figure 4.10.

Learners use string

Teacher 3 moved around the class and instructed the learners to “build a triangle with an area of 3”. While the learners followed Teacher 3’s instructions, she would move through the class and comment on the learner's work. Towards the end of the lesson, Teacher 3 engaged in a discussion with her learners by asking them to explain where to use the area and how it could help them in life.

The “it” that Teacher 3 is referring to is the concept of *area*. A learner in the class responds to Teacher 3’s question by saying “construction”. Teacher 3 did not affirm the learner’s response and prompted, “But how?”. Before the learners could respond, Teacher 3 answered her question by explaining:

> They [the construction workers] use area to determine the number of tiles needed for tiling and for calculating the amount of paint required for painting.

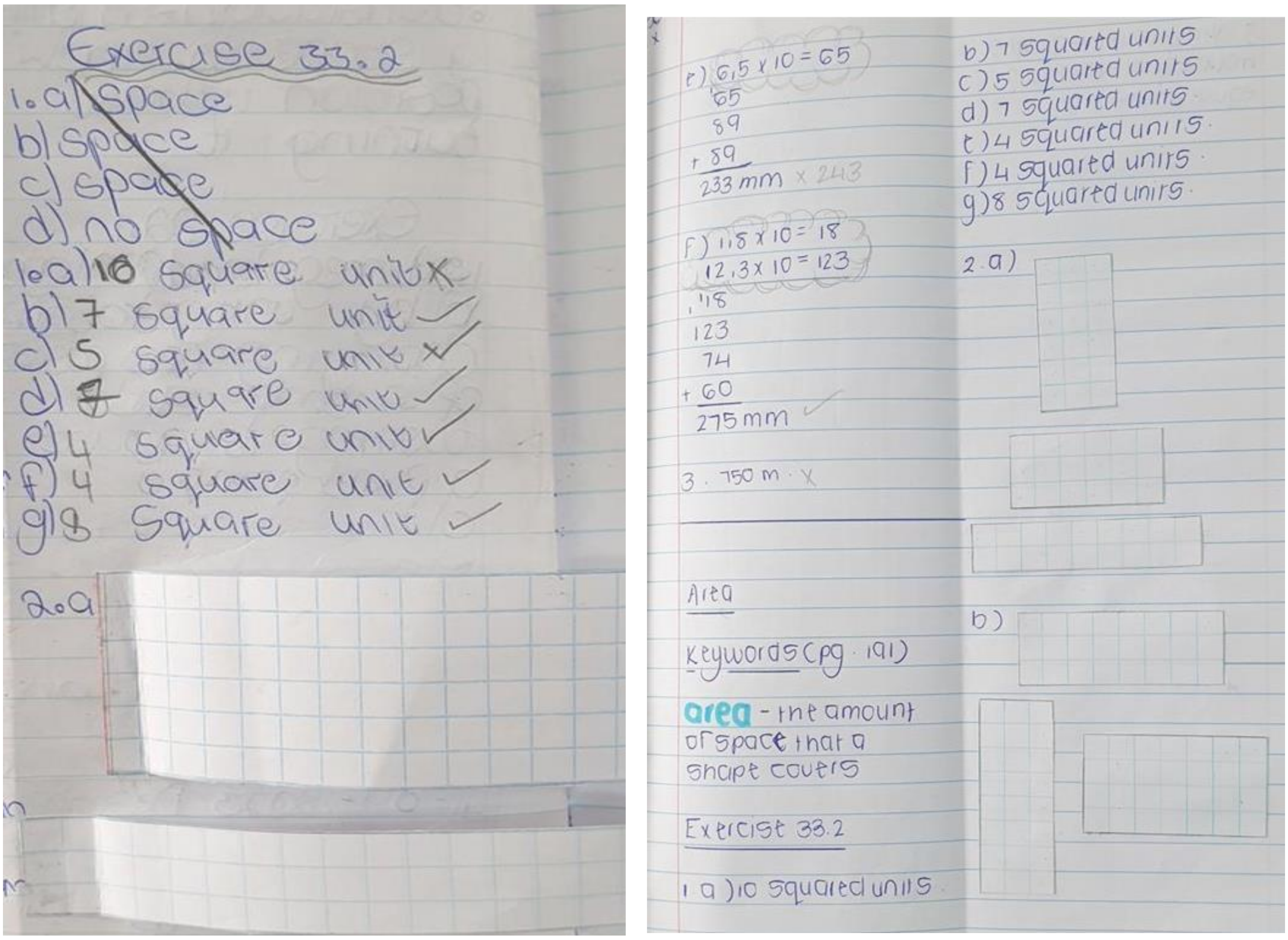
During my interview with Teacher 3, I inquired about the strategies Teacher 3 incorporated in her classroom that helped her learners feel connected to the content she taught. Teacher 3 explained:

> *By explaining how the content related to possible professions, as that seemed to interest learners as well as help them gain insight into what profession they might see themselves in one day. It also helps a lot by doing it practically, because our children struggle to gain insight without doing it practically first. It helps* a lot if we *do it practically first and then do it in our books*.

Teacher 3 used the classroom floor, string, and group work to incorporate hands-on learning to teach her learners about the concept of *area.* After our interview session, I requested to see the learners' books; despite their non-utilisation during her lesson, I was interested in understanding how the learners applied their practical side to the theory. I was provided with two books, as shown in Figures 4.11 and 4.12.

Figure 4 SEQ Figure_4 * ARABIC 12.

Learner's book with completed area activity



However, as Teacher 3 handed me the books, she apologised that none had been marked and added that she had already covered the material in Term 2. This was a deviation from the ATP prescripts, according to which the *area* concept should be taught in Term 3. While Teacher 3 acknowledged following the ATP, her actions indicated inconsistent adherence. Regarding lesson preparation, when I inquired about the absence of lesson plans and preparation, her response was, "*I think all my years in teaching maths have prepared me to whip something out of a hat. So… Yeah... I like to be prepared."* This remark underscores a reliance on improvisation rather than structured planning, raising questions about teaching approaches and methods and adherence to curriculum standards.

4.2.3. Learning activities to promote competence

Competence involves equipping learners with the essential skills, knowledge, and ability and feeling capable and skilled enough to tackle tasks effectively in the educational setting. (Ryan & Deci, 2000). Building competence means providing learners with experiences that challenge them while providing support, thereby helping them to develop their abilities, gain confidence, and succeed (Hui & Tsang, 2012).

4.2.3.1. Teacher 1

As previously mentioned, Teacher 1 did not have a lesson plan or specific preparation for teaching the concept of *area,* citing time limits and excessive stress as her reasons. Despite this, I was curious to explore how Teacher 1 fostered learners' competence in her lessons, while recognising that this was not a primary consideration before presenting her lesson, hence the absence of lesson plans and preparation.

During the lesson observation, Teacher 1 handed out a worksheet (see Figure 4.13) and instructed the learners to complete the questions. She gave them approximately 20 seconds to answer the first question before asking a learner for the response and then quickly moved on to the next question. The pace of the lesson was noticeably fast, causing certain learners to fall behind. Some learners resorted to copying answers from peers, seemingly too afraid to speak up, as breaking the strict no-talking policy could result in them being sent to the "tiny table" (see Figures 4.14 and 4.15).

Figure 4 13.

Worksheet given to learners

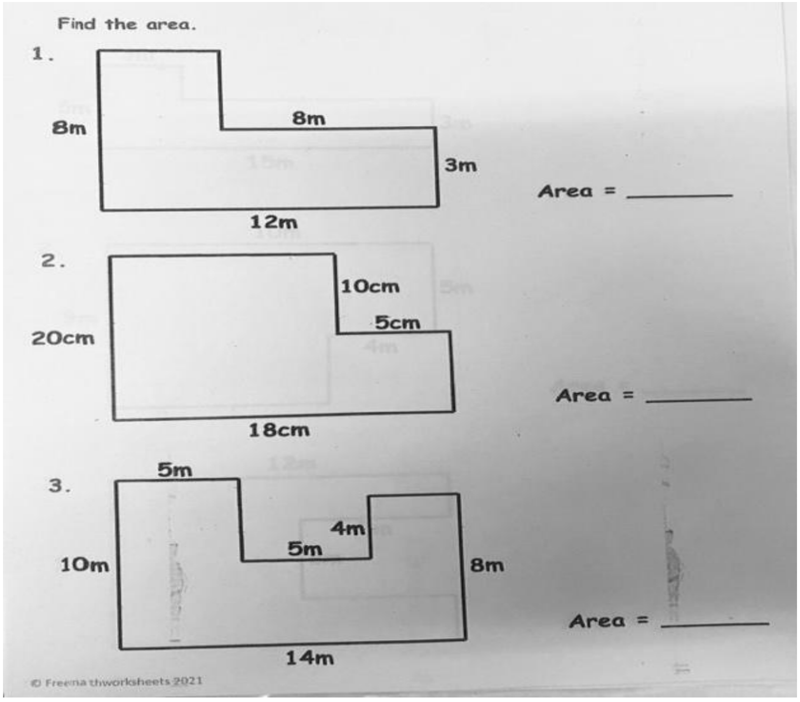


Figure 4.14.

Learner copying from a classmate

Figure 4.15.

Another learner copying from their classmate

During the interview, I asked Teacher 1 how she designed lessons that promoted her learner's competence and made them feel engaged, confident and motivated:

> *I think building confidence, you need to know your learners, you need to try to motivate them. I try to not yell at anybody. Rather give them that safe space where they can ask questions and motivate them if they get something right. Even if they ask the question never to let them feel silly or stupid or whatever.*

> *Listen to the question and take something from that question and turn it into something positive or something that is correct, not just dissing them and saying well, yeah, your answer is not correct or whatever, giving them opportunity, I think, to create a safe environment, you can motivate them because they will be self-motivated eventually hopefully.*

Teacher 1 further expressed that by motivating learners, they would *eventually [and] hopefully lead to them being self-motivated,* and ultimately, learners would develop their own competence.

Teacher 1 remained stationed at the front of the classroom throughout the lesson, as depicted in Figure 4.16. Although Teacher 1 had previously mentioned strategies for fostering learners' competence, such as *walking through the class to check on learners' understanding and offer assistance,* this approach was not observed during the lesson. While she had expressed the importance of *knowing her learners* and "motivating them to build confidence," these strategies were not evident in her classroom practice during the observed session.

Figure 4.16.

Teacher 1 is stationary at the front of the classroom

4.2.3.2. Teacher 2

As observed, while Teacher 2 presented a lesson, there was limited evidence demonstrating how learners' competence would be fostered during the presentation of her *area* lesson.

Although learners participated throughout Teacher 2's lesson by responding to her questions during the lesson, their contributions were not always acknowledged by the teacher. Teacher 2 responded with *No (nee)* and moved on to the next question:

> *As ek vir jou n 2D-vorm gee en ek vra vir jou beskryf vir my die oppervlak van hierdie vorm, hoe gaan jy dit doen? (If I show you a certain 2D shape and ask you to describe the area, how will you do that?)*

A learner responded to Teacher 2's question by explaining:

> *As hulle vir jou getalle gee dan maal jy die getalle om die oppervlakte uit te werk (If they give you numbers, you multiply the numbers to calculate it).*

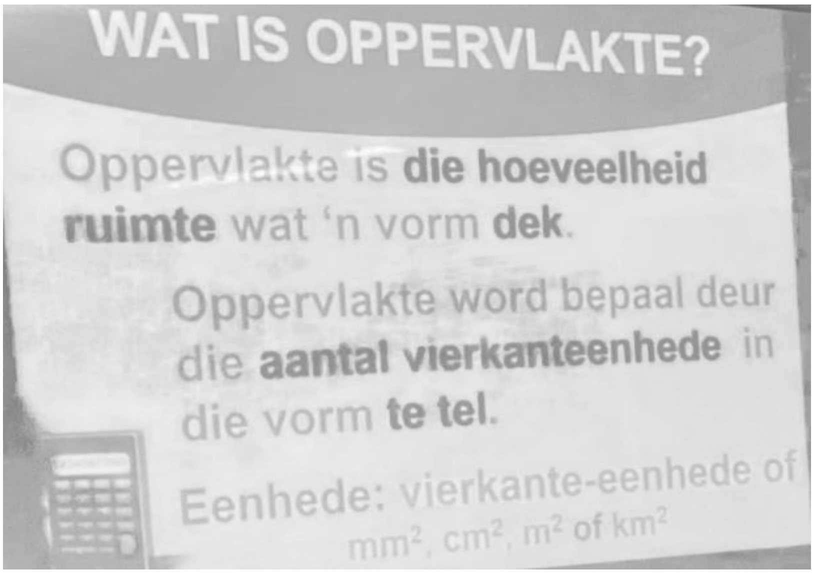
Teacher 2 responded to the learner and further explained:

> *Okay, dit is 'n manier hoe ons dit uitwerk. Maar ek sou sê, in die mees eenvoudigste manier, dit is die hoeveelheid ruimte binne hierdie vorm is (Okay, that is a way to calculate. But I would say, in the most simple way, it is the amount of area inside this shape).*

Teacher 2 did not correct the learner's responses. Instead, she answered the question by stating, *Hier is die mooi definisie (Here is the nice definition)*. She puts up a PowerPoint slide with the definition of oppervlakte *(area)*, (see Figure 4.17).

Figure 4.17.

Definition of area



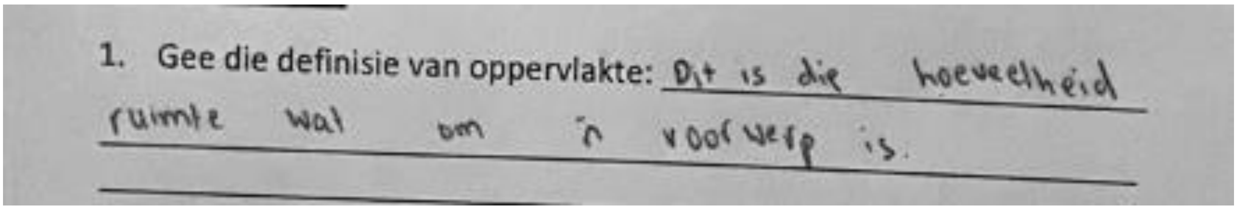
Teacher 2 prompted the learners further by inquiring, *en daar is iets wat baie belangrik is… (and what else is very important…).* All the learners responded by saying, *vierkant eenhede! (Square units!).* Teacher 2 then further prompted learners by asking, *Wat moet ons by die centimetre skryf (Ah! But what must we add to the centimetre?)* Before Teacher 2 could complete the question, all the learners shouted*, 'n Klein twee! (a small two!).*

Teacher 2 further inquired about the *Klein twee! (a small two!)* by asking her learners, *Hoekom skryf ons 'n klein twee? (Why do we write a small two?)* The learners responded, *want dit staan vir eenhede (It means units).* The teacher responded with *Nee (no*), and a different learner shouted, *Maal met twee! (Multiply by 2!).* Teacher 2 then explained *Nee, want ons het twee eenhede waarmee ons werk.* Lengte maal breedte *(No, because we have two units that we are working with, length multiplied by breadth).*

While learners completed the worksheet, I walked around to fully comprehend how they would answer question 1, which asked, "Gee die definisie van oppervlakte.*"* (give the definition of area). The responses I captured can be seen in Figure 4.18 below.

Figure 4.18.

Question 1


1. Gee die definisie van oppervlakte: Dit is die hoeveelheid ruimte wat om 'n voorwerp is.

The learner's response above says, *Dit is die hoeveelheid ruimte wat om 'n voorwerp is (It is the amount of space around a shape).* The response was exactly what Teacher 2 had presented on the PowerPoint presentation earlier on in the lesson.

