THESIS SUBMISSION

Title: **Creating an Action Research-Based Framework for Blended Mathematics Teacher Development in Rural South African Schools**

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Submitted in fulfilment of the requirements in respect of the **Doctoral** degree in **Higher Education Studies** in the **Department of Mathematics, Natural Sciences, and Technology** in the **Faculty of Education** at the University of the Free State.

Supervisor: **Dr AE Stott**

DECLARATION

I, Maryke la Grange-Taylor, with this declare that this thesis titled:

Creating an Action Research-based Framework for a Blended Mathematics Teacher Development Programme in Rural South African Schools, submitted in fulfilment of the degree Doctor of Philosophy, is my independent work, except where other sources have been acknowledged.

I, Maryke la Grange-Taylor, certify that this thesis has not been submitted to any other faculty or institution.

I, Maryke la Grange-Taylor, cede the copyright of this thesis in favour of the University of the Free State.

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Signature: Date: **26 November 2024**

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07-Aug-2023

Dear Mrs Maryke La Grange

Application Approved

Research Project Title:
Creating an Action Research-Based Framework for Blended Mathematics Teacher Development in Rural South African Schools

Ethical Clearance number:
UFS-HSD2023/0653

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
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TO WHOM IT MAY CONCERN

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I love You, LORD; You are my strength. Ps.18:1

DEDICATIONS

This Thesis I dedicate to the teachers in the Eastern Cape project schools.

Thank you for sharing your experiences, knowledge, and advice with me.

Thank you for sharing a smile after a long, tiring day.

Thank you for all the FUN we had.

Thank you for becoming my friends.

Without your contributions, this research would not have been possible.

2023 – 2024

ABSTRACT

This thesis describes a participatory action research study that creates a framework for a blended mathematics teacher development programme in rural South African schools. The literature highlights the importance of integrating cognitive, social, and teaching presence to enhance teacher engagement in blended learning environments. However, a gap exists between practice and theory, particularly in applying blended learning to mathematics teacher development in rural contexts. This study addresses the gap by moving from an online-dominant to a traditional face-to-face (F2F) blended approach, leveraging manipulative and structured curriculum resources to trigger teachers' interest in Mathematics Knowledge for Teaching (MKT). In this study, this approach led to open conversations, exploration of online MKT resources, and improved engagement.

The study employed a mixed-methods instrumental case study design across four action-research cycles, with 46 teachers from seven low-quintile schools participating in the PG Bison Infundo EC Schools Project. Data were collected through questionnaires, classroom observations, workshops, reflective journals, and semi-structured interviews. A combination of inductive and deductive qualitative data analysis was used, with the Community of Inquiry and Engagement Theory providing analytical frameworks for consistent indicator development.

The findings showed that teachers engage more meaningfully in the programme activities while following a traditional blended, low-tech approach. I suggest that this is due to low ICT skills and consistent connectivity issues in rural areas. The significance of this research is the explicit explanation of the importance of the low-tech traditional F2F approach to blended learning, how it can be designed and implemented, and the value of Community of Inquiry Theory through facilitating mathematics teacher development programmes. Furthermore, it highlights the difficulty of the online approach to blended learning in rural South African schools. This Blended Mathematics Teacher Development framework should be valuable to programme developers and contribute to educational and teaching practice in rural, under-resourced education contexts.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS/ACRONYMS

ACE	Advanced Certificate in Education
BEd	Bachelor of Education
CAPS	Curriculum and Assessment Policy Statement
CEO	Chief Executive Officer
CPTD	Continuing Professional Teacher Development
DBE	Department of Basic Education
F2F	Face-to-face
ICT	Information Communication Technology
ICT4RED	Information and Communication Technology for Rural Economic Development
IT	Information Technology
LMS	Learning Management System
MKT	Mathematics Knowledge for Teaching
PAR	Participatory Action Research
PGCE	Postgraduate Certificate of Education
POPI Act	Protection of Personal Information Act
SACE	South African Council of Educators
WA	WhatsApp
QMS	Quality Management System

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 : INTRODUCTION

"Blended learning is simply defined as a mix of instructional modalities, that is, both the F2F [face-to-face] learning and online learning modes."

(Badaru & Adu, 2022, p. 128)

This chapter provides a comprehensive overview of the thesis, serving as a guide for the subsequent chapters. It begins with an introduction and explores the background of blended mathematics teacher development. The problem statement is then presented, leading to the formulation of the research approach. The chapter further elucidates the theoretical underpinning of the study, which is grounded in the Community of Inquiry, Cognitive Load, and Self-determination theories. It proceeds to explain the significance of the study and its limitations, and outlines the structure of the study. This chapter establishes the foundation and structure for the ensuing chapters, offering a clear understanding of the study's context, goals, and methodology.

1.1 BACKGROUND AND RATIONALE

Education has undergone radical changes over the past five years, which became more evident during the COVID-19 pandemic when schools closed. Teachers were compelled to shift their teaching to online platforms, such as WhatsApp messages, images and videos, Google Classroom, etc. Regardless of their preparedness, teachers had to adjust and learn how to navigate this new approach. As I, jointly with other mathematics teachers, designed and made provision for online lessons, I was eager to acquire knowledge about designing and, in some cases, recording lessons for online presentations and the pedagogical considerations necessary for effective online instruction and teacher engagement.

This research study was conducted in the Eastern Cape of South Africa, focusing on seven primary, secondary, and combined schools, predominantly classified as Quintile 1-3, which serve economically disadvantaged communities. This region has high unemployment rates, limited economic opportunities, and a rapidly growing youth population, contributing to a resource-constrained educational environment. In response to these challenges, teachers in these schools participated in this professional development program to improve their pedagogical skills and integrate technology into their teaching practices. However, significant barriers, such as inadequate infrastructure, limited access to technology, and poor connectivity, impeded the implementation of the blended learning approach. These challenges are consistent with the issues faced by rural Information Communication Technologies (ICT) education initiatives, underscoring the need for sustainable solutions to support teacher development in resource-limited settings.

As an education specialist supporting and training mathematics teachers in their classrooms, my objectives and focus changed when schools closed. Recognising the challenges of using ICTs in rural South African schools, as well as some teachers' resistance to technology, I anticipated that my task would be daunting. In addition, teaching learners online was challenging, and the sudden change to online teaching proved overwhelming for the teachers and me. Although I offered my assistance, it soon became apparent that I needed to encourage teachers to contact me for collaboration and support. I sent messages via WhatsApp and email, contacting some teachers to offer assistance. While some teachers took advantage of the opportunity, others read the messages but did not respond.

Furthermore, I formed WhatsApp groups to encourage teacher collaboration and the development of teaching plans. Some teachers participated, while others did not respond at all. I also offered to share mathematics videos and materials teachers could use to support their learners at home, who need to be schooled. Some teachers welcomed the support, while others did not respond. This pattern persisted in all my engagement efforts.

According to research, integrating ICTs into mathematics teacher development programmes enhanced their effectiveness (Makonye, 2022; McCarthy & Oliphant, 2013; Jojo, 2017; Guskey, 2002; Moll et al., 2022). Moreover, technology-enabled learning was found to help overcome the challenges posed by physical distance between teachers and programme facilitators, which was particularly relevant for teachers in rural schools (Moll et al., 2022; Burns, 2011). However, it is essential to note that online teacher development and training can be challenging, especially in schools where teachers may resist ICT training and its implementation in the classroom (Moll et al., 2022; Burns, 2011), as was my experience in my effort to support the mathematics teachers, during the lockdowns imposed. Although the lockdowns imposed during the COVID-19 pandemic forced some of this resistance to subside, limited access to and proficiency in digital technologies presented challenges for teachers, particularly in rural South African schools (Moll et al., 2022; Burns, 2011). While distance learning supported by WhatsApp became the primary mode of teaching and learning, it proved insufficient for Mathematics Knowledge for Teaching (MKT), which requires structured interaction between facilitators and teachers, including written question-and-answer exchanges and feedback (Dewa & Ndlovu, 2022; Moll et al., 2022). This underscored the need to address teacher resistance to using complex and interactive ICTs in professional mathematics development.

Reviewing the literature, I discovered recent studies suggesting that it is possible to overcome teacher resistance to ICT adoption and integration (Mlotshwa et al., 2022; Herselman & Botha, 2014). For example, Mlotshwa, Ndlovu and Nyandoro (2022) found that teachers demonstrated enhanced adoption and integration of ICTs in their classrooms during ICT-related teacher development programs when infrastructure and e-content were available. Herselman and Botha (2014) also reported similar results in the context of teachers teaching in rural Eastern Cape schools, through the Information and Communication Technology for Rural Economic Development (ICT4RED) project. However, all these interventions were conducted offline and face-to-face (F2F), which had inherent limitations, particularly considering the need for continuous professional development in MKT (Makonye, 2022). Therefore, there is a need to expand the current understanding of conducting professional development using technology-enabled learning in rural areas, such as the ICT4RED framework, to include online and blended learning environments.

In early 2023, as I resumed school visits and continued supporting teachers online, I devised a new blended, two-year mathematics teacher development program guided by the Blended Block model (Cleveland-Innes & Wilton, 2018). This program was implemented in the second semester of that year and aimed to develop and assist mathematics teachers in rural areas of the Eastern Cape. My goals were to help teachers create quality online lessons, encourage the utilisation of mathematics content in their classrooms and on digital platforms, and foster the formation of mathematics communities of practice. However, due to the blended nature of the program, it became evident that I had to incorporate both online and offline ICTs and F2F and online facilitation. Consequently, I found that the ICT4RED framework, which focused solely on offline ICT usage, needed to be revised. As a result, I adopted the

Community of Inquiry framework, known for its effectiveness in designing and implementing online and blended courses (Stott, 2022; Cleveland-Innes & Wilton, 2018). The Community of Inquiry framework enables the expansion of the ICT4RED framework into online and blended instructional modes. Through this action research approach guided by the Community of Inquiry framework, my goal was to identify design and implementation features that promoted effective engagement among participants in this context.

1.2 RESEARCH PROBLEM

While blended learning has been well established in developed countries as a means to enhance access to educational resources and address teacher diversity (Gambini & Lénárt, 2021; Cleveland-Innes & Wilton, 2018), the same cannot be said for mathematics teacher development programmes in South Africa (Moll et al., 2022; Muhuro & Kangethe, 2021). This disparity highlights the pressing need to examine potential strategies for fortifying existing practices and establishing an implementation framework that aligns with the local context, utilising institutional evaluation data to inform strategies, support systems, pedagogical approaches, and available resources (Moll et al., 2022; Muhuro & Kangethe, 2021). Thus, this study aimed to address this knowledge gap by employing a participatory action research approach guided by the Community of Inquiry framework, identifying design and implementation elements that fostered effective engagement among participants, and adapting the Blended Block model to encompass online and blended instructional modes. Consequently, this study will hopefully contribute valuable insights to the existing body of literature on technology-enabled learning in education, offering guidance to education policymakers and practitioners in South Africa and other contexts.

1.3 RESEARCH APPROACH

The study investigated the design and implementation features that could comprise a framework for blended mathematics teacher development programmes in rural South African schools.

To achieve this aim, the study pursued the following objectives: To identify:

a) design and implementation features, specifically those related to cognitive presence, on promoting effective engagement in the programme.
b) design and implementation features, specifically those related to social presence, on promoting effective engagement in the programme.
c) design and implementation features, specifically those related to teaching presence, on promoting effective engagement in the programme.

A central question and specific sub-questions guided the data collection and analysis in this study:

What design and implementation features could comprise a framework for blended mathematics teacher development programmes in rural South African schools?

a) What design and implementation features regarding cognitive presence within this programme promote effective engagement?
b) What design and implementation features regarding social presence within this programme promote effective engagement?
c) What design and implementation features regarding teaching presence within this programme promote effective engagement?

The study employed a flexible approach that combined mixed action research methods within the pragmatic paradigm (McBeath, 2022). The pragmatic paradigm focuses on practical effectiveness, rather than absolute and objective truth, thus representing shared beliefs among specialists in a particular field (Brierley, 2017). By utilising a mixed-methods action research design incorporating quantitative and qualitative data collection, this study examined how teaching presence, cognitive presence, and social presence in the program could enhance effective teacher engagement. This mixed-methods research approach provided robust tools for investigating the intricate processes and systems involved (Mejeh et al., 2023).

Action research was deemed an ideal methodology to facilitate practical and emancipatory outcomes, while generating relevant and meaningful theory for the participants (Cresswell, 2018; Zuber-Skerritt, 2011, 2015). In this study, I employed key characteristics of the Participatory Action Research (PAR) model, specifically focusing on collaboration, mutual learning, and reflection. PAR is a collaborative and transformative approach that promotes the active participation of all stakeholders in the research process. It empowers participants—teachers in this case—not only to be subjects of the research but also co-researchers who engage actively in every phase of the study. This aligns with the core principle of PAR, which emphasises the joint identification of learning needs, collaborative problem-solving, and shared decision-making.

During both F2F and online (blended) teacher training sessions, teachers were involved in identifying their learning outcomes and interpreting observations for validation. This process enabled them to propose further training opportunities and solutions to challenges encountered in their classrooms. I applied the five integrated phases of PAR: (1) collaborative identification of needs, (2) deciding on the best action, (3) action implementation, (4) evaluation, and (5) reflection for further action.

In the context of this study, the collaborative identification of needs phase was central, where teachers worked together with me to identify areas for professional growth, such as teaching strategies for mathematical concepts and the use of technology. In the action implementation phase, teachers participated in workshops and were encouraged to implement new strategies in their classrooms, which were followed by reflective discussions. The evaluation and reflection phases were critical, as teachers reflected on their experiences and provided feedback for future action.

The decision to use these specific characteristics—collaborative identification of needs, action implementation, and reflection—was informed by the goal of promoting teacher autonomy and enhancing their professional development through an ongoing cycle of action and reflection. These characteristics facilitated a learning environment where teachers could actively engage with the content and each other, which was crucial in a blended learning context. The relationship-building phase was foundational, especially in the beginning, as it helped establish trust and open communication, necessary for the subsequent phases. The action learning set method, where teachers engaged in problem-solving and mutual support, played an essential role in maintaining focus and deepening the educational value of the process (Zuber-Skerrit, 2018).

Data collected from questionnaires, interviews, class observations, reflective journaling, and learning management system (LMS) engagement provided insights into the effectiveness of the approach. PAR, by bridging the gap between theory and practice, facilitated action learning and research that directly addressed the disconnect between research and real-world teaching practices (Zuber-Skerrit, 2018; Eperjesi & Forster, 2017).

My study focused on teachers in an Eastern Cape education district who participated in a blended mathematics teacher development programme. Electronic questionnaires were used to invite participation, and purposeful sampling was employed to select a diverse group of participants based on gender, race, qualifications, and experience. The selected teachers were interviewed, and their LMS engagement data were collected. In addition, class observations followed by reflective discussions, semi-structured interviews, and meetings were conducted to validate the findings. Throughout the study, I maintained a reflective journal (Wood, 2019; Creswell & Clark, 2018).

I performed an intrinsic case study design evaluating and analysing each participatory action research cycle to assess the extent of the engagement in the program activities and among the teachers. I sought explanations for the findings regarding various aspects of the intervention's design and implementation (Wood, 2019; Zuber-Skerrit, 2018). I used descriptive statistics for both quantitative and qualitative data. NVivo was employed to code the data deductively, using codes derived from the Community of Inquiry framework, and inductively when addressing other issues not covered by the framework. I then engaged iteratively with these analyses in each cycle, reflecting on what worked well, what should be retained, what needed to be changed for the next cycle, and how to implement those changes (Eperjesi & Forster, 2017; Bradbury, 2015).

1.4 THEORETICAL REFERENTS

This research explores critical terms and concepts in Higher Education studies, focusing on teaching and learning, course design, and student experience. It is grounded in the Community of Inquiry, Cognitive Load and Self-determination theory, specifically in Mathematics teachers' professional development. The study examines the South African context, practical effectiveness, and the constituents of the Community of Inquiry (cognitive presence, social presence, and teaching presence) and autonomy, competence, and connection in Self-determination theory.

1.4.1 Mathematics teachers' professional development

Mathematics teachers' professional development in the context of this study refers to the process through which mathematics teachers enhance their professional identity and practices over a specific period (Anabousy & Tabach, 2022). This study focuses on in-service professional development and support provided to mathematics teachers in rural South African schools. To guide the design and implementation of blended learning programmes for professional development, the Community of Inquiry theory has been identified as a suitable framework (Stott, 2022; Cleveland-Innes & Wilton, 2018). This framework serves as a guiding principle for structuring and organising blended learning experiences to enhance mathematics teachers' professional growth and learning in this context.

1.4.2 Community of Inquiry Theory

The Community of Inquiry theory involves a collaborative community of participants who engage in a shared endeavour to construct knowledge by critically examining their practices through questioning attitudes. Within this context, inquiry involves posing inquiries, identifying problems, exploring possibilities, and investigating solutions (Goodchild et al., 2013). In this study, the Community of Inquiry framework constitutes a group of mathematics teachers aiming to develop their ability to create high-quality online lessons, integrate mathematics content into their classrooms and digital platforms, and facilitate the formation of mathematics communities of practice.

The Community of Inquiry framework consists of three interrelated components: cognitive presence, social presence, and teaching presence. These presences are crucial in fostering academic and social engagement and facilitating the design and implementation of high-quality online and blended learning experiences (Stott, 2022; Cleveland-Innes & Wilton, 2018). These three presences intersect and intertwine to conceptualise the overall quality of blended and online educational experiences (Dixson, 2015; Harrell & Wendt, 2019).

1.4.2.1 Cognitive presence

Cognitive presence, a fundamental element for academic success, centres on teachers' capacity to construct meaning through ongoing dialogue and reflection. The Community of Inquiry framework leverages teaching and social presence to foster cognitive presence within courses. Cognitive presence is considered the "ostensible goal" that communities of teachers strive to achieve in higher education (Garrison et al., 2000; Dixson, 2015; Harrell & Wendt, 2019; Purdue University, 2020). It encompasses various aspects of a class or teaching that facilitate deep learning by stimulating curiosity, providing diverse perspectives, integrating different materials and activities that encourage reflection, debate, and insight, and promoting the immediate transfer of learning to real-world contexts or applications relevant to teachers' plans. In this taxonomy, cognitive presence includes the notion of course usefulness, which pertains to the immediate application of acquired knowledge and skills to practical situations or work settings, and the acquisition of knowledge, skills, and abilities aligned with teachers' future professional needs. Learning utility is enhanced through demonstrations, simulations, exercises, practice opportunities, and feedback for improvement (Van Wart, 2004).

1.4.2.2 Social presence

Social presence, within the Community of Inquiry Framework, refers to the facilitator or teacher's ability to present themselves as a genuine individual within a classroom setting. It facilitates cognitive presence and fosters critical thinking processes within a community of learners. Effective social presence in an online teaching environment, enables learners to freely express themselves, establish connections, and function as a cohesive group. As a result, it contributes to a meaningful and engaging learning experience (Garrison et al., 2000; Dixson, 2015; Harrell & Wendt, 2019; Purdue University, 2020). Social presence encompasses various elements within a class that encourage teachers to interact with others, promote a learning-community approach, and foster open discussions. These discussions prioritise peer-to-peer interactions over facilitator-led exchanges (Arbaugh et al., 2008; Bray et al., 2008). By cultivating a supportive and interactive environment, social presence enhances learner engagement, collaboration, and participation, which are fundamental to educational success.

1.4.2.3 Teaching presence

As the third element within the Community of Inquiry Framework, teaching presence encompasses the class's design, facilitation, and direction to achieve optimal learning outcomes. This study involves the design, delivery, and creation of course content, which is primarily the responsibility of the faculty. Careful consideration should be given to selecting appropriate course delivery methods to ensure effectiveness. Moreover, when technology tools are employed for in-service teacher training and development, course facilitation becomes a shared responsibility between the facilitator and the teacher. Effective teaching presence is vital for enhancing social and cognitive presence and improving educational outcomes (Garrison et al., 2000; Dixson, 2015; Harrell & Wendt, 2019; Purdue University, 2020). It encompasses various aspects, including the overall design of classes, material organisation, facilitation of the class and related rehearsal activities, and the provision of direct instruction and constructive feedback (Arbaugh et al., 2008; Bray et al., 2008).

1.4.3 Engagement Theory

In this study, Engagement Theory (Christenson et al., 2012) is used to evaluate the effectiveness of design and implementation choices. Previous research has shown a strong relationship between engagement level and learning outcomes (Chiu, 2022). Teacher engagement, a multifaceted motivational construct, involves a teacher's decision to invest their energy and resources in their work (Makonye, 2022). Therefore, it is crucial to identify and understand the factors that positively influence teacher engagement in a blended learning environment, during professional development initiatives to provide appropriate guidance and support.

This action research focuses on the dimensions of teacher engagement, cognitive, emotional, and social engagement (Klassen et al., 2013), to assess how participating teachers respond to the changes in program design and implementation, within the Community of Inquiry (CoI) framework. By examining teachers' cognitive, emotional, and social engagement, this study aims to gain insights into their reactions and engagement with the modified aspects of the professional development program guided by the CoI framework.

1.4.3.1 Cognitive engagement

Cognitive engagement involves actively applying strategic thinking and sophisticated learning strategies during the learning process (Klassen et al., 2013). It signifies individuals' absorption in their work and the allocation of cognitive resources to work-related tasks. In this study, cognitive engagement is one of the dimensions of teacher engagement, along with emotional and social engagement (Klassen et al., 2013). It is assessed in order to understand teachers' level of mental investment and active participation in the modified aspects of the professional development program, guided by the Community of Inquiry (CoI) framework. By examining cognitive engagement, this study reveals how teachers engage cognitively with the program's materials, tasks, and instructional strategies, indicating their commitment to enhancing professional knowledge and skills.

1.4.3.2 Emotional engagement

Emotional engagement encompasses experiencing positive emotions and high interest in class activities (Klassen et al., 2013). It focuses on teachers' positive emotional responses to their work and involvement in the learning process. In this study, emotional engagement is one of the dimensions of teacher engagement, together with cognitive and social engagement (Klassen et al., 2013). It is assessed to examine teachers' emotional connection and affective responses towards the modified components of the professional development program, guided by the Community of Inquiry (CoI) framework. By investigating emotional engagement, this study explores how teachers exhibit enthusiasm, enjoyment, and a sense of fulfilment in their engagement with the program's content, activities, and interactions, thus reflecting their commitment to professional growth and development.

1.4.3.3 Social engagement between facilitator and teacher

Social engagement between the facilitator and teachers involves teachers' active investment of energy in establishing connections with and showing concern for the facilitator and their colleagues (Klassen et al., 2013). It encompasses collaborative interactions, communication, and relationship-building within the professional development context. In this study, social engagement is one of the dimensions of teacher engagement, alongside cognitive and emotional engagement (Klassen et al., 2013). The examination of social engagement focuses on how teachers actively participate in discussions, contribute to group activities, seek feedback from the facilitator and peers, and demonstrate a sense of community and support within the professional development program, guided by the Community of Inquiry (CoI) framework. By exploring social engagement, this study aims to understand teachers' interpersonal involvement, social interactions, and collaboration, reflecting their commitment to building professional relationships and enhancing their learning experience through social connections.

1.4.3.4 Social engagement between teacher and teacher

Social engagement between teachers involves actively investing energy in establishing connections with and showing concern for their colleagues (Klassen et al., 2013). It encompasses the collaborative interactions, communication, and relationship-building among teachers, within the professional development context. In this study, social engagement is one of the dimensions of teacher engagement, along with cognitive and emotional engagement (Klassen et al., 2013). The examination of social engagement focuses on how teachers actively participate in discussions, collaborate with their peers, share ideas and resources, provide support, and foster a sense of community within the professional development program guided by the Community of Inquiry (CoI) framework. By exploring social engagement between teachers, this study aims to understand the level of interpersonal involvement, social interactions, and collaboration among colleagues, reflecting their commitment to building professional relationships and enhancing their learning experience through social connections.

1.4.4 Community of Practice

A Community of Practice is a conceptual framework developed by social learning theorists, such as Lave and Wenger (1991), to characterise a collective of individuals who share a common interest, domain, or profession, and engage in collaborative learning through their interactions. The defining features of a Community of Practice include a shared domain of knowledge, a collective identity, and a shared commitment to learning and developing expertise within the specific domain (Wenger, 1998). Members actively participate in ongoing interactions, discussions, and collaborative activities to deepen their understanding of the domain, collectively address challenges, and solve problems that arise within the community.

The Community of Practice provides a social structure and contextual environment that facilitates the exchange of knowledge, experiences, and best practices among its members (Wenger et al., 2002). Interactions within the Community of Practice can take various forms, such as face-to-face meetings, online discussions, joint projects, and shared resources. Through these interactions, members have valuable opportunities to learn from one another, gain new perspectives, and collectively advance their knowledge and expertise within the specific domain of the community.

In a Community of Practice, learning is viewed as a social process that emerges through active participation and engagement within the community (Wenger, 1998). The members' shared practices, experiences, and expertise contribute to the collective learning and development of the entire community. Within a Community of Practice, a supportive environment is fostered, enabling individuals to seek advice, receive feedback, and collaboratively solve problems, thereby promoting individual growth and the advancement of the community.

In summary, a Community of Practice is a dynamic and evolving social structure that empowers individuals to actively engage in shared learning, collaborative work, and knowledge creation, within a specific domain or profession. Participating in a Community of Practice can enhance their expertise, expand their understanding, and contribute to the collective advancement of knowledge and practice within the community.

1.5 SIGNIFICANCE OF THE STUDY

The results of this study will be beneficial to teacher professional development and support in blended teacher development projects and, eventually, the school education system of South Africa. The significance of this study would be the expansion of the Blended Block model into the context of blended mathematics teacher development programmes. This framework should be valuable to programme developers and contribute to educational and teaching practice in rural, under-resourced education contexts.

1.6 ETHICAL CONSIDERATIONS AND LIMITATIONS

Action research is practical, participatory, and emergent, focusing on contextual rather than universal truths (Eperjesi & Forster, 2017; Bradbury, 2015). My study focused on working in partnership with participants, rather than conducting research on them and reporting findings (Wood, 2019). Although familiarity with the teachers may introduce biases, a conscious awareness of this potential bias can mitigate its effects, as can using a critical friend and validation group (Eperjesi & Forster, 2017; Bradbury, 2015). Before data collection, all stakeholders were informed about the research to allow ample time to decide whether to consent to participating. Stakeholders were invited to ask questions on areas of concern or to improve clarity.

The following ethical considerations were noted and considered throughout the research design process (Schurink et al., 1998; Hammersley, 2017).

- Confidentiality and anonymity were assured by providing the participating teachers with code names; for example, Participant A, when referred to in the study report.
- The competency of the researcher and the scientific soundness of the project were assured by the rigorous processes of title registration and ethical clearance to which the project will be subjected.
- Voluntary participation was assured by allowing the participants to withdraw at any time during the research project. Not all teachers participating in the blended mathematics programme participated in the research project. Participants were allowed to take part in this study.

- For inclusion in the research, the participants gave their full written consent, after being informed about what the research entails and how they are expected to participate.
- Feedback regarding the results and findings of the research will be discussed with the participants after the results have been certified.
- The relevant stakeholders granted permission before conducting the study.
- The researcher obtained ethical clearance from the UFS Faculty of Education Ethics Board (UFS-HSD2023/0653).

1.7 STRUCTURAL OUTLINE

This thesis presents an action research study to develop a framework for blended mathematics teacher development in rural South African schools.

Chapter two provides a comprehensive literature review on the Blended Learning educational approach for mathematics teachers' professional development in rural South African schools.

Chapter three discusses the conceptual framework, which comprises the Community of Inquiry, Cognitive Load and Self-determination theory.

Chapter four focuses on the research methodology, justifying the chosen research design, explaining the data collection, analysis, and interpretation processes, and discussing the study's validity, reliability, and limitations.

Chapter five described the findings at the hand of the participatory action research cycles.

Chapter six is a thorough discussion that provides answers to the research questions.

Chapter seven presents an illustrated and detailed framework for designing and implementing the blended mathematics teacher development programme, followed by a discussion of the study's limitations, and suggestions regarding the implications of this work.

1.8 CONCLUSION

This chapter has set the stage for the subsequent chapters of the thesis. The study aims to improve teacher professional development in blended learning approaches, specifically in the context of mathematics knowledge for teaching education in under-resourced rural areas of South Africa. By expanding the Blended Block model, this research aims to enhance continuous teacher professional development programmes and contribute to the South African school education system.

The significance of this study lies in its potential to bridge the gap between theory and practice by applying the Blended Block model to blended mathematics teacher development. This framework provides valuable insights for designing effective initiatives in under-resourced contexts. The findings and recommendations are expected to contribute to educational practices and improve mathematics education in rural schools. The theoretical underpinning of the study, including the Community of Inquiry and Engagement theory, guides the exploration of collaborative learning, teacher engagement, and the role of technology-enhanced learning in blended mathematics teacher development programmes. The research design and approach ensure comprehensive and meaningful data collection, with a commitment to ethical considerations and participant confidentiality.

CHAPTER 2 LITERATURE REVIEW

"*If we teach today as we taught yesterday,*
we rob our children of tomorrow."
John Dewey

The aim of the literature review is for me to learn from previous studies on their findings on the best practices and procedures concerning mathematics teacher development globally. More specifically, I will interrogate the local South African context. In this chapter, I review the literature on Continuous Professional Teacher Development (CPTD) and discuss its evolution and importance. I also explore models and approaches for mathematics teacher development programmes. Consequently, I identify the challenges CPTD faces and the specific needs of mathematics teachers.
In the second part of this chapter, I focus on Blended Learning as an educational method and approach, for continuous mathematics teacher development. I explain what blended learning entails and what design and implementation features could comprise a framework for successful blended learning programmes. I conclude this section by describing theoretical models for designing and implementing blended learning.

2.1 CONTINUOUS PROFESSIONAL TEACHER DEVELOPMENT

2.1.1 Definition and significance in mathematics teacher development

Continuous Professional Teacher Development (CPTD) was described by Guskey (2000) as systematic efforts to change teachers' classroom practices, attitudes, and beliefs, resulting in improved teacher practices and learner achievement. In addition, Day and Sachs (2004) focus on formal and informal learning opportunities to improve teachers' skills and knowledge. Similarly, Dasoo and van der Merwe Muller (2020, p. 45)

> *"CPTD is both the end-product and practice of learning through explicit and implicit methods of development. Explicit methods of CPTD comprise workshops and seminars and more implicit methods include the teacher's reflection on problems and solutions with a colleague down the corridor."*

More recently, Havea and Mohanty (2020) defined CPTD as a global tool that uses various professional development strategies to build teacher capacity, resulting in better learner performance. This includes enhancing teachers' understanding of subject matter, pedagogy, and learner thinking. According to the South African Council for Educators (SACE), CPTD is defined as “a system for recognising all useful teacher development activities by approving quality and credible professional development providers” (SADC, n.d.). This definition emphasises the structured and recognised nature of CPTD activities in South Africa.

In South Africa, continuous professional development gained traction in the post-apartheid era, focusing on addressing educational inequities and improving teacher quality. The South African Council for Educators (SACE) played a pivotal role in formalising continuous professional development (SACE, n.d.) system that was introduced to ensure that teachers engage in meaningful professional development activities (DBE, 2019), particularly for mathematics teachers (Mogari, 2014).

Professional development for mathematics teachers is crucial globally and in South Africa for several reasons. In South Africa, the ultimate reason for mathematics professional development is the improvement of effective mathematics teaching, which is directly linked to improved learner performance (Venkat & Adler, 2020; Santos-Trigo, 2020; Bowie et al., 2019; Hill et al., 2005; Ball & Bass, 2003). This focus on learner achievement is central to the Department of Basic Education (DBE) and the National Education Collaboration Trust (NECT), whose joint goal was to have 90% of learners pass mathematics with at least 50% by 2023 (DBE, 2019). Although an increase over the past three years was noted, this goal was not achieved (DBE 2023). At the end of 2023, the national result of learners who passed mathematics with 50% or above, was 27,5%, with the Western Cape Province leading with 43% (see Figure 2-1). The DBE report concerning learner results, emphasised the need for mathematics teacher development.

Table 2.1: ***DBE report: Percentage of learners who achieved 50% and above in Mathematics for 2021-2023 in the NCS Examination***

Province	2021	2022	2023	Difference to 50% and above in 2023
Eastern Cape	16	16	21.8	28.2
Free State	25	24.6	29.2	20.8
Gauteng	31.7	28.9	33.5	16.5
KwaZulu-Natal	20.7	20.7	27.2	22.8
Limpopo	19.5	18	24.6	25.4
Mpumalanga	20.6	20.5	24.3	25.7
North West	28.5	22.3	26.8	23.2
Northern Cape	23.2	20	21.7	28.3
Western Cape	39.1	37.8	43	7

	2021	2022	2023	Difference to 50% and above in 2023
National	23	22	27.5	22.5

Luneta (2024) reports that over the past three years, about a third of learners who wrote the National Senior Certificate (NSC) mathematics examinations, 80% did not pass the subject with 50% or more. Fewer learners reached the 60% threshold for admission into science, technology, or engineering degrees. In 2021, for example, 13% (34 451 learners) scored 60% or higher in mathematics (Luneta, 2024).

In addition, South African learners consistently perform poorly in international assessments such as TIMSS (Trends in International Mathematics and Science Study) (Human Sciences Research Council, 2011; Spaull & Kotze, 2015; Zuze et al, 2017; Isdale et al, 2017; DBE, 2024). The 2019 TIMSS results showed that South African learners scored significantly below the international average (Reddy et al., 2020). Countries with solid mathematics education systems tend to perform better in international assessments, such as TIMSS and PISA (Programme for International Student Assessment) (Venkat & Adler, 2020; Graham et al., 2020). This finding drives the need for mathematics teacher development to keep teachers updated on the latest teaching strategies, methodologies (Spaull & Kotze, 2015; Graham et al., 2020), and approaches. The latter includes technological, pedagogical content knowledge (TPACK) for mathematics teachers to prepare learners for a global, technological society (McCarthy & Oliphant, 2013). Integrating technology in education requires teachers to be proficient in using digital tools to enhance learning (Mishra & Koehler, 2006). Unfortunately, many South African mathematics teachers lack sufficient content knowledge, pedagogical skills, and technological skills (Mlitwa & Van Belle, 2011; Spaull, 2013). Blignaut, Hinostroza, Els and Brun (2010) emphasise that professional development programmes focusing on technology integration are crucial for improving teachers' technological skills and confidence. The integration of digital technology in education has transformed mathematics teaching, reshaping the role of educators and pedagogical approaches, with tools like Logo, Geometer's Sketchpad, and modern mobile technologies revolutionising learning environments and creating dynamic, collaborative experiences beyond traditional classrooms (Borba, 2012). As technology continues to evolve, professional development must adapt to equip teachers with the necessary skills to effectively use digital tools, ensuring they can engage learners and foster understanding in an increasingly interconnected world, underscoring the urgency for practical solutions to address the existing gaps in teacher preparedness. The latter underscores the need for urgent and practical measures to address these shortfalls.

Another reason for the much-needed teacher development in South Africa is a shortage of qualified mathematics teachers (Bernstein, 2013; UNESCO, 2023). This shortage necessitates that schools appoint teachers with other qualifications relating in some way to mathematics. Consequently, these teachers might lack the necessary Mathematics Knowledge for Teaching (MKT) (Mokgwathi et al., 2023; Venkat & Adler, 2020). Hence, effective teacher development programmes for mathematics teachers could address this shortcoming and help teachers improve their content knowledge, pedagogical skills, and instructional practices (Day & Sachs, 2004; Taylor, 2021). This claim is supported by UNESCO (Okt, 2023) and SACE (SACE, n.d.) that emphasises the importance of CPTD in enhancing teacher competence and improving learner outcomes.

Mathematics teacher development programmes should integrate conceptual understanding with pedagogical strategies, ensuring that teachers are not just subject-matter experts but also skilled in making mathematics accessible to learners (Venkat & Adler, 2020). Venkat and Adler's discernment highlights the need for tailored teacher professional development programs in rural South African schools, to address specific deficiencies in MKT. In addition, Bowie and others focus on the convergence of curriculum design and teacher development. They argue for aligning professional development programmes with curriculum outcomes and learner needs, ensuring teachers can deliver the intended outcomes (Bowie et al., 2019). Dasoo and Van der Merwe Muller (2020) confirm the effectiveness of teacher development; that teachers form part of decision-making, and their input valued in the process. Hence, the focus shifts from purely on learner outcomes to prioritising focused teacher training and professional development.

In this study, mathematics teachers' professional development refers to enhancing their professional identity and practices over a specific period (Anabousy & Tabach, 2022). This mathematics teacher development programme focuses on innovative teaching strategies that promote active learning and engagement, supporting Hennessy, Ruthven and Brindley's (2005) argument that teachers need ongoing training to adopt and implement such strategies effectively, given the rapidly evolving educational landscape and the expanding array of resources available. Sticking to old habits simply because they are familiar, is no longer sufficient; teachers must adapt to new challenges and global trends. As Jojo (2017) noted, there is a need for CPTD to empower teachers, improve their instructional leadership, and help them adapt to curriculum changes. This argument aligns with the purpose of my study, which aims to identify design and implementation features that could comprise a framework for mathematics teacher development in rural South African schools. Research consistently indicates that well-designed CPTD programmes can positively impact teacher MKT and learner performance. However, the effectiveness of these programmes depends on their design, implementation, and the support provided to teachers (McCarthy & Oliphant, 2013; Spaull & Kotze, 2015).

In conclusion, this study focuses on in-service professional development and support provided to mathematics teachers in rural South African schools. Well-designed lessons, effective classroom practices, and clear learning objectives are foundational to improving learner performance. Research by Harsha and Newman (2021) shows that learners taught by well-trained teachers consistently perform better in mathematics. Consequently, I argue that teachers with a deep understanding of mathematical concepts and the ability to explain the reasoning behind abstract ideas are more successful in fostering learner comprehension. Such teachers can offer more precise explanations, effectively use concrete models, and translate complex mathematical language into everyday terminology, thereby enhancing overall learning (Hill et al., 2005; Harsha & Newman, 2021).

2.1.2 Teacher Development Programmes: Integration of ICTs

Globally, a shift from traditional to technology-enabled learning has been observed. Integrating Information Communication Technologies (ICTs) into mathematics teacher development programmes is becoming increasingly popular, especially after the lockdowns imposed by the COVID-19 pandemic (Jita & Dhliwayo, 2024; Makonye, 2022; Darragh & Franke, 2023). Online teacher development mainly facilitates online teaching and learning sessions, using virtual classes and other online tools (Stott, 2021; Staddon, 2020). Moreover, technology-enabled learning was found to help overcome the challenges posed by the physical distance between teachers and programme facilitators, which was particularly relevant for teachers in rural schools (Mogari, 2014; Moll et al., 2022; Burns, 2011).

Whilst innovations and integrations of ICTs into education programmes are increasing worldwide, research from South Africa proves otherwise (Jita & Dhliwayo, 2024; Havea & Mohanty, 2020; Mokgwathi et al., 2023). Jita and Dhliwayo (2024) report that "*South Africa has not been spared this lag in its teacher training programs despite evidence of upgraded ICT infrastructures within its higher education institutes*" (page 2). In addition, local studies report that more must be done to increase ICT uptake amongst teachers as universities are promoting ICT integration in education (Alenezi, 2023; Jakoet-Salie & Ramalobe, 2023; Kanyane, 2023; Mhlanga et al., 2022; Jita & Dhliwayo, 2024).

More importantly, in the transformation towards technology-enabled learning, facilitators and teachers become the 'hubs' of such innovations (Jita & Dhliwayo, 2024; Pedagoo, 2020). Teacher development programmes offer the opportunity to model and train best practices for teachers who effect desired changes, as stakeholders envisage. Therefore, the most significant challenges for South African teachers are ICT skills and the lack of digital integration (Jita & Dhliwayo, 2024; Havea & Mohanty, 2020). On the contrary, academics are advocating for improved ICT skills among teachers through teacher development programmes or other initiatives, as encouraged by the DBE and SACE (SACE, n.d.; DBE, 2019).

According to Graham and colleagues (2020), technology-enabled learning has remained inadequate in many countries, regardless of all the investments in devices, infrastructure, and ICT skills teacher development. Technology integration and utilisation are not supposed to be a noteworthy barrier anymore. However, even those who grew up using technology are not engaging or actively participating in technology-enabled learning (Moll et al., 2022; Makonye, 2022; Padayachee, 2016). Why are teachers disinclined to practically and adequately use technology with professional development and everyday classroom activities? Researchers have found that despite the perceptible presence and the rapid evolution of technology-enabled learning, the challenges and demands of using ICTs amount to a serious debate (Hennessy et al., 2005; Jita & Dhliwayo, 2024). Furthermore, ICT integration over the last decade has not brought about the progress that was anticipated, despite the prospective thereof (Hennessy et al., 2005; Havea & Mohanty, 2020; Jita & Dhliwayo, 2024). Jita and Dhliwayo (2024) found that "*even if adequate resources and technical support are available and teachers have sufficient knowledge of technology, it does not mean that they will use it*" (page 12). Their findings reveal the ineffectiveness, thus urging the government and schools to terminate financial investments in the latest technology and instead, focus on TPCK to integrate subject knowledge successfully. Hence, mathematics teacher development programmes should integrate conceptual understanding with MKT, ensuring that teachers can adequately access mathematics content knowledge through ICTs, even after training.

2.1.3 Technology: Challenges and Opportunities

Technology integration into South African schools comes with challenges and opportunities for those ready to receive it. Some initiatives have focused on integrating technology into teacher development programmes, promoting collaborative learning communities, and aligning teacher development activities with national education goals. The advent of digital technology in the 21st century revolutionised teacher development, making it more accessible through online courses, webinars, and virtual conferences, in some contexts. This period has also seen a greater emphasis on personalised learning and competency-based approaches (Mwila et al., 2022). These efforts aim to enhance the quality of education and address the specific needs of South African teachers (Jojo, 2017).

However, despite establishing frameworks, the implementation of CPTD faced challenges, such as resource constraints, varying levels of teacher engagement, and the need for more effective monitoring and evaluation (SACE, n.d.; Bernstein et al., 2013; van der Merwe & van der Merwe, 2008; Spaull & Kotze, 2015; Marfuah et al., 2022; Ndaba et al., 2023). In addition, balancing the demands of teaching with teacher development programme requirements was a significant challenge. Teachers often struggle to allocate sufficient training and collaborative planning time (Helmbold et al., 2021). This differs from top-performing schools establishing *collective staff time* for collaboration and professional development by extending the school day and formalising these activities (DBE, 2018). Furthermore, some schools have faced a lack of resources, as well as some resistance from teachers accustomed to traditional teaching methods. Others who participated, highlighted the need for ongoing support and guidance from mentors and facilitators (Helmbold et al., 2021; Mhakure, 2019). As a result, insufficient CPTD programmes can make it difficult for teachers to effectively implement new methodologies (Jojo, 2017; Govender et al., 2023).

Furthermore, DBE (2018) reports that teachers struggled with transitioning from traditional teaching methods to the new approach emphasised in the framework, particularly those who have used traditional methods for years. Researchers found similar results in their study; teachers are accustomed to traditional, teacher-centred instruction and find it challenging to adopt new, learner-centred approaches (du Plessis & Web, 2012; Dasoo & van der Merwe Muller, 2020). While professional learning communities provided some support, there was still a need for more consistent and accessible guidance from experienced mentors and facilitators. According to Jojo (2017), this might be especially true when teachers resist change, due to a lack of confidence in their ability to successfully implement new methods or a belief that traditional methods are more effective. As a result, teachers may feel that new methodologies do not align with their cultural context or the needs of their learners (Mosimege & Ismael, 2004; Govender et al., 2023).

Effective professional development involves considering and planning the desired outcomes and standards to contribute to the teachers' success. The teachers' success includes acquiring professional identity and practices (Havea & Mohanty, 2020; Anabousy & Tabach, 2022). Furthermore, it encompasses all in-service professional development activities that teachers can engage in, to enhance their teaching and learning practices, ultimately raising learners' academic performance (Havea & Mohanty, 2020). Therefore, in-service mathematics teacher professional development involves an intensive, comprehensive, and sustainable way of improving effectiveness and influencing changes in the teaching approach (Havea & Mohanty, 2020; Day & Sachs, 2004).

Recent studies suggest overcoming teacher resistance to ICT adoption and integration (Taylor, 2021; Herselman & Botha, 2014). For example, Ndaba, Maphalala and Ngubane (2023) found that teachers demonstrated enhanced adoption and integration of ICTs in their classrooms during ICT-related teacher development programmes, when infrastructure and e-content were available. Herselman and Botha (2014) also reported similar results in the context of teachers teaching in rural Eastern Cape schools, through the Information and Communication Technology for Rural Economic Development (ICT4RED) project.

The Information and Communication Technology for Rural Education Development (ICT4RED) initiative collaborated with the Council for Scientific and Industrial Research (CSIR), the Department of Science and Technology, and various provincial education departments. These partnerships were critical in providing the infrastructure and expertise required to integrate technology into rural South African schools. Thereby, teachers could be equipped with the skills needed to use tablets effectively in their classrooms (Herselman & Botha, 2014). This project sought to demonstrate how ICTs could transform education, particularly in resource-constrained environments, and bridge rural areas' digital divide (Botha et al., 2015). By focusing on practical classroom application, ICT4RED aimed to improve teaching practices through technological integration. This project was aligned with South Africa's broader education and digital goals, as outlined in the South Africa Connect national broadband policy, which supported the integration of ICT into education (Herselman & Botha, 2014).

Although ICT4RED did not focus exclusively on the development of mathematics teachers, the comprehensive and evolving framework followed by the project, included research and development; infrastructure setup; teacher training, and the development of educational technologies. The educational technologies used were limited to tablets, thus emphasising how to teach with a tablet. The teacher training curriculum ensured that technology was seamlessly integrated into pedagogical practices (Ford et al., 2014; Herselman & Botha, 2014). Furthermore, the approach followed was the combined F2F interactions with online components. Although platforms, such as Zoom or Google Meet were not part of the initiative, ICT4RED utilised web-based training modules, digital resource repositories, and virtual communities to support teachers remotely. F2F workshops and practical demonstrations were emphasised, mainly because many rural schools had limited internet connectivity, making these methods more accessible and effective for the target areas.

In summary, despite the challenges, such as the varying levels of ICT skills among teachers, limited resources, connectivity and other technical issues, some initiatives successfully fostered optimism about ICT integration into education. However, the literature highlighted the need to align technology-enabled learning with the national goals of enhancing teaching in disadvantaged environments. Such an example is the ICT4RED project, whose success was primarily due to the iterative, evidence-based framework followed. Thus, the ICT4RED framework was relevant to the mathematics teacher development programme and practical, as the environments are very similar in context. This flexible approach and continuous adaptation of the initiative based on actual feedback, ensured that the initiative introduced technology and promoted ongoing learning (Botha et al., 2015).

From this section, the initiatives reflect a comprehensive approach to enhancing mathematics education in South Africa by addressing both the pedagogical and contextual challenges in-service teachers face. In the next section, I look at Blended learning as the educational approach for designing and delivering the mathematics teacher development programme.

2.2 BLENDED LEARNING FOR MATHEMATICS TEACHER DEVELOPMENT

This section reviews blended learning as an educational approach, together with the guidelines and strategies for designing and delivering a teacher development programme. The Blended Block Model was selected to guide programme-structured F2F and online learning design and delivery. In conclusion, I turn to findings in the literature which recorded successes and barriers, for consideration.

2.2.1 Definition and Overview of Blended Learning

"*Blended learning systems combine face-to-face instruction with computer-mediated instruction.*" (Bonk & Graham, 2012, p. 2 [Chapter 1]). Hence, blended learning is an ongoing event with two ideas coming together in collaboration and mutual support. According to the *Guide to Blended Learning* by Dr Martha Cleveland-Innes and Wilton (2018, p. 2), "*blended learning is the use of traditional classroom teaching methods together with the use of online learning for the same students studying the same content in the same course*". Simply said, they describe it as a "*thoughtful fusion of face-to-face and online learning experiences*" (Cleveland-Innes & Wilton, 2018, p. 2). According to Ghimite (2022), blended learning is a hybrid instructional approach that combines traditional F2F and online instruction. In other words, "*blended learning is neither wholly face-to-face nor traditional learning nor entirely online; it is a combination of both*" (Ghimite, 2022, p. 89). Therefore, blended learning combines offline and online F2F learning and facilitates continuous communication. The delivery methods of the two learning experiences are different, in that one uses a traditional approach, and the other uses online.

For many years, creative and innovative teachers and facilitators considered design and delivery methods to combine teaching and learning strategies (Bonk & Graham, 2012; Badaru & Adu, 2022; Garrison & Vaughan, 2008; Ghimite, 2022; Chen & Jones, 2007). This combination of F2F and online design and delivery, created collaborative technology-enabled learning to the participant's doorstep. This blended-learning educational design emerged in the late 1990s and has evolved rapidly in various combinations (Cleveland-Innes & Wilton, 2018; Torrisi-Steele & Drew, 2013). In the next section, we look at its possible adoption in mathematics teacher development by focusing on the balance between F2F and online components, supported by examples from the literature.

2.2.2 Blended Learning in Programme Design and Delivery

Adopting blended learning in mathematics teacher development focuses on balancing F2F and online instruction. Hogarth (2010) focuses on the importance of teachers' collaboration and ability to participate actively in blended teacher development activities. Torrisi-Steele and Drew (2013) discuss the difference between minimal and transformative blends. Technology has a limited impact with minimal blends, and on the other hand, a significant impact on instruction with transformative blends. In addition, Alammary, Sheard and Carbone (2014) investigate three different blends: 1- the low-impact blend where the goal is to enhance the learning experience by adding online resources and activities to the programme; 2- medium-impact blend requires changes to the programme design and delivery with a balanced approach of utilising F2F and online benefits; and 3- the high-impact blend requires a redesign of the programme to create a cohesive and immersive blended learning experience. During my investigation, the blend used varied based on the specific context and situation of the schools, with different approaches being applied depending on the available resources and teacher readiness.

Garrison and Vaughan's (2008) extensive research on redesigning programmes to infuse blended instruction effectively, proposes principles that focus on intensified teacher engagement, interaction, and learning outcomes. Alammary, Sheard and Carbone (2014) emphasise the significance of inquiry-based planning and design with a focus on the needs of the teachers and facilitators when implementing the programme. Their article focuses on selecting the design that best fits the programme. Cleveland-Innes and Wilton's (2018) well-designed, step-by-step guide for designing and delivering blended learning includes practical tips for F2F classroom activities integrated with online activities. Furthermore, they focus on teacher development and continuous support to guide teachers to the new approach of F2F and online instruction.

Not only do Cleveland-Innes and Wilton (2018) accentuate the need for ongoing teacher training and support; Torrisi-Steele and Drew (2013) urge programme designers to understand the current blended learning practices of effective programme design. Badaru and Adu's (2022) study investigated how facilitators adapted to blended learning by combining F2F and online instruction. Their findings highlight the influence of the facilitator's perspective on the successful implementation of blended learning programmes. However, it is essential to note that online, blended learning instruction should be a natural extension of traditional classroom learning. Blended learning does not simply add to the existing F2F instruction and is not an entirely Internet-based learning experience; it should be noted that the intensity of online learning inherent to blended learning, is unclear (Garrison & Vaughan, 2008). Akyol, Vaughan and Garrison (2011) found that blending both F2F and online learning is more effective than only F2F or only online learning. Findings on university students enrolled in blended learning programmes showed decreased dropout rates and better academic performance, compared to F2F, traditional programmes (Alammary et al., 2014; Hogarth, 2010).

Blended learning effectively facilitates a community of inquiry by adding numerous forms of communication, which contribute to a crucial reflective component (Cleveland-Innes & Wilton, 2018; Padayachee & Campbell, 2021; Sweeney, 2022; Akyol & Garrison, 2011). Hybrid learning, a method and communication approach similar to blended learning, combines the interactive, practical advantages of F2F sessions with the flexibility of collaborative online sessions (Bergdahl & Hietajärvi, 2022; Setayesh, 2018). This approach runs a F2F and online session simultaneously, fostering more opportunities for engagement (Setayesh, 2018). It allows participation from different physical environments and ensures that teaching and learning can continue without interruption when physical attendance is impossible. Moreover, by offering choices in participation, hybrid learning shifts the focus from the facilitator to the participant, promoting a more autonomous, personalised educational experience (Bergdahl & Hietajärvi, 2022; Cleveland-Innes & Wilton, 2018). The online sections of the hybrid approach can take on multiple forms, including synchronous and asynchronous elements (van der Merwe & van der Merwe, 2008; Cleveland-Innes & Wilton, 2018). Indeed, while hybrid instruction and learning have many benefits, it also comes with challenges. Hybrid learning is resource-intensive in terms of time and financial impact, as it might require extra planning, additional resources, and a larger workforce.

Blended learning, on the other hand, focuses on integrating the best aspects of both methods to achieve teaching and learning outcomes. Therefore, blended learning extends thinking discourse over time and space, allowing for reflection and thoughtful response, which is impossible through either mode individually (Cleveland-Innes & Wilton, 2018; Ghimite, 2022). Furthermore, it significantly rethinks the educational experience, focusing on personal engagement in active and collaborative educational experiences (Cleveland-Innes & Wilton, 2018; Chen & Jones, 2007). Blended learning also provides flexibility in the educational process, accommodating unexpected changes and allowing customisation to meet specific teacher needs (Chen & Jones, 2007; Ghimite, 2022).

After the lockdowns imposed by COVID-19, multiple educational projects and programmes have not reverted entirely back to traditional educational methods of instruction and learning (UNESCO, 2023). The pandemic has led to a significant shift in the academic landscape, with institutions adopting new strategies and technologies to successfully overcome the problems posed by the crisis (Badaru & Adu, 2022; Ghimite, 2022). Blended learning was a solution to averting the spread of COVID-19, as it promoted social distancing, while at the same time provided access to a wide range of learning resources shared in print and multimedia (Badaru & Adu, 2022). Cleveland-Innes & Wilton (2018) noted in their Guide to BLENDED LEARNING that the challenges of blended learning include ensuring that all individuals participating in the programme have access to the necessary technology and reliable internet connectivity. The programme must integrate F2F and online activities supporting meaningful instruction and learning.

Teachers' mathematical knowledge and ability to support learners' reasoning, influence their instructional vision, which includes their beliefs about ideal classroom practices (Munter & Wilhelm, 2020). Therefore, well-structured, teacher-informed programmes for mathematics teachers' development could address gaps in mathematical concepts and improve reasoning and sense-making, which could lead to teachers creating more engaging and supportive learning environments. These environments can inspire learners and foster a positive attitude towards mathematics. Traditional teacher development programmes are an instructional method where, for example, mathematics is taught in person to a group of individuals simultaneously, in the same place (Setayesh, 2018; van der Merwe & van der Merwe, 2008; Harsha & Newman, 2021). This method allows for synchronous interaction between facilitators and teachers and is the most traditional type of instruction. This traditional method has significant advantages, not only in interaction between the facilitator and teacher but also between the teachers themselves. Teachers can work collaboratively and derive motivation from one another and the facilitator. Setayesh (2018) believes motivation increases, since activities and resources are varied, and experiential teachers are stimulated through interaction. It also increases teachers' participation and responsibility, without ignoring particularities within individual development.

Dasoo and van der Merwe Muller (2020) argue that structured learning environments allow teachers to share their experiences, refine classroom practice and engage in problem-solving activities. In addition, traditional methods foster collaborative relationships and personalised, on-demand learning opportunities. Research suggests that teacher development programmes should be collaborative, conducted in real classrooms, and embedded in constructivist, inquiry-based learning environments (du Plessis & Web, 2012; Dasoo & van der Merwe Muller, 2020). Traditional approaches, however, to teacher development are characterised as teacher-centred, presentation-style workshops that leave little room for teachers to apply new information to their instruction, while receiving ongoing support for those changes to take effect. Consequently, Schleicher (2011) critiques traditional approaches to teacher development as having proved ineffective, and that teacher training and professional development simply cannot set teachers up against the challenges they may encounter throughout their careers.

The ineffectiveness of workshops relates to the large amount of unfocused content, lack of intensity, and continual uniformity. Lecture-style traditional approaches reduce collaboration, creativity, and active learning among teachers. In addition, little time is spent on active classroom application, vicarious experiences, and mastery (du Plessis & Web, 2012). Williams and colleagues (2000) point out that poor facilitation, rushed pace, and information overload, contribute to unsuccessful implementation. They suggest that a practical approach, reflection, synchronous support, and idea sharing are essential elements during the design and delivery of teacher development programmes. Du Plessis and Web (2012) also highlight teacher reflection and add the sharing of ideas to embrace a community of practice, experiencing enjoyable and practical real-life content training. Teacher training must rise above the seminar, lecture-style approach "*and become situated within the teachers' working contexts, and move away from a transmission model*" (p. 47).

2.2.3 Blended Block Model: Initial Blended Learning Approach

An effective way of delivering a distance teacher development programme is through blended learning. The blended learning framework selected for this research study was the Blended Block Model (Cleveland-Innes & Wilton, 2018; FAO, 2021). This model is a structured guide for effectively designing and delivering the mathematics teacher development programme.

The programme design consists of the critical components of the blended block model, as illustrated in Figure 2-2.

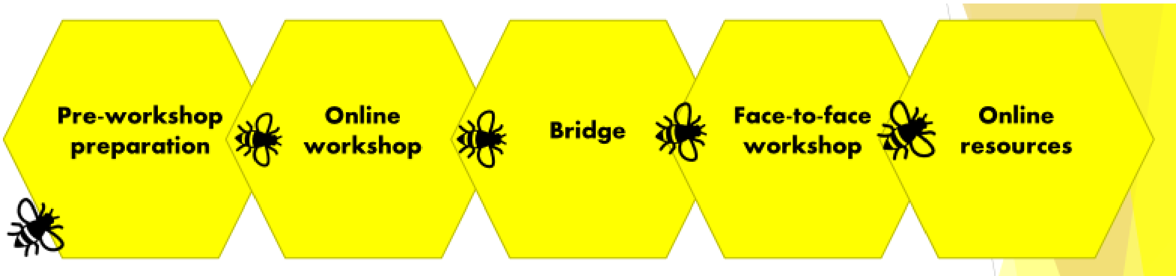

Figure 2.1: ***Blended Block Model adapted from Cleveland-Innes & Wilton (2018:7) and FAO (2021:14)***

The blended block model combines online and F2F sessions. Initiating the programme, the first phase is the *Pre-Workshop Preparation,* in which teachers are involved in the inquiry-based programme design. Teachers describe their needs, which assist the facilitator in tailoring the programme activities accordingly. In addition, teachers' biographical details, such as backgrounds, roles in the educational system, and specific skills, ensure personalised engagement and relevance. Following this phase, the *online workshop (core component*) is known as the heart of the programme*,* which lies in the online workshop, fostering individual study through online lessons and activities supported by facilitators. Both synchronous and asynchronous communication channels facilitated online discussions and group work, culminating in the formulation of individual activity plans. These plans served as reflective tools for teachers to assess their teaching situations and as resources for subsequent F2F activities. The *Bridge Period* is an interstitial phase bridging the online and F2F components, providing online support to aid teachers in preparing for the upcoming F2F workshops. This phase aimed to sustain engagement and facilitate smooth transitions between the programme blocks. Thereafter, the *traditional face-to-face workshop (Core Component)* constituted classroom activities wherein teachers presented and deliberated on their activity plans. This phase encouraged the application of teaching principles and techniques and further refinement of the activity plans, through practical exercises and discussions. Lastly, *post-course online resources* following the course's completion made supplementary online resources available to support teachers, in applying their newfound knowledge in their individual teaching settings. These resources aimed to facilitate the seamless transfer of learning outcomes into practical classroom applications.

The structured implementation of the Blended Block model within the mathematics teacher development programme exemplified an integrative approach, seamlessly interweaving F2F and online learning elements. This tailored design addresses the specific needs of teachers in rural areas, fostering engagement and equipping teachers with the essential skills for technology-enhanced mathematics education. In addition, policymakers and educational leaders believe that replacing some components of a learning programme with online or distance education, is a cost-effective way to deliver post-secondary education.

The blended mathematics teacher development programme also aligns with key components of the Blended Block model to equip rural area teachers with the requisite knowledge for accessing and utilising technology-enabled learning (FAO, 2021). However, the blended block model is known for its sequential "blocks" structured to incorporate F2F learning and online study. In comparison, the ICT4RED Initiative's goal is to enhance teaching and learning through technology and implement technology in rural area schools.

2.2.4 Framework for Blended Mathematics Teacher Development Programme

According to the Food and Agriculture Organization of the United Nations (FAO) (2021), the blended block model is a pedagogical approach that combines different learning methodologies to enhance capacity development. This model integrates self-paced e-learning courses, allowing students to progress at their own speed. The blended learning programme combines online and F2F learning experiences, providing large-scale interactive participation. The Blended Block Model is well structured for online tutored courses, offering specialised knowledge through online workshops that facilitate guided learning, with the support of tutors and mentors. Blended learning enables learning through ICTs and provides in-person, F2F training sessions. This model aims to transfer knowledge, skills, and competencies effectively, ensuring that students can apply what they have learnt in practical, real-life contexts.

One key component that resonates with the blended mathematics teacher development programme of the Blended Block Model, is its flexibility (Badaru & Adu, 2022; Padayachee & Campbell, 2021), which allows for a structured balance between online and F2F in-person learning experiences and focuses on optimising learning outcomes by effectively integrating different modes of teaching and learning (Ghimire, 2022). Furthermore, in contrast with ICT4RED, whose goal is to enhance teaching and learning through technology and implementing technology, the blended block model focuses on structured learning activities. Similarly, both aim to enhance learning experiences through thoughtful design, considering students' needs and engagement, and integrating technology into teaching and learning.

I learnt from this comparison that the structured implementation of the Blended Block model in the mathematics teacher development programme could be an integrative approach that interweaves online and F2F learning elements. This design could address the specific needs of mathematics teachers in South African rural areas, fostering engagement and equipping teachers with the essential skills for technology-enhanced mathematics education. However, when considering the latter in rural South Africa, it is essential to note that this design could pose problems (Badaru & Adu, 2022; Padayachee & Campbell, 2021).

Many rural areas face unstable or non-existent network coverage, which is crucial for the online components of blended learning (Ghimire, 2022; Badaru & Adu, 2022; Padayachee & Campbell, 2021). In addition, rural and remote educational environments often struggle with recruiting and retaining qualified teachers, exacerbated by the additional demands of blended learning (Havea & Mohanty, 2020). Hence, teachers may need to learn ICTs, and some might struggle to understand and effectively use learning management systems. Transitioning from traditional to blended learning requires patience and buy-in from all stakeholders. Addressing resistance carefully and managing expectations is essential.

Furthermore, ensuring reliable internet access, device availability, and technical assistance for teachers when needed, is crucial. Instructional challenges might occur from time to time, and effective online pedagogy needs to be considered. Adapting teaching methods for online components will be discussed in Chapter 3. Online teaching and learning can be intimidating, and adapting teaching and learning styles can be uncomfortable, initially. The facilitator should balance the modes to seamlessly integrate traditional F2F and online activities (Badaru & Adu, 2022; Padayachee & Campbell, 2021).

Outdated facilities and limited access to technology can hinder the implementation of blended learning strategies (Badaru & Adu, 2022). Therefore, encouraging collaboration among teachers and schools, could greatly benefit the programme's success. Collaboration, cooperation, and communication are vital for the success of a blended learning programme (Badaru & Adu, 2022; Garrison & Vaughhan, 2008; Padayachee & Campbell, 2021). Addressing communication gaps between online and F2F interactions could be done through WhatsApp groups that are easy to access, familiar to most teachers, and low-cost.

Last, in some rural areas, according to du Plessis and Web (2012), there might be a community of culture that does not value initiatives where technology integration in education is valued, which might result in a barrier to the acceptance and utilisation of blended learning. Padayachee and Campbell (2021) additionally found that shifting to a more self-directed blended learning approach might be challenging in a strong tradition of teacher-centred instruction. It was also reported by van Aswegen, Elmore and Young (2023) that teachers could resist adopting new teaching methodologies and professional development practices, particularly those perceived as overly influenced by Western, market-based approaches. Addressing these challenges involves planning, training, and ongoing support. Therefore, balancing F2F, online and mentoring phases requires careful planning. Teachers need clear guidance and the opportunity to share their thoughts and ideas on how this programme could address their needs. This could also lead to self-directed learning and participation, when teachers feel that they are part of the programme design. The programme design and implementation involve collective planning, communication, and adaptability.

While research on blended learning in South Africa is still emerging, notable cases and studies are related to in-service teacher professional development. These studies provide insights into the potential of blended learning for mathematics teacher development programmes in rural South African schools.

2.3 FINDINGS AND SUGGESTIONS FROM LITERATURE REVIEW

Technology benefits professional development in rural South African schools. Padayachee and Campbell's (2021) research study investigated how technology might enhance instructional design, offering interactive and adaptive learning, such as games in mathematics that support understanding. They incorporated data analytics to track teachers' progress and personalised learning experiences. Their findings highlighted that online platforms have the potential to provide continuous support to teachers because they are not restricted to a set environment. Teachers have entrée to the programmes and can access them conveniently. This flexible, scalable, and cost-effective approach combines F2F and continuous online delivery.

Similarly, focusing on technology tools to support mathematics teachers in South Africa, Moss (2021) explores “Using WhatsApp to Support Teachers: A Case Study of South African Mathematics Teachers”. The key point of this study is that the easily accessible and effective communication platform encourages teachers to collaborate and support one another. In addition, this platform provides opportunities for continuous teacher development, allowing teachers to engage in synchronous discussions and receive timely feedback. Moss (2021) highlights some universal challenges, namely the need for teachers to be trained in digital literacy and in addition, the potential for cognitive overload.

Case studies of successful blended learning implementations conducted by Cleveland-Innes and Wilton (2018), provide insights and list best practices for teacher development programmes. According to the findings of the cases, an overlapping trend could be seen in improved teacher engagement, collaboration with colleagues, and practical activities, resulting in better learning outcomes and skills development. According to Cleveland-Innes and Wilton (2018), the best takeaway practices for blended learning are flexibility, clear objectives, timely feedback and support, and interactive multimedia content for successful programme design and delivery. However, some challenges include adopting technology-enabled learning and resisting change.

Van der Merwe and Van der Merwe (2008) found that traditional F2F instruction delivers foundational skill-acquiring and collaborative learning. They advocate active and engaged CPTD workshops. Padayachee and Campbell (2021) assert that real-life contexts aligned with curriculum standards and learning outcomes, are essential to the programme's success.

Last, the FAO (2021), followed the Blended Block Model, as educational framework for designing and delivering e-learning solutions. The key points from their study included detailed content creation, informed by the participant's needs, learning platforms that support various instructional design techniques, and practical content-related activities. As discussed in the previous section, the Blended Block Model provides structure to the program for continuous learning.

2.4 CONCLUSION

I reviewed the literature on Continuous Professional Teacher Development (CPTD) in this chapter and highlighted its significance in mathematics teacher development. South African learners consistently perform poorly in mathematics, as the TIMSS results have shown. This finding drives the need for continuous mathematics teacher development to keep teachers updated with the latest teaching strategies, methodologies and approaches. In addition, I identify the challenges CPTD faces and the specific needs of mathematics teachers.

In the last section of this chapter, I focused on Blended Learning as an educational method and approach for teacher development programmes. Blended learning combines the collaborative and relational strengths of traditional F2F instruction, with the flexibility and cost-effectiveness of online instruction. In this study, I selected the Blended Block Model as an initial approach. I further discussed the Blended Block Model in Chapter 4 adjacent to the Participatory Action Research approach, as the two works are complementary to each other. To guide the design and implementation of blended learning programs for professional development, the Community of Inquiry theory has been identified as a suitable framework (Stott, 2022; Cleveland-Innes & Wilton, 2018). This framework is a guiding principle for structuring and organising blended learning experiences to enhance mathematics teachers' professional growth and learning in this context. In the next chapter, I discuss the Community of Inquiry Theory, the cognitive load theory, and the self-determination theory as they guide instructional design and information delivery.

CHAPTER 3 : CONCEPTUAL FRAMEWORK

"*If I have seen further,*
it is by standing on the shoulders of Giants."
Isaac Newton

The 4th Industrial Revolution is the trend towards automation and data exchange in technologies where basic education is not examined. Therefore, in learning to adapt, teachers must practise the ability to project themselves socially and academically in online and F2F communities of inquiry. Digital learning skills are essential, and blended learning courses can help teachers master these skills using various technologies. This chapter discusses the Community of Inquiry Theory, which informs programme design and delivery.

The blended mathematics teacher development programme is designed for and delivers F2F and online. Hence, learning outcomes for mathematics and ICT skills acquisition happen simultaneously. Therefore, instructional design and information delivery should be cautious of the teachers' minds. For this reason, cognitive load theory and information processing theory are discussed to provide a better understanding of how the human mind processes new information for optimal learning. Lastly, facilitation for autonomy is guided by the self-determination theory and the cognitive evaluation theory. In this chapter, I discuss autonomy, competence, and connection, under the guidance of the six components of the Organismic integration theory that guide my understanding of how facilitators promote intrinsic motivation.

3.1 Community of Inquiry Theory

The Community of Inquiry theory informed the design and delivery of the blended learning programme. Participatory Action Research design for developing effective blended learning includes an experimental and systems-based approach. Hence, I studied the "Community of Inquiry Blended Learning Evaluation" form (Cleveland & Wilton, 2018, pp. 74-77), designed to measure the extent to which the three presences are evident in a blended learning experience. As a result, the iterative system of planning, action, evaluation, and reflection guided the design and delivery of the mathematics teacher development programme.

3.1.1 Community of Inquiry Theoretical Framework

The Community of Inquiry theoretical framework, based on critical thinking and practical inquiry, has been a model for effective blended learning since 2000 (Garrison et al., 2000; Garrison & Arbaugh, 2007; Akyol & Garrison, 2008). It is based on John Dewey's work and constructivist views of experimental learning. The Community of Inquiry theoretical framework (Figure 3-1) explains deep and meaningful learning at the confluence of three energies: cognitive presence, social presence, and teaching presence (Garrison et al., 2010). In the context of my study, '*presence*' is defined as being present, engaging, and actively participating in the cognitive, social, emotional, and physical workings of individual and collaborative learning environments (Cleveland-Innes & Wilton, 2018).

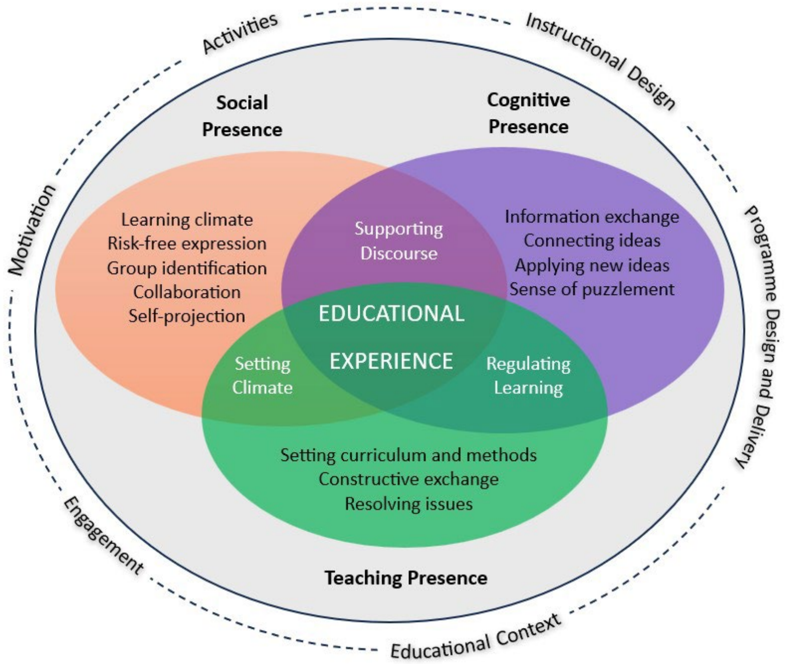

Figure 3.1: The community of inquiry framework Adapted from "Critical inquiry in a text-based environment: Computer conferencing in higher education" by D. R. Garrison, T. Anderson, and W. Archer (2000) The Internet and Higher Education, 2(1), p. 88.

Cognitive presence involves information exchange, connecting ideas, applying new ideas and a sense of puzzlement, resulting in deep learning. Social presence is reflected in a learning climate through risk-free expression, a sense of identification and belonging, collaboration and self-projected engagement. Hence, the confluence of social and cognitive presence creates a discourse that supports understanding and application. Teaching presence involves setting the curriculum and methods, focusing discussions, resolving issues, and sharing personal meaning through constructive exchange. After reviewing all three energies we see that teaching presence is the only energy we can control. In the context of the community of inquiry framework and the mathematics teacher development programme, *energies* refer to the community of inquiry components. However, I decided on that terminology to create a sense of the *energy* it brings to the programme dynamics. According to Garrison et al. (2000, p. 96), teaching presence is the binding energy, so the confluence of teaching and cognitive presence results in content selection and teaching and social presence in setting climate. The interrelation of the three energies and the tenacious nature of teaching presence influences social presence, and collectively impacts cognitive presence (Garrison et al., 2010).

Inquiry-based programme design and delivery for Continuous Professional Teacher Development (CPTD) is crucial, even more than previously, as both are a learning process and a subject of learning to learn (Cleveland-Innes & Wilton, 2018). Inquiry-based teaching and learning is an active form of learning that encourages teachers to identify their training needs for constructing their own knowledge. This leads to autonomy and deeper engagement. In contrast to content-based teaching, inquiry-based teaching is a more autonomous approach to CPTD that allows teachers more control over the content design and how they develop their knowledge base. Over and above content acquisition, inquiry-based learning promotes competence development in higher-order thinking skills (Garrison, 2016). As a result, inquiry-based learning requires meaningful engagement opportunities contrasting direct instruction that supports passive learning.

3.1.2 Creating a Community of Inquiry for a Blended Mathematics Programme

The community of inquiry framework promotes guided inquiry on the content and processes for blended learning. Blended learning, informed by the energies of the community of inquiry framework, offers opportunities for self-reflection, active empirical processing, engagement, and collaborative teaching. In addition, expert facilitation at the right time encourages engagement and active participation. Consequently, communities of inquiry, whether F2F, online or blended, are created.

Creating communities of inquiry in blended learning is the most widely investigated pedagogical approach (Garrison, Anderson & Archer, 2000). Thus, early studies by Richardson and Swan (2003) focused on understanding social presence to approach teaching, beyond strict transmission content delivery models. More recently, scholars focused on understanding and developing social presence in asynchronous online learning environments (Rourke et al., 2001; Swan & Shih, 2005; Kehrwald, 2008). Moving into the digital era, researchers are investigating teaching presence in online environments (Anderson et al., 2011), and exploring the relationships between the three energies and how they regulate one another in both F2F and online environments (Garrison et al., 2020; Akyol & Garrison, 2008; Szeto, 2015; Padayachee & Campbell, 2021; Singh et al., 2022).