During my interview with Teacher 2, I inquired about Teacher 2's approach to promoting her learner's competence when they complete class work and activities, to which she responded:

> *So even when a learner makes a mistake, I will help them, and I will encourage them. So, I will look at what they did and then I will compliment them on the things*

that they did right, and then I will help them with the things they didn't do that well or they didn't answer correctly. So, I will give them guidance on that. And especially when they answer things correctly in class, it doesn't matter how simple or how big it is, I will compliment them and tell them how proud I am and keep complimenting them, to encourage them not to give up and especially when they're doing their work or writing a test for assessment, and I can see that in a certain question, this learner really improved then I will also you know, write something there for them to encourage them to complement them, you know.

While Teacher 2 engaged with learners through prompting and questioning, there were some areas where the learners' understanding appeared superficial. For instance, the collective responses, such as *n Klein twee! (small two!)* and the initial incorrect explanation of its meaning suggested that while learners could recall terminology, their deeper conceptual understanding was limited.

4.2.3.3. Teacher 3

In the lesson dynamics by Teacher 3, even in the absence of a detailed lesson plan prior to the lesson, she appeared to foster competence in numerous ways. During the lesson observation, Teacher 3 divided the learners into groups of 2 to 3 and gave each group some string. Teacher 3 gave the learners verbal instructions, for example, *Build a triangle with an area of 3 square units,* and the learners completed the task, see Figure 4.19 below.

Figure 4.19.

Learners constructing a triangle

I noted that Teacher 3 often guided learners throughout the lesson by commenting on their tasks. She would say, *Try again* or *Almost remember I said a triangle with an area of 3 square units.* Some learners constructed equilateral triangles, while others constructed right triangles. Teacher 3 never constructed the shapes for learners or explicitly told her learners what they were doing incorrectly. She only engaged with the learners when they asked for assistance. For example, a group of girls raised their hands after challenging the construction of a triangle and asked Teacher 3, *May we use our textbooks to assist us?* to which Teacher 3 responded, *You may, good initiative.* Figure 4.20 below captured the group of girls using their textbook to understand the area of a triangle instead of relying on Teacher 3 for answers.

Figure 4.20.

Constructing a triangle

During my interview with Teacher 3, I inquired how Teacher 3 promoted her learner's competence when they completed their work tasks and activities. Teacher 3 responded as follows:

> *I have a rule in my class that we're not allowed to laugh at each other. Because the moment someone asked a question and another person laughs, you know they won't have any confidence again to ask a question. So, I usually boost them [the*

> *learners], and I walk through the learners when they're practising the work or doing their work by saying, "Yes, you are right," or "Look here you made a mistake," or "It's OK, but, but let's try again" I found that to be very, very helpful.*

Teacher 3 encouraged learners to take the initiative and explore solutions independently. She promoted their competence and nurtured critical thinking and problem-solving skills.

4.3. Incorporation and Facilitation of the 5Es of IBL in Mathematics Lessons

The section begins with a summary of the 5Es of IBL, with brief descriptions of each phase. This summary is intended to assist the reader in understanding the contents of Table 4.1, which shows the prevalence (or not) of the 5Es observed during teaching. Therefore Table 4.1 features three columns labelled Teacher 1, Teacher 2 and Teacher 3, alongside five rows representing the different phases of IBL. IBL is an educational approach that emphasises active, learner-centred learning. Rather than passively receiving information from a teacher, learners are encouraged to actively engage in critical thinking, problem-solving, and exploration (Thangjai & Worapun, 2022). The 5Es of the IBL model are designed to follow a sequential process, beginning with the engagement phase, followed by Exploration, Explanation, Elaboration, and concluding with the evaluation phase. Below is a summary of each phase:

Engagement Phase: The focus is on capturing learners' attention and fostering curiosity through activities that bridge new concepts with their existing knowledge (Marshall, 2013). Teachers must actively assess learners' prior knowledge and employ various instructional resources such as pictures, videos, demonstrations, and kinetic activities to stimulate discussions and promote idea sharing (Marshall, 2013).

Exploration Phase: learners actively engage in hands-on activities to generate new ideas and investigate mathematical phenomena (Thangjai & Worapun, 2022). Collaborative learning and critical thinking skills are encouraged (Marshall, 2013), to empower learners to take ownership of their learning journey and deepen their understanding of mathematical concepts through hands-on engagement and discovery.

Explanation Phase: learners focus on understanding the concept being taught, taking charge of their learning journey (Caswell & LaBrie, 2017). Teachers provide feedback, correct misconceptions, and introduce formal definitions to guide comprehension (Bybee, 2009; Duran & Duran, 2004; Thangjai & Worapun, 2022). This interaction fosters confidence and ensures a deep understanding of the mathematical concept being taught.

Elaboration Phase: During the Elaboration phase of an IBL mathematics lesson, learners apply newfound knowledge and reinforce skills acquired earlier (Thangjai & Worapun, 2022). Engaging in activities, and being guided by teachers, fosters deeper understanding through meaningful discussion and participation in IBL (Thangjai & Worapun, 2022). This phase encourages learners to elaborate on their answers and cultivate a sense of responsibility, transitioning from structured to open inquiry (Robyn, 2020; Artigue, 2013).

Evaluation Phase: During the Evaluation phase of an IBL mathematics lesson, learners assess their understanding, and teachers evaluate progress toward learning objectives (Thangjai & Worapun, 2022). By employing various assessments such as portfolios, investigations, and concept maps, teachers encourage their learners to test practices and formulate questions, completing the inquiry cycle (Justice et al., 2002).

Table 4.1 below provides a structured overview of the specific IBL phases; with each teacher incorporating the area concept into their lessons; offering context before presenting findings.

Table 4.1.

IBL phases incorporated by teachers in lessons on the concept of area

	Teacher 1	*Teacher 2*	*Teacher 3*
Engagement	×	√	×
Exploration	×	×	√
Explanation	√	√	√
Elaboration	×	×	×
Evaluation	×	×	×

4.3.1. Teacher 1

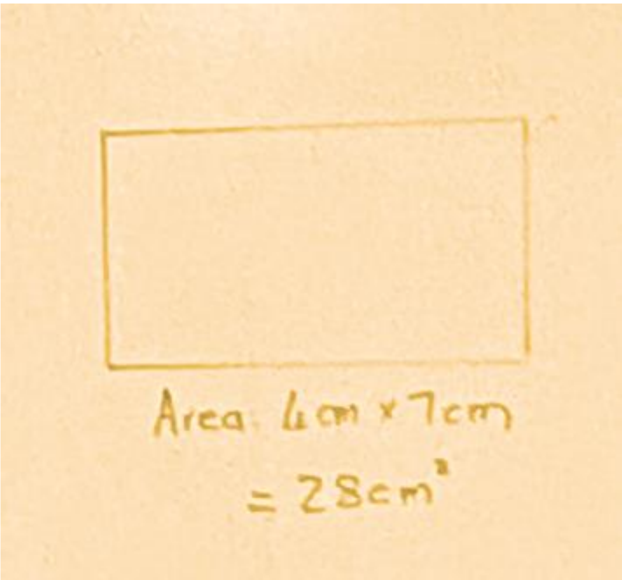
During my observation of Teacher 1's lesson, I noted that Teacher 1 integrated the explanation and evaluation phases of IBL into her lesson. However, other phases, such as Engagement, Exploration, and Elaboration, were not integrated into Teacher 1's lesson plan or teaching practice. Consequently, the analysis and findings presented in the next section focuses on the Exploration and Elaboration phases within Teacher 1's observed lesson.

Explanation

During the lesson observation, Teacher 1 distributed the grid paper to each learner and began by demonstrating the concept of *area* by using an example of '4 by 7' on the board (see Figure 4.21).

Figure 4.21.

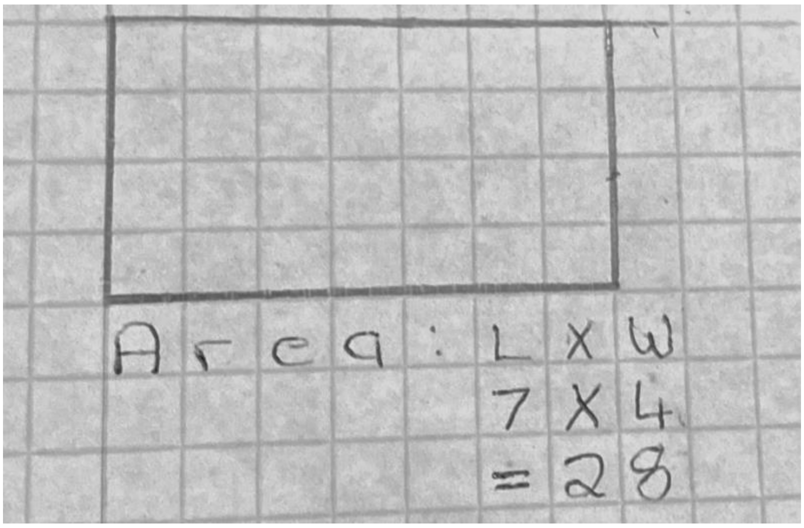
The example teacher 1 provided



Initially, Teacher 1 did not specify the units but instructed learners to draw a rectangle with '4 by 7' and follow the '1 block equals to 1cm' rule. This terminology is problematic as 'block' typically refers to a 3D object, which can be misleading in a 2D context. A more accurate term would be 'square" or "unit square,' clarifying that each square on the grid represents 1 cm. Figure 4.22 below illustrates how the learners interpreted and executed Teacher 1's instruction of '4 by 7' while solving the question on their grid paper.

Figure 4.22.

Learners' interpretation



After approximately 20 seconds, Teacher 1 asked the learners, "What's your area?"

A learner responded, "Four times seven equals 28." Teacher 1 did not affirm the learner's answer but added, "28 centimetres squares."

Teacher 1 instructed the learners to "go count to see if it works out. See if your answer is correct. Count all the blocks. Who got 28 squares? Show me a thumbs up"

Figure 4.23 below illustrates how learners responded to Teacher 1's thumbs up feedback method. Teacher 1's primary goal was to ensure that learners could count 28 squares within their rectangle. This approach allows learners to 'check' their answers by counting the squares, to confirm the accuracy of their calculated area.

Figure 4.23.

Thumbs up

However, Teacher 1 did not inquire how the learners answered 28 squares or whether they used the correct units and calculations. She previously mentioned in her interview that the "thumbs up" method was her way of receiving feedback on whether learners had engaged with the lesson and understood the material.

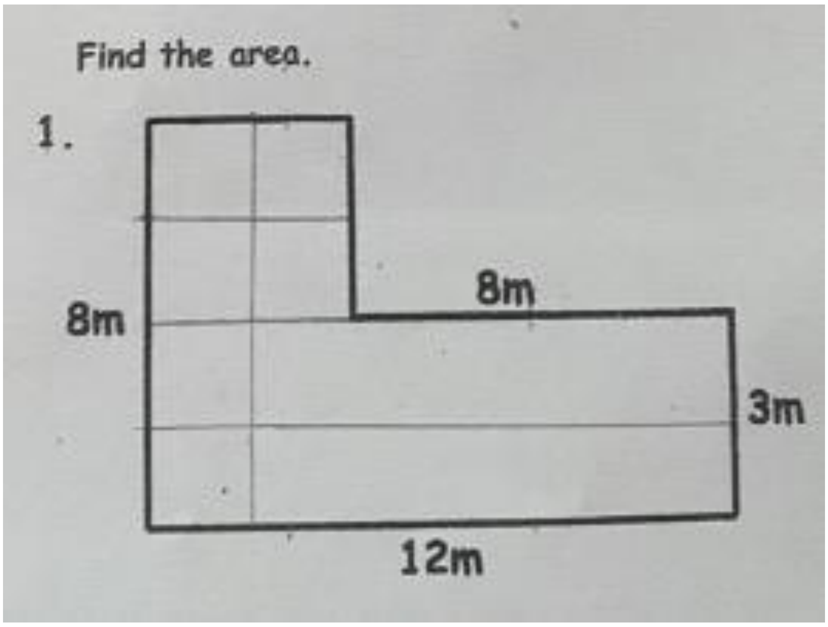
Evaluation

After completing the initial exercises with the learners, Teacher 1 distributed a worksheet. This worksheet had a different unit of measurement and did not adhere to the '1 block equals 1cm' rule provided earlier.

Consequently, the learners struggled to count 'blocks' as they had previously practised. Learners drew their own '1cm by 1cm blocks' to calculate the answers (see Figure 4.24).

Figure 4 24.

Learner completing worksheet



The above misconception was not addressed or corrected during the observation. The discrepancy between the unit of measurement used in the worksheet (metres) and the learners' reliance on 1 cm blocks had led to incorrect calculations.

After the learners completed the worksheet, Teacher 1 used brown paper to display an irregular shape on the whiteboard (see Figure 4.25).

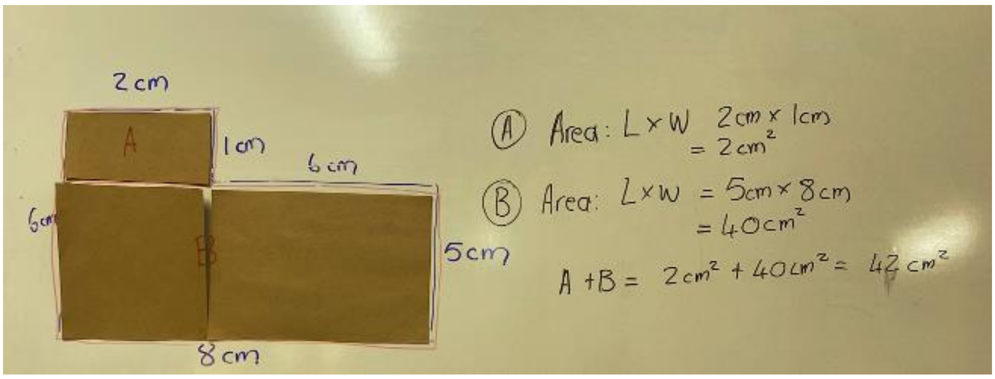
Figure 4.25.

Irregular shape

Teacher 1 introduced it by saying, "Now we have a problem," referring to the irregular shape as a challenge since the learners had not yet calculated the area of irregular shapes. She then asked the class, "Who has got a problem? Because I have a problem; this is not a perfect rectangle or square." Teacher 1 repeated, “Who else has got a problem?” and added, “We’ve got a problem!” She then said, “Can you help us solve our problem?” When a learner suggested counting, Teacher 1 interrupted and did not listen to the explanation. Instead, she said, “Okay, let me do this, hang on,” and quickly cut the irregular shape into regular pieces with scissors (see Figure 4.26). Teacher 1 had disregarded the learner’s input and completed the task herself.

Figure 4.26.

Teacher 1 cut irregular shapes into regular shapes



As seen in Figure 4.26, Teacher 1 continued to work through the problem independently, explaining each step and intermittently prompting the learners with statements like, “Okay guys, 5 seconds, come on, come on. This is easy,” or “I am giving you 20 seconds, go!” During these prompts, she asked the learners to calculate the areas of shape A and shape B using her diagram and calculations on the board rather than encouraging them to develop their own problem-solving strategies.

4.3.2. Teacher 2

During the observation of Teacher 2's lesson, I noted that Teacher 2 integrated the Engagement and Explanation phases of IBL into her lesson. However, other phases, such as Exploration, Elaboration and Evaluation, were not integrated into Teacher 2's lesson plan or lesson presentation. Consequently, the analysis and findings presented would focus on the outcomes of the Engagement and Explanation phases within Teacher 2's observed lesson.

Engagement

Teacher 2 began the lesson with an engagement activity by asking the class, *Ek wil eers by jou hoor, wat is oppervlak? As jy vir juffrou in jou eie woorde kan beskryf wat sal jy vir my sê is oppervlakte?” (I want to know from you, what is area? If you can tell the teacher, in your own words, what will you describe the area as?)* A learner responded, "Dit is die hoeveelheid vierkante wat in ‘n vorm is" (it is the number of squares found inside a shape.) Teacher 2 did not affirm or provide feedback on his response but asked if anyone else had a different answer. When no additional responses were given, Teacher 2 proceeded with the lesson. Next, Teacher 2 presented a follow-up question, *As ek vir jou so ‘n 2-D vorm gee, en ek vra vir jou beskryf oppervlakte van hierdie vorm. Hoe gaan jy dit in jou eie woorde sit?" (If I give you a certain 2-D shape, I ask you to describe the area of this shape. How are you going to do it, in your own words?)* A different learner answered, *"Ek sal die getalle bo vat, gemaal deur die getalle af"* (I will take the number at the top multiplied by the number downwards). Teacher 2 responded, *"Okay, dit is die manier hoe ons dit uitwerk. Maar, as ek in my eie woorde oppervlakte moet sê, sal ek baie eenvoudig sê dit is die ruimte wat binne hierdie vorm is. Stem julle saam?" (Okay, this is the way we calculate it. However, if I had to explain area in my own words, I would very simply say* *it is the space that is inside this shape. Do you agree?)* The class nodded in agreement. Teacher 2 then shifted the focus to the term *omtrek (perimeter)* and asked, *Wat het ons geleer is omtrek? (What did we learn is perimeter?).* The whole class responded, *Die buitekant! (The outside!).*

Finally, Teacher 2 used a PowerPoint slide to display the definition of area (see Figure 4.26), which stated: *oppervlakte is die hoeveelheid ruimte wat 'n vorm dek" (area is the amount of space that a shape covers), 'oppervlakte word bepaal deur die aantal vierkanteenhede in die vorm te tel (area is calculated through counting the amount of squares inside a shape), and listed units such as "vierkante eenhede of* mm^2, cm^2, m^2 *of* km^2*" (square units or* mm^2, cm^2, m^2 *of* km^2*).*

Figure 4.27.

Definition of area

As seen above, Teacher 2 began the lesson by reviewing the concept of area and perimeter. However, observations revealed a lack of engagement from the learners, as illustrated in Figure 4.28 below. Several learners showed disinterest, such as nail-biting, diverting attention elsewhere, rummaging in bags, or resting their heads on their hands. The introductory segment was extended, and the PowerPoint presentation was text heavy. Consequently, the presentation did not effectively engage the learners or enhance their understanding of the area concept.

Figure 4.28.

Learner’s show little interest

During our interview, I asked Teacher 2 how she ensured learners remained engaged during lessons and tasks. Teacher 2 explained, *When I start with the lesson. I will ask questions about the topic I will teach them. Then, as I go, I will also ask questions to see what the learners know and what they don't know, and if they are, say they are saying something that is not correct, then I will use the PowerPoints, which have colour and examples and yeah technology is really helpful.*

In the initial phase of the lesson, Teacher 2 posed questions related to the concept of *Oppervlakte (area),* incorporating both the current lesson topic and closely related previous topics such as *Omtrek (perimeter).* After explaining *oppervlakte (perimeter),* learners were given a worksheet to complete individually. While Teacher 2 moved around the class to assist, she faced difficulties addressing all questions due to frequent requests for help. It became evident that learners depended on continuous interaction and support to apply their knowledge and complete their tasks effectively.

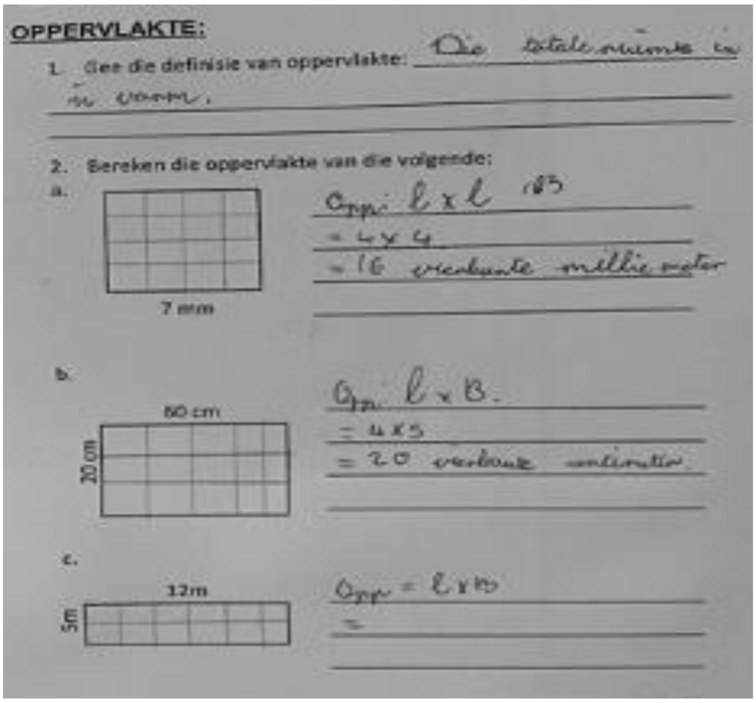
Explanation

During my observation, I noted a particular learner, seated in the back corner of the classroom, who frequently answered Teacher 2’s questions. This learner accurately defined area as *dit is die hoeveelheid vierkante wat in ‘n vorm is (it is the number of squares found inside a shape)*. However, when prompted for further explanation, the same learner responded with *Ek sal die getalle bo vat, gemaal deur die getalle af (I* *will take the number at the top multiplied by the number downwards (vertically)),* demonstrating a misunderstanding of how to calculate area. This approach reflects a rote learning method, where the learner has applied a formulaic approach—multiplying the top number by the side number—rather than understanding the conceptual basis of area. This indicates that the learner's grasp of the concept is not fully aligned with the correct area calculation. After this exchange, the lesson shifted from a class discussion to a PowerPoint presentation and an individual worksheet. There was no opportunity for group interaction, and all activities were completed individually, hence limiting the potential for correcting misunderstandings through collaborative learning.

I observed another learner who seldom sought assistance or participated in Teacher 2's class discussions and questions. Upon reviewing this learner's worksheets, shown in Figure 4.29 below, it became evident that a learner had completed the tasks incorrectly despite appearing self-sufficient. The learner consistently began by writing down the formula for each question and relied on the 1cm by 1cm 'blocks' to aid in problem-solving. However, this learner's lack of active engagement and feedback during discussions led to their misconception going unaddressed throughout the lesson.

Figure 4.29.

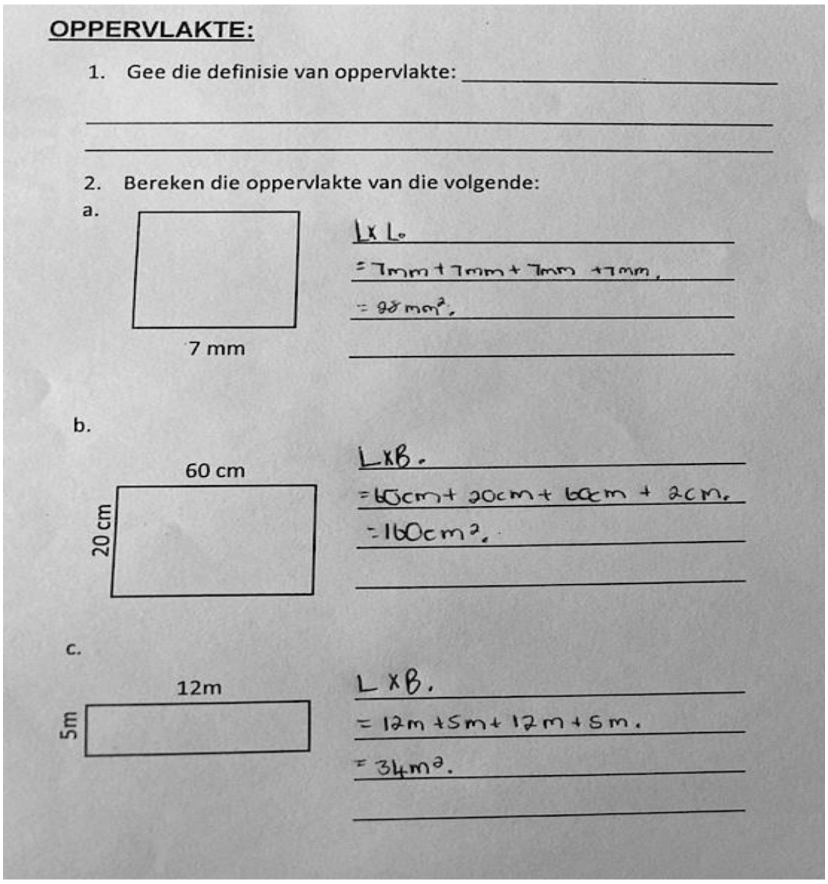
Learner's worksheet



Another learner in the class chose not to engage or participate in class discussions, instead quietly focusing on his worksheet, as shown in Figure 4.30 below. Upon examining the work, it was evident that this learner had left question 1 unanswered, which asked for the definition of area (*gee die definisie van oppervlakte).*

Figure 4.30.

A learner skipped question 1


OPPERVLAKTE:

1. Gee die definisie van oppervlakte: ________

2. Bereken die oppervlakte van die volgende:

a. 7 mm

L x L.
= 7mm + 7mm + 7mm + 7mm.
= 98 mm².

b. 60 cm, 20 cm

L x B.
= 60cm + 20cm + 60cm + 20cm.
= 160cm².

c. 12m, 5m

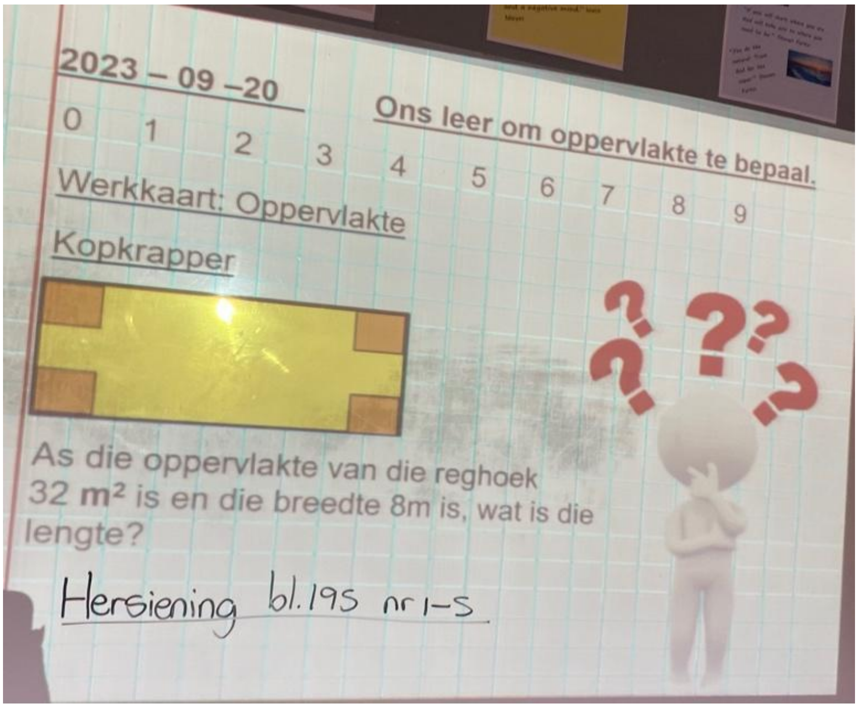
L x B.
= 12m + 5m + 12m + 5m.
= 34m².

When examining Figure 4.30 above, it is evident that the learner applied perimeter calculations to solve an area question. This confusion may have arisen from Teacher 2's review of both concepts—area and perimeter—t the beginning of the lesson.

After the learners completed the worksheet provided by Teacher 2, they were given a ‘kopkrapper (brain teaser)’ problem to solve, as shown in Figure 4.31. The brain teaser posed the question: *As die oppervlakte van die reghoek 32m² is, en die breedte 8m is, wat is die lengte? (If the area of a rectangle is 32m², and the breadth is 8m, what is the length?)* However, not all learners completed this problem; only those who had finished their worksheets before the lesson ended attempted it.

Figure 4.31.

Brainteaser question



The worksheets and *kopkrapper* (brain teaser) were neither reviewed nor discussed during the lesson, so learners could not explain their reasoning or calculations. Thus, the learners did not receive feedback or have an opportunity to address any misconceptions or incorrect calculations.

4.3.3. Teacher 3

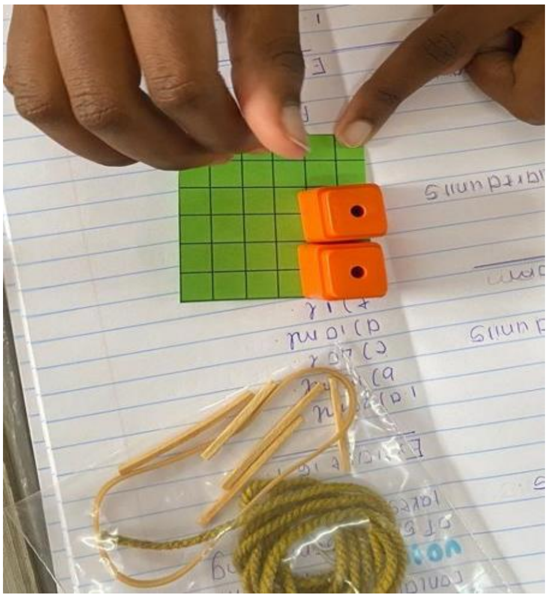
During my observation of Teacher 3's lesson, I noted that Teacher 3 integrated the Exploration and Explanation phases of the IBL model into their area lesson. However, other phases, such as Engagement, Elaboration, and Evaluation, were not integrated into Teacher 3's lesson plan or teaching practice. Consequently, my findings focused on the Exploration and Explanation phases within Teacher 3's observed lesson.

Exploration

During my observation, I noticed that Teacher 3's lesson was different from all my previously observed lessons due to its active and exploratory nature. Teacher 3's lesson immediately started with group work. Learners were divided into small groups, and as seen in Figure 4.32, various different resources, such as a string, matches, small cubes, and a small laminated grid paper, were handed out to each group.

Figure 4.32.

Resources handed out to each learner



Teacher 3 instructed the learners to use string to measure and create specific shapes on the floor. The learners positioned themselves around the classroom as directed. Teacher 3 gave verbal instructions, such as, *Create a square with an area of 3 square units.* While the learners completed the task, Teacher 3 moved around the room, observing and only intervening when learners requested assistance. See Figure 4.33 and Figure 4.34 below.

Figure 4.33.

Creating an equilateral triangle on the tiles using a string

Figure 4.34.

Creating a right-angled triangle on the tiles

At one point, a learner asked, *Teacher, may we use our textbooks to assist us?* Teacher 3 responded, *You may; good initiative*. Teacher 3 did not direct the learner where to look in the textbook or interfere by offering her help.

Teacher 3 frequently guided learners throughout the lesson by commenting on their tasks and providing encouragement and redirection when needed. For instance, Teacher 3 would say, *Try again*, or *Almost there, remember I said a triangle with an area of 3 square units,* or *It's fine, fix it. I want an area of 3 square units, not this.* Some learners constructed equilateral triangles, while others constructed right triangles. Teacher 3 appreciated the different approaches, noting that she liked it when her learners completed the same task in various ways.

Teacher 3 engaged in a post-activity discussion with the class, emphasising two key points she wanted the learners to remember from that day's lesson: firstly, *The same area with different shapes,* and secondly, *Two halves can make a whole.* She then asked the learners if they had any questions. One learner raised his hand and asked:

Learner: *Teacher, what happens if a shape has 3 halves [blocks]?*

Teacher 3: *Then it will be 1 and a half square units, just like with centimetres. For example, if I measure my pencil and it is 13 and a half centimetres, then I will write 13 and a half.*

Teacher 3 then asked the learners to apply their new knowledge by asking, *What are you going to use this area for in life?*

Learner: *Construction.*

Teacher 3: *What in construction?*

Learner: *To measure the floor.*

Teacher 3: *Hmm, the floor tiles. If I need to tile, then I need to use area to work out how many tiles I need to buy. Can I use it to work out how much paint I must buy?*

Learner: *Yes.*

Another learner asked: *Will you use area for the ceiling boards?*

Teacher 3*: Yes.*

Learner: *What about roof tiles?*

Teacher 3: *Yes, I never thought of that … They even use it when they design a building and need to know where things need to fit in.*

In the interview with Teacher 3, I asked how she creates opportunities for learners to explain their newly acquired knowledge. Teacher 3 replied by explaining:

> Okay, so what I usually do is walk around. If it's a topic that they are familiar with I will write a question down on the board and then they have to do it. So, then I will walk around and go: "OK, you're correct. You're correct." Alternatively, "No, look, you made a mistake." For me, it's important to know and to understand that learners know what and how to do it before we do the exercises or carry on with any other topic.