Measuring the extent to which the three presences are evident in a blended learning programme allows reflection for adjustment and further action (Cleveland-Innes & Wilton, 2018, pp. 74-77). An evaluation tool, supported by the Community of Inquiry Framework, was designed to be used by facilitators during or after training. The evaluation tool lists various activities that describe the 'presence' of each energy during the educational experience. Interpreting the results could inform the facilitator about the preparedness for technology-enabled learning in the specific educational environment (Kirkwood & Price, 2016, p. 88). Table 3-1 summarises the three energies according to the F2F and online activities, as well as the indicators of each presence in an educational environment.

Table 3.1: ***F2F and online activities in the respective educational environments and indicators of each presence*** (Cleveland-Innes & Wilton, 2018).

Energies	Educational Environment		Indicators
	F2F	**Online**	
Cognitive Presence	Exploration Integration Resolution Triggering Event	Exploration	Information Exchange Connecting Ideas Applying New Ideas Sense of Puzzlement
Social Presence	Open communication Personal / Affective expression	Open communication Group cohesion	Learning Climate and Risk-free Expression Group Identify or Collaboration Self-projection
Teaching Presence	Design & Organisation Facilitation	 Facilitation Direct instruction	Setting Curriculum and Methods Shaping Constructive Exchange Focusing and Resolving Issues

The indicators of cognitive presence listed in Table 3-1 involve 1. triggering events, where a need is identified for inquiry; 2. exploring, where the need is being explored; 3. integrating, reflecting on, and making sense of the identified need, and 4. resolving the stage where the need is addressed, and learning takes place (Garrison et al., 2001; Garrison & Arbaugh, 2007; Akyol & Garrison, 2011).

The indicators of social presence are open communication, group cohesion and valuable personal or affective expressions. It also refers to the ability of teachers in a community of inquiry to express themselves socially and emotionally through any means of communication (Garrison et al., 2000). Social presence creates a sense of belonging, supports freedom of expression, and sustains cohesiveness, referred to as cognitive presence. Therefore, social presence prepares the base for building higher-order discourse and thinking, but the energies of teaching presence are essential in developing cognitive presence (Garrison & Arbaugh, 2007).

Anderson et al. (2001, p. 5) describe teaching presence as: "*The design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educational worthwhile learning outcome*". Teaching presence binds all the energies together as its effectiveness improves cognitive and social presence, which creates an exceptional educational experience (Garrison et al., 2000). Teaching presence is measured by 1. Instructional design and organisation, 2. Facilitation of discourse, and 3. Direct instruction (Garrison, 2011). Teaching presence is critical in establishing the curriculum, teaching approaches, and facilitation methods. It brings social presence and cognition together effectively and efficiently. Teaching presence can strongly predict students' perceived learning, motivation, and satisfaction with the delivery medium (Arbaugh, 2007).

Emotional presence has been proposed, in addition to the three presences discussed above (Cleveland-Innes & Campbell, 2012; Stenbom et al., 2016). Emotional presence is described:

> *"As the outward expression of emotion, affect and feeling, by individuals and among individuals in a community of inquiry, as they relate to and interact with the learning technology, course content, students and instructor. Item indicators for emotional presence have been analysed with the instrument measuring the original three presences" (Arbaugh et al., 2008, in Cleveland-Innes and Wilton, 2018, p. 14).*

In addition, Cleveland-Innes, Ally, Wark and Fung (2013) suggest that emotional presence might be an addition as a separate element in the Community of Inquiry Framework; however, more research needs to be done. Therefore, this study will focus on the three energies, cognitive, social, and teaching presence, with recognition of the influence of emotion discussed as a component in the Cognitive Load Theory and the Self-determination Theory in the following sections.

3.1.3 Section Summary: Programme Design and Delivery

This section presented the community of inquiry framework with its three presences that should be considered in designing and implementing a blended teacher development programme. These presences refer to meaningful interaction between the student and other students (social presence), course content (cognitive presence), and the facilitator (teaching presence).

In the next section, I focus on cognitive load theory and its significance in designing effective instructional material. Understanding working memory's sensitivity to overload, has highlighted issues in blended mathematics learning, where overload can hinder schema formation and learning automation. In addition, the literature informed the interrelated changes in motivational beliefs and the functioning levels of cognitive load in the working memory. Hence, considering the aim of this study to promote an exceptional blended educational experience, I describe the Community of Inquiry framework, which is an application of Garrison, Anderson and Archer's (2000) work to guide my way.

3.2 COGNITIVE LOAD THEORY

Drawing from multiple disciplines, I find the Cognitive Load Theory, pioneered in 1988 by John Sweller, helpful in guiding instructional design and delivery. Cognitive Load Theory is a prominent cognitivist learning theory that focuses on the interplay between two essential memory components: working and long-term memory (Sweller et al., 1998; Baddeley, 2006). This warrants particular attention because instructional materials should account for the limitations of working memory. Therefore, studying the Information Processing Model guided my understanding of the core principles of Cognitive Load Theory.

3.2.1 Cognitive Load Theory: A Learning Designer's Guide

Learning designers plan and design learning experiences to improve learning outcomes and retention. This is one of the intended objectives of the blended mathematics teacher development programme. However, understanding how to design for an exceptional learning experience involves designing with an awareness of the architecture of cognitive load (Sweller et al., 1998; Van Merrienboer & Sweller, 2005). Cognitive load refers to the amount of information our working memory can process simultaneously. As a result, instructional materials and methods should avoid overloading the limited capacity of working memory (Xu et al., 2021; Sweller, 2020).

Cognitive Load Theory comprises three core principles that interact during learning: "*harmful extraneous, necessary intrinsic and productive germane*" (Stott, 2021, p. 270). Sweller (1994) proposed that cognitive load has at least two additive components: intrinsic and extraneous. Intrinsic cognitive load is "*the mental work resulting from the complexity of the content being studied*" (Clark et al., 2006, p. 322). Hence, the intrinsic cognitive load is specific to the topic: its unfamiliarity, inherent complexity, and difficulty (Stott, 2021). Initially, according to Paas et al. (2003), the intrinsic cognitive load was considered fixed, regardless of instructional manipulations, where instructional design and the complexity of the topic were chosen to fit the level of expertise. Thus, managing the intrinsic cognitive load with selection and sequencing, limits elemental interactivity (De Bruin & Van Merriënboer, 2017; Van Merriënboer, Kester & Paas, 2006). However, with inquiry-based design, the topics arise from inquiry. As a result, the full intrinsic cognitive load of complex topics must be faced (Van Merrienboer & Sweller, 2005).

Mathematics is complex and therefore offers considerable cognitive load (Tiruneh et al., 2018; Yohannes & Chen, 2023; Avgerinou & Tolmie, 2020; Ayres, 2001). Hence, Dong, Jong and King (2020) propose that to help manage intrinsic cognitive load, complex content should be sectioned into manageable parts and build the learning path from simple to complex. Researchers also suggest that this '*good*' instructional material design that relates effectively to students' prior knowledge could manage intrinsic cognitive load (Chen et al., 2017; Sweller, 2011).

In contrast, the effect of '*poor*' instructional material design adds extraneous cognitive load (Sweller, 1994). Seery (2012, p. 25) explains that "*poor materials or those that require a large amount of working memory to process will increase the load and leave little capacity for learning*". Extraneous cognitive load is often described as '*harmful*' because it prevents optimal schema formation and automation (Stott, 2021; Paas et al., 2003). However, extraneous cognitive load is also viewed as '*false*' because it appears from the design of instructional material and delivery methods (Skulmowski & Xu, 2021; Sweller,1994; Sweller, 1988, 2010). This may be particularly problematic in online learning, due to the multiple opportunities for exploration that the internet affords, relative to F2F instruction (Kirschner et al., 2018). In their article, *Understanding Cognitive Load in Digital and Online Learning*, Skulmowski and Xu (2021) aver that learning designers should minimise the unnecessary extraneous, cognitive load to divert '*stretching*' the cognitive capacity for dealing with the actual learning contents, as illustrated in Figure 3-2 below.

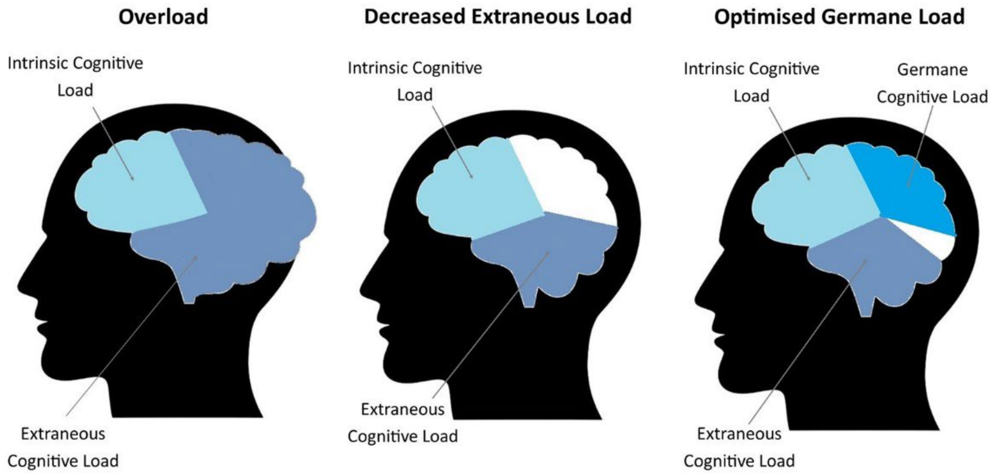

Figure 3.2: Interaction of intrinsic, extraneous, and germane cognitive load during information processing

As seen in Figure 3.2, decreased extraneous cognitive load enables information acquisition and increases the extent of learning, thereby optimising the germane cognitive load. The germane cognitive load, according to Paas et al. (2003), refer to the sense-making activity which involves linking new learning with prior knowledge to create understanding. Therefore, the germane cognitive load assists the learning process by identifying helpful parts from the instructional material and format, to reduce the parts' interactivity (i.e., the complexities among different interacting information parts – Sweller, 1994). In other words, germane cognitive load is the part of your mind saying, "*Ah, I understand; this is similar to...*" during the learning process. This cognitive process is specifically crucial for complex mathematics problem-solving. Cognitive Load Theory suggests instructional design and content delivery: “*Learning will be difficult if cognitive load is high, irrespective of its source*” (Sweller, 1994, p. 308). Therefore, significant deep learning terminates when the cognitive load is too high (Reid, 2008; Johnstone & El-Banna, 1989). However, the cognitive load can be utilised by reducing the extraneous cognitive load, carefully selecting the intrinsic cognitive load, and allowing mental capacity for processing the intended processing (germane load) (Figure 3-2) (Sweller, 2011).

Therefore, in the context of this study, this is partly inherent to the degree of complexity of mathematics content; it is also influenced by the clarity of the learning material and the level of teachers’ prior knowledge (Sweller, 2011; Tiruneh et al., 2018). Consequently, when the extraneous cognitive load results from paying attention to irrelevant details (Sweller, 2011), high levels of cognitive processing are required to deal with the extraneous cognitive load. This will reduce the capacity to acquire helpful schemas for learning (Kirschner et al., 2018). For example, technology-enabled learning requires teachers to invest in essential extraneous cognitive load, to allow certain forms of the germane cognitive load to occur (Skulmowski & Xu, 2021). Hence, when teachers have prior MKT knowledge and ICT skills, the extraneous cognitive load decreases, leading to an exceptional learning experience. In contrast, with limited pre-existing knowledge and poor instructional material, the learning experience can result in cognitive overload (Dong et al., 2020).

3.2.2 Information Processing Theory: A Facilitators Guide

The Information Processing Theory serves as a plan for understanding the iterative elements of Cognitive Load Theory. The Information Processing Theory builds on patterns of human thinking that are proposed as universal (Ausubel, 1968; Piaget, 1964). This is a well-renowned theory in cognitive psychology that has been continuously applied to describe and explain the complex processes of the human memory system (Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Baddeley, 1986, 2000, 2003; Cowan, 1988, 1995, 2001; Miller, 1956). Miller (1956) discovered the limited capacity of the working memory, also referred to as the short-term memory. Furthermore, he coined the term '*chunking*' when describing the functionalities of working memory. Aside from Miller, John William Atkinson and Richard Shiffrin proposed a multi-stage memory model, as illustrated in Figure 3-3 below (adapted from Atkinson & Shiffrin, 1968, 1977). This model shows the three subsections of human memory: sensory memory, working memory and long-term memory, and how they work together.

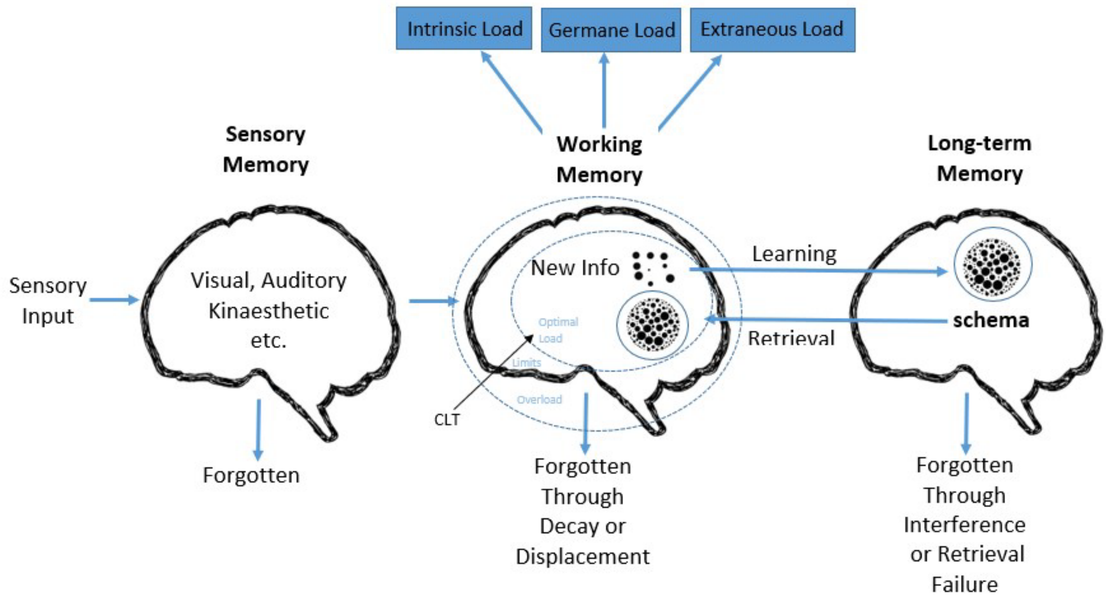

Figure 3.3: ***The multi-stage memory model adapted from Atkinson and Shiffrin (1968, 1977)***

As illustrated in Figure 3.3, the process includes both external stimuli and the already acquired 'schema' in a learning situation. Information processing begins with continuously receiving information from the learning environment using various senses, first linking with the perception filter before moving to the working memory. The perception filter is uniquely individual for each person and consists of prior knowledge and beliefs that are stored in the long-term memory, arising to assist with selecting relevant information from the information presented. According to this model, only some information presented to the short sensory memory is selected when the mind pays attention; some information may even be refused at this stage, if it does not make sense. Information is then moved to the working memory, a limited space in which information is stored and processed, where it is lost after a short while, if not rehearsed and 'chunked'. During rehearsal, links are formed within the 'chunks' of new information with pre-existing information in the long-term memory; there is a trade-off between how much can be temporarily stored and how much information can be processed. Sense-making and problem-solving occur in the working memory through iterative retrieval and the storage of information in the long-term memory. During this process, new information is encoded in the long-term memory and can be later retrieved to help process new information (Sweller, 2011, 2020). Hann et al.,(2007) noted that successful information processing and learning affect behaviour. In the expectancy theory of motivation (Bandura, 1977), expectations for success (i.e. competence-related beliefs) are more strongly linked to performance. Therefore, expectations based on previous learning experiences will enhance motivation to apply effort (and tolerate some extra extraneous cognitive load) to achieve the desired outcome.

Hence, this process of human memory brought awareness that a large ‘chunk’ of information or complex problems must be supported by scaffolding to minimise the cognitive load on the working memory. Many authors consider the capacity of the working memory to be the limiting factor in learning (Suppawittaya & Yasri, 2021; Lorenz & Tizon-Couto, 2019; Kirschner & Sweller, 2006). James Clerk Maxwell recognised the significance of the working memory in the 19th century: "I quite admit that mental energy is limited … efforts of attention would be much less fatiguing if the disturbing force of mental distraction could be removed" (Niaz & Logie, 1993, p. 511). A later study points out that working and long-term memory differ in various ways, especially in capacity and duration to retrieve information. It is accepted that information is shared at the same time interval with others; for example, in the context of this study of the blended learning approach, where students have to learn both new information regarding technology and the content of the subject, it is more challenging to recall because it shares its temporal cues for retrieval (Cowan, 2008; Skulmowski & Xu, 2021). Therefore, when sharing a list of information, working memory would most likely remember the most distinct one more temporally.

Suppawittaya and Yasri (2021) regard the strategy of 'chunking' information during instructional material design to improve working memory capacity as one of the best methods (Suppawittaya & Yasri, 2021). Chunking is grouping the presented information to compress the context effectively. This process will reduce cognitive load and improve working memory capacity. According to Suppawittaya and Yasri (2021), chunking can happen in two ways: either through strategic reorganisation of information based on prior knowledge or through grouping based on perceptual traits. In other words, instructional material could be designed so that information could be characterised in meaningful units or "chunks", which might increase the amount of recalled information and immediate memory capacity. However, complex or unfamiliar information may be less effective to remember even when the information is 'chunked' (Lorenz & Tizon-Couto, 2019). Suppawittaya and Yasri (2021, pp. 28-29) note in their article that "the experiments and explanations about chunking patterns and the comparison between the effectiveness of the human's memory to memorise… [information] are still limited". This process of new knowledge construction is more clearly highlighted in the Worked Example Effect, Element Interactivity, and the Expertise Reversal Effect. Taking a pragmatic approach, I consider it appropriate to combine the most valuable research evidence and the most helpful in reaching an understanding, within the context of this study (Cresswell, 2020).

Worked Example Effect, Element Interactivity, and the Expertise Reversal Effect

Considering the previous two sections, cognitive load theory suggests learning as a process in which schemata are constructed by linking new information with pre-existing knowledge in working memory (Figure 3-2). In addition, an overall assumption of cognitive load theory is that the capacity of working memory, in contrast to long-term memory, is severely limited in terms of the amount that can be processed simultaneously, i.e., '*seven plus or minus two*' elements of information (Adams et al., 2018). Another critical assumption of cognitive load theory is the distinction between the different types of cognitive load, which have an additive character concerning the capacity of working memory. According to Sweller (2020), when the six basic concepts of cognitive load theory are used as a basis for designing instructional material, it can have a demonstrable effect on student success.

Based on cognitive load theory, the *worked example effect* postulates that infusing step-by-step, already worked-out solutions in learning material (instead of solely presenting problem-solving activities), can benefit knowledge acquisition (Sweller, 2010; Jiang & Kalyuga, 2020; Wesenberg et al., 2022). Hereof, the student's learning process is supported by studying worked examples, i.e., 'pre-existing knowledge' in which schemata are constructed by linking it to the new chunks of information. As a result, these work examples provide a model for students to learn from, which manages the intrinsic cognitive load, lowers the extraneous cognitive load on the working memory, and increases the germane cognitive load (Chen et al., 2017; Paas & van Merrienboer, 2020; Wesenberg et al., 2022). Students can then apply this example as a '*road map'* or pattern to subsequent problems of a similar type.

Consequently, when students begin to '*grapple*' with complex new information, many concepts must be considered and coordinated. Element interactivity balances and coordinates these concepts simultaneously in the working memory (Chen et al., 2017;

Wesenberg et al., 2022; Sweller et al., 2011). From a broad perspective, element interactivity is the complexity of the information, based on the levels of element connectedness that depend on the type of information and the student's pre-existing knowledge. High-element interactivity occurs when concepts cannot be learnt independently and should be processed simultaneously. For example, the problem: "x + 9 = 12, solve for x" has high element interactivity for novice students because it contains five single mathematics elements (i.e., x, 9, 12, +, =) that students should have in existing schemata. However, the single mathematics elements will not assist in problem-solving, unless students simultaneously process the relations between the elements in their working memory to interpret the problem. Moreover, to solve the problem, novice students should know that by subtracting the value nine on either side of the equation, "x" should be found. The subtraction required to solve this problem adds interactive elements, resulting in high-element interactivity.

Conversely, students could be left to learn complex new information by *trial and error*. However, cognitive load theory rejects strategies such as discovery learning (Kirschner et al., 2006). Wesenberg et al. (2022, p. 22) noted "that pure problem-solving is associated with a heavy load because cognitive resources are expended on solving the task at hand". During problem-solving, the student must perform a means-end analysis to find appropriate operations for converting the actual state into the desired state. A more recent study by Salahudin et al. (2024, p. 330) found that the means-end analysis model

> *"had a positive effect on [low cognitive] mathematics learning outcomes … because in the delivery of material, it is always associated with problems that exist in students' daily lives. Learning has been running meaningfully if students can relate a subject matter to their understanding."*

Hence, pre-existing knowledge could affect students' dispositional characteristics. For example, Chen et al. (2017) found that when 'expert' students (i.e. students with pre-existing knowledge and skills) were presented with worked examples, the effect was reversed, and it was more redundant and a learning hindrance (increased extraneous cognitive load). This is called the *expertise reversal effect* (Chen et al., 2017; Wesenberg et al., 2022; Kalyuga et al., 2000).

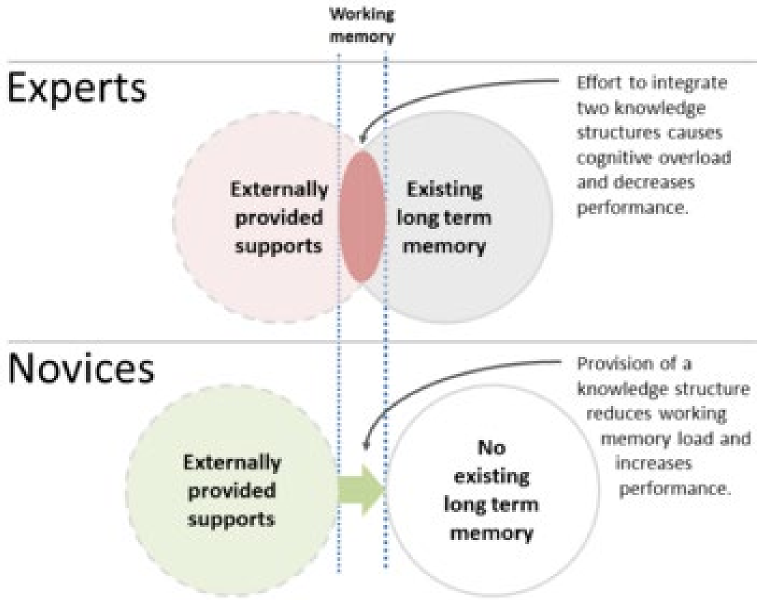

Figure 3.4: ***The differing effect of externally provided instructional guidance on students with varying levels of prior knowledge.***

As Figure 3.4 illustrates, experienced students are far more likely to have expertise already, in solving a mathematical problem, such as "x + 9 = 12, solve for x". Hence, studying a worked example on this basic concept might require extra effort to integrate two knowledge structures (i.e., existing method with a new proposed method), causing cognitive overload and decreased performance. Inversely, researchers found that novice students greatly benefited from worked examples. The knowledge structure of worked examples reduces the cognitive load on the working memory and increases performance (Brunstein et al., 2009; Kalyuga & Sweller, 2004; Rey & Buchwald, 2011). The impact of worked examples on cognitive load, both cognitive overload and cognitive load reduction, is significant when designing instructional material to enhance learning processes and ensure student success at all levels.

In summary, the overwhelming nature of cognitive load may lead to the loss of information in the working memory, when a cognitive overload occurs or, contrary, support the student's ability to understand information fully. Another aspect influencing cognitive load is students' previous experience (advanced, intermediate or novice). The latter relates to the frequency and type of instructional material (e.g., step-by-step worked examples, instructional scaffolding or problem-solving), required to optimise a student's cognitive load. However, novice students might be unable to perform a learning activity without supporting information and, as a result, rely on inadequate methods, such as means-end analysis. Nonetheless, too much support will likely burden more experienced students as they still must process redundant information already in their long-term memory (Feldon, 2007; Gobet, 1998; Ericsson & Kintsch, 1995; Sweller, 1988). Cognitive load theory aims to articulate many impact factors (e.g., students' expertise, element interactivity) to develop effective pedagogical procedures and interventions to enhance working memory's learning capacity and avoid cognitive overload in teaching and learning contexts.

3.2.3 Section Summary: Instructional Design for blended learning

Cognitive Load Theory initially failed to include the social nature of learning. Subsequently, the theory evolved to include notions of social agency in technology-enabled learning (Mayer, 2014, 2017; Kirschner et al., 2018; Sweller, 2020) and collaborative cognitive load in collective environments (Kirschner et al., 2011; Kirschner et al., 2018). Collaborative cognitive load is the '*joint-working*' of long-term memories in complex problem-solving (Kirschner et al., 2018), on the premise that the small size of working memory is the most significant limitation to learning (Sweller, 2011).

In the case of this study, teachers are expected to identify and learn MKT needs in a blended learning environment of technology-enabled learning. As previously mentioned, LMSses sometimes require teachers to invest in essential extraneous cognitive load to allow certain forms of germane cognitive load to occur. As a result, extraneous cognitive load decreases when students enhance their ICT skills working with technology, leading to a better learning experience. On the other hand, students with limited ICT skills can experience cognitive overload and feel overwhelmed and discouraged.

The relationship between emotions and learning effectiveness is complex and student-specific. In the cognitive load theory context, emotions involved in forming and changing motivation over time are often classified as *positive or negative emotions*. *Positive emotions* will likely enhance motivation and optimise intrinsic cognitive load, boosting working memory, creativity, and information recall from long-term memory (Murayama et al., 2013). Conversely, *negative emotions* can consume working memory, reducing recall, creativity, and the quality of learning outcomes (Plancher et al., 2018; Zlomuzica et al., 2016). Negative emotions, such as stress and anxiety can overburden ECL, thus hindering performance (Beilock et al., 2004).

Negative emotions (and sometimes positive emotions too), can overwhelm the extraneous cognitive load and reduce the working memory capacity, resulting in lower performance and reduced effectiveness (Baddeley, 2006). That said, within learning contexts in which emotions are part of the intended learning outcomes (e.g. learning the skill of resilience in an unpredictable, frustrating learning environment), processing and regulating negative emotions then become unavoidable and are therefore associated with the intrinsic cognitive load (Kirschner et al., 2018). The literature also suggests that certain negative emotions, such as frustration and confusion, might enhance mental effort and enable deep learning (Van Merrienboer & Sweller, 2005). For example, students shift their focus to learning activities to improve their understanding, while tolerating the frustration of not 'getting-it-right' after the first attempt; after obtaining the desirable outcome, schemata were formed in the LTM (Murayama et al., 2013; Lin et al., 2018). Hence, applying effort (and tolerating some extra extraneous cognitive load) to achieve the desired outcome will not easily forget this learning, heightened by emotion (Murayama et al., 2013). Unlike basic evolutionary skills, such as speaking and walking, students need motivation, blending self-interest and social norms, to acquire domain-specific knowledge, especially in formal education settings (Ryan & Deci, 2020). Several integrated learning theories and models have emerged out of the literature of educational psychology, where cognitive load theory is linked with the motivational and emotional dimensions of learning (Ryan & Deci, 2009, 2020; Sweller & Paas, 2017; Guo & Wei, 2019; Darragh et al. 2024).

3.3 SELF-DETERMINATION THEORY

Self-determination theory is a psychological framework that explains human behaviour, emphasisng the importance of *intrinsic and extrinsic motivation*. Self-determination theory identifies three basic psychological needs for promoting intrinsic motivation: autonomy, competence, and relatedness. When these needs are met, teachers are more likely to experience intrinsic motivation, leading to better learning, social interaction, academic accomplishment, and psychological development (Deci & Ryan, 1985; Ryan & Deci, 2017).

3.3.1 Cognitive Evaluation Theory

Cognitive Evaluation Theory suggests that a salient external reward or constraint can change the perceived locus of causality from internal to external, resulting in decreased intrinsic motivation. In contrast, the absence of a salient reward or constraint, and the presence of choice, can induce a change in the perceived locus of causality from external to internal, resulting in increased intrinsic motivation. In addition, a change in perceived competence might affect intrinsic motivation. Intrinsic motivation will increase if an educational event improves perceptions of competence. On the other hand, intrinsic motivation will decrease if perceptions of competence decline (Ryan, 1982; Hendijani et al., 2016).

In this study, as illustrated below in Figure 3.5, teachers motivated by their intrinsic needs for autonomy, connection, and competence, are likelier to show continuous persistence in professional development activities and, therefore, master job satisfaction and psychological wellness (Guiffrida et al., 2013). Facilitators should cultivate a more self-regulated educational environment, where teachers perceive that they can make meaningful choices within the teaching and learning context (autonomy), feel connected with the facilitator and other teachers and the programme learning outcomes (relatedness), and believe in self-mastery (competence) (Ryan & Deci, 2017).

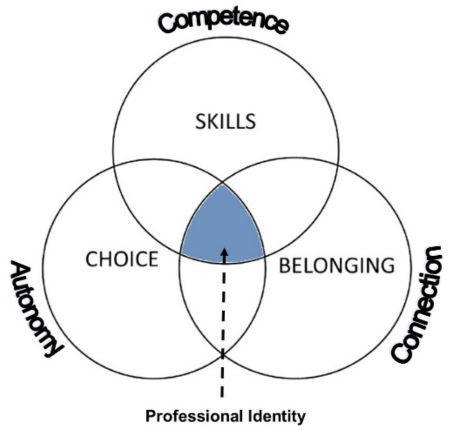

Figure 3.5: ***Self-determination theory (adapted from Ryan & Deci, 2000).***

In considering the relationship between intrinsic and extrinsic motivation, self-determination theory incorporates the idea that the internal and external circumstances, such as the sense of belonging and supportive environments, influence the internalisation of extrinsic motivation into a sub-theory, entitled organismic integration theory (Ryan & Deci, 2000). According to this theory, teachers could learn MKT for a reason distinct from MKT learning itself, and still be intrinsically motivated to learn MKT, with the internalisation level of extrinsic motivation, depending on the situation or environment (Kover & Worrell, 2010). Specifically, an extrinsically motivated activity will be easily internalised if undertaken in a context that supports teachers' experience of autonomy, competence, and relatedness to essential others (Kover & Worrell, 2010). The impact of a structured programme is that it restricts teachers' autonomy, supports teachers' competence, and cultivates teachers' community of practice (Maulana & Opdenakker, 2014).

3.3.2 Organismic Integration Theory

Organismic Integration Theory (Deci & Ryan, 1985) is a sub-theory of the self-determination theory that describes the different forms of extrinsic motivation and environmental factors. These factors either advance or obstruct the internalisation and integration of the regulation of these behaviours. Figure 3-5 illustrates the organismic integration theory terminology of motivational types, arranged from left to right, regarding the degree to which the motivations emerge from the self (i.e. self-determined). Internalisation refers to teachers' 'absorption' of a value (or regulation), and integration refers to the further alteration of that value into '*the own*' that, consequently, will come out of '*the self*'.

Self-determination theory recognises that extrinsically motivated actions can also become self-determined. Concerning this study with internalisation and integration, teachers can be extrinsically motivated and committed, as explained in Figure 3-5.

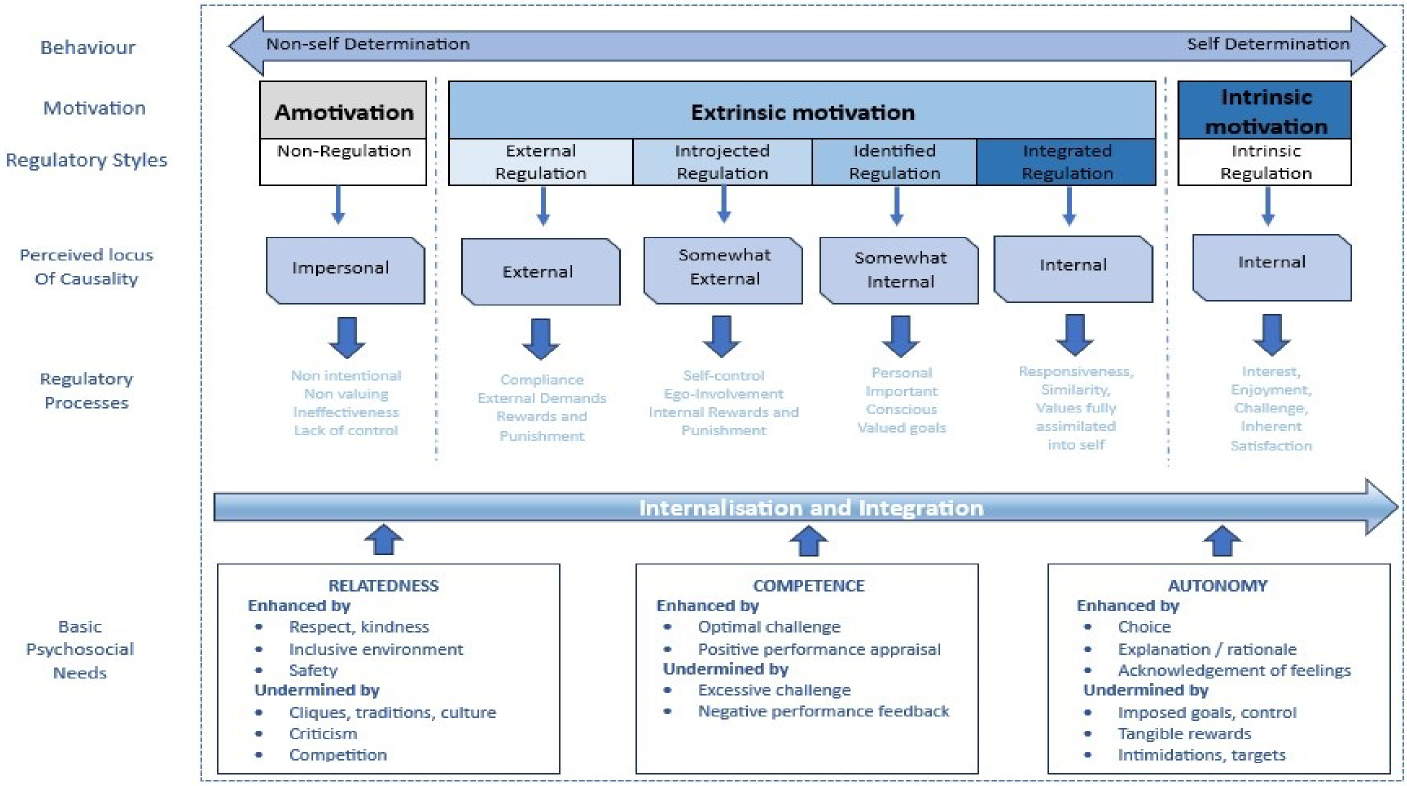

Figure 3.6: ***Self-determination theory (adapted from Ryan & Deci, 2000).***

Intrinsic motivation (far right in Figure 3.6), refers to performing an activity for its inherent interest in experiencing well-being, happiness, and prosperity inherent in the activity. Intrinsically motivated activities are purposeful and enjoyable, and are followed for inherent reasons, rather than as a distinct value (Coccia, 2018). On the other hand, extrinsic motivation involves active participation for external reasons, such as achieving distinct outcomes (e.g., rewards) or avoiding distinct outcomes (e.g., punishments; Ryan & Deci, 2000). Rewards are one of the main categories of extrinsic motivators. They can be categorised based on whether they are expected while an individual is doing the task and, if so, on what specific behaviours they are dependent on (Ryan et al., 1983). Such a reward eventuality plays an essential role in the effect of external rewards on intrinsic motivation and performance (Deci et al., 1999). Performance-contingent rewards are interpreted as rewards that are based on performance. For example, they can be given for performing up to, or above a specified level of performance, a standard, or some specific criterion (e.g. doing better than 80% of the other participants; Ryan et al., 1983).

3.3.3 Facilitation for Autonomy

A brief literature review indicated inconsistent research findings concerning the relationship between intrinsic and instrumental motivation. Several studies concluded that extrinsic motivation to learn, involving rewards, promoting learners or career achievements, significantly stimulates their intrinsic motivation to acquire new knowledge through engaging in activities and processes (Kover & Worrell, 2010). In contrast, other studies described the joyless behaviours of over-performers who have few personal interests but are eager to participate in the programme, indicating the detrimental effects of extrinsic motivation on intrinsic motivation among over-performing teachers (see Robbins, 2006). A significant concern about intrinsic motivation derived from extrinsic motivation is its sustainability. Because extrinsic motivation to learn is focused on outcomes that are extraneous to the learning materials, activities, and the process itself. Some self-determination theorists of academic motivation have predicted that the encouragement of instrumentally valued learning dampens inherent interest in and enjoyment of academic pursuits (Eccles et al., 1998).

Nevertheless, regardless of where a teacher is placed along the spectrum, we all have complex human minds with changing interests and conflicting desires. Hence, doing one thing may make us feel fully motivated, whereas doing another may make us feel nothing but a-motivated.

Self-determination theory asserts that instinctively driven to pursue learning activities that foster self-development, such as learning, social connection, and interaction, bring happiness and satisfaction (*intrinsic motivation*). However, the proactive disposition that forms motivation towards learning is not automatic but is influenced by external standards and values (*extrinsic motivation*) (Ryan & Deci, 2020). Intrinsic motivation has been demonstrated to play an essential role in predicting performance in formal education (Ryan & Deci, 2020; Ryoo & Ahn, 2021; Taylor, 2021; Iqbal, 2023; Zhang et al., 2023). Related studies across countries and learning contexts have also found that intrinsic motivation experienced reduction over time (Ryoo & Ahn, 2021), suggesting that formal education has not provided sufficiently supportive learning environments for accommodating learning needs (Ryan & Deci, 2020). Likewise, several empirical studies related to cognitive load theory have also documented the parallel between changes in motivational beliefs and changes in the functioning levels of cognitive load (Sweller & Paas, 2017; Guo & Wei, 2019).

3.4 CONCLUSION

From this section, I conclude that the effect of instructional design of the material for both F2F and online teaching and learning is crucial. In addition, one should be cautious not to overload the teacher's cognitive capacity, by considering how teachers process information. Applying the worked example effect could manage intrinsic cognitive load, reduce extraneous cognitive load and leave more space for germane cognitive load for learning. Last, teacher motivation plays a huge role in the level of learning that is taking place. According to the self-determination theory, teachers' motivation determines their level of engagement in the mathematics teacher development programme. The level of teacher engagement and how motivated, they also manage intrinsic cognitive load, and if they tolerate a little bit extra extraneous cognitive load in order to learn a new concept or skill, the little space left for germane cognitive load will be enough for deep learning to take place. In the next chapter, I discuss my research methodology for conducting participatory action research.

CHAPTER 4 : RESEARCH DESIGN AND METHODOLOGY

"Find a group of people who challenge and inspire you,
spend a lot of time with them, and it will change your life."
Amy Poehler

This chapter describes the research approach to investigate the design and implementation features of a blended mathematics teacher development programme in rural South African schools. The researcher's position and paradigm are presented in Figure 4-1, which informed the research design and methodological approach. Given the nature of the participatory action research-based approach, the context and nature of the study are strongly intertwined. The analysis section emphasises an instrumental case study design focused on teacher development in each implementation cycle, as reflections and findings must be incorporated in line with the principles of participatory action research. Lastly, I describe the methods used to ensure validity and reliability, as well as ethical considerations and limitations.

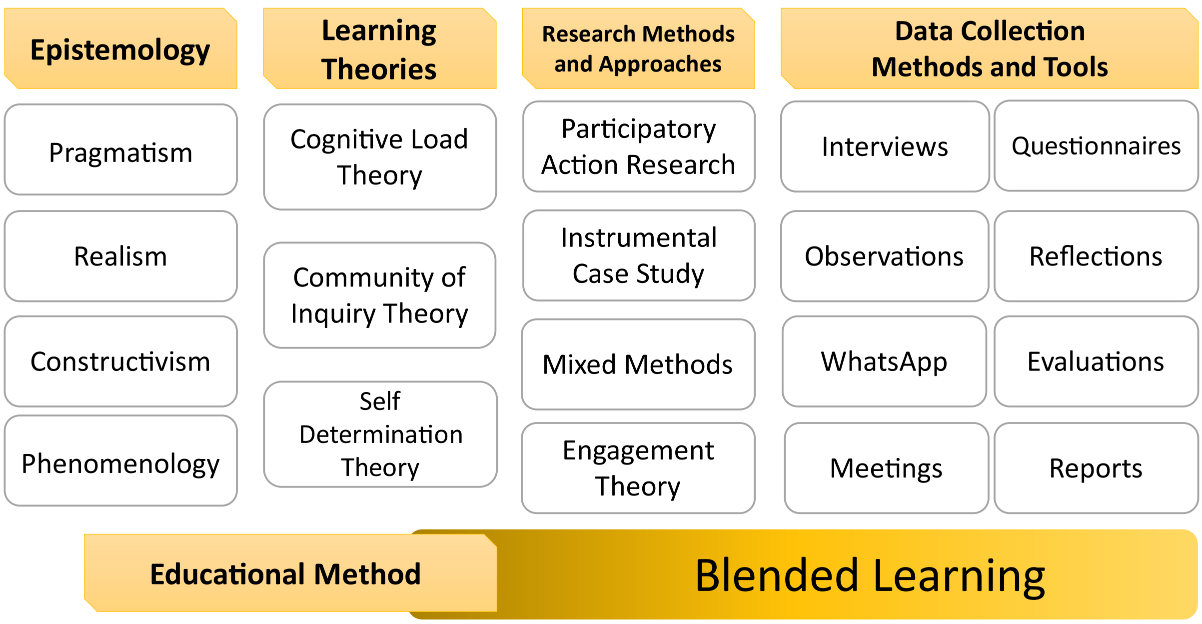

Figure 4.1: ***Relationships between epistemology, theoretical perspectives, research design and methodology in the blended learning educational method.***

4.1 PARTICIPATORY ACTION RESEARCH AND RATIONALE

This study aimed to address the gap in the literature on blended mathematics teacher development programmes in rural South African schools by identifying design and implementation features that could foster effective engagement among participants. However, first, in my opinion, there is respect for the mind of the teacher and the cognitive load (see 3.1) that the Mathematics Knowledge for Teaching (MKT) and Information Communication Technologies (ICT) skill acquisition may produce. Hence, Cognitive Load Theory informs my instructional design of material and programme delivery. I will attempt to address factors that encroach on the processing capabilities of the teachers' working memory. Cognitive Load Theory feeds naturally into Participatory Action Research (PAR); therefore, this collaborative approach should reveal the reality of teachers' barriers to developing their MKT and ICT skills. This research incorporates the use of Pragmatism, Realism, Constructivism, and Phenomenology to understand the complexities of teacher behaviour during the shift to online education. Pragmatism guided my solution-focused approach to supporting teachers, while Realism highlighted the external factors, such as poor infrastructure and limited access to technology, that shaped their responses. Constructivism emphasised the teachers' active role in adapting to online teaching, while Phenomenology allowed me to explore their lived experiences. Together, these frameworks provided a comprehensive understanding of teachers' engagement with the transition to online education. Acquiring knowledge in this research aims to be both practical and scholarly. However, patience, reflection, and adjustments along the cyclic journey of PAR are critical to achieving these goals.

4.2 RESEARCH PARADIGM

This study focuses on enhancing my practice by promoting teacher engagement and autonomy, necessitating careful consideration of the research paradigm. A paradigm, defined as a shared belief system, shapes the knowledge pursued by researchers and their interpretation of evidence (Kuhn, 1962; Kivunja & Kuyini, 2017; Morgan, 2007). Nairz-Wirth and Feldmann (2017, p. 21) emphasise that *"Researchers must recognize their personal, cultural, and historical contexts when conducting and interpreting research."* Therefore, my choice of participatory action research is motivated by the epistemological assumption that through critical self-reflection and collaboration with teachers, I can create conclusions and answers, applicable to self-improvement (McNiff & Whitehead, 2011).

Constructivism posits that knowledge is constructed within a social and cultural context (Creswell, 2018). In other words, understanding is shaped by interactions with other people and the cultural norms that influence those interactions. For example, observations followed by reflective discussions, could influence course creation (Cleveland-Innes, 2018). This course creation method rejects the positivist notions that a single, mind-independent reality is knowable (Maxwell, 2022). At the same time, I also reject the relativism of radical constructivism with the associated risks of accepting anything as truth (Feldman, 2007). Thus, from my point of view, I perceive a post-positivistic, realistic paradigm that recognises the difference between perceptions and reality, resulting in researchers interacting with teachers to understand their perceptions and, hence, reaching a partial understanding of the reality itself (Lebow, 2024).

In action research, the search for answers is driven by the questions; therefore, a more flexible approach to research design is needed. This creates an opportunity for evaluation and reflection for further action (McNiff & Whitehead, 2011; Eralcin & Duyan, 2023). This flexible approach, driven by what works, is appropriate for answering questions to improve practice (McNiff & Whitehead, 2011) and is consistent with a pragmatic research approach (Cresswell, 2018). Johnson and Onwuegbuzie (2004) describe pragmatism as the pursuit of practical solutions that integrate insights from both qualitative and quantitative research. This approach allows for practical and outcome-oriented inquiry, selecting the most effective methods to address research questions (Johnson & Onwuegbuzie, 2004; Onwuegbuzie & Johnson, 2006).

I adopted a pragmatic paradigm for this study because it recognises both the inner world of learning and "the existence and importance of the natural or physical world as well as the emergent social and psychological world that includes language, culture, human institutions, and subjective thoughts" (Johnson & Onwuegbuzie, 2004, p. 18). Onwuegbuzie and Leech (2005) advocate moving beyond strict dualistic paradigms, suggesting that pragmatic researchers can address diverse research questions, fostering collaboration and flexibility in navigating subjective, interpretivist and objective, positivist paradigms. This engagement cultivates an intersubjective relationship with the research process (Morgan, 2007).

4.3 RESEARCH DESIGN

In this study, I employ mixed methods as a methodological approach and participatory action research as a research design. According to Williams (2007), the strength of mixed methods is that scholars are able to test and design theories. Therefore, this methodological approach aligns well with the study's elected participatory action-based research. Mixed methods are the most favoured methodological approach in action-based research, in that varied and changing forms of data can be collected as the study is refined (Anderson & Shattuck, 2012; Ryu, 2020). Pragmatism underpins this study's methodological approach and research design (Cresswell, 2021; McBeath, 2022; Anderson & Shattuck, 2012).

4.3.1 Mixed Methods Methodological Approach

This action-based research adopted a mixed methods approach, integrating qualitative and quantitative research methods to address the research questions. Johnson and Onwuegbuzie (2004) argue that this combination enhances research quality by leveraging the strengths of both methodologies, while compensating for the individual weaknesses. Given the complexity of this study, employing both approaches was essential for a comprehensive investigation.

Mixed methods research involves collecting and analysing data, integrating findings, and making inferences by applying qualitative and quantitative techniques within a single inquiry (Tashakkori et al., 2020; Creswell, 2018). Therefore, this approach allows for a more thorough understanding of the subject than a single-method design. Teddlie and Tashakkori (2010) refer to this approach as methodological eclecticism, where the researcher decides on the most appropriate method to address the phenomenon.

First, qualitative data were broadly collected and analysed in this study to gather insights into the teachers' biographical information and access to Information Communication Technologies (ICTs). As the study progressed, the focus shifted towards quantitative methods to better identify and address barriers that teachers experienced in MKT and ICT skills. Data collection methods included questionnaires, interviews, observations, reflective discussions, reflective journals, and Learning Management Systems (LMS) data from the IT department, thus enabling a comprehensive understanding of the phenomenon (Creswell, 2021). I observed teachers in their classrooms and engaged in post-observation conversations to reflect on activities and support their development, ensuring that these discussions occurred at mutually convenient times. In addition, semi-structured interviews assessed teachers' needs regarding MKT content, pedagogical development, and ICT skills. Further interviews in the final research cycle were conducted to gather insights into their experiences with the development program.

Given the richness and depth of the qualitative findings, they were weighted more heavily in the analysis. The mixed methods approach allowed for thoroughly exploring the data and verifying findings across different methodologies (Onwuegbuzie & Leech, 2005). Furthermore, the approach offered diverse analytical techniques, enabling the simultaneous use of deductive and inductive analysis within the same study (Johnson & Onwuegbuzie, 2004).

4.3.2 Participatory Action Research

Participatory Action Research (PAR) design methodologies, developed in the 1970s, emphasise the importance of involving all stakeholders in the design and development of an initiative. The origin of PAR lies in the work of social science scholars, at the end of the Second World War, which is grounded in pragmatism, critical theory, phenomenology, social constructions, and systems thinking. Therefore, this study's research design was adapted from Karl Marx's (1970) and Paulo Freire's (1972) PAR methodology. Teachers were not only participants in the research programme but also actively involved in all phases of the research-action process (in SAGE Handbook of PAR: Reason & Bradbury, 2008).

Furthermore, the pragmatic approach supports PAR processes by prioritising practical solutions and actions that address real-world issues. Moreover, this approach aligns with PAR's goals of achieving tangible improvements and empowering participants through active involvement. By focusing on what works in practice, pragmatism helps ensure that the actions taken in PAR are practical, contextually relevant, and lead to meaningful change. "The pragmatic approach is to rely on a version of abductive reasoning that moves back and forth between induction and deduction – first converting observations into theories and then assessing those theories through action" (Morgan, 2007, p. 71). This definition of pragmatism underpins the essence of PAR as illustrated in Figure 4-2 below.

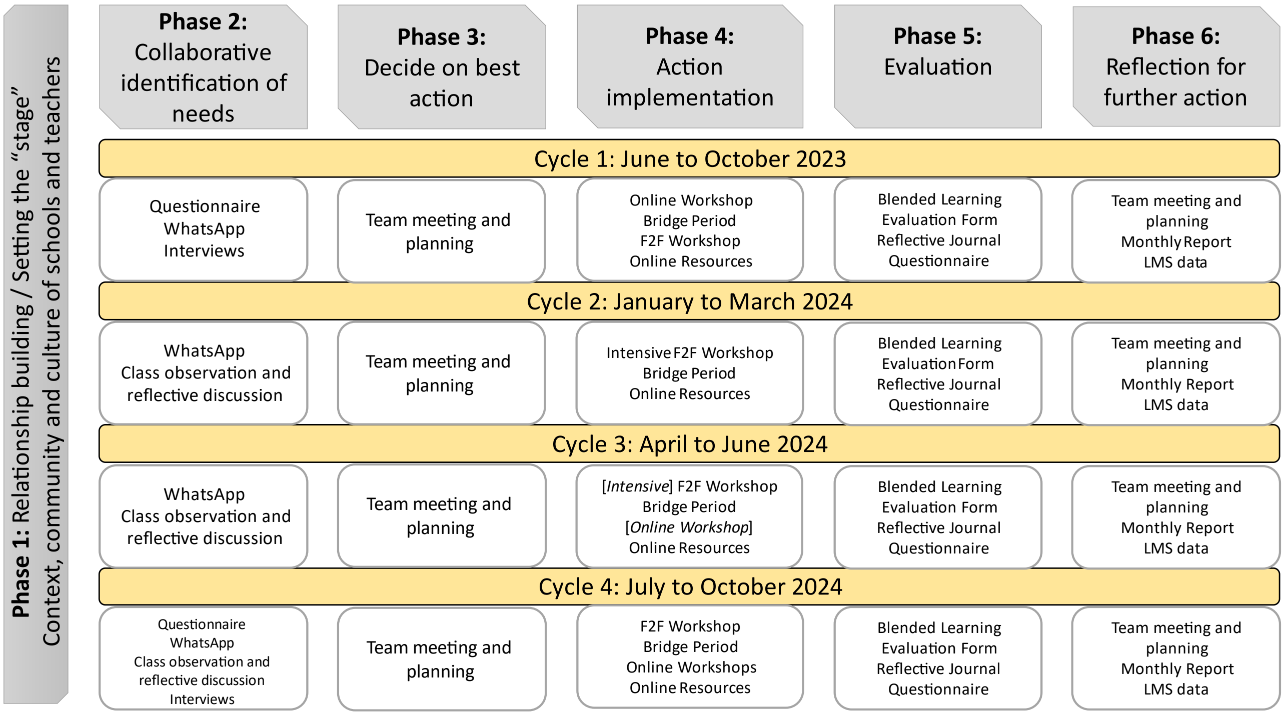

Figure 4.2: ***Research design and data collection process informed by mixed methods, participatory action research (PAR), and Blended Learning.***

Consistent with the PAR method, I initiated the research process. Phase 1 of the research process began with relationship building and understanding the context of the environment. Freire (1970) argues that the role of the researcher is to facilitate discussion, the act of knowing, authentic critical thinking, and reflection on issues through collaborative finding of a solution. Therefore, I met with all the stakeholders throughout the research process to maintain open communication and reflection. More specifically, the research process was flexibly designed to understand the teachers' daily experiences, attitudes towards the programme, available resources and needs for further training and development.

Since my involvement in the mathematics teacher development programme started in 2019, I already had an initial idea and sense of the context of the environment, the community and culture, and the teachers' biographies. The focus on building relationships with the participants within the action learning set creates caring connections (Meyer & Wood, 2020). The relationship building and setting the 'stage' for teacher development are beneficial for increasing participants' resilience, individually and collectively. This first phase, as illustrated in Figure 4-2, was pre-established, due to my established role as facilitator and programme manager in the in-service teacher development field. I commenced my action research when I received my ethical clearance from the ethics committee (UFS-HSD2023/0653). Teachers were willing and open to participating in the blended mathematics teacher development programme and my research study.

Phase 2 focused on the collaborative identification of teachers' needs. I distributed questionnaires, communicated on the mathematics teacher WhatsApp group or individual messages, and conducted semi-structured interviews. Later, in Cycle 2, I conducted class observations, followed by reflective discussions to confirm my observations and plan further action.

The purpose of Phase 3 was to reflect on the information gathered in Phase 2 and to decide on the best action. Hence, planning workshops and designing instructional material while considering that "Learning will be difficult if the cognitive load is high, irrespective of its source" (Sweller, 1994, p. 308). However, cognitive load can be manipulated by reducing the extraneous load by carefully selecting the intrinsic load, e.g., including worked examples and scaffolding the intended processing (Sweller, 2006). The planning included communicating the necessary details of the programme to the teachers, schools, and the project team. Effective communication and dialogue are crucial but challenging, especially in diverse groups with varying literacy levels, communication skills, and experience (Freire, 1970).

Followed by Phase 4, was the action implementation phase, during which the workshops were conducted online and F2F. These workshops initially followed the Blended Block model from *The Food and Agriculture Organization of the United Nations E-learning Academy* approach to blended learning (2011:14) and the Blended Block Model in the *Guide to Blended Learning* (2018:7). However, after the first research cycle, I adapted the Blended Block model to better fit the environment, and teachers' needs and abilities.

After the action implementation of Phase 5, the evaluation phase followed. I completed the Community of Inquiry blended learning evaluation form (adapted from Cleveland-Innes & Wilton, 2018), made entries in my reflective journal and requested teachers to complete the engagement questionnaires. The Community of Inquiry blended learning evaluation form (Cleveland-Innes & Wilton, 2018) is designed to assess teachers' readiness for technology-enabled learning and to guide improvement. I kept my reflective journal updated with narrative descriptions of what I observed and experienced within the pre-constructed elements of the Community of Inquiry and the Self-determination theories (see Chapter 3). For triangulation and to ensure that I interpreted the data accurately, I requested that the teachers complete an engagement questionnaire. This questionnaire measured engagement in the programme, and for evaluation, I used Kuh's definition of student engagement: "*the time and energy students devote to educationally sound activities*" (Kuh, 2003, p. 25, in Stott, 2022). In addition, I used the four engagement categories of Handelsman et al. (2005): skill, emotional, participation, and performance engagement, to guide data collection and analysis (Stott, 2022).

Phase 6 concluded the cycle through reflection for further action. There were similarities between Phase 3 and Phase 6 in that during these phases; team meetings occurred where the team reflected and planned for further action. Stakeholders conducted a thorough analysis of the implementation processes and outcomes. This detailed examination helped identify what worked well and what challenges arose, providing rich, contextual insights into the specific environment in which the programme operated. Instrumental case studies support the reflective nature of PAR by encouraging continuous reflection on the actions taken and their outcomes (Stake, 1994; McNiff, 2013). This iterative process helped refine and enhance the impact of the programme.

As part of the programme management, I had to compile monthly reports to describe activities, planning, and future actions. Reflecting on the research cycles while compiling monthly reports was a method of triangulation (Lewin, 1946). The documentation process's purpose was twofold: It comprised my activities (e.g. timesheet); registers (e.g. participant details); objectives (the content of the session/actions for participants); outcomes (actions to be taken for researcher/programme manager), and themes or strategies for the future. Phase 6 informed my planning for the following action research cycle.

4.4 CONTEXT OF THE STUDY

This section aims to provide the reader with an understanding of where the study was conducted, who participated and the events that ensued to collect the data.

4.4.1 Rural Environment Schools

I asked the principals and deputy principals of the seven project schools whether the schools and the mathematics teachers would be willing to participate in my research study (see Appendix L). Of the seven schools, 46 teachers participated in the mathematics teacher development programme. This programme offers professional development and support to Grade 4 to Grade 12 mathematics teachers. Two of the seven schools were only primary schools, and teachers taught Grade 4 to Grade 7 mathematics. Two were combined schools where teachers taught primary and secondary mathematics, Grade 4 to Grade 12. There were only three secondary schools where teachers taught mathematics in grades 8 to 12.

The school culture and climate differed from somewhat unstable and poorly disciplined to stable and disciplined, as indicated in Table 4-1 below. At three of the seven schools observed, a well-established routine and structure were evident, with teachers demonstrating a clear understanding of their responsibilities and school management actively involved and visible. In contrast, two of the seven schools exhibited some efforts to implement routine and structure in daily activities. However, school management's involvement was limited, requiring teachers to be largely self-reliant and depend on their own professional judgment.

For instance, at one school, the Grade 8 mathematics teacher is responsible for instructing all Grade 8 learners in a single classroom during the first period of the day. For the remainder of the day, the teacher attends to administrative and other non-teaching duties. This issue, which should be addressed by school management, remains unresolved. The teacher, unable to rectify the situation independently, must manage a mathematics class with over 140 students in a space that is insufficient for effective instruction. According to the teacher, this overcrowded environment contributes to significant disciplinary challenges.

The other two schools exhibited a lack of routine and minimal organisational structure, with inadequate representation of school management. For instance, although the school day officially commenced at 7:30 am, students were received at the gate by a security guard rather than school leadership. Late-arriving students were subjected to punitive measures or sent home, despite the inconsistency that the principal frequently arrived late, failing to model punctuality. Furthermore, many students remained outside classrooms during instructional time, engaging in activities such as walking around or sitting in the sun, while some teachers remained in the staffroom regardless of their scheduled teaching responsibilities. Only a minority of teachers demonstrated commitment by attending their classes and delivering lessons.

The effectiveness of school management also varied, ranging from unsupportive to highly engaged and committed to teachers' professional development. Three of the project school principals actively demonstrated interest in their staff, fostering innovation and professional growth. Conversely, the engagement of the other four principals was inconsistent, at times displaying limited interest and appearing unsupportive of the mathematics teacher development programme.

The mathematics teacher development programme was part of the Continuous Professional Teacher Development (CPTD) programme, addressing persistent challenges in South Africa's mathematics education system (see 2.1). In collaboration with PG Bison, Infundo, and the Eastern Cape Department of Education, the initiative aimed to bridge the gap between teachers' professional development needs and the availability of resources, particularly in under-resourced, low-quintile rural schools (Infundo, n.d.). PG Bison, the project's primary funder, supported this initiative as part of its community engagement efforts, investing in local schools to improve education outcomes. Despite significant government investment, mathematics performance in South Africa remains critically low, as reflected in international assessments (UNESCO, 2023). The project focused on enhancing teachers' subject matter knowledge (SMK), critical thinking skills, and pedagogical content knowledge (PCK) while promoting technology integration to strengthen Mathematics Knowledge for Teaching (MKT) and improve learner outcomes.

The seven participating schools, located in the Eastern Cape, were selected based on their classification as low-quintile, under-resourced institutions with limited access to professional development opportunities and technological resources. One of the major challenges faced by these schools was load shedding, which occurred in scheduled intervals of four times per day, lasting approximately two hours per session. This frequent power disruption severely impacted schools' ability to integrate technology into teaching and learning. Teachers who relied on digital tools, such as PowerPoint presentations, often found themselves unable to deliver their prepared lessons, leading to frustration and demotivation. Additionally, load shedding disrupted internet connectivity, affecting communication through emails and access to online resources. Given the high cost of mobile data in South Africa, 85% of participants reported being dependent on school Wi-Fi for internet access, while only 22.2% used school-provided devices for lesson preparation and resource access. Some schools had limited devices available for teachers who did not own personal laptops or tablets, further exacerbating the challenges of digital integration. In response to these issues, project management secured funding for Wi-Fi installation at all seven project schools, with full implementation completed by June 2023. However, connectivity remained unreliable during power outages, underscoring the ongoing infrastructural challenges faced by educators in these rural settings.

Table 4.1: ***Summary of the project schools.***

School	Contact person	Number of Mathematics Teachers	Grades	Quintile	Infra-structure and workspace for teachers	ICT facilities and connectivity	An environment conducive to learning	Management Support and Motivation
A	Principal & Deputy Principal	9	4 - 12	Q4	Good	Good	Good	Good
B	Principal & Deputy Principal	5	8 - 12	Q1-3	Fair	Poor	Fair	Fair
C	Deputy Principal	9	4 - 7	Q1-3	Poor	Fair	Fair	Poor
D	Principal & Deputy Principal	9	8 - 12	Q1-3	Poor	Poor	Poor	Fair
E	Principal	5	4 - 12	Q4	Good	Good	Good	Good
F	Principal & Deputy Principal	3	4 - 7	Q1-3	Good	Good	Good	Good
G	Principal	6	8 - 12	Q1-3	Fair	Poor	Poor	Poor

4.4.2 Selection of participants

Participant selection is essential in any research, as data quality depends on it. For my research, I applied purposeful sampling, where I selected participants intentionally based on their relevance to the research question (Stringer et al., 2019; Creswell, 2021). Hence, I approached potential participants who could provide rich, relevant, and diverse information about the phenomenon under study (Appendix M).

The selection of participants for my study was convenient mainly because the research was done in the schools where I was appointed mathematics programme manager. From the available mathematics teachers, I invited teachers according to specific criteria, in order to have a variety of participants in my research, namely:

- The school of a participant had to be part of the blended mathematics teacher development programme;
- The school had to have teachers who were in a facilitator-participant relationship with the researcher at the time of the study;
- The school had to have a diverse teacher corps concerning gender, race, qualification, experience, and access to ICTs;
- The teacher had to be directly affected by the identified issues (e.g., ICT skills and MKT training needs), and
- The teacher had to be willing to engage in the research process actively.

Table 4-2 illustrates the biographical information of the 46 (forty-six) teachers who participated in this study. There was a diversity in race and a balance between female (58,7%) and male participants (41,3%). Research done by Morante and colleagues (2017, p. 287) found that "*online behaviour of female students confirms previous research, which has shown that female students who engage more with their learning community achieve better results.*" This comparative study highlights the engagement and active participation differences between males and females, with females outperforming males in online activities.

The age of the teachers was equally distributed between 21 years old and teachers older than 51 years, likely providing a diversity of age-related views. This is important since age influences ICT uptake (Staddon, 2020). According to Staddon (2020), older students are more anxious about technology-enabled learning than younger students and hence, "Mature students use fewer technologies than younger students" (page 14). Furthermore, age is related to teaching experience, which ranged from 23,1% having six or fewer years, 34,6% between six and ten years, and 42,3% of the participants over twenty years of experience. Tabach and Trgalová (2019) investigated the knowledge and skills mathematics teachers require to adopt technology-enabled learning. Their analysis highlights the importance of mathematics teachers' attitudes, values, and confidence in effective technology use. Therefore, it was considered necessary for the sample to represent a range of teaching experiences and qualifications.

Table 4.2*: Information about the purposefully sampled participants*

Purposefully Sampled Participants		
Gender	Frequency	Percentage
Female (F)	27	58,7
Male (M)	19	41,3

Age range		
21 – 35	36 – 50	51 +
30,8%	38,5%	30,8%

School Quintile	
Quintile 1 – 3	Quintile 4
32 teachers	14 teachers

Teaching experience			
< 6	6 – 10	11 – 20	>21
23,1%	7,7%	26,9%	42,3 %

Highest Qualification				
BEd	PGCE	BEd Hons	Hons / Masters (other field)	ACE
32,3%	35,4%	12,9%	9,7%	9,7%

Race		
Classification	Frequency	Percentage
Black	33	71,7
Coloured	2	4,3
Indian	1	2,2
White	10	21,7

In South Africa, two qualifications are acknowledged: a Bachelor of Education (BEd.) degree or a Postgraduate Certificate of Education (PGCE) obtained by individuals with an undergraduate degree in another field. Pass rates according to the Policy Brief Demand and Supply of Teachers in South Africa, for the PGCE qualification "*are much* *higher, with 90%*" compared to the "*only 57% of full-time BEd students who enrolled*" (page 2). In this study, 36% held a Bachelor of Education (BEd.); 20% held a Postgraduate Certificate in Education (PGCE), and 20% had a BEd. Honours degree. Notably, two participants held advanced degrees: one had a Master's degree in a field outside education, and one held an Advanced Certificate in Education (ACE). These statistics indicate that this study's teachers were qualified and considered competent to teach mathematics.

I gave the participants pseudonyms to maintain privacy and confidentiality, as illustrated in Table 4.3 below. The 'names' of the participants begin with the same letter of the school's pseudonym; for example, *School A's teachers' names began with an A*. This allows for simplicity and consistency when I refer to schools and teachers throughout the study

Table 4.3: ***Sample schools, contact persons and teachers' pseudonyms as used in this report.***

School	Contact Persons	Mathematics Teachers
School A	Principal: Abram Deputy Principal: Ané	Andrew; Anne; Amy; Ava; Ayla; Alani; Alice; Aren; Amor
School B	Principal: Bongi Deputy Principal: Babs	Bongi; Bonnie; Bianca; Ben; Bella
School C	Deputy Principal: Cindy	Cindy; Cayla; Carl; Caleb; Carin; Christal; Clarissa; Clark; Cloë
School D	Principal D: Divan Deputy Principal: Danika	Denise; Dottie; David; Derek; Dan; Dion; Delia; Duke; Dillin
School E	Principal: Evelyn	Evelyn; Erin; Eric; Eve; Esta
School F	Principal: Fred Deputy Principal: Francis	Fay; Flinn; Farah
School G	Principal: Gretha	Gary; Greg; Ganor; Glen; Gus; Grant

4.4.3 Events

Participants participated in completing questionnaires (see Appendix A, B, E, H, I and J), semi-structured interviews (see Appendix F and K), and class observations, followed by reflective conversations (see Appendix G) as summarised in Table 4.4.

Table 4.4: ***Data Collection Instruments labelled, identified, and described.***

Data Collection Instruments (Identification and Description)		
Appendix A	Cycle 1 Phase 2	Biographical questionnaire 1
Appendix B	All Cycles Phase 2	Collective Identification of Mathematics Knowledge for Teaching (MKT) Needs
Appendix C	All Cycles Phase 5	Community of Inquiry Blended Learning Evaluation
Appendix D	All Cycles Phase 5	Reflective Journal
Appendix E	Cycle 1 & 4 Phase 5	ICT Skills Evaluation
Appendix F	Cycle 1 Phase 5	Semi-Structured Interviews Reflection and Feedback
Appendix G	Cycle 2, 3, 4 Phase 2	Class Observation and Reflection Collective Identification of Mathematics Training and Development Needs
Appendix H	Cycle 2 Phase 5	Teacher Engagement
Appendix I	Cycle 3 Phase 5	Engagement and Reflection
Appendix J	Cycle 4 Phase 2	Biographical Questionnaire 2
Appendix K	Cycle 4 Phase 2	Reflective Discussions Semi-structured Interview Questions

I conducted workshops and kept a reflective journal (see Appendix D) to make notes for evaluation, reflection, and reporting. After concluding each research cycle, I completed an evaluation form (see Appendix C). In the next section, I describe each data collection instrument in detail to illustrate its purpose in data generation for this study.

4.5 DATA COLLECTION

Data collection instruments are included as Appendices A - K (see Table 4.4). In addition, I have included the instruments in the illustration of the data collection process to create an overall view (see Figure 4-2). Each section of PAR activities served as an action research cycle. Four such cycles occurred during the two-year intervention, completing one full academic year. Each of these cycles informed the next cycle's activities and interventions. Thus, an Instrumental Case Study design was followed to analyse each research cycle and inform the design and implementation of the next cycle, enhancing the programme's effectiveness. Last, the mixed methods approach was employed, aligned with participatory action research, to comprehensively understand the study's central phenomenon (Creswell, 2021; Wood, 2020; Zuber-Skerritt, 2021).

4.5.1 Data Collection Procedures

The data corpus of the study is summarised in Table 4-5. The table presents the data collection methods per cycle and the quantity of each gathered. The data thus emanated from questionnaires; conversations with reflective entries; semi-structured interviews; LMS data; evaluation forms; reflective journals, and monthly reports. In addition, data from WhatsApp groups; emails; recorded meetings; resources, and evidence from photographs were also available to describe this study. As a result, a large amount and variety of data were collected, ensuring their rigorousness. In the following paragraphs, I explain the aspects of the data corpus and the motivation for the pragmatic choices made concerning the data collection.

Table 4.5: ***Data corpus: summary of data sources by action research cycle***

Data Collection Methods/Instruments	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Total
Questionnaires (Q)	64	28	22	26	139
Observation and subsequent reflective conversation (OR)	-	24	19	22	65
Interviews (I)	14	-	-	25	39
LMS data (LMS)	1	1	1	1	4
Evaluation forms (EF)	2	2	2	2	8
Reflective journals (RJ)	5	3	3	4	15
Monthly reports (MR)	5	3	3	4	15
WhatsApp mathematics group (WA)	*Continuous communication*				
Photos (P)	*Large number of photos per cycle*				

4.5.1.1 Research Cycle 1

In participatory action research, questionnaires are valuable tools for data collection (Creswell, 2021). They enable efficient data gathering from larger participant groups, providing insights into their perspectives, experiences, and opinions. In addition, questionnaires yield structured data, facilitating analysis and the comparison of responses (Creswell, 2021). The teachers answered online biographical questionnaires (see Appendix A), during the first action research cycle (Figure 4.3). Initially, I distributed the questionnaire by sharing the link on email and WhatsApp. with 17 of the 46 teachers who submitted the questionnaire needing help accessing it online. As a result, I printed the questionnaire, and teachers completed it on hard copies. This was acceptable, since incomplete or skipped responses can impact data analysis, especially when participants need assistance with comprehension in online formats (Debois, 2016). These data assisted me in developing a comprehensive understanding of the teachers' backgrounds, school contexts, and access to ICTs for professional development in mathematics.

In Phase 2, I also distributed the "Collective Identification of Mathematics Teaching and Development Needs" questionnaire (Appendix B) via email and WhatsApp. While teachers did not complete the form directly, they responded through WhatsApp. which was acceptable for identifying their training needs. These responses informed the workshop topics and objectives. Later, in Phase 5 of Cycle 1, I assessed teachers' ICT skills through another online questionnaire (Appendix E), to which 17 teachers responded. The data revealed a significant need for basic ICT training and helped assess participants' proficiency with educational software and tools.

However, a limitation of using questionnaires is their inability to capture emotional responses as effectively as interviews (Debois, 2016), despite including a Likert scale to gauge feelings. Addressing these, I conducted informal, semi-structured interviews after analysing the questionnaire data to confirm my interpretations. During Phase 5, I interviewed 14 teachers who indicated their willingness to provide additional information. The interviews were guided by a flexible protocol with follow-up questions, allowing for a deeper exploration of a participant's thoughts and feelings (Dejonckheere & Vaughn, 2019). While questionnaires offered valuable data, these interviews provided more nuanced insights into participants' experiences and perceptions, thus enriching the study (Merriam, 2009; Zuber-Skerritt, 2021).

I began each interview by explaining the purpose thereof and seeking permission to record the session, emphasising the importance of accuracy. Participants were encouraged to share openly, and ethical standards were upheld throughout (Babbie, 2014). I allowed participants to ask questions at the start to clarify expectations, as the initial moments of an interview are crucial to its success (Babbie, 2014; Ingham et al., 2009; Kvale & Brinkmann, 2009; Tracy, 2013). Interviews continued until data saturation was reached, ensuring sufficient data to answer the research questions (Tracy, 2013).

Given the complex social dynamics of interviews, I was mindful of potential biases and aimed to avoid leading questions (Oplatka, 2018). Conducting interviews in private settings ensured participants' confidentiality (Guest, Namey & Mitchell, 2013), and I scheduled interviews at times convenient for the teachers. After each interview, I reassured participants of their anonymity and thanked them for their contributions (Creswell, 2013). Following Mack et al. (2005), I waited until all interviews were complete before analysing the transcripts to avoid transferring biases or meanings between interviews.

Optimising the educational experience during the online and F2F workshops required a detailed evaluation of my instructional practices and the teachers' learning processes. This justified in-depth, in vivo observations of participants' experiences within MKT and ICT workshops. Systematic evaluation, reflection, and interpretation provided critical insights that guided the ongoing refinement of the programme, thus ensuring alignment with the study's objectives. After each action research cycle, I used the Community of Inquiry Blended Learning Evaluation form (Appendix C), adapted from Cleveland-Innes and Wilton's (2018) in conjunction with the interpretation tool (Figure 4-3) to evaluate and reflect on my instructional practices.

The evaluation form assessed the cognitive, social, teaching, and emotional presence (see 3.2) by listing a series of statements rating the presence of these elements. The rating was done by answering Likert-scale items: 1 = *strongly disagree/does not exist;* 2 = *disagree/only marginally demonstrates existence;* 3 = *neutral, neither disagree nor agree or otherwise is difficult to explain;* 4 = *agree or it does exist,* and 5 = *strongly agree or it definitely exists and is well established.* The interpretation tool was crucial in measuring the teachers' preparedness for technology-enabled learning, informing reflection for further action phases.

APPENDIX 4

Interpretation of Preparedness for Technology-Enabled Learning Questionnaire Results

In Appendix 3, section C, we listed a series of statements to assess institutional preparedness for Technology-Enabled Learning. See below for how to interpret the scores.