Teacher 3's approach to reinforcing the learners' understanding of area through real-life applications and encouraging questions demonstrated her commitment to deepening their conceptual grasp. However, while she provided opportunities for learners to ask questions and apply their knowledge, the emphasis on teacher-directed validation ("You're correct" or "You made a mistake") may limit the depth of learner-led exploration and peer interaction. This method could benefit from incorporating more opportunities for learners to explain their reasoning and receive constructive feedback from the teacher and their peers.

4.4. Conclusion

In Chapter 4, I presented the findings on implementing the IBL model in Grade 6 mathematics classrooms. The findings indicate that while there were varying degrees of alignment with IBL and SDT principles, but several challenges persisted. Teacher 1's approach, though structured, revealed shortcomings in the engagement and exploration phases, highlighting a reliance on more traditional, teacher-centred methods. Teacher 2 showed a balanced integration of the 5Es but struggled with the Elaboration and Evaluation stages, often defaulting to conventional practices. Teacher 3, despite an engaging and interactive style, faced difficulties in consistently fostering learner autonomy and competence, which affected overall learner involvement.

These observations indicate a significant gap between the theoretical ideals of IBL and SDT and their practical application in the classroom. The constraints of classroom setup, such as fixed seating arrangements and limited space, further compounded the challenges faced by teachers. To address these issues, it is crucial to provide teachers with targeted support and professional development, emphasising effective strategies for implementing IBL and SDT principles. This chapter underscores the need for ongoing reflection and adaptation in teaching practices to better align with inquiry-based education goals and to enhance learner engagement and motivation.

CHAPTER 5: DISCUSSIONS AND RECOMMENDATIONS

5.0. INTRODUCTION

In this chapter, I synthesised the findings of my study to determine the extent to which the 5Es of IBL and SDT are being promoted and incorporated into teachers' lessons and instructional practices when teaching the concept of area to Grade 6 learners. As Creswell (2014) highlighted, the discussion chapter is essential for comparing the study's findings with existing research, suggesting future directions, and highlighting practical implications. Merriam and Tisdell (2015) further argued that this chapter interpreted the results, reflecting on what the findings meant in a broader context and how learners answered the research questions. The discussion will address the study's three secondary research questions sequentially:

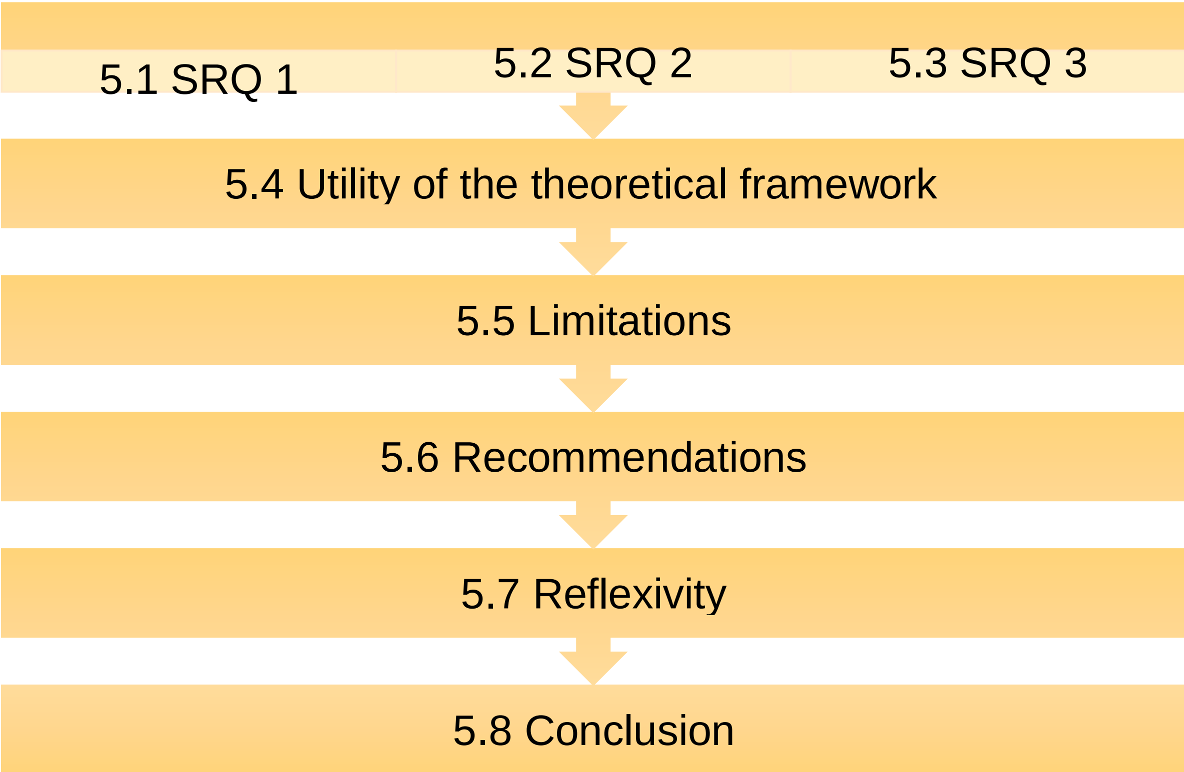
SRQ1: How do mathematics teachers design learning activities that promote autonomy, competence, and relatedness when teaching the concept of area? -
SRQ2: To what extent do mathematics teachers incorporate the attributes of the 5E's of IBL when teaching the concept of area?
SRQ3: How do mathematics teachers facilitate an inquiry-based lesson, and, if any, what related challenges do they experience when teaching the concept of area?

First, I discussed how mathematics teachers design learning activities to foster autonomy, competence, and relatedness. Second, I explored how the 5Es of IBL are incorporated into teachers' instructional practices when teaching the concept of area. Lastly, I examined how an inquiry-based lesson is achieved in teaching. To address these points, the discussion synthesised the findings from document analysis, classroom observations, and semi-structured interviews, comparing them against the existing body of empirical research related to the research questions.

Figure 5.1 below illustrates the flow of this chapter and highlights how each section addresses the study's secondary research questions and integrates the findings. Based on these findings, I proposed recommendations to enhance the application of IBL in Grade 6 mathematics classrooms. These recommendations aim to inform teachers, policymakers, and curriculum developers about effective strategies for improving instructional practices in teaching mathematical concepts through inquiry-based approaches. Finally, my study's headings critically examined the limitations encountered during the study, including constraints in methodology and data collection.

Figure 5.1.

Structure and flow of chapter 5



5.1. DESIGNING LEARNING ACTIVITIES THAT PROMOTE AUTONOMY, COMPETENCE AND RELATEDNESS

The issues about the promotion of autonomy, competence and relatedness are entrenched elements of SDT, and within my study, these elements are aligned with SRQ1. A significant challenge observed across the classrooms was the limited opportunities provided for learner autonomy. This was evident in how lessons were structured, emphasising teacher-led instruction and minimal learner-initiated activities. For example, when introducing the concept of *area*, learners were often given precise instructions on how to construct or calculate 2D shapes that were presented to learners as absolutes. However, varying approaches exist to solve the problem. Furthermore, learners were not provided with explanations about why the area is calculated in a particular way or why they should approach the activities using specific methods. This lack of reasoning limits learners' ability to develop a sense of agency, as they are not empowered to understand the underlying concepts and make informed decisions about their learning. This approach can hinder the development of autonomy, as it reduces opportunities for learners to make choices, experiment with ideas, and take ownership of their learning process (Muir, 2020).

The lack of opportunities for learner autonomy has significant implications for teaching mathematics and IBL in particular. When learners are not encouraged to explore and experiment with various ways to solve a certain mathematics problem, they may develop a passive and monolithic approach to learning, relying heavily on the teacher for direction and validation (Minner et al., 2010). This can be particularly problematic in the context of IBL, where the goal is to foster independent inquiry and critical thinking. Without opportunities to make choices and take risks, learners may struggle to engage deeply with mathematical concepts or see their relevance in everyday life.

Evidently, the issue of professional development suggests that teacher programs should focus on strategies to enhance learner motivation within the IBL framework. For instance, workshops could aim to equip teachers with techniques to foster autonomy by encouraging learners to ask questions, competence by offering scaffolding during exploratory tasks, and relatedness by promoting collaborative activities. These programs could also provide resources for creating lesson plans that align with the CAPS curriculum while incorporating motivational strategies based on SDT.

In terms of fostering competence, the reliance on direct instruction and formulaic approaches to teaching the concept of *area* was prevalent. Learners were frequently provided with ready-made solutions or formulas, limiting their critical thinking and problem-solving engagement. For instance, when working with rectangles or squares, the emphasis was often on memorising and applying formulas rather than on understanding the underlying mathematical concepts.

This approach can lead to superficial learning, where learners can perform calculations but struggle to apply their knowledge in novel contexts, such as determining the *area* of irregular shapes or relating it to real-life applications like tiling a floor (Dobber et al., 2017). Thus, when teaching learners the concept of *area*, it is crucial to provide learners with opportunities to reflect on their work, identify mistakes, and understand the reasoning behind correct solutions (Van de Walle et al., 2014). This process can be supported by formative assessments that focus not just on the final answer but on the investigations that led to the answer.

Moreover, the learning environments observed did not always support relatedness development. Classrooms where learners were not encouraged to collaborate or discuss their work with peers missed failed to benefit from opportunities to build a sense of connection and mutual respect. For instance, in some lessons, learners who struggled with concepts like square units were not given adequate support or encouragement to ask questions or engage in discussions, as the 'classroom rules' forbade speaking and collaboration between peers.

This lack of interaction can create a classroom atmosphere where learners feel isolated or reluctant to participate, ultimately undermining their motivation and sense of relatedness. The lack of a supportive and interactive classroom environment can hinder the development of relatedness, which is essential for fostering motivation and engagement.

Creating opportunities for group work, discussions, and collaborative problem-solving in the teaching area can help build a sense of community and shared purpose among learners (Zhao et al., 2021). For instance, learners could work in groups to explore how the concept of area applies to different real-world situations, such as comparing the areas of various 2D shapes or planning a garden layout (Niemiec et al., 2009; Deci & Ryan, 2012). Such activities deepen understanding and promote social interaction and a sense of belonging.

To foster a deeper understanding of the area concept, it is essential to incorporate tasks that challenge learners to think critically and apply their knowledge in various contexts. For example, instead of simply calculating the area of given shapes, learners could be asked to design a floor plan for a room, and determine how much material is needed for tiling or carpeting. Such tasks reinforce the mathematical concept and demonstrate its practical applications, making the learning experience more meaningful. Additionally, if learners are allowed to work collaboratively with their peers, that will also assist in fostering a deeper understanding of the area in which learners engage in self-driven activities (Gholam, 2019).

Reverting to and responding to SRQ1, my findings suggest that while some efforts were intended teach the concept of area, these were often limited by traditional, teacher-centred approaches that did not fully support autonomy, competence, and relatedness. To enhance the effectiveness of mathematics instruction, particularly in the context of SDT, it is crucial to adopt strategies that empower learners to take an active role in their learning, provide them with meaningful feedback, and create a classroom environment that fosters collaboration and mutual respect (Zhao et al., 2021). These steps are essential for helping learners to develop a deeper, more connected understanding of mathematical concepts and for promoting long-term engagement and success in mathematics.

The IBL approaches outlined in this study also have the potential to be adapted to other areas of mathematics, such as fractions, algebra, and data handling. For instance, the Exploration phase could involve learners experimenting with manipulatives to understand equivalent fractions, while the Elaboration phase might include applying algebraic concepts to solve real-world problems. By demonstrating the versatility of IBL, this study contributes to broadening its applicability across the mathematics curriculum, fostering deeper understanding and engagement in diverse topics.

5.2. INCORPORATION OF THE 5Es OF IBL IN MATHEMATICS LESSONS

Incorporating the 5Es of IBL into mathematics lessons, particularly when teaching the concept of area, provides a valuable opportunity to deepen understanding, foster critical thinking, and increase engagement among learners (Wang et al., 2019). However, several challenges were identified in the observed lessons that hindered the effective implementation of the 5E model proposed by Bybee (2009): Engage, Explore, Explain, Elaborate, and Evaluate.

Missed Opportunities for Initial Engagement

The engage phase is essential for capturing learners' interest and linking new concepts to their prior knowledge (Boaler, 2016; Vygotsky, 1987). Research emphasises the importance of engaging contexts that make learning meaningful and relevant to learners' lives (Joynes et al., 2019; Silva, 2008). Boaler (2016) highlighted that connecting mathematical concepts to real-world contexts significantly enhances learner motivation and engagement. However, initial engagement was often superficial in the observed lessons, with minimal effort to connect the area concept to learners' everyday experiences. For example, teachers frequently relied on traditional methods of instruction, emphasising the rote learning of the formula for area and the use of formal definitions.

The absence of real-world applicability in the observed lessons, such as relating the concept of area to familiar, everyday items like a classroom desk or a notebook, made learners less motivated and curious about the topic. Moreover, the classroom management strategies observed, such as ensuring learners had dividers, stationery, and books to maintain silence, further stifled initial engagement. When learners are discouraged from interacting with each other, the opportunity to link new concepts to prior knowledge through discussion and exploration is lost. This setup contradicts the principles of IBL, where collaboration and active inquiry are crucial for engagement.

Limited Opportunities for Hands-On Exploration

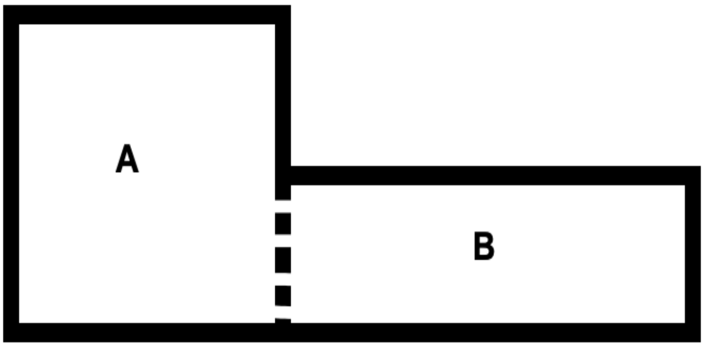
The exploration phase involves learners actively investigating and experimenting with concepts (Thangjai & Worapun, 2022). Effective IBL requires adequate time for learners to explore and engage in deep thinking (Gholam, 2019). Boaler (2016) emphasised that learners need ample opportunities to explore and manipulate mathematical concepts to achieve a meaningful understanding. However, some teachers imposed strict time limits, giving learners approximately 5 to 20 seconds to solve problems related to shapes. This severely hindered their ability to explore the various problem-solving strategies, as there was insufficient time for learners to digest and internalise information, so they could explore their ideas and understand what was being taught.

Hattie (2009) supports the idea that learners need time and space to engage actively with content for deconstructing or decomposing irregular shapes. Learners were not allowed to explore different deconstruction methods. If the exploration phase had been successfully implemented, learners should have been allowed to manipulate the shapes and explore various methods of calculating the area of irregular shapes. Drawing from the activity given by teachers, I used Figure 5.1 to demonstrate my view regarding exploration as one of the attributes of IBL. Notwithstanding the limited opportunities created by the teacher regarding exploration, I should hasten to commend the teacher for choosing this purposeful activity in Figure 5.2.

Figure 5.2.