- Score below 55: Negligible preparedness. There is no comprehensive Technology-Enabled Learning system or infrastructure, and policies are incomplete. The structures in place need immediate attention.
- Score 55–94: Limited preparedness. The institution has addressed some aspects of the Technology-Enabled Learning system, policies and infrastructure, but they need further development.
- Score 95–129: Developing preparedness. The institution has put in place some of the aspects of a Technology-Enabled Learning system, policies and infrastructure, and is in the process of developing a robust system.
- Score 130–164. Established preparedness. The institution has an established Technology-Enabled Learning system as well as policies, infrastructure and practices in place.
- Score 165 and above. Exceptional preparedness. The institution has successfully implemented a Technology-Enabled Learning system and its effect can be easily observed.

Figure 4.3: ***Appendix 4 from Kirkwood and Price (2016)***

http://oasis.col.org/handle/11599/2363

Throughout the four research cycles, I maintained a reflective journal (Appendix D), an appropriate tool for qualitative data collection (Rodriguez, 2017). Reflective journaling enabled me to capture sensitive observations that might not have surfaced during face-to-face interviews or conversations. Reflective journaling, like autobiographical writing or storytelling, challenges traditional boundaries (Rodriguez, 2017). This constructivist approach promotes critical thinking, new knowledge construction, and development, both for myself and the participants (Creswell, 2021; Hermansyah, 2016). Through reflective conversations, teachers and I discussed lesson planning, MKT, ICTs, and effective classroom practices (Busher, 2006). These dialogues helped identify support areas and fostered critical thinking and self-reflection, building participants' trust and a sense of agency (Russell & Kavanaugh, 2011).

4.5.1.2 Research Cycle 2

The second participatory action research cycle commenced after stakeholders reflected on further action in the first research cycle. This research cycle commenced at the beginning of the 2024 school calendar. I again distributed the "Collective Identification of Mathematics Teaching and Development Needs" questionnaire (Appendix B) via email and WhatsApp. Although teachers did not use the Google Docs link, they responded through WhatsApp, effectively allowing them to self-identify their training needs. These responses helped shape workshop topics and objectives, aligning with the participatory action research methodology (Reason & Bradbury, 2008).

After low questionnaire submissions in the first cycle, I modified my approach by visiting classrooms to observe teachers and hold reflective conversations after their lessons. Teachers scheduled appointments, and this in-person engagement allowed for a deeper understanding of their development needs in mathematics, based on first-hand observations in their teaching environments. This shift towards F2F interactions addressed the challenges of the primarily online format in Cycle 1, ensuring better alignment with the traditional classroom environment.

Classroom observations provided valuable data that complemented the teachers' reflections (Appendix G). Participant observation is a skill that can be honed through classroom visits and interviewing, allowing researchers to capture routine behaviours that may not surface in conversations (Reason & Bradbury, 2008). I conducted 24 classroom observations followed by reflective discussions, collaboratively identifying critical areas for teacher development and incorporating these into the instructional design of workshops (Creswell, 2013; Reason, 2003).

As in Cycle 1, I used the blended learning evaluation form (Appendix C) to assess the programme's delivery, participation, and engagement. Furthermore, I kept a reflective journal (Appendix D) to track teachers' needs. A teacher engagement questionnaire (Appendix H), was also distributed to measure the level of engagement in the programme, which, as Sing and Maringe (2021) suggest, is crucial for effective learning. The questionnaire examined how actively teachers engaged with synchronous and asynchronous resources. Only 17 out of 46 teachers completed the questionnaire, reflecting the ongoing resistance towards ICT engagement, a pattern supported by LMS data from the IT department.

After each cycle, the research team engaged in reflective discussions to outline the following steps, allocate responsibilities, and establish timelines. Regular online meetings facilitated the exchange of findings and critical reflections, which informed programme adjustments for the next cycle (Reason, 2003). This continuous reflection and refinement cycle evolved the research and relational dynamics.

4.5.1.3 Research Cycle 3

In this study, WhatsApp emerged as the most effective communication tool for engaging with teachers, particularly in rural South Africa (Moss, 2021). Frequent load-shedding and electricity interruptions caused internet and cell phone connectivity issues, making consistent communication problematic for the PAR approach. Despite these difficulties, WhatsApp remained reliable, even during power outages. Given the rural context, WhatsApp was faster, more convenient, and cost-effective than email or the BeeLine LMS, which posed accessibility challenges. Many teachers were already familiar with WhatsApp, while some struggled with managing emails or downloading documents. WhatsApp's ease of use and minimal data requirements made it the preferred platform.

In research cycle 3, I again shared a Google Doc link via WhatsApp for teachers to identify their needs. However, most preferred to respond directly through WhatsApp. Their feedback emphasised the need for concrete resources, printed instructional materials, and F2F training in MKT, which shaped the activities for this development programme cycle. Furthermore, I requested classroom visits to observe how teachers implemented the training from previous workshops and to assess their MKT practices. These observations helped identify needs that may not have surfaced in discussions, as behaviours often provide more insight than words (Reason & Bradbury, 2008). By combining observations with follow-up discussions and using the lesson observation tool (Appendix G), I better understood the teachers' needs, ensuring the workshops addressed them effectively (Creswell, 2013; Reason, 2003).

As in cycle 2, I used the blended learning evaluation form (Appendix C), to assess the programme's delivery and participation. Reflective journaling (Appendix D), continued to provide insights into teachers' evolving needs. In addition, I distributed a teacher engagement questionnaire (Appendix I), which included a section on professional development. Of the 46 teachers, 19 completed the questionnaire, offering a clearer understanding of their views on professional development. This was important for exploring the link between teachers' emotions and their learning effectiveness, as positive emotions can enhance motivation and improve cognitive load management, while negative emotions, such as stress can hinder performance (Pekrun & Linnenbrink-Garcia, 2012; Plancher et al., 2018; Zlomuzica et al., 2016). Teachers who lack interest in teaching or learning are less likely to engage in the programme; a concept I explore further in Chapters 5 and 6.

After each cycle, my team and I held reflective discussions to plan the following steps, assign tasks, and set timelines. These regular online meetings were crucial for sharing emerging findings, critically reflecting on the data, and shaping the programme's future direction. Reflective learning sessions were vital in guiding subsequent cycles, helping refine research questions and adjust the study's vision (Reason & Bradbury, 2008). This continuous process allowed both the research and participant relationships to evolve together.

4.5.1.4 Research Cycle 4

During the final action research cycle (Figure 4-6), I distributed a biographical questionnaire (Appendix J), to gather data on teachers' experience; enjoyment of teaching mathematics; motivations for becoming mathematics teachers, and what drives them to perform well. This helped me understand why some teachers actively engaged in the programme while others did not. After analysing the data, I conducted follow-up interviews (Appendix K), to confirm my findings. These interviews provided additional insights into teachers' access to Wi-Fi, internet connectivity, commitment to professional development, and the evaluation of the mathematics teacher development programme. I distributed the "Collective Identification of Mathematics Teaching and Development Needs" questionnaire (Appendix B), via email and WhatsApp as in previous cycles. Teachers responded through WhatsApp, and their input again guided the workshop topics and objectives. Classroom observations, reflective conversations, and completion of the lesson observation tool (Appendix G) were conducted. This was followed by the blended learning evaluation form (Appendix C), and reflective journal (Appendix D), continuing the process established in earlier cycles.

4.5.2 Documentation and other tools

I used my monthly reports as a critical documentation tool to maintain clarity and organisation throughout the action research process. This report, required by my employer, tracked the progress of each research cycle. It recorded interactions with teachers, including participant details, session times, dates, platforms (online or F2F), and schools involved. It also documented session objectives, content, outcomes, and future strategies. This systematic approach ensured accurate feedback and interpretation, which is crucial for identifying collective needs (Phase 2 of the PAR cycle). Monthly and debrief meetings, particularly after site visits, guided my decision-making on the best facilitation methods (Phase 3), were held. These sessions allowed for reflection and informed the implementation phase (Phase 4), following the Blended learning approach. Core activities, such as workshops and teacher training were carefully planned for both F2F and online sessions. The subsequent evaluation (Phase 5), provided insights that shaped the action research-based framework for blended mathematics teacher development in rural South African schools, informing future actions (Phase 6).

Team meetings were crucial for collaboration and reflection, helping to eliminate biases and encourage critical discussions. A teacher assistant/tutor, working three days a week, also played a key role, supporting workshops and reflective conversations and enhancing teaching, and being a social and cognitive presence. These interactions, guided by self-determination theory, helped explore teacher engagement and improve facilitation methods.

Systematic documentation, supported by visual and interactive tools, ensured the research process was reflective and aligned with PAR principles. WhatsApp was an essential communication platform, helping overcome challenges, such as load-shedding and electricity interruptions, thus ensuring sustained engagement in rural areas.

All interactions were recorded for analysis, with only relevant materials retained for the study. Written consent was obtained from the company’s CEO, the teacher assistant, and the project team for data use. NVivo software was employed for data analysis, facilitating both deductive and inductive coding to extract meaningful insights. I describe this process in more detail in the next section.

4.6 DATA ANALYSIS

In this action research study, data analysis was conducted after each cycle to ensure the information remained fresh and to facilitate timely reflection on the data collected during fieldwork. This ongoing analysis was essential for planning and preparing the subsequent online workshops following the F2F sessions. Data from various sources (see 4.5), were systematically organised. Teachers identified specific MKT topics and content areas for further training through questionnaires and, more conveniently, via WhatsApp communications. After transcribing interviews and categorising the questionnaire responses, data from LMS logs, reporting documents, and reflective journals were synthesised to comprehensively understand the teachers' professional development needs.

4.6.1 Themes and Coding

The analysis focused on identifying common themes or patterns related to the MKT content teachers highlighted needing development (Table 4.5). An iterative process aligned the data with the research questions, particularly concerning in-service mathematics teacher professional development. The themes emerged around vital mathematical concepts, challenges in using ICTs for teaching, and specific professional development needs. I applied a mixed methods approach, placing more weight on the qualitative findings, due to their richness and depth. The strength of this approach lies in its ability to thoroughly explore the data and verify findings using different methodologies (Onwuegbuzie & Leech, 2005). The diversity of analysis techniques available in mixed methods allowed me to employ deductive and inductive analysis simultaneously (Johnson & Onwuegbuzie, 2004).

Table 4.6: ***Deductive codes predefined based on theories per action research cycle***

Deductive Codes (Predefined Based on Theories)	
Engagement Theory: Engagement theory focuses on participation, interaction, and motivation. Here are some codes based on this theory:	
Cognitive Engagement	Active involvement in problem-solving, critical thinking, and application of learning.
Behavioural Engagement	Observable actions, such as attending sessions, completing tasks, and interacting with materials.
Emotional Engagement	Teachers' emotional investment, enthusiasm, and attitudes toward the programme.
Social Engagement	Instances where teachers engage with peers, share ideas, and collaborate on tasks.
Active Participation	Teachers were contributing to discussions, activities, or workshops.
Resource Usage	Engagement with online tools, materials, and instructional resources (e.g., LMS data, WhatsApp interactions).
Barriers to Engagement	Factors that limit participation (e.g., lack of access to ICT, load-shedding, personal issues).
Self-Determination Theory (SDT): SDT categorises motivation along a continuum from external to intrinsic motivation. Use these codes to assess teacher motivation:	
Amotivation	Lack of motivation or feeling disengaged from the programme.
External Regulation	Participation is driven by external rewards (e.g., completing the programme for certification or job requirements).
Introjected Regulation	Participation is driven by guilt, pressure, or internal expectations (e.g., "I should do this because others expect me to").
Identified Regulation	Participation because the programme aligns with personal goals or values (e.g., "I want to improve my teaching").

Intrinsic Motivation	Engagement is driven by interest, enjoyment, and a genuine learning desire.
Autonomy	Instances where teachers show independence in directing their professional development.
Competence	Teachers express confidence in their ability to implement skills learnt.
Relatedness	Connection with others in the programme, peer support, or feeling valued as part of a learning community.

To manage the qualitative data, I utilised NVivo software, facilitating both the deductive and inductive coding processes. Deductively, I analysed the data by testing and measuring how I facilitated the mathematics teacher development programme, according to the Community of Inquiry Theory and the fundamental concepts of Self-Determination Theory to gauge teachers' engagement levels. However, during the analysis, I also identified emergent patterns that were not initially anticipated, leading to the inductive coding of additional findings relevant to the study. This combination of deductive and inductive approaches enriched the analysis by allowing for the validation of predetermined themes, while remaining open to new insights.

Table 4.7: ***Inductive codes emerging from data per action research cycle***

Inductive Codes (Emerging from Data)	
Challenges with ICT	Specific difficulties teachers face in engaging with technology (e.g., poor internet, lack of familiarity).
Preferred Learning Methods	Teachers expressing preference for face-to-face vs. online learning or teaching strategies.
Emotional Responses	Feelings related to the programme (e.g., frustration, satisfaction, anxiety).
Support Systems	Peer support, administrative support, or mentoring that influences engagement.
Cultural Influences	References to cultural or community factors affecting participation (e.g., educational views, technology use).
Personal Development Goals	Teacher-stated goals related to professional growth, improvement in teaching skills, or long-term career aspirations.
Engagement Shifts Over Time	Changes in participation or motivation across research cycles, based on reflection or personal circumstances.

4.6.2 Organising the Codes

These codes assisted me in systematically assessing both engagement levels and motivation across my dataset, thereby supporting a robust analysis that ties theory to the realities in my programme.

Themes for Engagement Theory:

- Cognitive, Behavioural, and Emotional Engagement → How teachers think, act, and feel about the programme.
- Barriers and Drivers of Engagement → External and internal factors influencing engagement.

Themes for Self-Determination Theory:

- Motivational Continuum → Positioning teachers along the spectrum from amotivation to intrinsic motivation.
- Autonomy, Competence, and Relatedness → SDT's critical components related to engagement and self-directed learning.

I used open coding to identify other emerging patterns (e.g., personal circumstances, institutional barriers) and refined these as I organised the data codes.

4.6.3 Interpretation

The instructional design and delivery of the programme were guided by cognitive load theory, which states that instructional materials are effective conditionally; that it does not cognitively overwhelm the teachers, given the abstract nature of MKT and ICT usage. This approach was crucial in balancing the complexity of the MKT content with the teachers' existing knowledge and ICT skills. Reflection on the findings was an integral part of the process, with validation achieved through member checking with participants (Reason & Bradbury, 2008) and comparing the findings against the existing literature. The Community of Inquiry framework (Garrison et al., 2000), guided the delivery of the blended mathematics teacher development programme, particularly in balancing social, cognitive, and teaching presences to foster a supportive learning environment. Attention to a framework can enhance content-rich professional development and make it pedagogically sound and engaging. The findings were reported in a structured format, encompassing methodology, data collection, analysis, and conclusions. In addition, the Self-Determination Theory (Deci & Ryan, 1985) provided insights into the factors driving teacher engagement, allowing for the refinement of facilitation methods. This theory emphasised the importance of autonomy, competence, and relatedness in sustaining motivation, directly influencing the effectiveness of the professional development program. Ethical principles were strictly adhered to throughout the data analysis, respecting the confidentiality and dignity of all participants, together with being consistent with the principles of Participatory Action Learning and Action Research.

4.7 VALIDITY AND RELIABILITY

This study ensured validity and reliability by applying PAR cycles, and fostering a robust and contextually relevant research process. Teachers in the mathematics in-service development programme actively co-designed the programme by identifying their own training needs. This embodied the collaborative nature of PAR, where participants serve as co-researchers. Iterative cycles of observation, reflection, and action, along with reflective conversations, ensured that my interpretations accurately reflected teachers' perspectives, thus enhancing credibility.

Validity was further reinforced through the alignment of training materials with the specific mathematics topics identified by the teachers. This alignment ensured the intervention was relevant and applicable, supporting the outcomes' validity (Wood, 2019). Continually refining research components through PAR cycles ensured the study's relevance to participants and their context.

Reliability, or the consistency of findings, was achieved through the iterative process and the active involvement of participants in data collection and reflection. Rigorous methodologies, such as triangulation, member checking, and participant involvement in data interpretation strengthened reliability (Koen, 2021; Reason, 2003). Reflective practices deeply understood the context, ensuring the findings were consistently grounded.

In nature, our default is more towards autocracy than democracy, and these opposing forces must be addressed for successful change. Hence, the selective and tailored application of PAR enhanced productivity and success, when participants helped shape their own environment. Critical reflection and rigorous processes underscore the study's validity and reliability (Reason & Bradbury, 2008). The research maintained transparency, consistency, and credibility by adhering to these principles, which align with PAR's reliability criteria (Reason & Bradbury, 2008). Therefore, the study's validity and reliability are well-supported by both the methodological framework and the active engagement of participants throughout the research process.

4.8 LIMITATIONS AND ETHICS

The use of action research, particularly within a participatory framework, presents several challenges that must be acknowledged, especially when attempting to convey the non-linear and complex processes inherent in such methodologies within the rigid structure of academic writing (Wood, 2019). Presenting findings derived from Participatory Action Learning and Action Research (PAR), requires innovative approaches that often deviate from traditional formats (Wood, 2019). This can be particularly challenging when reviewers or readers are unfamiliar with participatory research designs. The iterative and emergent nature of action research means that the outcomes and focus areas often shift from the original proposal, complicating articulating this dynamic process for academic audiences (Mertler, 2016). Furthermore, action learning is inherently ongoing, meaning that research findings are provisional and should be viewed as "temporary resting places" rather than definitive conclusions (Barber, 1992, p. 110). This provisional nature can clash with academic requirements that demand the encapsulation of learning in static text, making it challenging to represent the nuanced interactions and learning processes among participants adequately. Whitehead and McNiff (2006) argue that educational research should not be constrained by rigid validity rules, supporting the introduction of finnovative data generation methods and reporting formats. However, to influence the broader educational research community, it is necessary to provide rigorous scholarly justification for these alternative approaches, within a systematic research design.

Despite its adaptability, action research is often limited by its challenges in generalisability, making replication difficult and reducing its applicability to broader contexts (Eperjesi & Forster, 2017; Bradbury, 2015). Ethical complexities also arise concerning privacy, informed consent, and participant autonomy. These issues are compounded by practical concerns, such as the extensive time commitment required for preparation and execution, which often exceeds that of more traditional research paradigms (Eperjesi & Forster, 2017; Bradbury, 2015). Moreover, potential conflicts of interest may emerge, due to my dual roles as both teacher and researcher, along with challenges posed by professional and cultural barriers (Hammersley, 2017).

Similarly, PAR, while well-suited for in-service teacher training research, faces its own set of limitations. Bridging the gap between theory and practice, a core objective of PAR, can be particularly challenging, given the disparities between academic learning and classroom realities (Neethling & Nel, 2021). Managing the collaborative processes central to PAR is also tricky, especially when working with diverse groups of participants (Wood & Zuber-Skerritt, 2013). Furthermore, the resource-intensive nature of PAR projects—requiring significant time and investment—can be a limiting factor, especially in resource-constrained settings (Neethling & Nel, 2021; Wood, 2019). PAR’s emergent and participatory nature may also encounter resistance within academic environments that are more accustomed to traditional research paradigms (Wood, 2019; Wood & Zuber-Skerritt, 2013). Ethical considerations are paramount in PAR, particularly regarding informed consent, privacy, and the respectful treatment of participants (Neethling & Nel, 2021; Wood & Zuber-Skerritt, 2013). Therefore, PAR's success hinges on community members' confidence and perceptions, which can limit their full engagement, if not adequately addressed (Wood, 2019).

The pragmatic paradigm also presents specific challenges, such as the time-intensive nature of conducting studies, potential discrepancies in data from diverse sources, and difficulties in determining the optimal sequencing of various data collection methods (Zurba et al., 2022). Although pragmatism emphasises practical outcomes, its consequentialist perspective may limit the pursuit of deeper truths or understanding (Johnson, 2023; Zurba et al., 2022). Furthermore, maintaining consistency in ontological, epistemological, or methodological approaches can be difficult when integrating different research methods within a pragmatic framework (Zurba et al., 2022).

Recognising these limitations is essential for adopting a nuanced approach that carefully navigates the strengths and weaknesses of each methodology used in the study. Every research method has inherent strengths and weaknesses, and a clear understanding of these limitations is crucial for effectively planning and executing research.

Throughout the F2F workshops, I maintained attendance registers to document participation. Teachers provided their details and gave permission, as required by the POPI Act, to use their information and photos for research and reporting purposes. This documentation ensured that the workshops were both well-organised and compliant with data protection regulations.

4.9 SUMMARY

This chapter described the participatory action research (PAR) and mixed methods research approaches employed in this study. Various data collection methods were utilised, including questionnaires, semi-structured interviews, and observations of participants in their natural settings. In addition, reflective conversations, evaluation forms, monthly reports, and LMS data were gathered to comprehensively understand the teachers' behaviours, perspectives, and experiences (Creswell, 2021). These methods were instrumental in assessing the impact of the blended mathematics teacher development programme on the participants.

The primary focus of the data collection was to gain insight into the mathematics training and development needs of the teachers and to evaluate the effectiveness of the blended mathematics teacher development programme. This evaluation aimed to enhance teaching, cognitive and social presence, and improve facilitation methods. Applying Self-Determination Theory (SDT) was particularly significant in guiding my understanding of the teachers' motivation and engagement throughout the program. In the next chapter, I will discuss the research findings in detail.

CHAPTER 5 : FINDINGS

"…the value of using technology is not to think that it can ever replace a teacher (facilitator), but that it can enhance teaching and learning and transform traditional methods of teaching…"

(Marlien Herselman & Adele Botha, 2014, viii / p.11)

Chapter 4 outlined the research method, the cyclical data collection, and the analysis process used in this study to inform the action research-based framework for blended mathematics teacher development programmes in rural South African schools. After each research cycle, I employed an instrumental case study design for evaluation and reflection, following a mixed methods participatory action research approach. The analysis used predefined deductive and inductive codes that emerged from the data, allowing for both validation of themes and openness to new insights.

In this chapter, I present the findings on what design and implementation features promote effective teacher engagement, specifically those related to cognitive, social, and teaching presence. First, I describe the intervention project and the context of the environment in which the study took place. An overview of the blended mathematics teacher development programme and the action research cycles follows this. In conclusion, I discuss my experience as a programme manager, facilitator, and mentor, aiming to create an exceptional learning experience employing cognitive, social, and teaching presence.

5.1 INTERVENTION PROJECT

The intervention project formed part of the in-service teachers' continuous professional teacher development (CPTD) and addressed the ongoing challenges in South Africa's mathematics education system (see 2.1). In partnership with PG Bison, Infundo, and the Eastern Cape Department of Education, this initiative seeks to bridge the gap between teachers' development needs and the available resources, particularly in low-quintile, under-resourced rural schools (Infundo, n.d.). Despite substantial government investment, learner performance in mathematics remains critically low, as evidenced by international assessments (UNESCO, 2023). Hence, the intervention project aims to enhance mathematics teachers' subject matter knowledge (SMK) and critical thinking skills, equip teachers with pedagogical content knowledge (PCK), and promote technology integration. This comprehensive approach seeks to improve Mathematics Knowledge for Teaching (MKT) and elevate learner outcomes in mathematics.

PG Bison, a significant employer in the Eastern Cape since 2006, plays a crucial role in community development, especially in education, recognising its importance in combating poverty and unemployment in the region, which has an unemployment rate of approximately 42,4% (Koteli, 2024; Kap,2024). By committing to local education initiatives, together with Infundo, PG Bison supports socio-economic upliftment and enhances education in under-resourced areas through the CREATE initiative.

The CREATE initiative, launched in 2009, focuses on systems-level change in education. Initially working with three schools, CREATE has expanded to support seven schools, indirectly benefiting over 16,000 learners across 22 high schools. While mathematics remains the core focus, CREATE also addresses critical subjects, such as science and accounting. Its comprehensive approach integrates CPTD, leadership training, and resource allocation, resulting in notable improvements. For instance, one school increased its pass rate from 23% to 69% within a year, and district-wide matric pass rates have stabilised, with increases of up to 20%.

Over the past six years, CREATE has implemented vital interventions, including special needs support, leadership mentoring, and teacher counselling. In-class assistance, teacher assistant programmes, and tutoring in mathematics and science have also enhanced teacher effectiveness and learner outcomes. The initiative's impact was especially evident in 2019, with two schools achieving 100% pass rates. As a result, in 2020, PG Bison was recognised for its contributions to the programme's success.

Since joining Infundo as an associate in 2019, my focus has been establishing a programme for in-service mathematics teacher development to improve educational outcomes. Initially, this programme mainly consisted of a traditional component, where I visited the schools and training was conducted in person. However, during the COVID-19 lockdowns, I organised online workshops and shared MKT through Zoom, Google

Meets, email, and WhatsApp. This technology-enabled learning strategy has proved to be essential for maintaining a continuous presence in geographically dispersed schools during this time.

After evaluating and reflecting on the programme at the end of 2022, I designed a blended learning approach, focusing on technologically-enabled learning, incorporating digital tools, such as WhatsApp and BeeLine. My proposal for a blended learning approach, presented in March 2023, demonstrates our ongoing commitment to addressing teachers' MKT needs. This also aligned with research advocating ICT integration in teacher CPTD programmes. This intervention will remain a core component of the CREATE initiative, continuing its work beyond the current research phase.

5.2 CONTEXT OF THE ENVIRONMENT

5.2.1 The Project Schools

This research study was conducted in South Africa, specifically in seven primary, secondary, and combined schools, predominantly classified as Quintile 1-3, which serve economically disadvantaged communities in the Eastern Cape (Figure 5-1). This region is marked by a lack of economic opportunities, high unemployment rates, and low incomes, resulting in a declining pool of economically active individuals and a growing youth population (Koteli, 2024). Hence, it exemplifies a resource-constrained environment defined by Shohel et al. (2022), as where low-income communities face limited bandwidth and access to essential resources.


Figure 5.1: ***These photos illustrates the environmental context of most schools where the research was conducted.***

In this context, teachers participate in the programme to enhance their professional skills and integrate technology into their MKT practices. However, expected challenges occurred in the online component of the blended learning approach. As a solution, ICT infrastructure was established to enhance connectivity and ensure sustainability beyond the initiative, thereby achieving meaningful integration into educational processes. This endeavour aligns with the critical challenges identified in rural ICT in education initiatives (Herselman & Botha, 2014).

71% of the schools (five out of the seven) are non-fee-paying (Quintile 1 - 3), and the infrastructure and facilities at the schools are limited. I confirm this from my observations and remarks made by teachers:

> *"…because our classrooms are not up to standard and we do not have our own classrooms, we cannot display charts, no plugs, no projectors, no laboratory, no chemicals… vandalism is also the problem." (C1 Bonnie: I)*

School infrastructure varies between very poor, moderate, and relatively good (Table 4-1). Teachers in two of the seven schools (also classified as Quintile 4), have sufficient resources, classrooms, and enough workspace. However, teachers must rotate in four out of the seven schools because there are not enough classrooms to allocate to each teacher. In some cases, teachers do not even have a communal space to store their resources, work or receive visitors, as when I visited the school. Hence, in such instances, I would meet teachers in class for classroom observation and have a reflective discussion outside on the verandah or under a tree. As an example, at one of the schools (Figure 5-2), more space is needed to accommodate two clerks and 26 teachers in a communal work area, as noted by Francis, during one of our reflective discussions (26/02/2024):

> *"..we need more space; teachers have to share a minimal space, and when they want to talk to you, they use my office, which is also jam-packed… as you can see… but we try our best." (C2 Francis: OR)*

Figure 5.2: ***This is the school reception, administration room, two clerk's offices, and the staff room for 26 teachers*.** (Permission was granted by participants to publish this photo)

Situations like these make it difficult for teachers to participate effectively in the teacher development programme activities. This is frustrating and leaves teachers unengaged and demotivated. Moreover, the school culture and climate of the seven project schools also range from somewhat unstable and poorly disciplined to stable and disciplined. At three of the seven schools where management is highly involved in the school's running, I noticed the routine and structure, where teachers know what is expected of them. On the other hand, at two schools where the involvement of the school management was limited, where teachers were self-supported and had to rely on their insights, there was limited routine and structure in the day-to-day activities. The other two schools displayed no routine and minimal structure, and the school management needed to be better represented, as noted by one of the participants:

> *"…I could discover that the system is not applied or implemented effectively. I noticed that there are some delaminate? heads, even deputies and principals. In fact, some cases are clueless regarding supporting us teachers…" (C4 Divan: I)*

Another participant reported the opposite:

> *"All I can say is that we have a supportive principal… this school cannot do better. She represents the school on various levels and has a passion for the learners, too. As you can see, our school is well disciplined and well maintained." (C1Eve: I)*

Considering this, school management varies from unsupportive to supportive of the CPTD programme. Three of the principals were actively interested in teacher development; for example Divan, principal of School D, who welcomed the programme after explaining that CTPD is required by the Department of Basic Education and is aligned with the QMS and SACE activities, wherein teachers must engage:

> *"…professional development is also another good plan… Professional Teacher Development is called continuous professional teacher development. That thing should be taken serious. Teachers should attend workshops." (C1 Divan: I)*

The programme's success greatly depends on a stable internet connection. In conjunction with other responsibilities, funding was granted to install Wi-Fi at all seven project schools. By June 2023, schools had Wi-Fi installed, and 47,1% of the participants reported that they could connect to the internet. By the end of June 2024, 81,8% reported they could connect to the internet. In Figure 5.3, a summary of the monthly Wi-Fi usage in GB by each school is displayed.

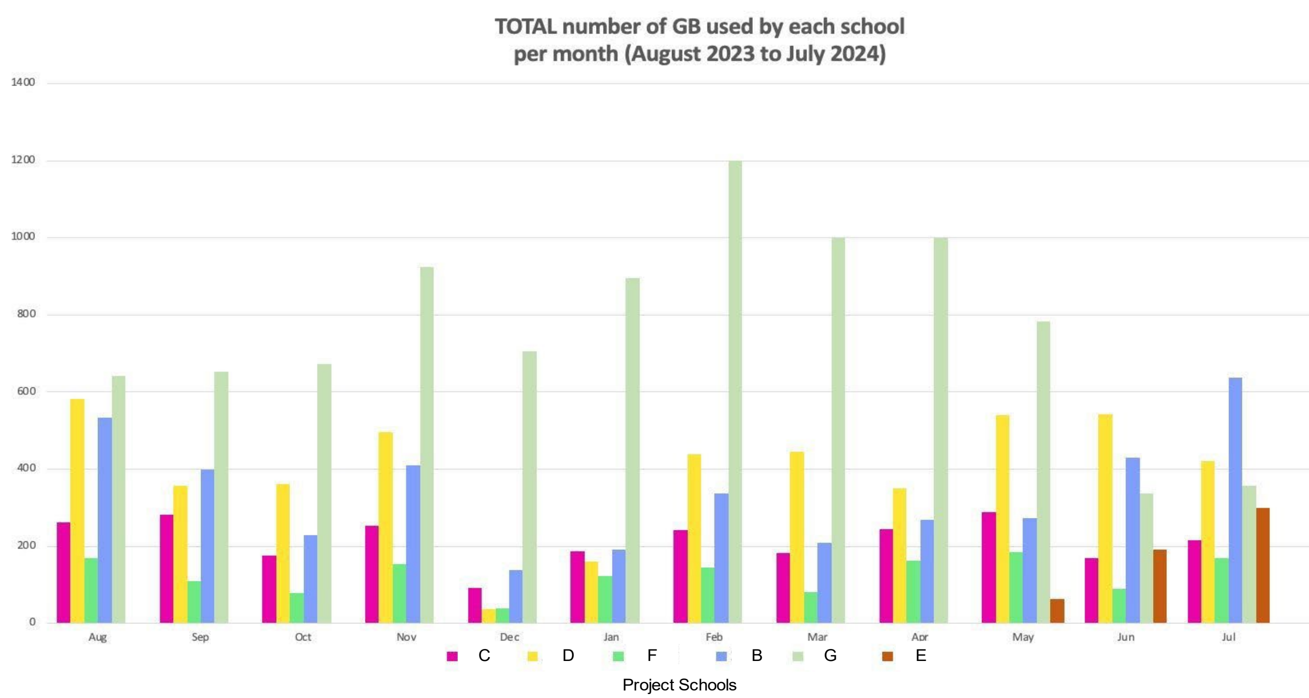

Figure 5.3: ***Summary of each school's monthly Wi-Fi usage in GB (C4: MR).***

Nevertheless, during load shedding, connectivity was still a huge problem. In addition, data is costly in South Africa, and 85% of participants reported that they could only access the internet when connected to the schools' Wi-Fi (Table 5.1).

Table 5.1: ***Teachers' access and connectivity to the internet (Q: 31/08/2023)***

Access and connectivity at	very little to none because of the high cost	very little to none because of poor coverage in the area	fair to good speed, but limited data	data is unlimited or enough for my needs, but speed stops me from being able to do what I need	excellent: unlimited or enough for my needs, and the speed is sufficient for my needs
Home	29,6%	7,4%	14,8%	33,3%	14,8%
School	7,4%	29,6%	11,1%	33,3%	11,1%

As shown in Table 5.2, 95,5% of the teachers involved in the programme reported having access to a laptop (or other device) for their teaching. These devices are not necessarily their own; some teachers use the schools' devices to access the internet or do other school-related tasks. Only 3,7% of the participants reported that they cannot access a computer at home or school. One participant reported in the first questionnaire: "*My computer does not work always,*" and another participant: "M*y tablet (iPad) is old/outdated*" (C1_Q:31/08/2023).

Table 5.2: ***Teacher's access to ICTs (Q: 31/08/2023)***

Description of ICTs	I own at least one of these, so that I can use it at home or school	Someone at home owns one of these, so I can use theirs at home	My school lets me use one of theirs, and I can take it home with me, too	My school lets me use one of theirs, but only at school	I do not have access to one of these at any time - home or school
Smartphone	92,6%	-	-	-	-
Tablet	22,2%	7,4%	18,5%	3,7%	55,5%
Computer (laptop/desktop)	77,8%	3,7%	7,4%	3,7%	3,7%

It is noteworthy that some schools have limited devices that teachers can use, if they do not have their own devices, resulting in teachers sharing devices. Moreover, considering all contributing factors, the Wi-Fi installation and teachers' access to devices, improved technology-enabled learning and teacher engagement levels, leading to the programme's success.

5.2.2 The Mathematics Teachers

The participants in this study were mathematics teachers involved in the blended mathematics teacher development programme. The participant group included 46 teachers from the seven project schools. Unfortunately, five teachers left the programme during the two-year intervention period (2023–2024), due to transfers or retirement. These teachers contributed valuable insights to the research, with one retired teacher expressing reluctance to continue her participation, arguing that the knowledge gained would not be applicable in the near future. The teachers who replaced them willingly agreed to take part in the programme. Additionally, newly graduated teachers beginning their careers expressed that they found the programme to be a valuable source of support and guidance, helping them navigate their early teaching experiences.

I used pseudonyms names (Table 4-3) to protect the schools' and teachers' privacy and confidentiality. The ‘names’ of the participants started with the same letter of the school’s pseudonym; for example, *School A’s teachers’ names started with an A*. This allowed for simplicity and consistency when referring to schools and teachers throughout the study. I also used codes for a short-hand system; for example, *C1 Maryke: I,* indicated Cycle 1, participant name and data collection method. When using data from questionnaires, the response date substituted the participant's name because all questionnaires were anonymous (see Table 4-5 & 4-4). The biographical data collected during the first research cycle (Table 4-2) informed my understanding of the teachers' backgrounds and experiences (see section 4.4.2) while designing the programme.

5.3 BLENDED MATHEMATICS TEACHER DEVELOPMENT PROGRAMME

This study was comprehensive and rigorous in its design and implementation, following the participatory action research (PAR) cycles (Figure 4-2). The four research cycles spanned a ten-week school term and were treated as an instrumental case study (see section 4.3.2). During each term, collaboratively identified mathematics topics were addressed in online and F2F workshops, available as synchronous and asynchronous activities—topics aligned with the Curriculum and Assessment Policy Statement (CAPS). Throughout the programme, I considered the minds of the teachers and the cognitive load that introducing new knowledge might have (see 3.2). Hence, Cognitive Load Theory would inform attempts to mitigate factors that encroached on the processing capabilities of the teachers' working memory (Garrison & Vaughan, 2008; Akyol et al., 2011). From my perspective, cognitive load theory feeds naturally into PAR; therefore, the combination should progressively reveal the reality of the difficulties that teachers face in developing their MKT and ICT skills.

Furthermore, the Community of Inquiry theory elements were integrated into the programme design to enhance cognitive, social, and teaching presence during programme delivery (see 3.1). It also provided teachers with opportunities for self-reflection, peer collaboration, and expert facilitation at critical moments. Incorporating the Community of Inquiry framework into the blended learning programme, allowed a balanced approach between structured guidance and teacher autonomy (see 3.3).

Initially, the programme focused on a more online-driven approach, assuming teachers would adapt quickly to technology-enabled learning. However, findings from the first research cycle revealed that teachers valued F2F interaction far more than online engagement, mainly due to F2F communication's social aspect and immediacy. As a result, later cycles shifted towards a more balanced blended learning approach, emphasising F2F workshops while maintaining online support for continuity and resource sharing.

After evaluation and reflection, the programme was continuously refined for further action (see 4.3.2). Consistent with constructivist principles, the programme design was dynamic, flexible, and responsive to the opportunities presented by blended learning. However, substantial customisations were made only after the first research cycle. The programme design followed a temporal sequence, beginning with engagement, followed by immersion in the experience, and concluding in preparation for this thesis, with the research culminating in Cycle 4.

5.4 CYCLE 1: THE INITIAL DELIVERY OF THE BLENDED MATHEMATICS TEACHER DEVELOPMENT PROGRAMME

At the start of 2023, I proposed a blended mathematics teacher development programme. The programme initially followed the Blended Block Model (see section 2.2.3), structured into five stages, as illustrated in Figure 5-4 below.