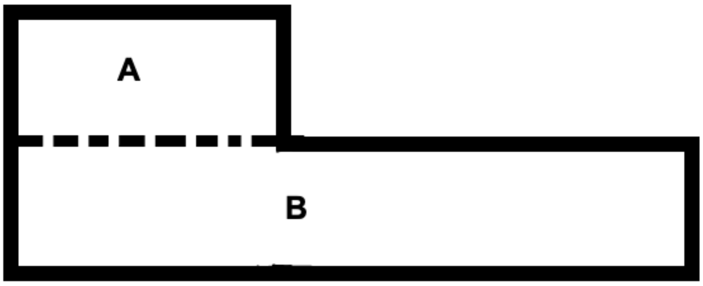
Solutions to deconstruct an irregular shape

Solution 1



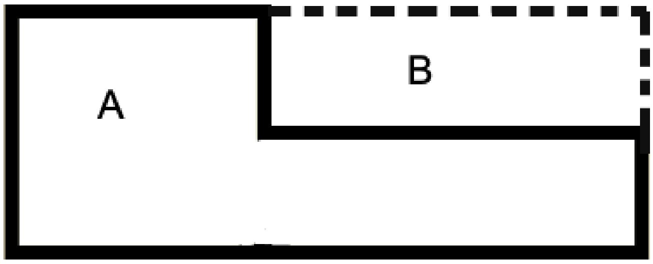
Area of square **(A)** + Area of rectangle **(B)** = **Total area** of the irregular shape

Solution 2



Area of rectangle **(A)** + Area of rectangle **(B)** = **Total area** of the irregular shape

Solution 3



Area of **total rectangle** – Area of rectangle **B** = **Total area** of the irregular shape **A**

Overemphasis on Formulaic Understanding

The explain phase requires learners to articulating their understanding, with teachers introducing formal concepts (Darling-Hammond et al., 2023). However, there was an overemphasis on formulas and procedural knowledge without ensuring that there was also conceptual understanding (Boaler, 2016; Schoenfeld, 2016). For example, when being taught the formula for area (area = length × breadth), there was no learner affirmation to ensure understanding, and as a result, some learners formulated incorrect conceptual understandings, such as thinking that area is the top number of a 2D shape multiplied by the bottom number.

In the observed lessons, the lack of structured planning led to confusion among learners due to inconsistent use of terminology and explanations. Terms like “blocks” and “squares” were used interchangeably without clear definitions, thus leading to misunderstandings. When learners encounter the term ‘blocks’ in the context of measuring area, they may mistakenly associate it with volume calculations. This confusion arises because ‘blocks’ suggest three-dimensional objects, which are relevant to volume rather than area. Area is a measure of the extent of a two-dimensional surface, typically expressed in square units (e.g., square metres or square centimetres). In contrast, volume measures the capacity of three-dimensional objects and is expressed in cubic units (e.g., cubic metres or cubic centimetres).

Using “blocks” to describe units of area can lead learners to apply volume-related concepts and methods and consequently calculating area incorrectly. For instance, learners might use methods that are appropriate for volume calculations, such as multiplying dimensions to find the total space inside an object, rather than correctly applying area-specific formulas, such as length times width for rectangles. This misapplication can result in incorrect calculations and a fundamental misunderstanding of measuring two-dimensional spaces versus three-dimensional volumes (Boaler, 2016; Schoenfeld, 2016).

Insufficient Application to Real-world Contexts

The elaborate phase extends learners' understanding by applying it to new situations. The observed lessons lacked opportunities for learners to apply their knowledge of the area in diverse and meaningful contexts (Thangjai & Worapun, 2022). Research advocates for connecting learning to real-world applications to deepen understanding (Joynes et al., 2019). However, tasks such as designing a garden or comparing areas of different geographical regions were absent, limiting learners' ability to see the practical value of the area concept. The lack of diverse examples, particularly in using both regular and irregular shapes, further constrained learners' understanding. For example, teachers often demonstrated area calculations using cm and grid squares. However, they distributed worksheets with measurements in metres and no grids, thus leading to confusion and a fragmented understanding of the concept of area.

Lack of Reflective Feedback and Self-Assessment

The evaluate phase involves reflecting on learning and receiving feedback (Thangjai & Worapun, 2022). Effective evaluation should include opportunities for self-assessment and peer feedback to support continuous improvement (Rosli et al., 2022). However, there was a lack of meaningful evaluation in the observed lessons, with little follow-up on learners' progress.

The absence of feedback and reflective opportunities hindered learners' ability to identify and correct misconceptions. For example, learners' books were not marked, peer discussions were discouraged, and learners were given insufficient time to reflect and conduct self-assessments. Moreover, the classroom management strategy of isolating learners and punishing interaction stifled collaborative reflection and opportunities for discussion. This lack of interaction is particularly detrimental in mathematics, where discussing different problem-solving methods can lead to a deeper understanding.

Reverting to and responding to SRQ2, which examines the extent to which mathematics teachers incorporate the attributes of the 5Es of IBL when teaching the concept of area, it is evident from the observations and analysis that several key elements of the 5E model were either inadequately implemented or absent. The challenges identified in the Engage, Explore, Explain, Elaborate, and Evaluate phases highlighted a disconnect between the theoretical principles of IBL and their practical application in the observed lessons (Wang et al., 2019; Bybee, 2009).

The engage phase was often superficial and critical for sparking interest and connecting new concepts to learners' prior knowledge. Teachers' reliance on traditional methods, formal definitions, and strict classroom management strategies hindered effective engagement. The lack of real-world applicability in lesson activities diminished learner motivation and curiosity (Joynes et al.,2019; Silva, 2008).

In the exploration phase, the observed lessons often imposed restrictive time limits on problem-solving activities, which constrained learners' opportunities for meaningful exploration (Thangjai & Worapun, 2022). Additionally, the absence of varied methods for deconstructing irregular shapes limited learners' ability to engage deeply with the content.

The explain phase over-relied on formulaic and procedural knowledge without ensuring conceptual understanding (Bolar, 2016; Schoenfeld, 2016). The inconsistent use of terminology and the misapplication of volume-related concepts for area calculations contributed to learners' misunderstandings.

The elaborate phase lacked opportunities for applying knowledge to diverse and meaningful real-world contexts (Thangjai & Worapun, 2022). The observed lessons did not incorporate tasks that would help learners see the practical value of area, such as designing a garden or comparing areas.

The evaluation phase was underutilised, with minimal feedback and reflection opportunities for learners (Bybee, 2009). Without meaningful evaluation strategies, learners' ability to address and correct misconceptions was impeded. These findings underscore the need for a more robust integration of the 5Es of IBL in Mathematics lessons to foster a more effective and engaging learning environment (Wang et al., 2022). Addressing these gaps can enhance the teaching of mathematical concepts like area, thus ensuring that the principles of IBL are fully realised in practice.

5.3. FACILITATE AN IBL WHEN TEACHING THE CONCEPT OF AREA

The 5Es of IBL provide a robust framework for deepening learners' understanding of mathematical concepts, particularly the area concept of area. By engaging learners in active learning and critical thinking, IBL aligns with the CAPS curriculum's objectives to develop problem-solving skills and foster a more meaningful understanding of mathematics (DBE, 2011). However, as observed in section 5.2, significant challenges need to be addressed to successfully incorporate the 5E's of IBL in the teaching area. This section discusses a variety of ways to promote IBL in the teaching area. In section 5.2, it was noted that missed opportunities in the engage phase resulted in superficial learner engagement.

To promote IBL, teachers can introduce the area concept by linking it to everyday objects that learners are familiar with, such as the area of a television screen or the top surface of a box of cookies. These examples make the learning experience more relatable and meaningful, sparking curiosity and motivating learners to explore further (Darling-Hammond et al., 2023). The observed classroom management strategies, which involved dividers that did not promote learner interaction, hindered engagement. To promote IBL, teachers should create an environment encouraging interaction and collaboration. Group activities where learners discuss and explore the concept of area together can enhance engagement and allow learners to connect new knowledge with their prior experiences.

The explore phase was significantly impacted by strict time limits, giving learners as little as 5 to 20 seconds to solve problems. Promoting IBL requires addressing this challenge by allowing more time for exploration, enabling learners to engage deeply with the material. For example, teachers can provide opportunities for learners to deconstruct irregular shapes at their own pace, exploring various methods of calculating area as depicted in Figure 5.2. This hands-on exploration is crucial for developing a solid understanding of area (Van Uum et al., 2016).

Additionally, the lack of exploration opportunities can be mitigated by incorporating manipulatives, such as digital tools like interactive whiteboards or geometry software.

These resources enable learners to visualise and manipulate shapes, facilitating a deeper understanding of how the area is calculated. Section 5.2 highlighted an overemphasis on formulaic teaching, a notable challenge about IBL. Teachers often focus predominantly on teaching formulas, such as area = Length × Breadth, without ensuring conceptual clarity. To address this challenge, teachers should balance formula instruction with a focus on the underlying concepts. For instance, teachers should help learners understand what area represents and how it relates to real-world contexts (Bybee, 2009).

Engaging learners in discussions about the practical implications of the area and encouraging them to explain their reasoning can help prevent misconceptions, such as a confusing area with volume (Darling-Hammond et al., 2023). The elaborate phase often failed to connect learning to real-world applications. To promote IBL, teachers should incorporate project-based and investigation tasks where learners apply their area knowledge to solve real-world problems (Thangjai & Worapun, 2022). Examples could include designing a school garden, planning a playground layout, or comparing the areas of different geographical regions. These activities not only reinforce the concept of the area but also demonstrate its practical value. The limited use of diverse examples in the observed lessons restricted learners' understanding of the area.

To address this, teachers should include a variety of examples, including both regular and irregular shapes, and use measurements in different units (e.g., centimetres and metres). This variety helps learners apply their knowledge in different contexts, promoting a more comprehensive understanding of the concept of area (Van Uum et al., 2016). A lack of reflective feedback and self-assessment in the observed lessons was also noted (Thangjai & Worapun, 2022). To promote IBL, teachers should integrate self-assessment and peer feedback into the evaluation phase. For example, learners could reflect on their problem-solving methods or engage in peer discussions to critique each other's approaches to calculating areas. This reflective process helps learners internalise their understanding and identify areas for improvement. The absence of meaningful evaluation in the observed lessons limited learners' ability to correct misconceptions.

Teachers should provide continuous, formative feedback throughout the learning process to address this challenge rather than relying solely on summative assessments. Regularly reviewing learners' work and providing constructive feedback can help them refine their understanding of the area and address any errors before they become entrenched (Wang et al., 2019). Promoting IBL in teaching the area concept is essential for fostering a deeper understanding of mathematics among learners (Muir, 2020). By addressing the challenges identified in section 5.2 and implementing strategies that align with the principles of IBL, teachers can create a more engaging, exploratory, and reflective learning experience. This approach not only helps learners grasp the concept of area more effectively but also equips them with the critical thinking and problem-solving skills needed for success in mathematics and beyond (Bybee, 2009)

In answering SRQ3, I conclude that the successful facilitation of an inquiry-based lesson when teaching the concept of area requires a balanced approach that integrates the 5E's of IBL with careful consideration of time management, engagement strategies, and conceptual clarity. Teachers must move beyond formulaic instruction and incorporate real-world applications, interactive tools, and collaborative activities to foster deeper understanding. By addressing the identified challenges and providing continuous feedback, teachers can enhance learners' autonomy, competence, and relatedness, thereby promoting meaningful engagement with the concept of area. These practices align with the CAPS curriculum objectives and are essential for cultivating problem-solving skills and critical thinking in mathematics education.

5.4. UTILITY OF THE THEORETICAL FRAMEWORK

Reflecting on my study, I understand that initiating change in a classroom begins with the teacher. While numerous departments within a school must support and comprehend the change before it reaches the teacher, the responsibility for implementing effective teaching approaches and strategies ultimately lies with the teacher. A teacher surrounded by unmotivated colleagues may also resist change; thus, a positive driving force and environment are essential.

The SDT and the 5E framework, foundational to my study, were instrumental in several key aspects. These frameworks provided invaluable insights and played a crucial role in conceptualising the research questions, determining the focus of my literature review, identifying themes for the findings, and guiding my discussions. They offered straightforward guidelines on how to use IBL effectively. As teachers need a supportive environment and a positive driving force, so do learners. Immersing myself in my study and observing classroom challenges through interviews, I realised the necessity and relevance of combining and synergising SDT and IBL. The 5E's framework cannot be effectively implemented if learners lack the motivation to engage with teachers and peers. This realisation led me to explore why learners are reluctant to engage. Open-ended questions often went unanswered, highlighting a need for learners to feel capable, relevant, and independent to be motivated to participate actively in class. Motivation is complex and challenging to measure, yet its absence hinders the success of IBL.

SDT is crucial for the successful implementation, facilitation, and utilisation of IBL. By the end of my study, I reflected on my initial goal: demonstrating how to engage learners in the 5E cycle—Engage, Explore, Explain, Elaborate, and Evaluate. I aimed to show how learners can become self-driven and self-determined, taking ownership of their education. This empowers them to explore independently, evaluate their findings, and confidently explain their insights to others.

5.5. LIMITATIONS

The study had limitations that impacted the scope and depth of the findings. Firstly, the sample size was limited to only three teachers from three different schools and their learners, which, while providing valuable insights, did not offer a comprehensive understanding of the incorporation and utilisation of IBL in Grade 6 mathematics. Additionally, all participating teachers were from the same district, which constrained the study geographically. Due to time limitations, I could not visit schools in other districts. Comparing data from various districts could have provided a broader perspective on the differences and similarities in IBL implementation across regions.

Furthermore, data collection was restricted to specific school terms and mathematics topics, i.e. area. Ideally, collecting data throughout the entire academic year would have given a more holistic view of how IBL is integrated into the curriculum. Another significant limitation was the focus on the content area. I could not gather data on numeric patterns, a topic well-suited to IBL, because it falls in Term 1, and the education department does not allow researchers to collect data during Term 1 and 4. Consequently, I settled for the concept of *area*, which revealed significant insights into the effectiveness of IBL. Moreover, the study was purely qualitative. Employing a mixed methods approach could have been beneficial. Quantitative data and qualitative insights might have provided a more robust and nuanced understanding of IBL's impact on teaching practices and learners' learning outcomes. This mixed methods approach could have offered measurable evidence to support the qualitative findings, strengthening the study's overall conclusions.

5.6. RECOMMENDATIONS

Based on the findings of this study, several recommendations can be made to enhance the implementation and effectiveness of IBL in the South African education system. Firstly, many content areas within the CAPS curriculum could benefit from the facilitation, utilisation, and incorporation of an IBL approach. It is recommended that these content areas be explored to identify how they can be adapted to incorporate IBL. Additionally, policy changes to CAPS should emphasise the use and importance of IBL, thereby ensuring that lesson plans require teachers to consider the 5Es and SDT principles in their planning. This helped to integrate IBL into the curriculum and support its effective application in classroom practices.

Teachers need to be equipped with the skills and knowledge that are necessary to implement IBL effectively. This includes understanding the distinctions between projects, investigations, and assessments. Many teachers currently rely on continuous formative assessments due to their familiarity, so proper training should address these distinctions to enable teachers to plan and execute IBL lessons more effectively. Furthermore, there is a pressing need for more research on creating interactive classrooms within South Africa, as many teachers still use traditional methods despite contemporary educational needs (Ramnarain, 2014). Encouraging regular meetings among teachers within the same district to discuss integrating and utilising IBL in their lessons could foster a support system and facilitate the sharing of best practices.

Additionally, while this study focused on the effect of IBL on teachers, it would be valuable to consider the long-term impact of consistent IBL implementation on learners. Teachers reported positive initial responses from learners, but a longitudinal study is needed to understand whether this approach influences learner progress over time. Such a study should monitor trends in learner experiences and progress with regular IBL implementation.

Finally, lesson planning remains a critical issue. Effective lesson plans should incorporate IBL and address teachers' specific challenges in its implementation. Developing detailed, adaptable lesson plans that integrate the 5E 's effectively, could help overcome obstacles and ensure that IBL is applied consistently and meaningfully in the classroom.

5.7. REFLEXIVITY

As the researcher, I recognise that my background, experiences, and perspectives have inevitably influenced this study. Coming from a background in education with a particular interest in innovative teaching methods, I approached this research with a positive bias towards IBL. My enthusiasm for the subject may have influenced how I interacted with participants and interpreted their responses.

Throughout the data collection process, I was aware of the potential power dynamics between myself and the participating teachers. Given my status as a young researcher eager about IBL, my presence in their classrooms may have been perceived as intrusive. Many teachers asked about my age, what I was studying, and where I worked, finding it unusual to see a young teacher furthering their studies. To address this, I consciously tried to build rapport and ensure that participants felt comfortable about sharing their honest opinions.

I always encouraged participants to answer honestly without fear of implications, emphasising that their responses were solely for my research. Additionally, being fully bilingual proved advantageous, as it allowed me to put participants at ease who were not confident in English. I reassured them that they could take their time to think about their responses and offered to simplify difficult terms by translating them. This approach helped create a more relaxed and open environment for data collection.

Moreover, my experience as a special needs teacher at a school for learners who are blind and partially sighted has driven me to seek alternative teaching methods. Traditional methods are often ineffective in my school, where we do not have blackboards or whiteboards. Instead, we are committed to interactive and engaging education. This background has fuelled my interest in IBL and reinforced the importance of finding innovative ways to facilitate learning.

Despite these efforts, it is possible that my presence influenced their responses, particularly regarding how they presented their teaching practices. I continually reflected on my assumptions and biases during the analysis phase. Engaging in regular discussions with colleagues helped me to challenge my interpretations and remain open to findings that contradicted my initial beliefs. This reflexive practice was crucial for ensuring that the study's conclusions were grounded in the data rather than in my preconceptions.

By incorporating reflexivity, I aimed to present a balanced and credible account of the challenges and opportunities associated with implementing IBL in Grade 6 mathematics classrooms. Recognising the impact of my own positionality has allowed me to approach the findings with greater transparency and critical insight.

5.8. CONCLUSION

The persistence of traditional teaching methods in mathematics education has led to a troubling trend of declining interest and weak learner performance in South African schools. This study underscores the urgent need to introduce and support the adoption of more effective teaching methods. Despite resistance within the educational realm to the idea of moving away from traditional approaches, embracing contemporary methods, such as IBL, can significantly enhance the teaching and learning environment, even in resource-limited settings.

Prior research has demonstrated that IBL can foster increased interest and participation among learners. Drawing inspiration from John Dewey's advocacy for active engagement and hands-on experiences, which are crucial for developing thinking processes and deeper understanding, this study reinforces the effectiveness of alternative teaching methods over the traditional "chalk and talk" approach.

This research contributes to the growing body of evidence by highlighting the value of IBL in promoting SDT principles within mathematics education at primary school level. The findings revealed that IBL engages learners and nurtures their autonomy, competence, and relatedness—key factors that sustain their motivation and interest in mathematics. The study's insights into the relationship between Grade 6 teachers' incorporation and utilisation of IBL characteristics and their teaching practices underscore the limitations of using monotonous teaching methods. Such methods can lead to boredom, burnout, and diminished understanding among learners. In contrast, IBL promotes independent problem-solving through investigative activities, fostering skill and knowledge acquisition. IBL is grounded in the assumption that humans have an innate desire to discover knowledge and continue aiming to develop intellectually disciplined and curious thinkers.

Therefore, teachers are encouraged to embrace, rather than dismiss, IBL, considering how inquiry-based methods can be effectively incorporated into their teaching contexts. When integrated with SDT principles, IBL offers a promising pathway to revitalising mathematics education. Hopefully, this research inspires further exploration and adoption of IBL, contributing to a more dynamic and effective educational landscape. By committing to contemporary methods, we can address the decline in interest and performance in mathematics, paving the way for a brighter future for our learners.

REFERENCES

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology*, *103*(1), 1–18. https://doi.org/10.1037/a0021017

Artigue, M., & Blomhøj, M. (2013). Conceptualizing inquiry-based education in Mathematics. ZDM, 45(6), 797–810. https://doi.org/10.1007/s11858-013-0506-6

Artigue, M., Dillon, J., Harlen, W., & Léna, P. (2012, December). The resources for implementing inquiry in science and in mathematics at school. Fibonacci. Retrieved March 22, 2023, from http://fibonacci.uni-bayreuth.de/resources/resources-for-implementing-inquiry.html

Babbie, E. (2021). The practice of social research (15th ed.). Cengage Learning.

Babbie, E. & Mouton, J. (2000). The practice of social research. Oxford: Oxford University Press.

Basit, T. (2003). Manual or electronic? The role of coding in qualitative data analysis. Educational Research, 45(2), 143–154. https://doi.org/10.1080/0013188032000133548

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study Design and implementation for novice researchers. The Qualitative Report. https://doi.org/10.46743/2160-3715/2008.1573

Beauchamp, T. L., & Childress, J. F. (2013). *Principles of biomedical ethics* (7th ed.). Oxford University Press.

Berkwits, M. & Inui, T.S. (1998). Making use of qualitative research techniques. [Online] Available from: https://pubmed.ncbi.nlm.nih.gov

Binns IC & Popp S. (2013). Learning to teach science through inquiry: Experiences of preservice teachers. *Electronic Journal of Science Education*, 17(1):1–24. Available at http://ejse.southwestern.edu/article/view/11346/81 16.

Boaler, J. (2016). Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages, and innovative teaching. Jossey-Bass.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bybee, R. W. (2009). The BSCS 5E Instructional Model and 21st Century Skills. Colorado Springs, CO: BSCS.

Bybee, R. W., and Landes, N. M. (1990). Science for Life & Living: An Elementary School Science Program from Biological Sciences Curriculum Study. The American Biology Teacher 52(2): 92-98.

Calleja, J., & Buhagiar, M. A. (2022). Students' resistance to learning mathematics through investigations, Journal of Curriculum Studies, 54:1, 123–146, https://doi.org/10.1080/00220272.2021.1981457

Caswell, C. J., & LaBrie, D. J. (2017). Inquiry-based Learning from the Learner's Point of View: A Teacher Candidate's Success Story. Journal of Humanistic Mathematics, 7(2), 161–186.

Chan HO. (2010). How do teachers' beliefs affect the implementation of inquiry-based learning in the PGS Curriculum? A case study of two primary schools in Hong Kong. PhD thesis. Durham, England: Durham University. Available at http://etheses.dur.ac.uk/320/1/The_thesis_of_Angu s_FINAL.pdf?DDD29+.

Crabtree, B. F., & Miller, W. L. (1999). Doing Qualitative Research. Sage Publications Inc.

Cohen, L., Manion, L., & Morrison, K. (2011). Research methods in education. Routledge.

Collins, C. S., & Stockton, C. M. (2018). The central role of theory in qualitative research. International Journal of Qualitative Methods, 17(1), 1–10. https://doi.org/10.1177/1609406918797475

Connelly, L.M. (2016). Trustworthiness in qualitative research. Medsurg Nursing, 25(6), 435–437. Construction and reconstruction concept in mathematics instruction. In Journal of Physics: Conference Series (Vol. 943, No. 1, p. 012011). IOP Publishing. Constructivist learning theory.

Crawford BA. (2014). From inquiry to scientific practices in the science classroom. In NG Lederman & SK Abell (eds). *Handbook of research on science education* (Vol. 2). London, England: Routledge.

Creswell, J. W. (2018). Research design: qualitative, quantitative, and mixed methods approach. Sage Publications.

Creswell, J. W., & Poth, C. N. (2017). Qualitative inquiry and research design: Choosing among five approaches. Sage.

Crotty, M. (1998). The foundations of social research: Meaning and perspective in the research process. SAGE Publications Inc.

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., & Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology*, *11*(1). https://doi.org/10.1186/1471-2288-11-100

Darling-Hammond, L., Schachner, A. C. W., Wojcikiewicz, S. K., & Flook, L. (2023). Educating teachers to enact the science of learning and development. Applied

Developmental Science, 28(1), 1–21. https://doi.org/10.1080/10888691.2022.2130506

Dawadi, S. (2020). Thematic Analysis Approach: A Step-by-Step Guide for ELT Research Practitioners. *Journal of Nepal English Language Teachers' Association*, *25*(1). https://doi.org/https://files.eric.ed.gov/fulltext/ED612353.pdf

Deci, E. L., & Ryan, R. M. (2012). Motivation, personality, and development within embedded social contexts: An overview of self-determination theory. In R. M. Ryan (Ed.), The Oxford handbook of human motivation (pp. 85–107). Oxford University Press.

Denzin, N. K., & Lincoln, Y. S. (2000). The SAGE handbook of qualitative research. Sage Publications.

Department of Basic Education. (2011). Curriculum and Assessment Policy Statement Grades 4-6 Mathematics. Government Printers.

Department of Basic Education. (2018). Mathematics Teaching and Learning Framework for South Africa: Teaching mathematics for understanding. Government Printers.

Dewey, J. (1938). Experience and Education. Scientific Research.

Dey, I. (1995). Reducing fragmentation in qualitative research. In Kelle, U. (ed.) Computer-aided qualitative data analysis: Theory, methods and practice. London: Sage.

Diener, E., & Crandall, R. (1978). Ethics in social and behavioral research. University of Chicago Press. Guillemin, M., & Gillam, L. (2004). Ethics, reflexivity, and "ethically important moments" in research. Qualitative Inquiry, 10(2), 261-280. https://doi.org/10.1177/1077800403262360

Dobber, M., Zwart, R., Tanis, M., & Van Oers, B. (2017). Literature review: The role of the teacher in inquiry-based education. Educational Research Review, 22, 194–214.

Duran, L. B., & Duran, E. (2004). "The 5E Instructional Model: A Learning Cycle Approach for Inquiry-Based Science Teaching." Science Education Review 3(2): 49-58.

Ebneyamini, S., & Sadeghi Moghadam, M. R. (2018). Toward Developing a Framework for Conducting Case Study Research. International Journal of Qualitative Methods, 17(1), 160940691881795. https://doi.org/10.1177/1609406918817954

Etikan, I., Musa, S. A. & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. American journal of theoretical and applied statistics, 5(1), 1-4.

Furrer, C., & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. Journal of Educational Psychology, 95(1), 148–162. https://doi.org/10.1037/0022-0663.95.1.148

Gagné, M., Parker, S. K., Griffin, M. A., Dunlop, P. D., Knight, C., Klonek, F. E., & Parent-Rocheleau, X. (2022). Understanding and shaping the future of work with self-determination theory. Nature Reviews Psychology, 1(1), 378–392. https://doi.org/10.1038/s44159-022-00056-w

Gholam, A. P. (2019). Inquiry-based learning: Student teachers' challenges and perceptions. Journal of Inquiry and Action Education, 10(2), 112–130.

Gormally, C., Brickman, P., Hallar, B., & Armstrong, N. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. International Journal for the Scholarship of Teaching and Learning, 3(2). https://doi.org/10.20429/ijsotl.2009.030216

Graneheim, U.H. & Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse education today, 24(2), 105-112

Guillemin, M., & Gillam, L. (2004). Ethics, reflexivity, and "ethically important moments" in research. Qualitative Inquiry, 10(2), 261-280. https://doi.org/10.1177/1077800403262360

Hadi, M.A. & Closs, S.J. (2016). Ensuring rigour and trustworthiness of qualitative research in clinical pharmacy. International journal of clinical pharmacy, 38(3), 641–646.

Hamilton, L., & Corbett-Whittier, C. (2013). Using case study in education research. SAGE Publications Ltd, https://doi.org/10.4135/9781473913851

Harlen, W. (2013). Inquiry-based learning in Science and Mathematics. Review of Science, Mathematics and ICT Education, 7(2), 9–33. https://doi.org/https://doi.org/10.26220/rev.2042

Hattie, J. (2009). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. Routledge.

Hoffman, B. (2016). Motivation for learning and performance. Academic Press.

Hui, E. K., & Tsang, S. K. (2012). Self-determination as a psychological and positive youth development construct. The Scientific World Journal, 2012, 1–7. https://doi.org/10.1100/2012/759358

Ibrahim. (2007). Penelitian dan Penilaian Pendidikan. Bandung : Sinar Baru Algensindo.

Joynes, C. (2019). Emerging issues report: 21st century skills: Evidence of issues in definition, demand, and delivery for development contexts. https://assets.publishing.service.gov.uk/media/5d71187ce5274a097c07b985/21st_century.pdf

Justice, C., Warry, W., Cuneo, C., Inglis, S., Miller, S., Rice, J., & Sammon, S. (2002). A grammar for inquiry: Linking goals and methods in a collaboratively taught social sciences inquiry course. *The Alan Blizzard award paper: The award-winning papers*, (1).

Laursen, S., Hassi, M.-L., Kogan, M., & Hunter, A.-B. (2011). Evaluation of the IBL Mathematics Project: Student and Instructor Outcomes of Inquiry-Based Learning in College Mathematics. ATLAS Assessment and Research Center.

Levers, M.-J. D. (2013). Philosophical paradigms, grounded theory, and perspectives on emergence. SAGE Open, 3(4), 215824401351724. https://doi.org/10.1177/2158244013517243

Li, Y., & Schoenfeld, A. H. (2019). Problematizing teaching and learning mathematics as “given” in STEM education. International Journal of STEM Education, 6. https://doi.org/10.1186/s40594-019-0197-9

Liaga, M. (2019). Instructional Strategies Used by Teachers to Facilitate Construction of Mathematics Knowledge by Visually Impaired Learners. http://hdl.handle.net/2263/76885

Lincoln, Y. & Guba, E. (2007). Judging interpretations: But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation. New Directions for Evaluation. 2007(114):15–25.

Liu, C. H., & Matthews, R. (2005). Vygotsky’s philosophy: Constructivism and its criticisms examined. International Educational Journal, 6(3), 386–399.

Louw, E. (2015). Investigation into mathematics instruction for learners with learning difficulties (Doctoral dissertation, University of Pretoria).

Luft, J. A., Jeong, S., Idsardi, R., & Gardner, G. (2022). Literature reviews, theoretical frameworks, and conceptual frameworks: An introduction for new biology education researchers. CBE—Life Sciences Education. https://doi.org/10.1187/cbe.21-05-0134

Mabena, N., Mokgosi, P. N., & Ramapela, S. S. (2021). Factors contributing to poor learner performance in Mathematics: A case of selected schools in Mpumalanga Province, South Africa. Problems of Education in the 21st Century,79(3), 451-466. doi:10.33225/pec/21.79.451

Maguire, M. & Delahunt, B. (2017). Doing a Thematic Analysis: A practical step-by-step guide for learning and teaching scholars, 3(1):12–47.

Maree, K. (2007). First steps in research. Pretoria. Van Schaik Publishers.

Maree, K. (2016). First Steps in Research. Pretoria: Van Schaik Publishers.

Marshall, J. C. (2013). *Succeeding with inquiry in science and math classrooms*. ASCD.

McCombs, B. L. (2015). Developing responsible and autonomous learners: A key to motivating students. American Psychological Association. https://www.apa.org/education-career/k12/learners

McCusker, K., & Gunaydin, S. (2014). Research using qualitative, quantitative or mixed methods and choice based on the research. Perfusion, 30(7), 537–542. https://doi.org/10.1177/0267659114559116

McMillan, J.H. & Schumacher, S. (2010). Research in Education: Evidence-Based Inquiry, MyEducationLab Series. USA: Pearson.

Merriam, S. B. (1998). Qualitative Research and Case Study Applications in Education. Revised and expanded from" Case Study Research in Education." Jossey-Bass Publishers, 350 Sansome St, San Francisco, CA 94104.

Merriam, S. B., & Tisdell, E. J. (2015). Qualitative research: A guide to design and implementation (4th ed.). John Wiley & Sons.