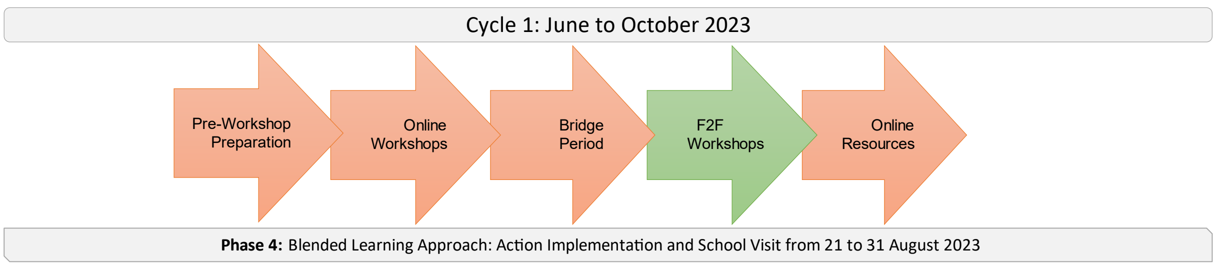

Figure 5.4: ***Blended Block Model illustrating the five critical stages of blended learning.***

5.4.1 Stage 1: Pre-Workshop Preparation

The first stage, pre-workshop preparation, involved inquiry-based planning of the online workshops, bridge period, F2F workshops and online resources. During this stage, I considered the teachers' backgrounds, environments, available facilities, and resources (see 5.2). The latter would greatly influence the programme's success which the reader will better understand by reading through this chapter.

Action implementation

The programme's design in Cycle 1 was based on the teachers' self-identified needs and the insights gained from my experience while working on the project. I summarised the online and F2F interventions during the first research cycle in Figure 5-5.

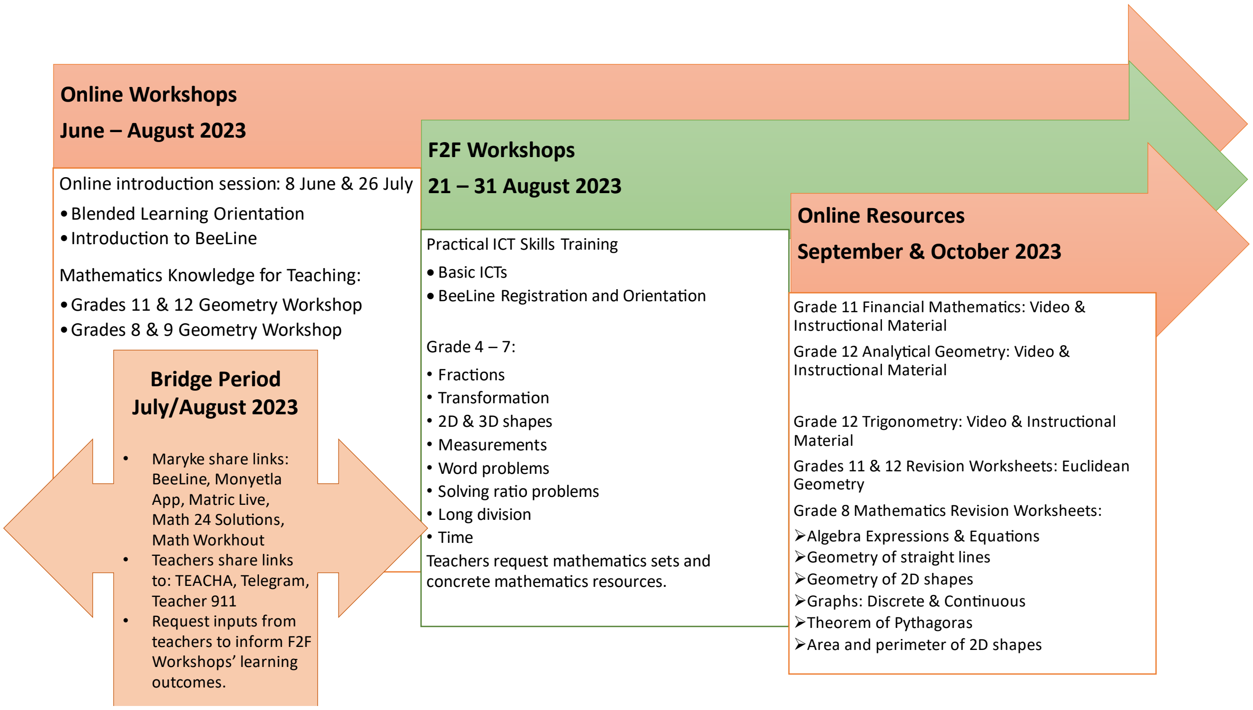

Figure 5.5: ***Cycle 1 online and F2F interventions.***

In the following sections, I report on the findings of the activities in the blended learning stages, as listed in Figure 5.5.

5.4.2 Stage 2: Online Workshops

Online workshops aimed to introduce the blended mathematics teacher development programme, and following this, providing flexibility, scalability, and access to a broader range of mathematics resources and experts (see 2.2.2). Workshops focused on MKT were conducted from June to August 2023 (see Figure 5.5).

After extensive communication, planning, and arrangements, three contact persons from the seven project schools confirmed their mathematics teachers' attendance. Consequently, Zoom-invitation links were emailed to all participants. Despite these efforts, attendance and participation in online workshops was limited.

5.4.2.1 Action Implementation

The first online workshop was scheduled for 8 June 2023 at 13h00. Around this time, Francis informed me that the DBE had visited the school, and the teachers were not ready to join the meeting. She added that she would remind the teachers who were not engaged in the meeting to join the online workshop. In addition, School C was having difficulties connecting to Zoom, as Cindy responded at 13h 21:

> *"Maryke, we are having trouble connecting. It seems the internet is not connecting, and the teachers are impatient because they have to leave with their transport." (C1 Cindy: WA)*

It is concerning that only two of the seven schools attended the first online workshop. While attendance could have been higher, subsequent attempts to engage teachers in an additional online workshop were met with a limited response. Nevertheless, a second attempt was scheduled for 26 July 2023 at the teachers' convenience. This attempt succeeded, with the same two schools attending the online workshop. School C gathered all the teachers in the computer lab, and School F set up the projector with the Zoom link, so that all teachers could attend the meeting together (Figure 5.6).

Figure 5.6*: Teachers at School F during one of the online workshops conducted in Cycle 1 on 26 July 2023 (13h00 – 14h00).*

5.4.2.2 Evaluation

I used the Community of Inquiry Blended Learning Evaluation form (see Appendix C) to evaluate and analyse my instructional practices. Doing this after conducting online workshops assisted me in reflecting and rethinking my instructional practices and teachers' preparedness for technology-enabled learning (see 4.5.1). Hence, Table 5.3 summarises my evaluations, supported by examples extracted from the data collected during Cycle 1, and guides my discussion in this section.

Noteworthy, are the items in Table 5.3 which are organised according to cognitive, social, and teaching presence; therefore, the reader will notice the difference in the numbering of the items in the table to those in Appendix C. In addition, as mentioned in 3.1.2, this study focuses on these three energies, with a recognition of the influence of emotion, discussed as a component in the cognitive load theory and the self-determination theory. While I describe each energy as a component on its own, it is essential to remember that they are interrelated and can, in practice, not stand alone. According to Cleveland-Innes and Wilton (2018), the interdependence of these energies creates an engaging learning environment, resulting in an exceptional learning experience.

Cognitive presence results from teachers' ability to construct and affirm meaning through sustained reflection and discourse within a critical community of inquiry (Garrison et al., 2010). During the online workshop, I applied a practical inquiry model comprising exploration involving information exchange (Cleveland-Innes & Wilton, 2018). I posed questions related to the topic of discussion and consequently, encouraged teachers to work together to find a solution or even more than one solution. Thus, I aimed to offer teachers the opportunity to exchange ideas and practical examples of their MKT. Throughout facilitation, I encouraged teachers to think about the benefit of online resources in their lesson planning (Table 5.3, nr 15).

Although teachers seemed hesitant to engage and actively participate, they might have broadened their instructional toolkit by hearing first-hand how others approach activities or challenges (Table 5.3, nr 19). Furthermore, this could result in teachers reflecting on the online discussions, triggering their interest in exploring shared ideas and resources (Table 5.3, nr 24).

In addition, online workshops encouraged teachers to actively participate in solving content-related questions by pooling their knowledge and collaboratively finding resources (Table 5.3: social presence). Through brainstorming and sharing, teachers could gain access to diverse strategies and materials that could directly address their specific teaching challenges. Even though the teachers' engagement during collaborative opportunities was not what I expected it to be, online workshops were extended into the bridge period (Stage 3), where teachers had another opportunity to be part of, and build a support community and develop adaptable solutions for effectively teaching complex concepts (Table 5.3, nr 35). This design of incorporating exploration into bridge periods allowed teachers autonomy, competence, and connection, which could benefit diverse tasks beyond teaching (see 3.3).

Creating a social presence in the online workshop was challenging to measure and reflect on. Social presence is best described as a new way to approach teaching beyond traditional transmission models of delivery (Cleveland-Innes & Wilton, 2018). I focused on two sub-elements during online workshops: open communication and group cohesion (see Table 5.3).

Table 5.3: ***Summary of the completed Community of Inquiry Blended Learning Evaluation form (Cycle 1: Online)***

Element	Evaluation	Rating	Examples of online instructional practices
Cognitive Presence	**Exploration**	**Indicated by Information Exchange**	
	15. Discussions are facilitated in a valuable way to help teachers appreciate different perspectives.	*Agree*	"How do you think online resources could benefit you during lesson planning?" (C1 Maryke: Online)
	19. Brainstorming and finding relevant information helps teachers resolve content-related questions.	*Neutral*	"Presented practical tools and ideas to take back to classrooms. Encourage teachers to share their ideas and experiences." (C1 Maryke: RJ)
	24. Teachers utilise a variety of information sources to explore problems posed in my workshop.	*Neutral*	"Share links to online websites, e.g. BeeLine, where resources could be located. Share resources discussed in the workshop on the WhatsApp group." (C1 Maryke: RJ)
	35. Teachers can apply the knowledge created to their work or other non-class-related activities.	*Neutral*	"Teachers are invited to continue sharing resources and experiences in an ongoing discussion on the WhatsApp group, where they can post updates on how they implemented the strategies and the outcomes they observed in or outside their classrooms." (C1 Maryke: RJ)
Social Presence	**Open Communication**	**As indicated by the Learning Climate and Risk-free Expression**	
	26. Teachers feel comfortable interacting with other participants.	*Neutral*	"At the beginning of the online workshop, I welcomed all the teachers, introduced the blended learning team, and acknowledged the schools that were present." [This was done in a positive tone to build familiarity among teachers.] (C1 Maryke: RJ)
	30. Teachers feel comfortable conversing.	*Disagree*	"I encourage each teacher to ask questions and to share what they have learnt even after the online workshop on points discussed, where they need clarity or more information." (C1 Maryke: RJ)

	36. Teachers feel comfortable participating in discussions.	*Disagree*	"I emphasise that a collaborative spirit will continue throughout the blended mathematics programme, creating a space for teachers to ask for support and to share openly." (C1 Maryke: RJ)
	Group Cohesion	**Indicated by Identifying with the Group or Collaboration**	
	12. Teachers feel comfortable disagreeing with other participants while still maintaining a sense of trust.	*Agree*	"I modelled respectful feedback by highlighting contrasting viewpoints and reinforcing the value of diverse perspectives in professional growth." (C1 Maryke: RJ)
	22. Teachers feel their point of view is acknowledged by other participants.	*Neutral*	"I encouraged teachers to share final thoughts or questions in the chat, emphasising what they learned from one another during today's online workshop." (C1 Maryke: RJ)
	39. Discussions can help teachers to develop a sense of collaboration.	*Disagree*	"I encouraged teachers to share their resources with others on the WhatsApp group. These will be accessible to all teachers for their use and appreciation." (C1 Maryke: RJ)
Teaching Presence	**Direct Instruction**	**Indicated by Focusing on and Resolving Issues**	
	9. I provide feedback in a timely fashion.	*Agree*	"I provided answers and guidance to teachers' questions during the online workshop." (C1 Maryke: RJ)
	10. I provide feedback that helps teachers understand their strengths and weaknesses relative to the goals and objectives.	*Agree*	"I encouraged teachers to ask when they need support or more information. Some teachers' MKT and other teachers' ICT skills are better than others. Together, we can develop our own and others' skills by supporting and assisting one another." (C1 Maryke: RJ)
	34. I help to focus discussion on relevant issues in a way that allows teachers to learn.	*Agree*	"I show teachers practical examples of accessing and utilising online resources." (C1 Maryke: RJ)
	Facilitation	**Indicated by Shaping Constructive Exchange**	
	2. My actions reinforce the development of a sense of community among workshop participants.	*Neutral*	"Invite teachers to briefly share problems they experience in their MKT, to create a sense of ongoing support and accountability." (C1 Maryke: RJ)
	11. I help to identify areas of agreement and disagreement on topics in a way that allows teachers to learn.	*Agree*	"How could online resources help you prepare for varying skilled classes? " (C1 Maryke: Online)

	16. I encourage participants to explore new concepts.	*Agree*	“Sharing practices, and diverse approaches help teachers to appreciate different methods and refine their own instructional choices, based on collective insights.” (C1 Maryke: RJ)
	23. Participants feel comfortable taking on the role of teacher when the opportunity arises.	*Neutral*	“Allow teachers to describe their MKT approaches to identified topics.” (C1 Maryke: RJ)
	25. I keep teachers engaged and participating in productive dialogue.	*Neutral*	“Guide conversations and make sure the dialogue is on topic.” (C1 Maryke: RJ)
	38. I help guide teachers towards understanding topics in a way that allows them to clarify their thinking.	*Neutral*	“I ask questions to guide the teacher's thinking process to discover their own solution.” (C1 Maryke: RJ)

Open communication occurs when there is a feeling of safety in the learning climate, resulting in risk-free expression (see Table 3.1). Therefore, starting online workshops by welcoming everyone sincerely and acknowledging the teachers' presence, set the tone of the learning climate (Table 5.3, nr 26). This allows teachers the voice necessary to explore their thoughts and emotions, integrate what they are learning with prior knowledge, and come to a solution of application and understanding (Table 5.3, nr 30). However, active engagement during online workshops was low, and there was limited communication. Moreover, during online workshops, I reminded teachers that the MKT topics and ICT resources were available for discussion, even after the end of the online workshop (Table 5.3, nr 36). Jones (2020) opines that encouraging communication adds to group cohesion and connection, resulting in a feeling of safety and support. Creating an initial bond through personal stories and reinforcing that everyone's input is valued, whether you agree or disagree—aimed to boost participation and encourage supportive interactions throughout the workshops (Table 5.3, nr 12, 19). Unfortunately, teachers' collaboration and participation in the discussions were limited. To mitigate this, I encouraged teachers to share their resources with other teachers to support each other (Table 5.3, nr 39). Some teachers responded that it is time-consuming to look for online resources and that most resources on the internet are not CAPS-aligned, as Carin responded in the chat of the Zoom meeting (Figure 5-7):

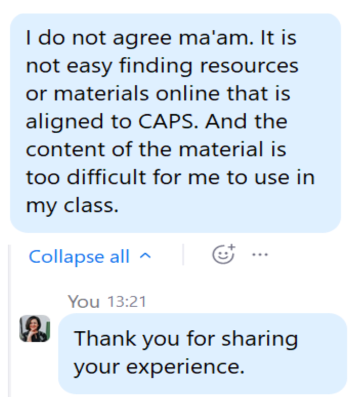

Figure 5.7: ***Screen Print of Carin's chat thread of the recorded Zoom meeting of the online workshop held on 26 July 2023 (13h00 – 14h00).***

Carin’s chat triggered some responses, resulting in teachers expressing differing opinions, indicating that they felt their perspectives would be valued. Following this response, Francis noted that the three teachers from School F agreed with what Carin had said. However, Fay added to the conversation:

> *“I think that the BeeLine platform will help us in looking for resources which are similar to Telegram because all the material there is CAPS aligned.”*

I tried to enhance risk-free communication in meetings by encouraging teachers to share their thoughts. I also encouraged collaboration by allowing teachers to exchange ideas, as seen in Table 5.3. This can result in connection and autonomy (Reeve & Jang, 2006). Teaching presence refers to the initiatives that manage the social and cognitive activities in the programme (Padayachee & Campbell, 2021; Cleveland-Innes & Wilton, 2018). I want to remind the reader that teaching presence in this teacher development programme includes setting curriculum and methods; focusing on discussions (social presence); resolving issues, and sharing personal meaning through constructive exchange (cognitive presence). Thus, the confluence of teaching and cognitive presence results in content selection (inquiry-based design); teaching and social presence set the programme's climate. Teaching presence is the binding energy and the interrelation; the tenacious nature of teaching presence influences social presence and collectively impacts cognitive presence (Garrison et al., 2010; Jones, 2020).

The activities and interactions are adjusted throughout the programme as teachers’ needs change and the programme evolves. Beyond design and organisation, teaching presence also includes direct instruction and facilitation (see Table 3.1). Direct instruction is indicated by focusing on and resolving issues collaboratively, while participants support and develop one another. Providing feedback in a timely fashion (Table 5.3, nr 9), helps teachers understand and build on one another's strengths can be beneficial (nr 10). Furthermore, showing teachers examples of accessing and utilising online resources (nr 34) emphasises shared practices and diverse approaches. This results in teachers appreciating different methods and refining their own instructional choices, based on collective insights.

The facilitation of learning refers particularly to cognitive support but can include all kinds of learning support and encouragement (Reeve & Jang, 2006; Jones, 2020). This can be done by both the facilitator and the teachers themselves. Hence, reflecting on my activities during online workshops, I focused on shaping constructive exchange through facilitation (Table 5.5, nr 2, 11, 16, 23, 25, 38). However, teacher's low engagement levels made the evaluation of the successful creation of a sense of community and trust complex. Nevertheless, I aimed to help teachers develop a sense of belonging and shared purpose (see 3.1.2 *Emotional Presence*). The question is, did it work? This question will be answered only later as the programme evolves and teachers build connections.

5.4.2.3 Reflection for further action

As can be seen from Figure 5.3, evaluating some of my instructional practices was not that easy because of low online attendance and engagement. The teachers that did attend did not actively engage in the discussions, as noted in my reflective journal on 29 July 2023:

> *"Teachers seem disconnected during the online workshop. I designed the workshop in a way to engage with the teachers and to spark their interest. I was excited and looking forward to sharing with them about the blended mathematics programme and that I would continue to support them even though I was not with them on-site in the schools. I put effort into designing lessons on the BeeLine platform to show them how to access the lessons and how interactive they are. This workshop did not happen in the way that I planned it. Teachers were not on time, and they were coming and going. It felt as if I was presenting an information session. I must think about my approach and what the missing factor is. Why did the teachers act the way they did? What am I missing?" Maryke C1: RJ)*

Despite these initial setbacks, the online component of the program served two essential purposes: 1. online workshops aimed at developing and supporting teachers' MKT through platforms, such as Zoom, Google Meet, and WhatsApp; 2. the design and dissemination of instructional materials, worksheets, and other resources to support teachers' MKT. These resources were provided synchronously, in real-time via WhatsApp or email, and asynchronously through the BeeLine LMS (but not limited to BeeLine LMS), allowing teachers to access resources conveniently.

As this was early in the programme, I did not fully know the teachers' ICT skills level. I wanted them to have positive experiences grappling with the mathematics interacting on the BeeLine LMS, but I sensed many were apprehensive about the program. I tried to be encouraging without indicating what I experienced; I suspected that many were confused. In addition, these in-service teachers might not have had online workshop experiences in which their role was to share their thoughts, identify their needs and collaboratively work towards addressing them. I ended each online workshop by encouraging teachers to think about the areas in mathematics where they need training and support. In conclusion, I confirmed dates for the in-school visits to conduct F2F workshops (Figure 5.5).

In this section, I used one of the online workshops to guide my thoughts and present the findings. This guiding workshop was at the beginning of the programme, and I used it to create a background of how the blended program started. The programme evolved by investing time, patience, perseverance, and resilience, resulting in teachers' self-confidence, motivation, and skills being developed, which changed the findings over time.

5.4.3 Stage 3: Bridge Period

The Bridge Period (see 2.2.3) is characterised by ongoing support, encouraged application, reflective practice, and planning. While reflecting on and learning from the first online workshops highlighted the importance of the bridge period. During the bridge period, the synchronous online workshop was extended, so as to continue open communication and collaboration synchronously and asynchronously, resulting in information exchange via ICTs, such as WhatsApp.

5.4.3.1 Action *Implementation*

After online workshops encouraging application, I shared links to online and other resources (see Table 5.3, nr 24, 35). Sharing these on the "*Mathematics Professional Support"*- WhatsApp group fostered continuous synchronous assistance and convenient asynchronous access to share resources. In addition, teachers were asked to identify specific MKT needs (Stage 1). Despite distributing *Collective Identification of Mathematics Teaching and Development Needs* questionnaires (Appendix B), no responses were received. This trend continued throughout the implementation of the program. Consequently, following up by directly messaging each teacher on WhatsApp yielded inquiry-based responses, as can be seen from Francis's message (Figure 5-8):

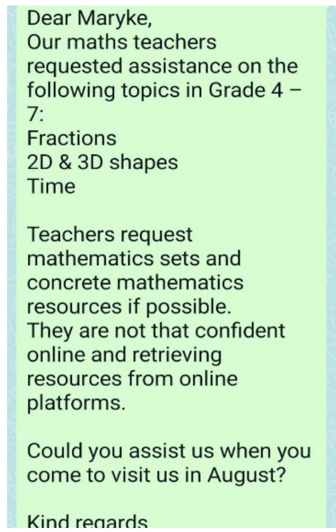

Figure 5.8: ***Francis's WhatsApp message to communicate the mathematics teachers' identified needs (02/08/2023).***

These requests informed teacher-specific learning outcomes of the F2F workshops (Stage 4), promoting autonomy, competence, and connection (see 3.3). As a result, I shared the programme for the planned F2F workshops, requesting teachers to comment for adjustment. Unfortunately, again, there was not much response from the teachers. Cindy responded on 4 August 2023:

> *"…please could you add transformations, how to solve word problems and measurement problems. Our grade 7 especially, they struggle with these topics…" (C1 Cindy: WA)*

Nevertheless, the mathematics topics identified by the teachers (see Figure 5-6) informed my programme design with consideration for teachers' varying levels of proficiency with ICTs and MKT.

5.4.3.2 Reflection *for further action*

Reflecting on this stage, teachers were initially not very active in the WA group but instead, communicated through private WA messages. In the article "Using WhatsApp to Support Teachers: A Case Study of South African Mathematics Teachers", Moss (2021) found that WA provided opportunities for ongoing professional development, allowing teachers to ask questions and engage in discussions that leverage directed support. This finding was supported as my programme evolved and teachers developed autonomy, competence, and connection; they were more active and willing to share their thoughts, ideas, and activities.

Furthermore, it is critical to remember that the Blended Block Model (see 2.2.3), blended learning approach aligns with technology-enabled learning (FAO, 2021; Cleveland-Innes & Wilton, 2018). Reflecting on the programme so far, low levels of teacher engagement are concerning. Teachers signed up for the programme, knowing it consisted of online and blended learning activities; however, I suspect they possessed varying levels of ICT skills. Therefore, expecting teachers to develop their MKT and ICT skills simultaneously could add to the already extraneous cognitive load, leaving less space for deep processing of new information (see section 3.2). I considered the latter while planning and designing the F2F workshops that followed this bridge period.

5.4.4 Stage 4: F2F Workshops

I conducted F2F school visits in the eleven days between 21 and 31 August 2023. During this time, I conducted thirty 1-hour F2F workshops to address ICT skills development and the teachers' self-identified MKT needs (Figure 5.6). These workshops included collaborative group discussions, interactive activities, and feedback sessions during school and some after-school hours.

5.4.4.1 Action *Implementation*

The Practical ICT Skills Training workshops focused on basic ICT skills training and registering teachers on BeeLine, followed by orientation sessions. The decision to conduct these workshops at the seven project schools stems from poorly attended online workshops. The focus was on technology-enabled learning; therefore, I invited the schools' IT teams to be informed and handle any possible technical difficulties. In addition, to highlight the *blended* aspect of the programme, the BeeLine support team assisted me in presenting the BeeLine component of the workshop via Zoom. At the same time, I facilitated the session in person, encouraging participation in activities and group discussions. Together, we reflected on BeeLine and discussed how the LMS could support teachers' lesson planning. One of the teachers at School A suggested that she could use BeeLine's interactive lessons while planning lessons for her multi-grade classroom:

> *"…one of my grades can do an interactive activity on BeeLine, while I teach the other grade. I have tablets that I can distribute, even if learners work in pairs…" (C1 Alice: 21/08/2023)*

During these discussions, teachers shared their experiences with online platforms, such as TEACHA, Telegram, and Teacher 911, that they sometimes use to prepare their mathematics lessons. I shared my experience with applications, such as the Monyetla Bursary Project, Matric Live, Math 24 Solutions and Math Workout. We reflected on the effectiveness of technology-enabled learning and the role technology plays in the blended learning programme. As a result, the F2F workshops were, in comparison to the online workshops, successful in building trusting relationships with the teachers, offering a safe space for sharing ideas and refining instructional approaches. Feedback was collaboratively analysed, with adjustments made to improve practices and programme design, ensuring the continuous development of both teachers and the blended mathematics programme.

The MKT workshops followed a purposeful sequence to opportune teachers during the school visits to identify MKT needs. Given that I had prepared for topics identified by teachers during Stage 2 and Stage 3, I offered training on those topics and allowed time to address teachers' additional needs. I conducted twenty-three MKT workshops on the pre-confirmed days and times (Table 5.4).

Table 5.4: ***Scheduled school visits and time of MKT workshop***

School	*21/08*	*22/08*	*23/08*	*24/08*	*25/08*	*26/08*	*28/08*	*29/08*	*30/08*	*31/08*
A	12:00 14:00							15:00		
B		12:00			10:00			12:00		10:00
C		13:30				9:30		13:30		
D			10:30 12:00						11:00 13:00	
E				12:00			15:00			13:30
F				13:00		11:00			13:00	
G					12:00 13:00		13:00			

However, I conducted two workshops at one school in four cases, to accommodate all teachers' schedules. Informal MKT discussions occurred during unscheduled, 'in-the-moment invitation' classroom visits.

5.4.4.2 *Evaluation*

Similar to evaluating the online workshops, I used the Community of Inquiry Blended Learning Evaluation form (see Appendix C) to evaluate and analyse my F2F workshops' instructional practices. However, there is a difference between online and F2F evaluation elements (see Table 3-1), as seen in Table 5.5—the summary and examples extracted from the data collected guide my discussion in this section.

My goal for the F2F workshops was to create an exceptional learning experience, while establishing deep and meaningful learning of MKT and ICT skills. Consequently, I focused on cognitive presences' four distinct but overlapping elements of practical inquiry: exploration, integration, resolution, and triggering events. While comparing the exploration activities during the F2F workshop with those of the online workshops, it was clear that teachers engage much better in the social environment of the F2F workshops. For example, compared to the online workshop, I posed a similar question to the one during the ICT skills training workshop (compare Table 5.3 and 5.5, nr 15). The effect was very different. In the online workshop, teachers seemed hesitant to engage and participate; in contrast, in the F2F workshop (see extract below form (C1_OR: 28/08/2023), teachers easily engaged and actively participated in discussions.

Glen: *"…and if I simply ask learners to bring the boxes from their homes?"*

Ganor: *"You can do that."*

Gary: *"We will have more and can share it with other classes."*

Ganor: *"Then how do we begin the lesson… you know - the learners will not know what to do?"*

Gary: *"Maryke, would you say we begin with the boxes or writing on the board?"*

Facilitator: *"Well, what do you think? Play first… then write the formula and practise?"*

Gerda: *"Yes, they can play first. Then you write and practise."*

This conversation during the workshop at School G concerned 2D and 3D geometry calculations, with formulae lesson planning for Grade 8 and Grade 9 learners. The conversation flow was comfortable while I was guiding the discussion, and teachers derived their own conclusions.

Table 5.5: ***Summary of the completed Community of Inquiry Blended Learning Evaluation (Cycle 1: Appendix C).***

Element	Evaluation	Rating	Examples of my F2F instructional practices
Cognitive Presence	**Exploration**	**Indicated by Information Exchange**	
	15. Discussions are facilitated in a valuable way to help teachers appreciate different perspectives.	*Agree*	"Can anyone give me an example of how you use online resources to help you with your lesson plan?" (C1 School A: 21/08/2023)
	19. Brainstorming and finding relevant information helps teachers resolve content-related questions.	*Agree*	"During the BeeLine workshops, I assisted teachers to register on BeeLine and guide them in locating resources. This session was interactive and creative." (C1 School C: 25/08/2023)
	24. Teachers utilise a variety of information sources to explore the problems posed.	*Strongly Agree*	"Refer to the shared resources on the WhatsApp group." (C1 School A: 21/08/2023)
	35. Teachers can apply the knowledge created to their work or other non-class-related activities.	*Strongly Agree*	"Teachers are encouraged to give feedback on how they used new knowledge." (C1 School F: 24/08/2023) "Teacher share photos on WhatsApp group." (C1 Flinn: WA)
	Integration	**Indicated by Connecting Ideas**	
	13. Reflection on content and discussions helps teachers understand fundamental concepts.	*Strongly Agree*	In summary of the most valuable aspect of the workshop: "Reflecting on the 2D and 3D shapes and discussing the relevant MKT." (C1 School F: 30/08/2023)
	18. Combining new information helps teachers answer questions raised in activities.	*Strongly Agree*	"Demonstrate through worked example, a step-by-step method of doing long division." Share a video on the WA group afterwards. (C1 School C: 26/08/2023)

	21. Learning activities help teachers construct explanations/solutions.	*Strongly Agree*	"Working through *Word Problems* with your guiding my thoughts on explaining it in my classroom." (C1 School F: 29/08/2023)
	Resolution	**Indicated by Applying New Ideas**	
	1. Teachers can describe ways to test and apply the knowledge learnt.	*Strongly Agree*	"Using concrete resources to teach time, assisted me in my lesson planning." (C1 School F: 29/08/2023) The teacher shared a photo on the WA group using self-created resources. (C1 Fay: WA)
	37. Teachers develop solutions to relevant problems that can be applied in practice.	*Strongly Agree*	"Teacher created concrete resources to teach fractions." (C1 School A: 29/08/2023) The teacher shared a photo on the WA group using the self-created resource. (C1 Alani: WA)
	Triggering Event	**Indicated by a Sense of Puzzlement**	
	3. Teachers in my workshop are motivated to explore content-related questions.	*Strongly Agree*	"Teachers participate actively in group discussions and activities during the workshop." (C1 School F: 30/08/2023)
	4. Workshop activities pique teachers' curiosity.	*Strongly Agree*	"Teachers ask questions and engage in conversation with each other." (C1 School C: 26/08/2023)
	32. Problems posed increase teacher interest in content.	*Strongly Agree*	"How can we use the sweets and toothpicks to teach the number and shape of the faces in 3-D objects… the number of vertices and the number of edges? Who can tell me what a vertex is?" (C1 School F: 30/08/2023)
Social Presence	**Open Communication**	**As indicated by the Learning Climate and Risk-free Expression**	
	26. Teachers feel comfortable interacting with other participants.	*Strongly Agree*	"Welcome to today's workshop. Thank you so much for inviting me and making this time available for us to work together. This workshop is all about you and what you need. Please make yourselves comfortable. But first, tell me how you are doing, and what is new and exciting here at your school?" (C1 School F: 30/08/2023)

	30. Teachers feel comfortable conversing.	*Strongly Agree*	“Teachers take part in conversations and problem-solving activities. They ask when they are unsure about a certain calculation or method.” (C1 School F: 30/08/2023)
	36. Teachers feel comfortable participating in discussions.	*Strongly Agree*	“I emphasise that we are working together, collaborating, and supporting one another to understand mathematics better and to share ideas on how to teach mathematics topics. This is the purpose of the blended mathematics programme; creating a space for teachers to ask for support and to share openly.” (C1 School C: 31/08/2023)
	Personal / Affective Expression	**Indicated through Self-projection**	
	7. Teachers in my workshop can form distinct impressions of other participants.	*Agree*	“She is good at explaining Euclidean Geometry. When I must plan a lesson on Euclidean Geometry, I ask her to help me and sometimes present the lesson to my learners, and then I will sit and watch her doing it.” (C1 Ben: 29/08/2023)
	29. Knowing other participants gives teachers a sense of belonging.	*Agree*	“It is evident that the teachers work well together, and the way they talk and share examples, makes it clear that they have regular conversations about their successes and difficulties.” (C1 School E: 28/08/2023)
	31. Online or web-based communication is an excellent medium for interaction with and among teachers.	*Disagree*	“There is minor communication on the WA group; only when I post activities, resources, or ideas will some teachers comment with an emoji.” (C1 Maryke: RJ)
Teaching Presence	**Design and Organisation**	**Indicated by Setting Curriculum and Methods**	
	6. I communicate important dates/time frames for learning activities.	*Strongly Agree*	“Follow-up with schools – confirm dates and time of visits, planning and special requests from Mathematics Teachers.” (C1 Maryke: RJ)
	8. I communicate essential goals.	*Agree*	“I start every workshop with the Learning Outcomes, making sure teachers know what the goal of the workshop is.” (C1 Maryke: RJ)
	17. I communicate essential topics.	*Strongly Agree*	“Follow-up with schools – confirm dates and times of visits, planning and special requests from Mathematics Teachers.” (C1 Maryke: RJ)

	27. I provide clear instructions on how to participate in learning activities.	*Strongly Agree*	"All learning activities come with a cover page and clear instructions." (C1 School E: 28/08/2023)
	Facilitation	**Indicated by Shaping Constructive Exchange**	
	2. My actions reinforce the development of a sense of community among workshop participants.	*Strongly Agree*	"I regularly ask questions to reflect on the information shared and the teachers' perceptions." (C1 School E: 28/08/2023)
	11. I help to identify areas of agreement and disagreement on topics in a way that allows teachers to learn.	*Strongly Agree*	"While discussing different ways to teach trigonometry, I allowed teachers to share their experiences and best practices. Bianca and Ben agreed on most of the approaches. I then asked them how they would teach trigonometry to learners with learning barriers. This led to an exciting discussion where Bianca and Ben disagreed on some ideas shared." (C1 School B: 29/08/2023)
	16. I encourage participants to explore new concepts.	*Strongly Agree*	"Sharing different practices and diverse approaches to teach 2D geometry helped teachers refine their own instructional choices, based on collective insights." (C1 School F: 30/08/2023) "Teacher shared photos on WhatsApp group." (C1 Flinn: WA)
	23. Participants feel comfortable taking on the role of teacher when the opportunity arises.	*Agree*	"Allow teachers to demonstrate how they would teach the Theorem of Pythagoras." (C1 School C: 26/08/2023)
	25. I keep teachers engaged and participating in productive dialogue.	*Strongly Agree*	"Guide conversations through asking questions on topic, thereby creating a sense of curiosity." (C1 School F: 30/08/2023)
	38. I help guide teachers towards understanding topics in a way that allows them to clarify their thinking.	*Strongly Agree*	"Asking questions to guide the teacher's thinking process to discover solutions to their questions." (C1 School B: 29/08/2023)

One of the learning outcomes of the ICT skills training workshop was registering teachers on BeeLine, followed by an orientation session. In contrast to the online workshop's 9,08% attendance, 76,3% of the teachers attended the F2F workshop and registered on BeeLine (Table 5.5, nr 19). During orientation, teachers explored the BeeLine LMS and discussed finding ways to create technology-enabled learning environments (see 5.4.4.1, Alice's comment). In addition, I referred to the shared resources on the WA group (Table 5.5, nr 24):

> *"After the online workshop, I shared the resources we discussed on the WA group… I also shared the links to the websites and the applications… Can you remember? Did you look at it or even use some of it?" (C1 Maryke: 21/08/2023)*

School A's teachers did not attend the online workshop. However, they did receive the information as it was shared on the WA group. Five of the nine teachers indicated they looked at the information, but the other four did not. In contrast, the teachers at school F reported that they used the information and were eager to share their experiences. In addition, Flinn posted photos of his applying his new knowledge to the WA group (Table 5.5, nr 35).