Mills, J., Harrison, H., Franklin, R. & Birks, M. (2017). Case study research: Foundations and methodological orientations. Forum Qualitative Sozialforschung/Forum: Qualitative Social Research, 18(1), 17

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it, and does it matter? Results from a research synthesis years 1984 to 2002. Journal of Research in Science Teaching, 47(4), 474–496.

Moalusi, K. (2020). Numbers conceal the intricacies in categorising qualitative research in organisational studies: What lies beneath the surface? SA Journal of Industrial Psychology, 46(1). https://doi.org/10.4102/sajip.v46i0.1692

Morgan, K., & Henning, E. (2011). How school history textbooks position a textual community through the topic of racism. Historia, 56(2), 169–190.

Motsoeneng, T. J., Makhasane, S. D., & Nicholas, H. (2021). Challenges faced by rural accounting teachers in implementing web-based collaborative learning. Perspectives in Education, 39(3). https://doi.org/10.18820/2519593x/pie.v39.i3.7

Mueller, A. E., & Segal, D. L. (2015). Structured versus semistructured versus unstructured interviews. The Encyclopedia of Clinical Psychology, pp. 1–7. https://doi.org/10.1002/9781118625392.wbecp069

Muir, T. (2020). Self-determination theory and the flipped classroom: A case study of a senior secondary mathematics class. Mathematics Education Research Journal, 33(3), 569–587. https://doi.org/10.1007/s13394-020-00320-3

Ndlovu, M. (2015). Learner Perceptions of Inquiry in Science Fair Projects: A Case Study of a Regional Science Fair in South Africa. *International Journal of Educational Science*. 10(2):347–358.

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence, and relatedness in the classroom: Applying self-determination theory to educational practice. Theory and Research in Education, 7(2), 133–144. https://doi.org/10.1177/1477878509104324

Nieuwenhuis, J. 2016. Introducing qualitative research. In Maree, K. (Ed.). First steps in research. Pretoria: Van Schaik Publishers.

Noreen, R., & Rana, A. M. K. (2019). Activity-Based Teaching versus Traditional Method of Teaching in Mathematics at Elementary Level. Bulletin of Education and Research, 41(2), 145–159.

O'Brien, B. C., Harris, I. B., Beckman, T. J., Reed, D. A., & Cook, D. A. (2014). Standards for reporting qualitative research: a synthesis of recommendations. Academic medicine: Journal of the Association of American Medical Colleges, 89(9), 1245–1251. https://doi.org/10.1097/ACM.0000000000000388

Patton, M. Q. (2015). Qualitative research & evaluation methods: integrating theory and practice (Fourth edition. ed.). Thousand Oaks, California: SAGE Publications, Inc.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. Educational Research Review, 14(14), 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Phillips, H. N. (2023). Developing critical thinking in classrooms: Teacher responses to a Reading-for-Meaning workshop.Reading & Writing, 14(1). https://doi.org/10.4102/rw.v14i1.401

Powell, K., & Kalina, C. (2009). Cognitive and social constructivism: Developing tools for an effective classroom. Education, 130(2), 241–251.

Ramdhani, A., Ramdhani, M. A., & Amin, A. S. (2014). Writing a literature review research paper: A step-by-step approach. International Journal of Basic and Applied Science, 3(1), 47–56.

Ramnarain, U., & Hlatswayo, M. (2018). Teacher beliefs and attitudes about inquiry-based learning in a rural school district in South Africa. South African Journal of Education, 38(1), 1–10. https://doi.org/10.15700/saje.v38n1a1431

Roblyer, M. D., & Doering, A. H. (2010). Integrating educational technology into teaching. Pearson Publishing.

Robyn M., G. (2020). *Inquiry-Based Science Education*. https://doi.org/10.1201/9780429299179

Rosli, M. S., Saleh, N. S., Md. Ali, A., & Abu Bakar, S. (2022). Self-Determination Theory and Online Learning in University: Advancements, Future Direction and Research Gaps. Sustainability, 14(21), 14655. MDPI AG. Retrieved from http://dx.doi.org/10.3390/su142114655

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55(1), 68–78. https://doi.org/10.1037/0003-066x.55.1.68

Saad R & BouJaoude S. (2012). The relationship between teachers' knowledge and beliefs about Science and inquiry and their classroom practices. *Eurasia Journal of Mathematics, Science and Technology Education*, 8(2):113–128. https://doi.org/10.12973/eurasia.2012.825a

Santrock, J. W. (2017). Educational Psychology. New York, NY: McGraw-Hill Education.

Schoenfeld, A. H. (2016). Mathematical thinking and problem-solving. Routledge.

Schoonenboom, J., & Johnson, R. B. (2017). How to Construct a Mixed Methods Research Design. Kolner Zeitschrift fur Soziologie und Sozialpsychologie, 69(Suppl 2), 107–131. https://doi.org/10.1007/s11577-017-0454-1

Scotland, J. (2012). Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. Canadian Center of Science and Education, 5(9).

Şen, C., Sonay AY, Z., & Güler, G. (2021). The Effectiveness of Inquiry-based Learning on Middle School Students' Mathematics Reasoning Skill. ATHENS JOURNAL of EDUCATION, 8(4), 417–430. https://doi.org/10.30958/aje.8-4-5

Senzeni Sibanda, & Rambuda, A. M. (2021). The implementation of formal assessments in intermediate phase mathematics as a foundation of teaching and learning enhancement. Universal Journal of Educational Research, 9(12), 1915–1927. https://doi.org/10.13189/ujer.2021.091204

Silva, E. (2008). Measuring Skills for the 21st Century. Washington D.C: Education Sector

Simpson, S. H. (2015). Creating a data analysis plan: What to consider when choosing statistics for a study. The Canadian Journal of Hospital Pharmacy, 68(4), 311–317. https://doi.org/10.4212/cjhp.v68i4.1471

Singh, A., & Singh, S. (2021). Significance of Research Process in Research Work. Quasi-Experimental Design for Health Psychology. https://doi.org/doi.org/10.13140/RG.2.2.32664.93445/1

Stemler, S. E. (2001). An Overview of Content Analysis. [Online] Available from https://www.researchgate.net> [Accessed on 10 May 2019]

Stake, R. E. (1995). The Art of Case Study Research. Thousand Oaks, 49–68.

Suto, I. (2013). 21st Century Skills: Ancient, Ubiquitous, Enigmatic? Cambridge: A Cambridge Assessment Publication.

Thangjai, N., & Worapun, W. (2022). Developing Inquiry Learning Characteristics of Grade 7 Students Using Integrated 5E's of Inquiry-Based Learning and Game-Based Learning. Journal of Educational Issues, 8(1), 137–150.

Thanh, N.C., & Thành, T.T. (2015). The Interconnection Between Interpretivist Paradigm and Qualitative Methods in Education.

Tobin, G.A. & Begley, C.M. 2004. Methodological rigour within a qualitative framework. Journal of Advanced Nursing. 48(4):388–396.

Trautmann N, MaKinster J & Avery L. (2004). What makes inquiry so hard? (and why is it worth it?). In D Zandvliet (ed). *Proceedings of the NARST 2004 Annual Meeting*. Vancouver, Canada: NARST. Available at http://www.ei.cornell.edu/pubs/NARST_04_CSIP. pdf.

Tularam, G. A., & Machisella, P. (2018). Traditional vs Non-traditional Teaching and Learning Strategies–the case of E-learning. International Journal for Mathematics Teaching and Learning, 19(1), 129-158.

Ulker, V., & Ali, H. F. (2023). Inquiry-based learning implementation: Students' perception and preference. International Journal of Social Sciences & Educational Studies, 10(2). https://doi.org/10.23918/ijsses.v10i2p220

Umugiraneza, O., Bansilal, S., & North, D. (2018). The concepts of area and perimeter: Insights and misconceptions of Grade 10 learners. *Pythagoras -Journal of the Association for Mathematics Education of South Africa*, 1012–2346. https://doi.org/10.4102/pythagoras

Van de Walle, J. A., Karp, K. S., & Bay-Williams, J. M. (2014). Elementary and middle school mathematics: Teaching developmentally. Pearson Education.

van Uum, M. S. J., Verhoeff, R. P., & Peeters, M. (2016). Inquiry-based science education: Towards a pedagogical framework for primary school teachers. International Journal of Science Education, 38(3), 450–469. https://doi.org/10.1080/09500693.2016.1147660

Vannoni, M. (2014). What are case studies good for? Nesting comparative case study research into the Lakatosian Research Program. *Cross-Cultural Research*, *49*(4), 331–357. https://doi.org/10.1177/1069397114555844

Van Graan, D. C. (2020). Exploring inquiry-based education in a professional learning programme for science teachers. Department of Curriculum Studies, Faculty of Education Stellenbosch University.

Verma, S., Yacob, M. S., & Kirpalani, A. (2023). Outcomes of inquiry-based learning in health professions education: a scoping review. *Canadian Medical Education Journal*, *14*(2). https://doi.org/10.36834/cmej.75144

Wahyuni, D. (2012). The research design maze: Understanding paradigms, cases, methods and methodologies. Journal of Applied Management Accounting Research. 10(1):69–80.

Wake, G. (2011). *Promoting inquiry-based learning in mathematics and science education across Europe Policy: contextualising the European policy space in support of inquiry-based learning in mathematics and science*. [Online], Available: http://www.primas-project.eu/.

Wallace CS & Kang NH. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching*, 41(9):936–960. https://doi.org/10.1002/tea.20032

Wang, C. K. J., Liu, W. C., Kee, Y. H., & Chian, L. K. (2019). Competence, autonomy, and relatedness in the classroom: Understanding students' motivational processes using the self-determination theory. Heliyon, 5(7). https://doi.org/10.1016/j.heliyon.2019.e01983

Webb, N. M., Franke, M. L., Ing, M., Wong, J., Fernandez, C. H., Shin, N., & Turrou, A. C. (2014). Engaging with others' mathematical ideas: Interrelationships among student participation, teachers' instructional practices, and learning. International Journal of Educational Research, 63, 79–93. https://doi.org/10.1016/j.ijer.2013.02.001

Whitehead, J. (2009). Generating living theory and understanding in action research studies. Action Research, 7(1), 85–99. https://doi.org/10.1177/1476750308099599

Willingham, D. T., & Riley, B. (2020, July 9). Perspective: Why calls to 'reinvent schooling' in response to the pandemic are wrong. The Washington Post. https://www.washingtonpost.com/education/2020/07/09/why-calls-reinvent-schooling-response-pandemic-are-wrong/

Wu, H.-K., & Krajcik, J. S. (2005). Inscriptional practices in two inquiry-based classrooms: A case study of seventh graders' use of data tables and graphs. Journal of Research in Science Teaching, 43(1), 63–95. https://doi.org/10.1002/tea.20092

Yazan, B. (2015). Three approaches to case study methods in education: Yin, Merriam, and Stake. The qualitative report, 20(2), 134–152.

Zhao, F. F., Roehrig, G., Patrick, L., Chantal, L. B., & Cotner, S. (2021). Using a self-determination theory approach to understand student perceptions of inquiry-based learning. Teaching & Learning Inquiry, 9(2). https://doi.org/10.20343/teachlearninqu.9.2.5

ANNEXURES

Annexure A – Consent form for the Gauteng Department of Education

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	04 August 2023
Validity of Research Approval:	08 February 2023– 30 September 2023 2023/314
Name of Researcher:	Cunningham N
Address of Researcher:	122 Uitspan road,
	Die Wilgers, Pretoria
Telephone Number:	0828170080
Email address:	u17126844@tuks.co.za
Research Topic:	Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool.
Name of University:	University of Pretoria
Type of qualification	Masters
Number and type of schools:	3 Primary Schools
District/s/HO	Tshwane West

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

04/08/2023

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1

Making education a societal priority

1. *Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. ***Because of the relaxation of COVID 19 regulations researchers can collect data online, telephonically, physically access schools or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate.***
4. ***The Researchers are advised to wear a mask at all times, Social distance at all times, Provide a vaccination certificate or negative COVID-19 test, not older than 72 hours, and Sanitise frequently.***
5. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
6. *A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
7. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
8. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
9. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
10. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
11. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
12. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
13. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
14. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
15. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
16. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Dr Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: 04/08/2023

Annexure B – Consent form for the relevant district

Faculty of Education

Enquiries: Nicole Cunningham
Email: U17126844@tuks.co.za

District Director
Tshwane West
2216 Klipgat Rd
Mabopane
0190

Dear Tshwane West District Director

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY

I am a masters student at the University of Pretoria, and I am conducting a research study titled: **Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool.** The purpose of this study is to explore how Grade 6 mathematics teachers implement Inquiry-based learning (IBL) approach, as prescribed in the mathematics curriculum, when teaching the concept of *area*. This letter serves to request your permission to conduct the research at Capital Park Primary school, Generaal Nicolaas Smit Primary school and Danie Malan Primary School where one teacher and his/her learners per school will be requested to participate in the study.

This study involves observing teachers while they teach the concept of *area*. I will be a passive participant and I will do audio/video recordings and take field notes while the teacher and the learners are busy in class. I will observe two lessons per school. The lessons will be observed as they appear in the school timetable to avoid any disruption.

This research project will also involve semi-structured interviews with mathematics teachers after school hours. The obtained information will be treated with the strictest confidentiality and used solely for this research.

I also would like to request your permission to use the data provided, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and use the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

For any additional information, you may contact me, Nicole Cunningham, at 0828170080 or my supervisor, Dr RD Sekao at, 012 420 4640 or david.sekao@up.ac.za.

Yours Sincerely

Ms. N Cunningham (student)	Dr D Sekao (lecturer)

Annexure C – Consent form for the principals of the school

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Enquiries: Nicole Cunningham
Email: u17126844@tuks.co.za

The Principal

Capital Park Primary School

Dear Principal

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY

I am a masters student at the University of Pretoria, and I am conducting a research study titled: ***Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool.*** The purpose of this study is to explore how Grade 6 mathematics teachers implement Inquiry-based learning (IBL) aspects, as prescribed in the mathematics curriculum, when teaching the concept of *area*. This letter serves to request your permission to conduct the research in your school where two lessons of one Grade 6 teacher and his/her learners will be observed.
The District Director has granted permission in this regard, and I have attached the letter of permission.

If permission is granted, the Grade 6 mathematics teacher will be invited to participate in this study by:

a) being observed and audio/video recorded when teaching the concept of *area*.
b) providing me with the lesson plan on the concept of *area* for analysis.
c) participating in an interview session (about 30 minutes), which will be audio/video recorded.

The learners will, after their parental consent is obtained, be invited to participate in this study by being observed during two lesson presentations. In addition, note that *participation* of the teachers and learners is completely *voluntary* and if they agree to participate, I will ensure that the following ethical principles are adhered to:

- *Informed consent:* teachers' consent and learners' assent to participate will be based on their understanding of the purpose and process of the study as I would have explained them.
- *Safety in participation:* the teachers and learners will not be exposed to any risk or harm of any form because they will not be required to deviate from their day-to-day teaching and learning process.
- *Privacy*: The names of teachers and learners will be kept confidential and anonymous, therefore the data collected will not be linked to any teacher or learner.

- *Trust*: teachers and learners will not be subjected to deception or betrayal in the research process or its published findings.

I also would like to request your permission to use the data provided, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and use the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

For any additional information, you may contact me, Nicole Cunningham, at 0828170080 or my supervisor, Dr RD Sekao at, 012 420 4640 or david.sekao@up.ac.za.

Yours sincerely

Ms N Cunningham (student)

Dr RD Sekao (Supervisor)

Annexure D – Consent form for the teachers

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Enquiries: Nicole Cunningham
Email: u17126844@tuks.co.za

Dear Teacher

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY

I am a masters student at the University of Pretoria, and I am conducting a research study titled: ***Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool.*** The purpose of this study is to explore how Grade 6 mathematics teachers implement Inquiry-based learning (IBL) aspects, as prescribed in the mathematics curriculum, when teaching the concept of *area*. I, therefore, request you to participate in the aforementioned study.