An element of cognitive presence is the integration of activities which occur when ideas are connected (see 3.1.2). An example of this is the teachers reflecting on the characteristics of 2D and 3D shapes (Table 5.5, nr 13) and preparing lessons to describe, sort and compare 3-D objects in terms of the number and shape of faces, vertices, and edges (see Table 5.5). I provided teachers with manipulatives, *jelly sweets and toothpicks* to engage all the participants. I started the workshop by confirming that learners learn best by using all their senses. Following my statement, I commented on the sweets and toothpicks I had brought to the workshop, telling the teachers that we would use them to design a lesson plan addressing the learning outcome mentioned above. Fay mentioned that the learners in her class struggled to remember and recall these concepts. I asked the group to tell me how they thought *jelly sweets and toothpicks* could help them teach this concept in a fun way (Table 5.5, nrs 3, 4, 32). The following is an extract from the workshop under discussion (C1_OR: 30/08/2023), where exploration (cognitive presence) and open communication (social presence) are tenacious with facilitation (teaching presence):

> ***Facilitator:*** *You know learners learn by using all their senses, right?*
>
> *Teachers agree by nodding and saying “yes”.*
>
> ***Facilitator:*** *Well, I brought some sweets and toothpicks to the workshop today.*
>
> *(Teachers smile, and some are talking to each other)*
>
> ***Facilitator:*** *How do you think we can use these to help us teach 2D and 3D shapes? Yes?*
>
> ***Flinn:*** *I don’t know. This is sweets.*
>
> ***Facilitator:*** *Yes, those are sweets. And what does it look like?*
>
> ***Fay:*** *It is a round sweet. I hope we can eat them later.*
>
> *(The group is laughing)*
>
> ***Facilitator:*** *Yes, you may when we’re done. But first, how can we use the sweets and toothpicks to teach the number and shape of faces in 3-D objects… the number of vertices and the number of edges? Who can tell me what a vertex is?*
>
> ***Fay:*** *Ma’am, it is where a shape's sides come together at the point…*
>
> ***Facilitator:*** *Good, well said. And if you have to keep those sides together, how would you do that… in real life? (picking up two toothpicks and pointing the sharp ends at each other)*
>
> ***Fay:*** *I would paste it together.*
>
> ***Facilitator:*** *(Picking up one jelly sweet) And the jelly sweet is sticky; it can most probably paste something together… (Sticking a toothpick into the jelly sweet) What else? Who can explain the meaning of edge?*
>
> ***Farah:*** *The edge is the outer side of the shape.*
>
> ***Facilitator:*** *Good. And if you look at the toothpick now… and the jelly sweet? Are there any creative thoughts you want to share with us? (Sticking one toothpick into a jelly sweet)*

__Fay:__ Yes, ma'am. We can make a shape. (Building a square)

***Facilitator:** Well done. You have a 2D shape called?*

***Fay:** A square.*

***Facilitator:** Can you build a 3D shape?*

(Flinn quickly built a cube)

***Flinn:** Yes, look at mine.*

(The group smiles, and one can sense the happiness and feeling of competence)

***Facilitator:** Oh, great, Flinn. Can you tell me what a face is and where you can see it in your cube?*

***Flinn:** Yes, this open part forms the square, which is the face of the cube with the jelly sweets and the vertices and the toothpicks as the edges. This is very nice.*

Teachers were open to communicating, expressing themselves, actively participating in the discussion, and finding solutions to the problem. I conducted the same workshop at the seven project schools. The teachers enjoyed this workshop and are still talking about it. This workshop taught the teachers to think outside the box and explore different teaching methods. Flinn was the first to share photos (Figure 5-9) on the Mathematics WhatsApp group showing how he implemented his newly found teaching method:

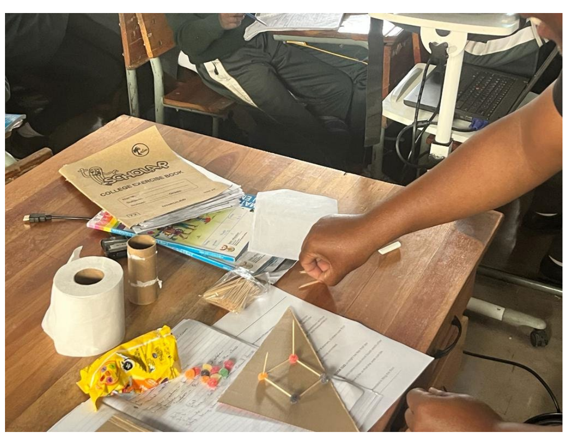

Figure 5.9: ***Teachers create their own resources to teach the classification of 3D shapes according to their vertices, edges and faces in their mathematics classrooms.***

Rather than instructing the teachers directly, I distributed instructional materials and concrete resources, allowing the teachers to plan lessons collaboratively. Teachers actively engaged in the different workshops, discussing how to approach each topic using the provided materials, and then collaboratively developing and presenting lesson plans (Table 5.5, nr 36). The sessions fostered collaborative learning, with teachers offering feedback to one another and reflecting on how to apply the strategies in their classrooms, such as in nr 11(Table 5.5):

> ***Bianca:*** *No, Ben, I would begin my lesson with an overview of the basic trig functions and… just quickly run over the definitions with them…*
>
> ***Ben:*** *They have to know the basics; you waste time…*
>
> ***Bianca:*** *I don't think so; doing a recap, actually saves time.*
>
> ***Ben:*** *I don't know… Why would you?*
>
> ***Bianca:*** *I address the possible questions before they ask it… one at a time – now everyone knows…*
>
> ***Ben:*** *…makes sense…*

I facilitated these discussions, offering guidance and sharing my experiences while encouraging teachers to take ownership of their learning (Table 5.5, nr. 2, 11, 16, 23, 25, 38).

5.4.4.3 Reflection for further action

The workshops I conducted for primary school teachers (Grades 4–7) during the site visit, yielded more engagement and active participation than those conducted for secondary school teachers. None of the secondary school teachers responded to the opportunity to identify mathematics teaching and development needs before the site visit. During the semi-structured interviews, I asked the relevant teachers why they did not respond to the opportunity to identify MKT needs. The majority of the secondary school teachers explained that they lose too much teaching time when attending compulsory workshops, and that they would instead use the time they had, to focus on their current responsibilities (C1 I: 28/08/2023):

> *"…this is just adding to the workload, not necessarily seeing it as a resource... So yeah, I think they feel that there isn't time to go through everything even to them and then go and select what can be used… where we have a textbook in class that they can just carry on from…" (C1 Evelyn: I)*

> *"… and then I sit in the workshop like the ones we have to attend… and I know what to do and how to do it… rather bring me hard copies of your resources. I will use that. That will help me, but not another workshop…" (C1 Eric: I)*

However, during the first week of the school visits, some secondary school teachers identified MKT topics in which they would like training. The majority of the F2F workshops focused on crucial mathematics topics such as fractions, transformations, 2D and 3D shapes, measurements, and word problems. Teachers expressed a strong need for physical resources, such as geometry sets, to aid and support their teaching of related topics (Figure 5-8). Additionally, it was observed that primary school mathematics teachers were more open to communication, frequently seeking assistance and training. In contrast, secondary school teachers primarily communicated via private messages, requesting targeted support or materials. Furthermore, during school visits, secondary school mathematics teachers preferred engaging in conversations outside the classroom. Only a few teachers were willing to allow observation of their teaching sessions and engage in reflective discussions afterwards.

After the F2F workshops, teachers' active participation in the WA group increased. From about seven to ten posts per week, posts increased to an average of thirteen per week. As recorded in Table 5.5, teachers shared photos of how they applied their new knowledge in their classrooms. Teachers also requested resources and instructional materials on the WA group. The latter answered my question posed in 5.4.2.2: "*As the programme evolves and teachers develop trust, self-confidence, and safety, they might* *be more engaged and willing to share their thoughts, ideas, and activities more freely".* It is clear that teachers' need for connection and to experience a sense of belonging was more substantial than their need to acquire new MKT or ICT skills. Teachers connect through social interaction, which results in their utilising information to explore solutions to problems, creating autonomy and competence. Hence, teachers experienced a feeling of mastery. This also results in teachers applying the knowledge created to their lesson planning, teaching, and in-class-related activities.

I want to add to my previous statement (comparing Table 5.3 and Table 5.5) that the blended learning approach, which allows for online and F2F workshops, must be designed carefully. In the South African school context, where technology-enabled learning is still an unexplored educational approach (Torrisi-Steele & Drew, 2013), incorporating both methods as a blend, added extra strain to most teachers (Ravitz, 2016). Furthermore, South African teachers display a strong community of social culture that creates a sense of belonging, with members supporting one another and reinforcing shared customs and ways of thinking (see 2.2). Thus, collaborative learning is expected in the project schools and between teachers. Working together, teachers share the mental effort required to understand complex concepts, such as those in MKT, effectively distributing the cognitive load across the group (Kirschner et al., 2018). Seeing that the teachers identified the MKT where they need training, these identified topics become the learning outcomes of the workshops.

On the other hand, at this point in the programme, I thought there would still be opportunities to develop their ICT skills. Developing ICT skills will support not only teachers' work-related activities but also non-class-related activities. The planning and design of the rest of the programme would need to be managed carefully, and teachers would not be expected to develop their MKT and ICT skills simultaneously. The rest of the programme should be processed to accommodate all teachers, those ready for technology-enabled learning, and those who prefer traditional F2F workshops. The programme must not be designed to add to the already extraneous cognitive load, leaving less space for deep processing of new information (see section 3.1.1). This newly learnt knowledge will inform my planning and designing of the blended learning activities in the second research cycle.

5.4.5 Stage 5: Online Resources

Online Resources were available after completing the F2F workshops. This stage is essential for assisting teachers in transferring their new knowledge to their teaching settings.

5.4.5.1 Action Implementation

Developing resources is part of the blended mathematics teacher development programme. Teachers identified the need for quality CAPS-aligned resources for lesson planning or classroom use (see 5.4.1.1). Online resources, instructional material, and other resources were planned and designed, and the worked example effect was applied, while being aware of the possibility of cognitive overload (see 3.1). Introducing new MKT and ICT information without linking it to prior knowledge or demonstrating the benefit thereof might produce high levels of cognitive processing, resulting in cognitive overload. This could leave teachers demotivated and unwilling to engage in the programme (see 3.1). Hence, resources were available on BeeLine, and additionally shared on WA or via email.

Online resources' instructional design follows the "*I do, We do, You do*" educational strategy, which supports the progress from initial understanding to independent practice. I connect prior knowledge with new knowledge by applying the worked example effect to the *"I do"* and *"We do"* components. The "*I do*" component explains and demonstrates the new mathematics concept. For example, I solve a mathematics problem step-by-step at the hand of a worked example. This is followed by a video clip (Teach for Life, 20216) to reinforce the learning process and to adhere to visual and audio learning. The *"We do"* component consists mainly of several interactive worked examples (see 3.2.2). The question appears on the screen, followed by an interactive option to select the answer from a dropdown or multiple-choice format. The last component, *"You do"*, requires independent practice (Figure 5-10). Exercises must be completed independently, and the answers are available in the next window.

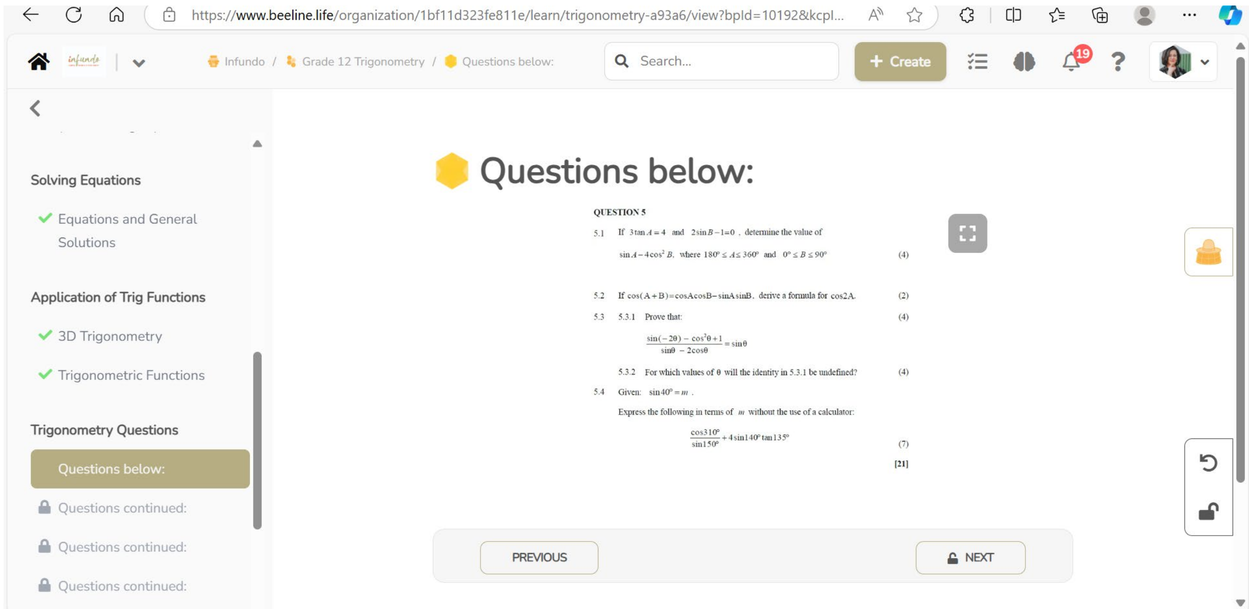

Figure 5.10: ***Asynchronous lessons on mathematics topics on BeeLine are available as requested by teachers during Cycle 1 of this study.***

The benefit of the online resources is that teachers can access them at any time. Videos uploaded can be saved to the phone gallery for convenient access. In addition, teachers can create their own lessons on BeeLine for learners to access.

5.4.5.3 Evaluation

Online resources served as ongoing support and mentoring to teachers. Once more, I used the Community of Inquiry Blended Learning Evaluation form (see Appendix C) to evaluate and analyse my online teacher support and mentoring. However, during this stage, the focus was on the online delivery of the instructional material. I also used the LMS data to evaluate the teachers' engagement.

The integration of F2F workshops with online learning resources aimed to create a seamless learning experience for teachers (Padayachee & Campbell, 2021). I used the F2F training sessions to build relationships and address immediate concerns (see 5.4.4). Following this, I leveraged online tools for follow-up, practice, and reflection. The online MKT material was carefully planned and designed, while sensitive to the teacher's cognitive capacity (see 3.2.1). Moss (2021) advocates the benefits of technology-enabled learning but also identifies that low ICT skills have the potential for information overload. From this, I distributed an ICT Skills Evaluation form (see Appendix E) at the end of cycle 1, which informed me of the teachers' level of ICT proficiency. In Figure 5.11, I compiled a staggered bar graph to represent the self-reported ICT skills of the teachers in the seven project schools.

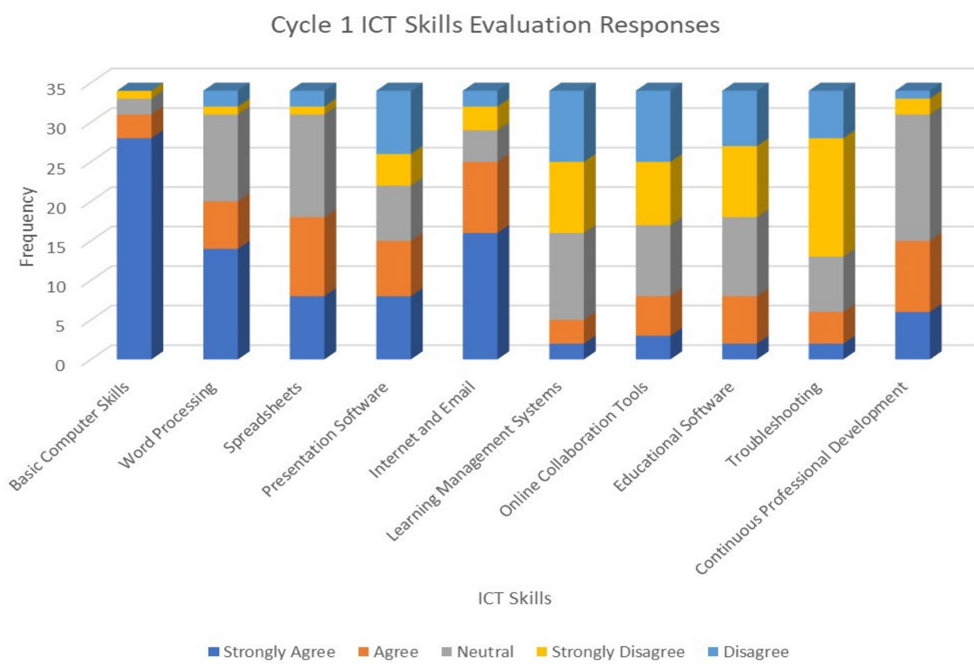

Figure 5.11: ***Results of the self-reported ICT skills of teachers at the end of Cycle 1 according to Appendix E.***

Figure 5.11 illustrates that 82% of the teachers reported at the end of Cycle 1 that they could effectively use essential computer functions. However, considering all ten questions, on average, nine of the thirty-four respondents selected '*strongly agree*'. On the other hand, on average, five of the thirty-four respondents selected '*strongly disagree*' to all ten questions. As a result, twenty out of the thirty-four respondents reported some level of ICT proficiency. These results indicated the need for ICT skills training. Moreover, it explains the low engagement and participation levels. Adjusting the programme delivery slightly by combining asynchronous online resources available on BeeLine with asynchronous and synchronous resources on the WA group, seemed to be a solution (Moss, 2021; Padayachee & Campbell, 2021).

Furthermore, evaluating the instructional design of the material on BeeLine LMS, I asked teachers for constructive feedback. Teachers highlighted the fact that the lessons on BeeLine align perfectly with the CAPS curriculum and that it was easy to understand.

> *"The lessons on BeeLine are structured in such a way that I can even share them with my learners. The initial step-by-step explanation… and then the examples beginning with an easy example and then the next one is more difficult… And then it gave me the classwork for my lesson. This helps because I do not have enough textbooks, you know." (C1 Greg: 14/09/2023)*

> *"I do not have to worry if the lesson is in the CAPS for the specific term because it is always like that when I use one of the lessons from you. That helps me a lot." (C1 Bianca: 18/09/2023)*

> *"I use the lessons at the end of the term for revision. It saves me time, and the learners enjoy the lessons because it is short, and they can do different ones in one mathematics period. So, yes… I used it for that reason." (C1 Eve: 21/09/2023)*

The teacher's feedback shaped my ideas and informed my lesson design and delivery. Some teachers report that they experience connectivity problems and that it is difficult to access online resources. The BeeLine LMS can download material and videos for later use. Even though Wi-Fi installations were completed by this time (see 5.2.1), problems due to load shedding and connection interruptions in the rural areas resumed. To address this problem, I downloaded the lessons and forwarded them to the teachers via the WA group. Given that WA is a low-tech ICT that gives teachers direct access to specific material, teachers can quickly access it, download it, and store it when connected (Moss, 2021; Padayachee & Campbell, 2021).

The data collected from the BeeLine LMS indicated an increase in activity. Teachers gain access to BeeLine through login details, where I can link the activity to the registered person's credentials. The BeeLine report at the end of July 2023 indicated "*an activity of 507 log-ins between 1 and 31 July 2023*" (C1_MR: 31/07/2023). The log-ins were grouped according to the credentials of the teacher and the BeeLine activity they accessed. The most accessed activity was *Geometry Revision 2024*, which had 69 log-ins from different credentials, more than once. This was followed by *Euclidean Geometry* with 54 log-ins. By the end of August 2023, the report showed *"an activity of 543 log-ins between 1 and 31 August 2023"* (C1_MR: 31/08/2023), with Financial Mathematics being the most accessed activity (71 log-ins). For September 2023, the activity report showed *"an activity of 512 log-ins between 1 and 30 September 2023"* (C1_MR: 30/09/2023), with *Statistics* being accessed 55 times. By the end of October 2023, the activity report showed *"an activity of 589 log-ins between 1 and 31 October 2023"* (C1_MR: 31/10/2023), *Functions: Algebra & Trigonometry* being the most accessed, with 82 log-ins.

According to Hogarth (2010), integrating various technological tools and platforms ensures continuous access and support in blended learning. Technology should be a resource, not a burden. This section shows that teachers access resources and that engagement increased over time.

5.4.5.2 Reflection for further action

While reflecting on the activities, teachers showed some initial resistance, as mentioned in 5.4.4.3 during an interview with Eric (C1: 28/08/2023). Eric explained that printed resources that align with CAPS would be of more value to him than any online resource. This and the fact that teachers experienced problems with connectivity made me think about alternative ways to provide resources for the online resource stage. According to Padayachee and Campbell (2021), supporting rural and under-resourced schools by combining on-site training with offline-capable digital tools, ensures that schools with limited connectivity could benefit from online CPTD programmes. In addition, ICT4RED also followed this approach with their three-year tablet intervention in rural schools (Herselman & Botha, 2014).

I came to realise that some teachers still resist adopting the online component of the blended learning program. This is possibly due to the lack of familiarity, connectivity issues, and concerns about the effectiveness of online components or the additional time it requires to learn new ICT skills (Ravitz, 2016). Therefore, I plan to continue with ICT skills training workshops and MKT online lesson design. Offering interactive and adaptive learning resources could support conceptual design and encourage teachers to engage in the online content. I was sharing the same information via WA (together with the online link to the same content), to motivate teachers to explore BeeLine (Padayachee & Campbell, 2021; Moss, 2021). Furthermore, I plan to compile teachers' resource files with printed material to deliver to each of the seven project schools during the site visit in cycle 2.

5.4.6 Key Findings from Cycle 1

Reflecting on the findings from the first cycle of the blended mathematics teacher development programme, I have gained valuable insights that challenge my initial assumptions and reshape my understanding of what design and implementation features could comprise a framework for blended mathematics teacher development programmes in rural South African schools. While the first cycle successfully established a foundation for the programme by addressing teachers' specific needs, it also revealed significant challenges, particularly in the online component, where low participation and technical barriers hindered effective engagement.

For example, teachers had trouble completing the online Biographical questionnaire (Appendix A), so I printed it out for them to complete on hard copies. In addition, the teachers did not complete the Collective Identification of Mathematics Teaching and Development Needs questionnaire (Appendix B); instead, two teachers replied via WA, and other teachers requested support for MKT on-site during the school visit (see 5.4.1.3). WA became the most effective way for teachers to communicate and actively engage in the programme's activities.

Furthermore, reflecting on the evaluation form of the online workshop (see Table 5.3), teachers showed limited preparedness for technology-enabled learning (see Figure 4-3). The evaluation form assessed the cognitive, social, teaching, and emotional presence (see 3.2) by listing a series of statements rating the presence of these elements (see Appendix C). The rating was done by answering Likert-scale items: 1 = *strongly disagree/does not exist;* 2 = *disagree/only marginally demonstrates existence;* 3 = *neutral, neither disagree nor agree or otherwise is difficult to explain;* 4 = *agree or it does exist,* and 5 = *strongly agree or it definitely exists and is well established.* The interpretation tool was crucial in measuring the teachers' preparedness for technology-enabled learning, informing reflection for further action phases. I utilised this form throughout cycle 1 to evaluate the evolving programme and to reflect on my facilitation methods, as well as the teacher's engagement and preparedness for technology-enabled learning.

According to the interpretation of preparedness for technology-enabled learning, a score of 91 indicates that "*the institution has addressed some aspects of the Technology-Enabled Learning system, policies and infrastructure, but they need further development"* (Kirkwood & Price, 2016, p. 88). On the other hand, when applying the same evaluation to the F2F workshops, a score of 162 indicates that schools are prepared for F2F interactions more than online learning. This finding correlates with my reflection in 5.4.1.3. Evaluating these presences revealed that F2F interactions fostered a strong sense of community and collaboration, essential for building trust and sharing best practices. In contrast, online engagement was marked by lower emotional involvement, emphasising the need for more supportive and interactive online environments.

Nevertheless, the F2F workshops effectively promoted collaboration and active learning, demonstrating the potential of blended learning. This dual approach highlighted both the advantages and limitations of online support, underscoring the need for a more nuanced strategy to engage teachers with digital platforms. My initial expectations, shaped by the COVID-19 pandemic context, assumed that teachers had effectively adapted to using ICT tools. I believed integrating online components, such as Beeline LMS, would be straightforward. My findings align with the existing literature on blended learning and teacher professional development (Badaru & Adu, 2022; Antón-Sancho et al., 2023). It is essential to tailor ICT skills training to meet teachers where they are, starting with basic ICT skills training, rather than assuming proficiency with advanced digital platforms. Research consistently points to the challenges of technology adoption in rural contexts, where traditional teaching practices often dominate. For example, similar to the findings by Shea and colleagues (2009), a robust teaching presence is vital for enhancing both social and cognitive presence. While some blended learning models have shown practical online components (Arbaugh, 2007), this study illustrates a digital divide, as many teachers resist online learning due to low ICT skills and infrastructure, echoing the observations made by Hogarth (2010). As a result, I recognised the need to recalibrate the programme to ensure that teachers could fully engage with online and blended learning opportunities.

Therefore, this cycle has underscored the necessity of balancing F2F and online learning in blended teacher development programmes in rural South African schools. While F2F engagement proved essential for fostering cognitive and social presence, improving digital literacy and ensuring better connectivity will be critical for the future success of online components. These insights emphasise the importance of context-responsive, culturally relevant professional development. In Cycle 1, culturally relevant training was integrated through the inclusion of locally applicable mathematics content and teaching strategies that reflect the unique cultural contexts of rural South African classrooms. For example, the use of indigenous knowledge, culturally relevant word problems, and teaching methods that acknowledge local practices were incorporated into workshops. These culturally responsive approaches not only ensured that professional development resonated with teachers' lived experiences but also contributed to more meaningful and impactful learning. This experience provides a clear direction for refining the blended learning framework to meet the specific needs of rural mathematics teachers. Ultimately, embracing adaptability, understanding the diverse starting points of teachers, and incorporating culturally relevant materials will be crucial as I move forward in supporting teacher professional development.

5.5 CYCLE 2: INTENSIVE F2F APPROACH

Cycle 2 commenced at the beginning of the 2024 school calendar after the first action research cycle ended in 2023. Figure 5-12 concisely summarises the PAR phases during Cycles 2, 3 and 4. To answer the research question, I will focus on the action implementation phase and report on the findings obtained through the Community of Inquiry Blended Learning Evaluation form (see Appendix C) and other data collection methods (see Tables 4-4 & 4-5). I follow suit in sections 5.6 and 5.7.

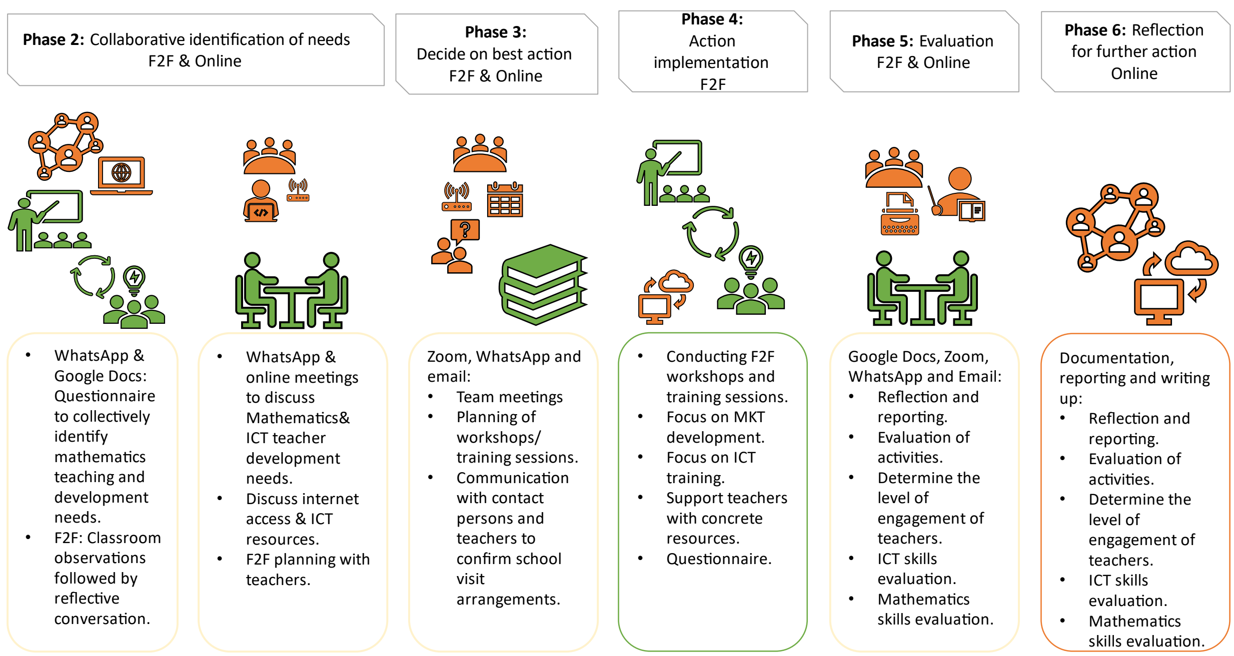

Figure 5.12: ***Summary of participatory action research, blended learning, and data collection methods in cycle 2.***

In Figure 5.12, the coloured icons represent F2F (green) and online (orange) icons (see Figure 5.13). These icons give the reader a *once-off glance* idea of how the programme evolved throughout the study.

Figure 5.13: ***Key to green and orange icons used in Figures 5-12.***

Initially, the blended learning approach (see 2.2.3) was an online-focused blend that soon became evident that it did not work in the context of rural South African schools. Therefore, adapting to what worked better slowly manifested, through the action research phases of action, evaluation, and reflection.

5.5.1 Action Implementation

In the second action research cycle, I again distributed the "Collective Identification of Mathematics Teaching and Development Needs" questionnaire (Appendix B), sharing the link via WhatsApp. Although teachers did not use the Google Docs link, they responded through WhatsApp, effectively allowing them to self-identify their training needs (Padayachee & Campbell, 2021; Moss, 2021). As mentioned in previous sections (see 5.4.3.2 & 5.4.5.3), WhatsApp is preferred by and convenient to teachers. Teachers use WA to communicate and access information.

The teachers' responses informed my programme design and delivery. Learning from Cycle 1, I knew that teachers feel more comfortable with familiar traditional learning, while addressing their more complex MKT needs. This is consistent with the work of Atkinson and Shiffrin (see 3.2) regarding the complex processes of the human memory system. Teachers unfamiliar with MKT or ICT skills can feel overwhelmed by the barrage of information they receive, while figuring out how online platforms work and focusing on the MKT lesson. In addition, "*the mental work resulting from the complexity of the content being studied*" (Clark et al., 2006, p. 322) can leave them demotivated and discouraged.

As a result, the second research cycle's programme design and delivery focused on more intensive F2F workshops and concrete material delivery (Figure 5-14).

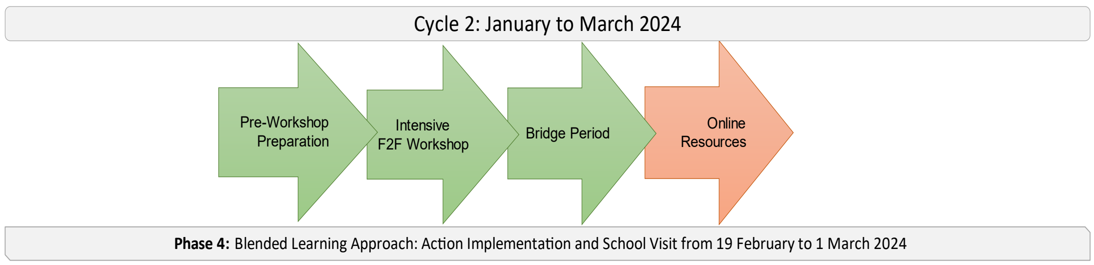

Figure 5.14: ***Blended Learning approach illustrating a more intensive traditional F2F approach.***

The F2F school visits occurred over twelve days between 19 February and 1 March 2024. This was an opportunity to meet with the mathematics teachers and conduct workshops. I conducted seven ICT skills and thirty-two MKT training workshops at the seven project schools. Workshops were scheduled for 1 hour, but I gave lenience for open discussions after the workshop had ended. Thus, I scheduled workshops half-an-hour to an hour apart, to avoid being rushed or late for the next workshop.

Consequently, I offered ongoing support during the bridge period and encouraged application and reflection. While reflecting on and learning from the F2F workshops, the importance of the bridge period's continuing support became apparent. During the bridge period, the synchronous F2F workshops were extended to continue open communication and collaboration synchronously and asynchronously. Online resources were available after the bridge period to assist teachers in transferring their new knowledge to their teaching settings. Online resources were available on BeeLine LMS and low-tech ICTs, such as WhatsApp.

5.5.2 Evaluation

As in Cycle 1, I used the Community of Inquiry Blended Learning Evaluation form (see Appendix C) to evaluate and analyse my F2F workshops' instructional practices, online teacher support and mentoring, and consequently evaluated the teachers' readiness for technology-enabled learning. Reflecting on my findings, cognitive presence was evident in triggering events, exploration, integration, and resolution. According to Akyol and Garrison (2011), a report on cognitive presence requires a balance between cognitive, social and teaching presence. The F2F workshops were planned according to the teacher-informed learning outcomes (pre-preparation stage) to address their specific MKT needs. One of the learning outcomes was creating mathematics resources to support them in their lesson planning. Consequently, I delivered the teacher files that I had prepared, learning from cycle 1 that there is a need for printed resources. This triggering event flowed into exploration and integrations, becoming a resolution. Reflecting on this, the teacher files with printed material sparked conversations with all the teachers who received them. These conversations (social presence), led to discussions on resource design, which I guided (teaching presence). According to Andresen (2009), discussions enhance learning by promoting critical thinking, reflection, and deeper understanding. Furthermore, teachers actively participated in activities during the workshops, while reflecting on their own classroom practices (C2_OR: 26/02/2024).

Alani: I used pool noodles… (giggle)

Facilitator: Oh? Tell us about that.

Alani: Well, I can show you… (show picture on cell phone) (see Figure 5-15)

Amy: That is so creative, Alani…

Anne: That is clever. (nodding her head)

Facilitator: How do you use it in your class? Do you allow learners to play with it? You know… work and play?

Alani: Yes, but I use it to explain fractions. It is like this fraction wall that you included in these files… but now the learners can see it, and they can come to the front of my class to explain their answer, like adding fractions together… I must actually show you what I do…

Figure 5.15: ***Alani made concrete resources to explain fractions to the Grade 4 learners in her class. Alani shared her photo on the WA group, where all the teachers could see the idea and employ it or something similar.***

In addition, I kept a reflective journal (Appendix D) to reflect on my own practices and to track teachers' levels of engagement. I distributed an engagement questionnaire (Appendix H) at the end of the second cycle to measure the teachers' self-identified level of engagement in the programme and how they compare with online and F2F facilitation. Furthermore, the questionnaire examined how actively teachers engaged with synchronous and asynchronous resources. According to Sing and Maringe (2021), knowing the level of teachers' engagement is crucial for effective learning. 17 responses out of 46 teachers reflected ongoing resistance towards ICT engagement, a pattern supported by LMS data from the IT department.

None of the teachers responded to the "Collective Identification of Mathematics Teaching and Development Needs" questionnaire (Appendix B). As a result, I modified my approach by visiting classrooms to observe teachers and hold reflective conversations after their lessons (see 4.5). 19 out of the 46 teachers scheduled one-period observations, and all were willing to converse afterwards. During these observations and conversations, MKT needs were collectively identified. For example, teachers expressed challenges in effectively teaching fractions, geometry, and word problems, particularly in relation to learners' varying levels of understanding. These needs were addressed by providing targeted professional development in these areas, with follow-up workshops that focused on practical strategies and resources for teaching these topics. In-person discussions allowed for a deeper understanding of teachers' MKT development needs, providing insights into how to tailor support based on direct observations of their teaching practices. This hands-on, F2F approach proved effective in addressing the identified MKT gaps, aligning with Patton's (2002) assertion that observation, complemented by interviews, enables researchers to capture routine behaviours and challenges that may not emerge in conversations alone (Wolcott, 2002). Additionally, online resources were made available for ongoing support and reinforcement of the concepts discussed during the observations.

Once more, I used the Community of Inquiry Blended Learning Evaluation form (see Appendix C), to evaluate and analyse my online teacher support and mentoring. However, during this stage, the focus was on the online delivery of the instructional material. The integration of F2F workshops with online learning resources aimed to create a seamless learning experience for teachers (Padayachee & Campbell, 2021). I used the F2F training sessions to build relationships and address immediate concerns (see 5.4.4). Following this, I leveraged online tools for follow-up, practice, and reflection. The online MKT material was carefully planned and designed, while sensitive to the teachers' cognitive capacity (see 3.2.1). Moss (2021) advocates the benefits of technology-enabled learning but also identifies that low ICT skills have the potential for information overload.

5.5.3 Reflection for Further Action

In summary, reflecting on the second cycle, I observed that there was still resistance towards ICT integration. However, the intensive traditional approach opened conversations and opportunities to explore different ICTs. Addressing the ICT resistance may require targeted ICT skills workshops, as both mathematics and ICTs involve cognitively demanding secondary knowledge requiring formal learning (Ravitz, 2016; Torrisi-Steele & Drew, 2013). F2F interactions allow primary knowledge to reduce cognitive load, but online learning often disrupts communication cues and adds extraneous cognitive load (Stott, 2021). This continuous reflection and refinement evolved the research and relational dynamics.

Highlights of workshops conducted during Cycle 2 include ten online sessions for MKT and two for ICT skills training. F2F workshops consisted of thirty-two MKT and seven ICT skills training. The MKT sessions were two-fold: 1. class observations and subsequent reflective conversations (Table 4-5), and 2. traditional workshops covering teachers' teaching and development needs. However, some teachers still showed limited preparedness for technology-enabled learning, by evaluating and reflecting on these workshops, such as the process in Cycle 1 (see Tables 5-4 and 5-5). Comparing schools, teachers from Schools C, E and F engagement was marked higher than the others. Overall, scores of 89 for online workshops and 166 for F2F workshops indicated that schools are more receptive to traditional, in-person workshops.

5.6 CYCLE 3: A BLEND OF OPPORTUNITIES

The third research cycle spans the second school term from April to June 2024. The summary of the phases in Figure 5-12 also represented the organising, planning and flow of events in Cycle 3. The only difference was that Cycle 3 offered a blend of opportunities in which to participate, as Figure 5-15 illustrates.

5.6.1 Action Implementation

During the F2F school visits in the twelve days between 13 and 24 May 2024, I conducted follow-up ICT skills training workshops at the seven project schools. According to Ghimire (2022), this ongoing training requires professional teacher development in blended learning programmes. Moss (2021) reminds us that ICT training would minimise teachers' potential for cognitive overload. Badaru and Adu (2022) state that a lack of training can potentially promote technology resistance.