If you agree to participate in my study, you will be requested to:

a) Allow for observations and audio/video recordings during the presentation of two lessons focusing on the concept of *area*.
b) Provide your lesson plan for analysis.
c) Participate in an interview session, which will be audio/video recorded.

The learners will also be invited to participate in this study by being observed during two lesson presentations. In addition, note that your *participation* is completely *voluntary* and if you agree to participate, I will ensure that the following ethical principles are adhered to:

- *Informed consent:* your consent to participate will be based on your understanding of the purpose and process of the study as I would have explained to you.
- *Safety in participation:* you will not be exposed to any risk or harm of any form because you will not be required to deviate from your day-to-day teaching process.
- *Privacy:* your names and the data you provide will be kept confidential and anonymous.
- *Trust:* you will not be subjected to deception or betrayal in the research process or its published findings.

I also would like to request your permission to use the data provided, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and use the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

For any additional information, you may contact me, Nicole Cunningham at 0828170080 or my supervisor, Dr RD Sekao at, 012 420 4640 or david.sekao@up.ac.za.

Yours sincerely

____________________ ____________________

Ms N. Cunningham (student) Dr R.D. Sekao (Supervisor)

Annexure E – Consent form for the learners

Faculty of Education

Enquiries: Nicole Cunningham
Email: u17126844@tuks.co.za

Dear learner

INVITATION TO PARTICIPATE IN THE RESEARCH STUDY

I am a student at the University of Pretoria, and I am doing research titled: ***Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool.*** The purpose of this study is to understand how your teacher teaches the concept of *area* in mathematics. I, therefore, request you to allow me to observe two mathematics lessons when your teacher teaches you the concept of *area*.
Please note that you are not forced to grant me permission to observe the lesson when you are being taught; however, if you give me permission, which I will greatly appreciate, I will ensure that:

- you fully understand the purpose and process of the study as I would have explained them.
- you will not be exposed to any risk or harm of any form since I will observe the lessons during the time reflected on your timetable, therefore you will not be required to do anything outside of your day-to-day teaching and learning process.
- your names and the information you provide will be kept confidential and anonymous.
- you will not be subjected to any act of deception or betrayal in the research process or its published findings.
- you may choose to withdraw from being observed at any time without any consequences.

I would also like to ask for your permission to use the data you will provide, without revealing your name and identity, for further research purposes with the University of Pretoria.

For any additional information, you may contact me, Nicole Cunningham, at 0828170080 or my supervisor, Dr RD Sekao at, 0124204640 or david.sekao@up.ac.za.

Yours sincerely

______________________ ______________________
Ms. N. Cunningham (student) Dr RD Sekao (Supervisor)

Dear Ms Nicole Cunningham

ACCEPTANCE TO PARTICIPATE IN YOUR RESEARCH STUDY

I,……………………….…. a Grade 6 learner at ______________________, voluntarily and willingly agree to participate in the study titled: ***Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool.*** I understand that as part of the study to which I agree to participate, I will be observed during two lessons when my mathematics teacher teaches the concept of *area*.
I declare that I understand the purpose of the study and that you promise to obey the ethical research principles, including safety, privacy (not revealing my name and identity) and trust as you explained to me.

In addition, I grant the University of Pretoria permission to use the data provided for this study, without revealing my name and identity, for further research purposes.

Given the above information, I voluntarily agree to participate in your study.

______________________	_____________	___________
(**Name** and **surname**)	Signature	Date

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Annexure F – Consent form for the parents

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Enquiries: Nicole Cunningham
Email: u17126844@tuks.co.za

Dear Parent

REQUEST FOR YOUR CHILD'S PARTICIPATION IN THE RESEARCH STUDY

I am a masters student at the University of Pretoria, and I am conducting a research study titled: ***Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool.*** The purpose of this study is to understand how Grade 6 mathematics teachers teach the concept of area in your child's class. I, therefore, request your permission to observe two mathematics lessons in your child's class.
Note that you are not compelled to grant permission, and your child is also not compelled to be observed, however, if you give me permission, which I will greatly appreciate, I will ensure that the following ethical principles are adhered to:

- *Informed consent*: I will provide any additional information you may need so that you clearly understand the purpose and process of the study I have explained herein.
- *Safety in participation*: your child will not be exposed to any risk or harm of any form because they will not be required to do anything outside their day-to-day teaching and learning activities taking place in the classroom.
- *Privacy*: your child's name and the information generated will be kept confidential and anonymous.
- *Trust*: your child will not be subjected to any act of deception or betrayal in the research process or its published findings.

I would also like to request your permission to use the data that your child will provide, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and use the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

For any additional information, you may contact me, Nicole Cunningham, at 0828170080 or my supervisor, Dr RD Sekao at, 012 420 4640 or david.sekao@up.ac.za.

Yours sincerely

Ms. N. Cunningham (student) Dr RD Sekao (Supervisor)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Dear Ms N. Cunningham

LETTER OF CONSENT FOR MY CHILD TO PARTICIPATE IN THE RESEARCH STUDY

I, ……………..………………..……………., parent of………….……..………………….………, voluntarily and willingly permit my child to participate in the research study titled: ***Grade 6 mathematics teachers' use of Inquiry-Based Learning as a pedagogical tool.*** I understand that the participation of my child in the afore-mentioned study to which I am granting permission, will involve being observed during the two lessons taught by their teacher(s). I declare that I understand the purpose of the study and that you subscribe to the ethical research principles, including *informed consent, safety, privacy* and *trust.*

In addition, I grant the University of Pretoria permission to use the data provided for this study, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and use the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Given the above information, I give permission for my child's participation in the study.

______________________	______________	____________
(**Name** and **surname**)	Signature	Date

Annexure G – Document analysis checklist

A document analysis checklist used to investigate the participants' lesson plans and preparations.			
Site Location:	**Date:**	**Start Time:**	**End Time:**
ASPECTS	**YES**	**NO**	**COMMENT**
1. Is there evidence that the learners are actively engaged during the lessons?			
2. Is there evidence indicating that the learners are allowed to explore during the lessons?			
3. Do learners have any opportunity provided to them during the lesson to articulate and explain their newly acquired knowledge?			
4. How did the teacher ensure that the learners could apply the knowledge taught to new and unfamiliar situations?			
5. How does the teacher create an opportunity for learners to reflect on their knowledge?			
6. How does the teacher foster the learners' autonomy? (allowing them to work independently).			
7. How does the teacher foster the learners' competence? (allowing them to feel confident and able to do the work).			
8. How does the teacher foster the learners' relatedness? (allowing them to feel connected to the content being taught).			

Annexure H – Observation sheet

<table>
<tr><th colspan="4">Observation Sheet</th></tr>
<tr><td>Site Location:</td><td>Date :</td><td>Start Time:</td><td>End Time:</td></tr>
<tr><td colspan="4">Research Issue</td></tr>
<tr><th>Areas of Observation</th><th colspan="3">Comments</th></tr>
<tr><td>1. Engagement (are learners engaged with challenging situation(s)? Is their prior knowledge being activated? Are questions thought-provoking?)</td><td colspan="3"></td></tr>
<tr><td>2. Exploration (are learners investigating any phenomenon? Is the learner’s prior knowledge being challenged, and are learners creating new ideas?)</td><td colspan="3"></td></tr>
<tr><td>3. Explanation (did learners receive an opportunity to explain the phenomenon? Did learners gain new knowledge?)</td><td colspan="3"></td></tr>
<tr><td>4. Elaboration (did learners apply their knowledge towards a new learning situation? Is their knowledge deepened and extended during the lesson?)</td><td colspan="3"></td></tr>
<tr><td>5. Evaluation (did learners reflect on their knowledge and learning process/assessments?)</td><td colspan="3"></td></tr>
<tr><td>6. Autonomy: How does the teacher promote the learner's autonomy (allowing them to work independently)?</td><td colspan="3"></td></tr>
<tr><td>7. Competence: How does the teacher promote the learners' competence? (allowing them to feel confident and able to do the work).</td><td colspan="3"></td></tr>
<tr><td>8. Relatedness: How does the teacher promote the learners' relatedness? (allowing them to feel connected to the content being taught).</td><td colspan="3"></td></tr>
</table>

Annexure I - Semi-Structured interviews

Hello teacher, I hope you're doing well today. I'm Nicole Cunningham, and I want to thank you again for taking the time to meet with me. As I mentioned before, I'm a master's student from the University of Pretoria, and I am doing my research on interactive math education, particularly with a focus on the Grade 6 math class and teaching the concept of *area*. This interview is not to evaluate your teaching but to gain insight into your and the learner's experiences as a teacher. There are no right or wrong answers, and your participation is voluntary. Let us get to it. I will ask you some questions, and you will answer as best you can, and I will also make notes as we go.

School:	**Date:**	**Start Time:**	**End Time :**

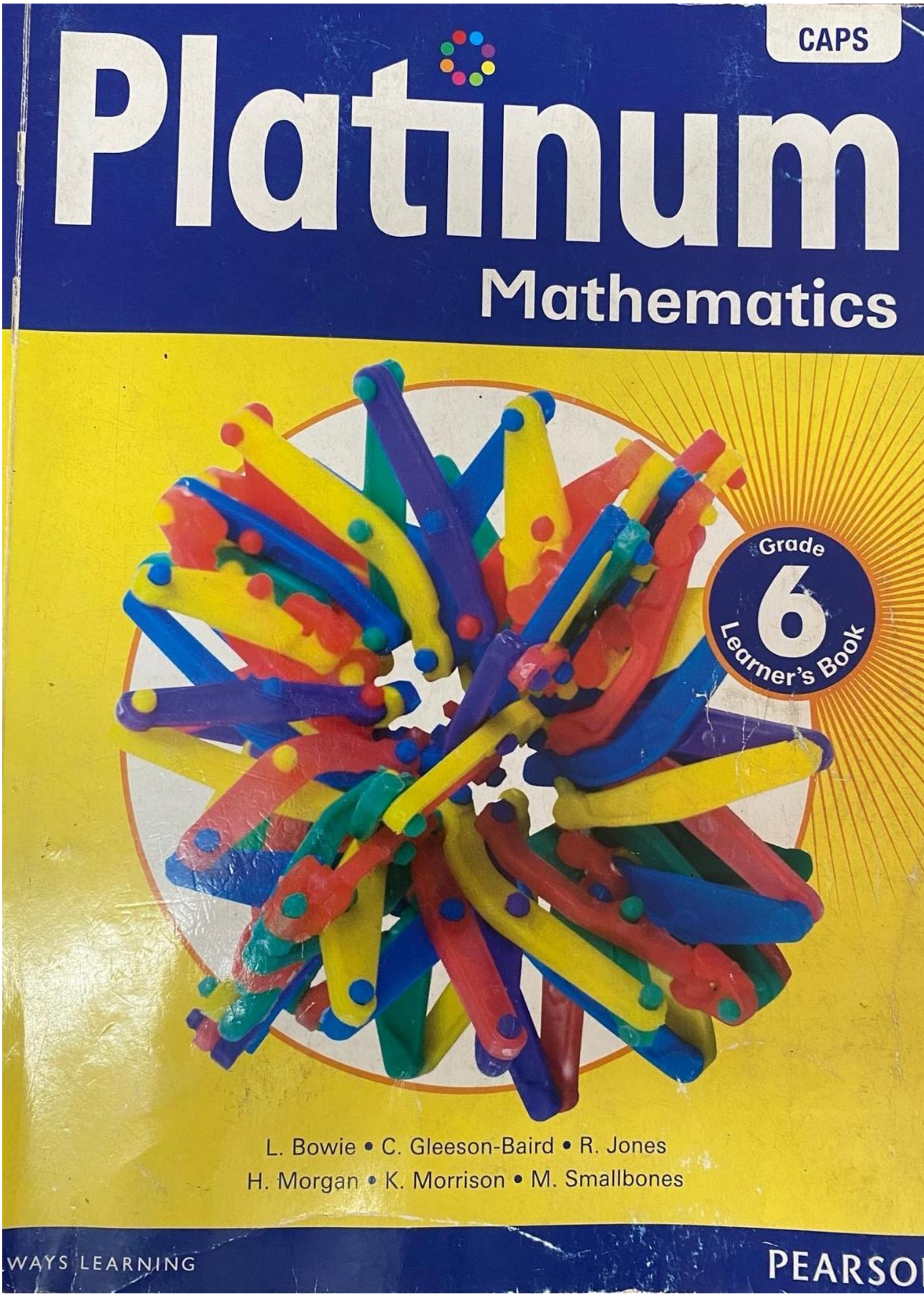
Questions	Participants Answer
1. How do you ensure learners are engaged during your lessons and activities?	
2. How do you ensure learners can explore new ideas and phenomena?	
3. How do you create an opportunity for learners to explain their newly acquired knowledge?	
4. How do you ensure learners can apply knowledge taught to new situations?	
5. How do you create an opportunity for learners to reflect on their knowledge	
6. How do you promote an independent work environment?	
7. How do you help learners to feel confident when completing work tasks?	
8. How do you create a classroom environment that connects learners to the content being taught?	
9. What obstacles or difficulties do you face when designing interactive and captivating lessons? Could you elaborate on these challenges and explain why they possibly arrived?	

Annexure J – Teacher 1's document analysis

Mathematics Grade 6 Homework Term 3

Date	Topic	Page nr DBE BOOK	Page nr TEXTBOOK	Parent signature
24-28 July	Length	P94,95,96,97,98,99,100, 101,102,103,104,105, 106, 107	Topic 27 P162,163,164,165	
31 July-4 Aug	Properties of 2D shapes	**BOOK 1** P54,55,56,57,58,59,60 61,62,63	Topic 6 36,38,39,40	
7—11 Aug	Properties of 2D shapes	P50,51	Topic 21 P132,133	
14 Aug-18 Aug	Angles	P52,53,54,55	Topic 6 37	
21 Aug - 25 Aug	Symmetry	**BOOK 1** P104,105,106,107	Topic 13 84,86	
28Aug - 1 Sept	Transformations	P56,57,58,59,60,61 P192,193,194,195,196,197,198,199,200,201,202, 203,204,205	Topic 22 P136,138	
4-8 Sept	Properties of 3D objects	**BOOK 1** P94,95,96,97 **BOOK 2** P150,151,152,153	Topic 11 P70,71,72,73,74,75 Topic 31 182,184,185,186	
11-15 Sept	Area, perimeter and volume	P154,155,156,157,158,159,160,161,162,163	Topic 33 P190,192,193,194	
18-22 Sept	Area, perimeter and volume	↓		
26– 29 Sept	Revision	Consolidate concepts		

Annexure K – Teacher 1's document analysis



Annexure L – Teacher 2's document analysis

LESPLAN: Wiskunde

						VAK	Wiskunde
GRAAD	6	DATUM	20 Sept 2023	TYDPERK	Week 10	TYD	90 min

TEMA	ONDERWERP
Tema 33: Omtrek, Oppervlakte, Volume en Buite-oppervlakte.	**Oppervlakte:** Wat is oppervlakte? ; Hoe bepaal ons die oppervlakte: Tel die blokkies/ teels of gebruik die vormule (Opp = L × B).

HULPBRONNE	ASSESSERING AKTIWITEITE
Plantinum Wiskunde Gr.6 Powerpoint: Les oor Oppervlakte met voorbeelde.	**Informeel:** Werkkaart (Oppervlakte)
DIFFERENSIASIE	
Leerders met moontlike leeruitvalle: Moontlike druipelinge.	**Leerders wat bo standaard presteer:** Geen – Leerders word nog getakseer.
2 periodes Per 1: Bied les aan oor oppervlakte met gepaste voorbeelde. Leerders begin met werkkaart. Per 2: Leerders voltooi werkkaart. Vereiking/nog oefening: Hersiening bl.195 nr 1-5 in handboek.	**KLAS** 6/ E1 6/F3