The F2F workshops were conducted at all seven project schools, offering a blend of learning opportunities to address the teachers’ needs, as illustrated in Figure 5-16.

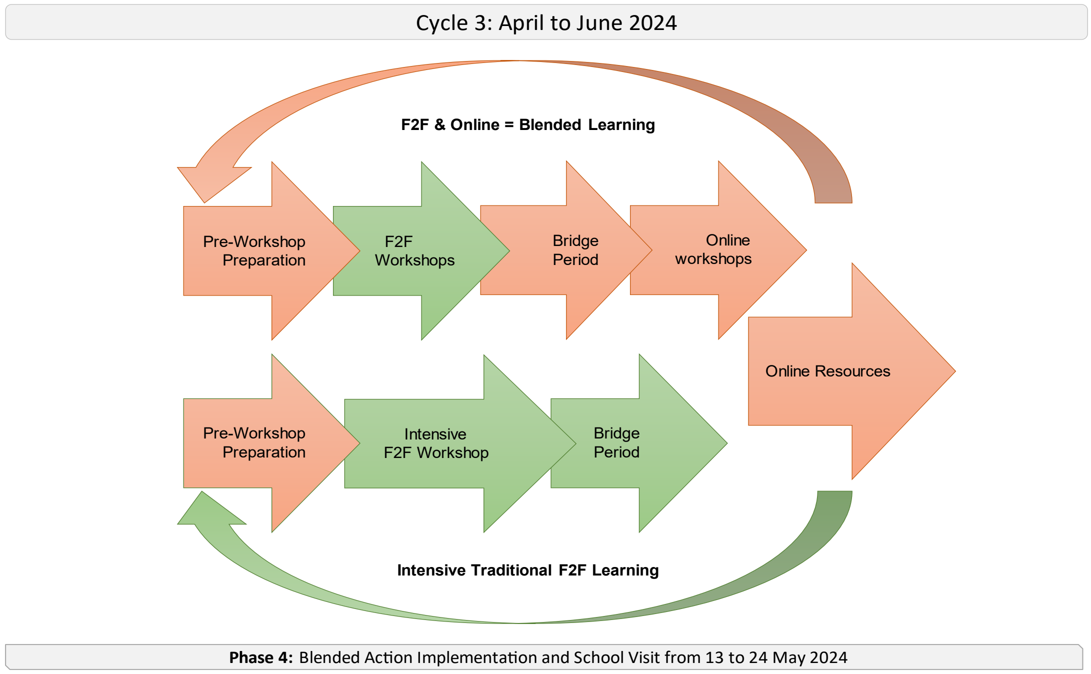

Figure 5.16: ***Blended Learning approach illustrating a blend of learning opportunities.***

This approach enhances autonomy and might result in teachers' higher levels of effective engagement (Reeve & Jang, 2006). Hence, F2F workshops continue for all teachers to attend following the bridge period, and thereafter, there is the option for another F2F workshop. The teachers who felt confident and wanted to attend the second workshop online had that option. The online resources followed the second round of workshops to promote implementation and continuous learning for all the teachers in the programme, as can be seen in Figure 5.16.

Following the same strategy, I again distributed the "Collective Identification of Mathematics Teaching and Development Needs" questionnaire (Appendix B), sharing the link via WhatsApp. According to Akyol, Vaughan and Garrison (2011), time and duration positively impact a programme. Repeating a process becomes known to the participants and develops a community of inquiry. Hence, repeating the process could foster trust that leads to engagement. However, again, the majority of the teachers preferred responding directly to WA. Their responses emphasised the need for concrete resources, printed instructional materials, and F2F training in MKT.

Similar to Cycle 2, I asked the teachers if I could visit them in their classrooms to observe how they implemented the training from previous workshops and evaluate their mathematics teaching practices. Ghimire (2022) recommends that ongoing training must be provided to teachers and that the effective implementation of newly formed knowledge must be supported. As a result, the classroom observations guided me to understand teachers' practices and to identify possible MKT needs that may not have surfaced in discussions. Behaviours often provide more insight than words (Jita & Dhliwayo, 2024). By combining observations with follow-up discussions and using the lesson observation tool (Appendix G), I better understood the teachers' needs, ensuring that the workshops addressed them effectively (FAO, 2021).

5.6.2 Evaluation

Evaluating Cycle 3, I applied the Community of Inquiry Blended Learning Evaluation form (see Appendix C), to evaluate and analyse my F2F workshops' instructional practices and evaluate online workshops and the teachers' readiness for technology-enabled learning. The results for the F2F workshops, a score of 167, indicate that schools are prepared for F2F interactions more than online learning, with a score of 93. According to Kirkwood and Price (2016), a score of 55 – 94 indicates limited preparedness. The schools addressed some aspects of technology-enabled learning but need further development. Padayachee and Campbell (2021) are concerned that online learning does not exacerbate existing challenges. Hence, their research encourages the development of low-bandwidth, and mobile-friendly solutions to ensure inclusivity in technology-enabled learning. I will explore this recommendation planning forward.

However, the interpretation of the evaluation confirmed my blended learning approach, offering a blend of opportunities to address the teachers' varying needs. Effective teacher development programmes must address the specific challenges and needs of the teachers who participate in the programme (Venkat & Adler, 2020; Ghimire, 2022). Furthermore, according to Cleveland-Innes and Wilton (2018), this approach to blended learning programme design is sometimes called mixed-mode learning or hybrid learning. These types of designs offer autonomy and greater engagement. When teachers have the freedom to make their own choices, according to Ryan and Deci (2009), they engage more deeply, resulting in mastery. In addition, self-paced learning has been shown to reduce cognitive load, especially when using ICTs for resource sharing and LMS for interactive training (Hogarth, 2010). These online learning environments offer asynchronous delivery that can help teachers with self-paced processing of information. Therefore, teachers who are ready for a more technologically-enabled learning experience have the option to attend online workshops and access online resources. On the other hand, the teachers who prefer F2F workshops with concrete resources, continue with traditional learning. WhatsApp remained the preferred option for communication. However, some teachers managed to communicate via email, and utilise cell phone applications for lesson planning (e.g. Matrix Live app); others used BeeLine and other LMSs (Moss, 2021).

5.6.3 Reflection for Further Action

In summary, an evaluation of LMS data from the IT department showed increased activity on the ICT platforms, indicating a rise in teacher engagement with the programme's digital resources. The BeeLine report at the end of this cycle indicated "*an activity of 711 log-ins between 1 and 30 June 2024*" (C3_MR: 30/06/2024). Comparing the log-ins with July 2023 that showed *"an activity of 507 log-ins between 1 and 31 July 2023"* (C1_MR: 31/07/2023), showed an increase with 204 log-ins.

Teachers have the option to participate in F2F workshops or online workshops. ICT skills training continues to focus on ICT skill development and workshops are essential; mathematics and ICTs require mastering complex secondary knowledge (Venkat & Adler, 2020). F2F sessions, reducing cognitive load and leveraging primary knowledge, help alleviate some of the challenges online learning poses, such as asynchronous communication and the absence of non-verbal cues (Andresen, 2009). Online collaboration can also add extraneous cognitive load, complicating navigation and comprehension of complex content (Ravitz, 2016; Moss, 2021).

In summary, Cycle 3 is perceived as the programme's turning point. While conducting twenty-five online lessons for MKT and four for ICT skills training, teachers' levels of engagement increased, and excitement existed at the end of this cycle.

5.7 CYCLE 4: PLANNING FOR BALANCED BLENDED LEARNING

Cycle 4, the last research cycle in this study, spanned from July to October 2024. The summary of the phases in Figure 5.12 also represented the organising, planning and flow of events in Cycle 4. Figure 5.16 illustrates Cycle 4; the difference from the other cycles is that it offers a more balanced blended learning approach, considering the social-cultural preferences of the teachers in the project schools (Lubinga et al., 2023; Arends et al., 2017).

5.7.1 Action Implementation

During Cycle 4, the school visit programme was reduced to five days between 29 July and 2 August 2024. I focused on MKT workshops, followed by the bridge period. After the bridge period, I prepared for online workshops and ended this cycle with online resources. These workshops included collaborative group discussions, interactive activities, and feedback sessions. Ultimately, Figure 5-17 illustrates balanced blended learning that shifted towards balanced blended learning in Cycle 4, emphasising F2F workshops, while maintaining online support for continuity and resource sharing.

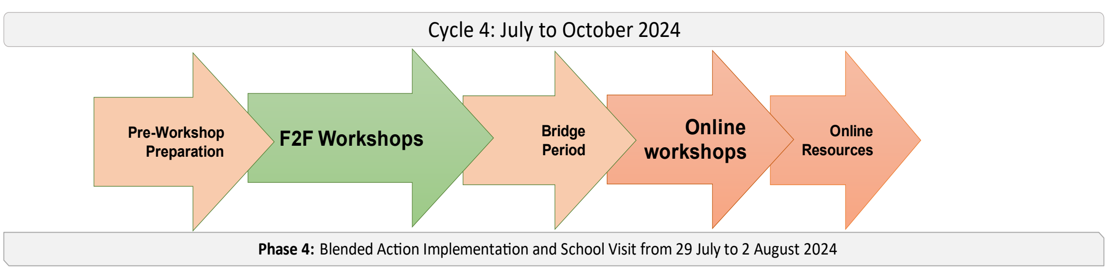

Figure 5.17: ***Balanced Blended Learning educational experience model.***

The quality of the instructional material that relates effectively to teachers' prior knowledge could manage cognitive load (see 3.2). This, in return, influences teachers' willingness to engage and actively participate in the programme. When teachers experience competence, it might lead to higher levels of engagement (see 3.3). When designing for autonomy, the option remained for teachers, preferring traditional learning, to participate in F2F workshops and selective blended learning opportunities. Teachers' motivation levels would inform their choices (see 3.3).

During the final action research cycle, I distributed a biographical questionnaire (Appendix J) to gather data on teachers' experience; enjoyment of teaching mathematics; motivations for becoming mathematics teachers, and what drives them to perform well. This helped me understand why some teachers actively engaged in the programme, while others did not. After analysing the data, I conducted follow-up interviews (Appendix K) to confirm my findings. These interviews provided additional insights into teachers' access to Wi-Fi, internet connectivity, commitment to professional development, and evaluation of the mathematics teacher development programme.

I distributed the "Collective Identification of Mathematics Teaching and Development Needs" questionnaire (Appendix B) via email and WhatsApp, as in previous cycles. Teachers responded through WhatsApp, and their input again guided the workshop topics and objectives. Classroom observations, reflective conversations, and completion of the lesson observation tool (Appendix G) were conducted, followed by the blended learning evaluation form (Appendix C) and reflective journal (Appendix D), thus continuing the process established in earlier cycles.

5.7.2 Evaluation

Similar to evaluating the online workshops, I used the Community of Inquiry Blended Learning Evaluation form (see Appendix C) to evaluate and analyse my F2F workshops' instructional practices. However, there is a difference between online and F2F evaluation elements (see Table 3-1) as seen in Table 5.5—the summary and examples extracted from the data collected guide my discussion in this section.

After the MATHS with LEGO training, excitement existed at the end of Cycle 3 (see 5.6.3), clearly spilling over into Cycle 4, with teachers' attendance and engagement increasing in online training sessions. The fourteen F2F MKT training sessions were followed by forty-two MKT and five ICT skills training sessions. This improvement in online engagement might have been a result of the teachers' improved ICT. Hence, at the end of Cycle 4, I redistributed the ICT Skills Evaluation form (Appendix E) to collect and compare the data (Figure 5-18) with the data received from the first cycle (see 5.4.5.3).

According to the self-reported data, there was an overall increase in the ICT skills of the teachers.

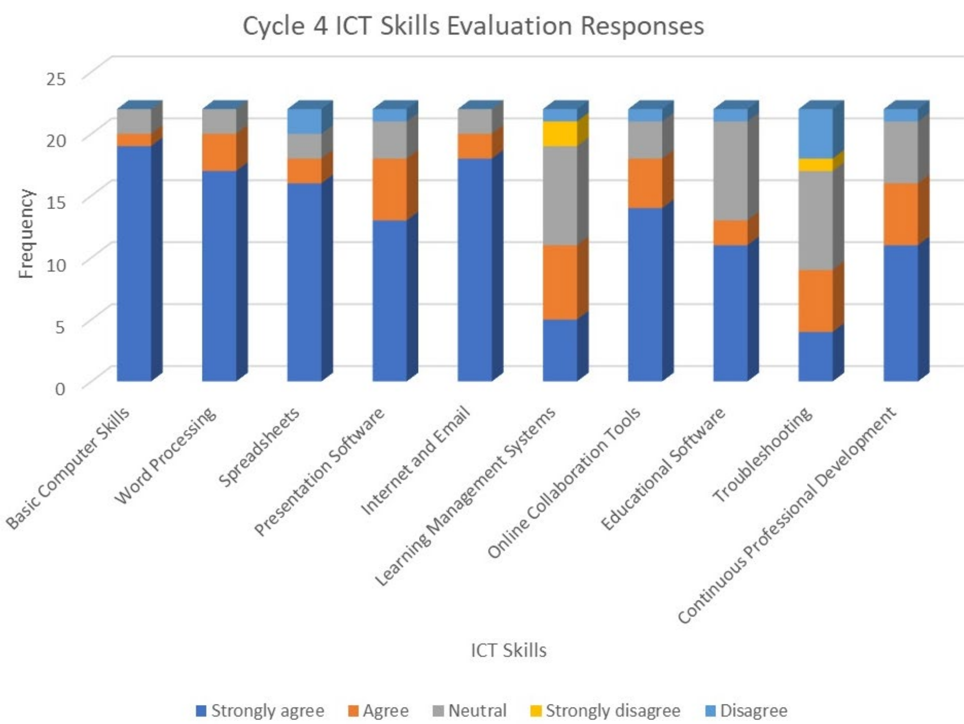

Figure 5.18: ***Results of the ICT skills evaluation of teachers in Cycle 4.***

From the data the majority of teachers reported that they had basic computer skills during Cycle 1 with 82% and Cycle 4, 86,36%. Furthermore, increases in ICT skills could be seen in Word Processing, with 36,1 % 'strongly agree', and Spreadsheets 49,7%. Teachers' responses from Cycle 1 on Presentation Software 'disagree' was 23,5%. However, from Cycle 1 to Cycle 4, an improvement of 35,5% in Presentation Software could be seen. There was also an improvement in skills regarding Internet and email (from 47% to 81,8%) and LMS (5,8% to 22,7%). Online Collaboration Tools (8,8% to 63,6%) and Educational Software (5.9% to 50%) show the most significant skills development. Troubleshoot indicated a minor increase from 8,9% to 18%. Teachers were seemingly more excited about Continuous professional development, increasing from 17,6% to 50%.

According to Ryan and Deci (2020), to be motivated and retained in self-development programmes, a sense of community and an overall feeling of belonging need to be developed. From this, I can report a notable difference in teacher engagement and active participation from the beginning of the programme until the last data collection in cycle 4.

5.7.3 Reflection for Further Action

In summary, LMS data from the IT department showed increased activity on the ICT platform for sharing resources and instructional materials. A balance between F2F and online instruction shaped the blended approach of this mathematics teacher development programme. The programme's intended outcomes were to create an exceptional learning experience for mathematics teachers to effectively address their MKT needs (see 2.2). This aligned with the schools' project objectives and with the CPTD programme of the DBE and SACE (see 2.1). The Community of Inquiry Theory (see 3.1) informed the programme design and delivery to enhance cognitive, social, and teaching presence. Being cautious of the teachers' minds, the Cognitive Load Theory (see 3.2), guided instructional material design. Consequently, the delivery of the material was informed by the Information Processing Theory and the Worked Example Effect through scaffolding. Mathematics is a complex subject which requires extra energy and patience. Therefore, individual and collaborative learning opportunities were offered through F2F and online training (see 2.2). For enhanced autonomy, competence, and connection (see 3.3), teachers identified their specific MKT needs, which informed the learning outcomes of these training sessions. Following an intrinsic case study design, I completed the Community of Inquiry blended learning evaluation form (see Table 4-5) after each research cycle, to evaluate the progress made by teachers. Cycle 4 showed a better preparedness for technology-enabled learning (see 5.4.2).

The Cognitive Load Theory informed my instructional design and programme delivery, keeping the teachers' cognitive load in mind. Plass and Kalyuga (2019) emphasise that, unlike basic evolutionary skills, people need the motivation to acquire domain-specific knowledge (see 3.2). Therefore, instructional design can leave a teacher motivated or demotivated to engage. The content I designed for the F2F workshops differed from the content for online workshops and the BeeLine LMS.

5.8 CHAPTER SUMMARY

The initial programme design which followed the Blended Block Model (see 5.4), mainly focused on online and blended learning. However, reflecting on the findings of Cycle 1, adjustments were made to the programme delivery method. School visits were conducted during Cycles 2 and 3, opportuning twelve days per cycle to conduct F2F workshops and provide in-person support. The duration of Cycle 4, however, was only five days. The learning outcomes of the workshops were informed by the results from the ICT skills evaluation questionnaire (see 5.4.6) and the teachers' self-identified MKT needs. The latter were identified during Cycle 1's semi-structured interviews (Table 4-5), and the pre-workshop preparation stage of Cycle 2.

Figure 5-19 represents the MKT training sessions conducted for both online and F2F workshops. This summary shows the increase in online workshops and fewer F2F workshops, as the blended learning program evolved. These MKT teacher training sessions include the initial online workshops via Zoom and subsequent online workshops, using additional platforms, such as Google Meets and WA video calls.

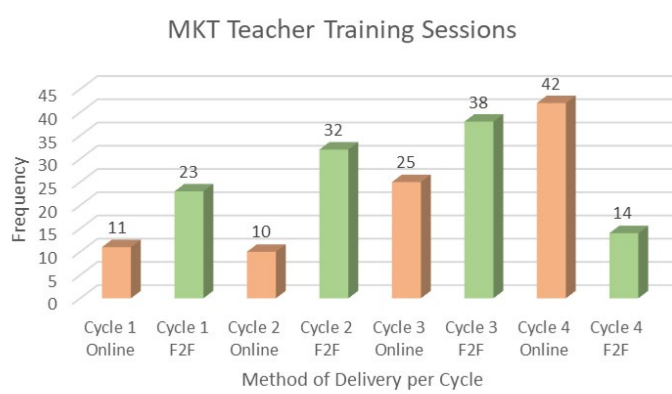

Figure 5.19: ***Mathematics Knowledge for Teaching Training Sessions conducted both online and F2F throughout the four research cycles.***

The learning outcomes for the F2F workshops were practical for MK, with printed content and concrete resources as requested by teachers (see 5.4). Similar to the "jelly sweets and toothpicks" workshops in Cycle 1. In Cycle 2, I incorporated bottle tops for counting,

number patterns, and data handling. Participants also collected various boxes from household items and brought them to the workshop to create teaching material for measurement lessons. During Cycle 3, the LEGO Foundation donated 768kg of LEGO to the project schools. This created excitement and high engagement during the workshops. Manipulatives are known to make abstract concepts tangible and promote more profound understanding (see 3.2). During Cycle 4, follow-up workshops with LEGO and the LEGO Foundation were conducted. As a result, the mathematics teachers welcomed concrete materials and printed resources. Hence, my actions reinforced a sense of community among teachers and me, working towards one goal (see 3.1). In addition, teachers not only felt a sense of belonging and that they mattered, but sharing the concrete material captured their interest to explore online resources.
In addition, Figure 5.20 presents the ICT teacher training sessions conducted throughout the four cycles. The primary outcome of these sessions was to acquire basic ICT skills. F2F workshops were conducted during school visits, except during Cycle 4, due to the limited time of the scheduled 5-day visit. These workshops were open to all the teachers who wished to attend.

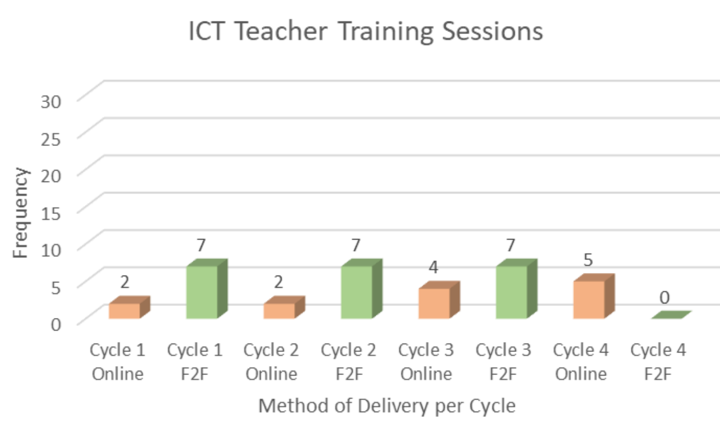

Figure 5.20: ***ICT skills Teacher Training Sessions conducted both online and F2F throughout the four research cycles.***

The BeeLine LMS lessons contain various content, including videos, interactive lessons with drop-downs and multiple-choice questions. However, as the programme evolved, I managed to create more lessons on the BeeLine LMS to cater to the needs of the teachers. These lessons aligned with the CAPS curriculum and were designed accordingly. The engagement in the online platforms increased from Cycles 1 to 4, as teachers' ICT skills improved, and a possible explanation for this was that they gained trust in the programme, resulting from the F2F training sessions. Ryan and Deci (2020) assert that a person is instinctively driven to pursue learning activities that foster self-development, such as learning, social connection, and interaction with others, which will bring them happiness and satisfaction (see 3.3). From this, I conclude that the F2F interactions and activities ultimately created an exceptional learning experience, motivating teachers to engage with online resources.

Teachers' engagement and participation levels improved as the programme evolved. Low online engagement and participation in the early stages of this program might have resulted from a sense of isolation. Nevertheless, creating an online and F2F environment that supports discourse and discussion is essential to promote engagement (Mosimege, 2017; Andresen, 2009), as is creating interest and shared responsibility for learning (Andresen, 2009). I created the latter in the F2F sessions (see 5.4.4 & 5.5.2). In contrast, as explained in 5.4.6 and 5.5.3, teachers were not fully ready for technology-enabled learning. Nevertheless, teachers' participation in F2F sessions yielded better responses, as teachers made efforts to participate meaningfully (see 5.4.4 & 5.5.2). This created a sense of belonging and motivation to explore the online component of the blended learning programme.

To evaluate the online learning experience, I distributed a self-reported engagement questionnaire (see 4.5) to garner the teachers' perspective on comparing their F2F learning experiences to online learning experiences. The questionnaire asked, "Compared to previous face-to-face learning experiences, how would you rate your online learning experiences or using online resources with the following?" The teachers had to evaluate themselves by scoring each of the 28 items, ranking from 1 Much Better to 5 Much Worse. I collected these data at the end of Cycles 2 and 3 and represented them in the figures below (Figures 5-21 and 5-22).

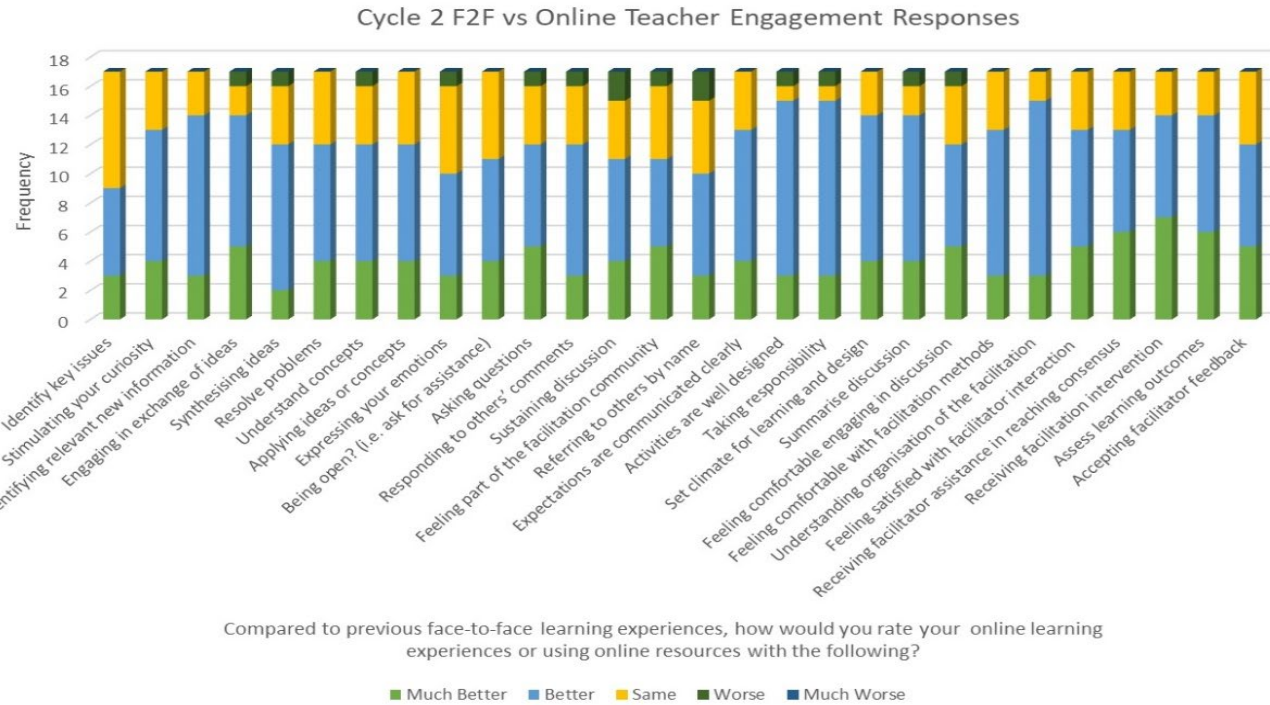

Figure 5.21: ***Teachers compare their online learning experience to their F2F learning experience in Cycle 2.***

In Figure 5.21, the *better* (blue) and *same* (yellow) are prominent in the graph, compared to Figure 5.22, where the *better* (blue) remains, and the *much better* (green) increases. This shows that the teachers' online experience increased, compared to the teachers' preferred F2F experience.

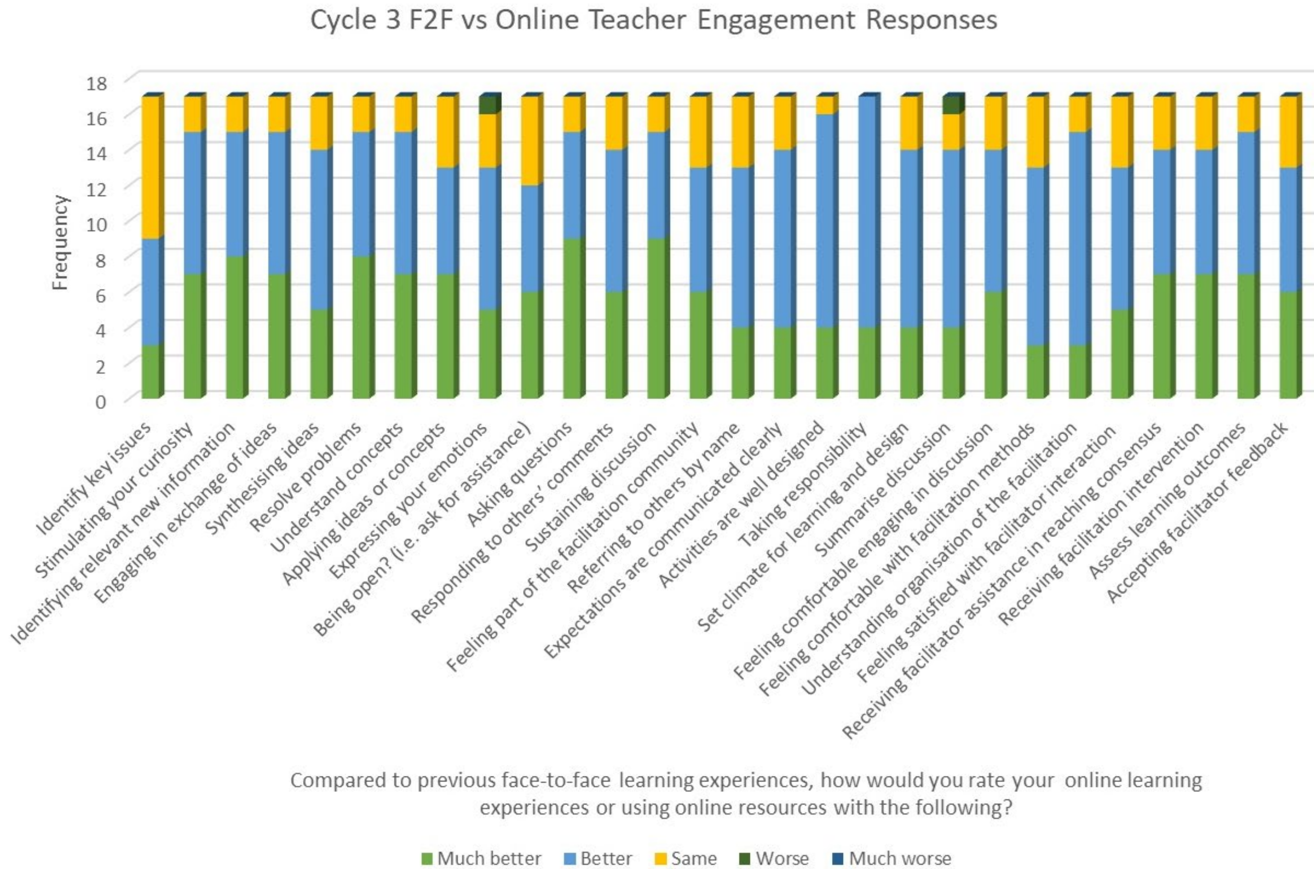

Figure 5.22: ***Teachers compare their online learning experience to their F2F learning experience in Cycle 3.***

The barriers to engagement in this programme were mainly poor or no internet connection, due to load shedding or expensive data (see 5.2.1 & 5.4.2). The Wi-Fi installations partly addressed the connectivity issues at the schools, as well as teachers' low ICT skills and time constraints to explore online resources and LMSs (see 5.2.1 & 5.4.5). Time also played a role in the F2F component of the blended learning programme, as teachers did not always have the time to engage in conversations or to participate in sessions (see 5.4.2 & 5.4.4). This said, some teachers signed up for the programme and agreed to participate in the research study but did not engage or attend any online or F2F sessions.

5.9 CONCLUSION

In this chapter, the intervention project and environment are described. Consequently, an overview of the blended mathematics teacher development programme and the research cycles were presented. The initial delivery of the programme was analysed as an instrumental case study and was used to guide the evaluation, reflection, and discussion of the remaining cycles. Throughout these cycles, the three energies of the Community of Inquiry theory informed my refining of the design and the delivery strategies of the blended mathematics teacher development programme. As the cycles progressed, it became evident that addressing the identified areas for improvement would lead to an exceptional learning experience for teachers and, subsequently, their students. This iterative process of reflection and adjustment, as well as the discussion of these findings in terms of the literature and theory, given in the next chapter, have informed my creation of a framework for blended mathematics teacher development in rural South African schools. This framework will be presented in the final chapter.

CHAPTER 6 : DISCUSSION

“competence + belonging + autonomy = happiness, well-being, energy.”

Dr Hayley Lewis

In the previous chapter, I presented a detailed description of my participatory action research cycles. This chapter focuses specifically on answering the research questions repeated here:

What design and implementation features could comprise a framework for blended mathematics teacher development programmes in rural South African schools?

- What design and implementation features regarding cognitive presence within this programme promote effective engagement?
- What design and implementation features regarding social presence within this programme promote effective engagement?
- What design and implementation features regarding teaching presence within this programme promote effective engagement?

To answer these questions, I present several assertions, each supported by reference to the data of the study, explained in terms of the study’s conceptual framework, and discussed in terms of the existing literature. These assertions refer to the study’s findings and are organised according to the cognitive, social, and teaching presence. However, it is essential to remember that these energies are interrelated and can, in practice, not stand alone. Thus, while each subsection focuses on one of these energies, its interaction with the other two is also discussed.

Focusing on the interrelatedness of the three energies, I also recognise the influence of emotion, a component in the cognitive load theory (Murayama et al., 2013; Plancher et al., 2018; Zlomuzica et al., 2016) and the self-determination theory (Ryan & Deci, 2020). Acknowledging emotional presence as a basic psychological need, can enhance cognitive, social, and teaching presence, leading to more effective and efficient learning experiences (Dixon et al., 2024; Ryan & Deci, 2020). Together, these energies create an engaging learning environment, resulting in an exceptional learning experience (Cleveland-Innes & Wilton, 2018; Akyol et al., 2011).

After answering the sub-research questions, I answer the main research question by presenting the Blended Mathematics Teacher Development Framework in Chapter 7. Notably, this is not the only way a blended mathematics teacher development programme can be designed and implemented; this is a framework tailored for the rural schools project in the Eastern Cape, South Africa.

6.1 COGNITIVE PRESENCE

Assertion 1: Concrete resources (e.g. manipulatives and printed, structured curriculum instructional material) effectively motivate teachers' engagement with Mathematics Knowledge for Teaching content in a blended technology-enabled environment. Key strategies include: Information Exchange with Hands-on Guidance; Connecting Ideas through Manipulatives; Applying Concepts via Practical Activities Supported by Online Resources, and Fostering Engagement through a Sense of Puzzlement.

6.1.1 Information Exchange with Hands-on guidance

Concrete resources, such as manipulatives and printed, curriculum-aligned instructional material, effectively engaged teachers with MKT content, in a blended, technology-enabled environment (see 5.4.4). Padayachee and Campbell (2021) explain that integrating F2F workshops with online learning modules creates a seamless learning experience for teachers. They also note that using traditional sessions to build relationships (see social presence in 3.1) and address immediate concerns (see teaching presence in 3.1), while leveraging online tools for follow-up, practice, and reflection is a practical approach to blended learning. Hogarth (2010) highlights the importance of online resources, as they enable teachers to access material and explore learning activities at their own pace and convenience (see 5.4.5). This flexibility is particularly beneficial for teachers with varying schedules and commitments (see 5.8).

The findings of this study confirm that well-designed instructional materials enhance exploration (see 5.4.5 & 5.5.3). In addition, discussions were facilitated to help teachers appreciate different perspectives (see 5.4.2). In addition, brainstorming and finding relevant information enabled teachers to resolve MKT content-related questions (see 5.4.4). Teachers utilised a variety of information sources, first concrete and later online, to explore problems posed during face-to-face workshops (see 5.4.6). They could apply the knowledge created to their professional work or other non-class-related activities (see 5.4.4).

6.1.2 Connecting Ideas Using Resources

Physical resources effectively motivated teachers' learning and understanding of MKT concepts by making them concrete and visual, allowing exploration, investigation, and connecting ideas for knowledge acquisition. These resources included well-structured printed material as resources for MKT. Based on cognitive load theory, the use of manipulatives to "chunk" complex problems into familiar concepts and scaffolding knowledge, minimises the cognitive load on working memory. Sweller (2006) emphasises that manipulating cognitive load by reducing extraneous load through careful selection of intrinsic load, scaffolding, and worked examples, can optimise the process of forming coherent arguments, drawing conclusions, and relating content to teachers' own experiences and prior knowledge.

Many authors consider the capacity of the working memory to be the limiting factor in learning (Suppawittaya & Yasri, 2021; Lorenz & Tizon-Couto, 2019; Kirschner & Sweller, 2006), especially in the 21st century, where teachers must learn numerous new concepts in a technology-enabled environment. Moss (2021) highlights that ICT training is crucial in helping to minimise teachers' potential for cognitive overload. Badaru and Adu (2022) on the other hand, noted that insufficient training can promote resistance to the use of technology. Given the already high cognitive load imposed by abstract mathematical concepts, the limit of mental energy and attention would be significantly less taxing if new information were distributed more effectively, thereby reducing cognitive strain (Niaz & Logie, 1993).

In this study, the worked example effect emerged as a solution, positing that step-by-step, already worked-out solutions in learning materials, rather than solely presenting problem-solving activities, enhance knowledge acquisition (see 5.4.4, 5.4.5 & 5.7.3). In my F2F workshops, I combined the worked example effect with LEGO bricks. I found that LEGO bricks are an effective tool for teaching abstract mathematical concepts, such as geometry (see 5.8). I used LEGO to model corresponding, alternate, and co-interior angles, supported by a scaffolded “I do, We do, You do” worksheet (see 5.4.5). The activity enhanced engagement, fostered meaningful discussions about lesson planning for Grade 9 learners, and made abstract concepts tangible.

Aligned with Deci and Ryan's (2000) theory, LEGO fostered intrinsic motivation by internalising values and enhancing working memory, creativity, and information recall (Murayama et al., 2013). Reducing extraneous cognitive load optimised germane cognitive load, facilitating the connection between new concepts and prior knowledge (Paas et al., 2003; Sweller, 1994), a critical process for solving complex mathematical problems. Therefore, teachers’ learning processes are supported by studying worked examples, which constitute "pre-existing knowledge" that helps construct schemata by linking new chunks of information. Consequently, worked examples provide a model for teachers to learn from; managing intrinsic cognitive load; reducing extraneous cognitive load on the working memory, and increasing germane cognitive load (Chen et al., 2017; Paas & van Merrienboer, 2020; Wesenberg et al., 2022). Teachers can then apply these examples as a "road map" or pattern to solve subsequent problems of a similar type.

6.1.3 Applying New Ideas through Hands-on practical activities supported by online resources

According to the literature, the integration of newly acquired knowledge through reflection, discussion, and practical activities builds memory, and hence, learning takes place (Hogarth, 2010; Andresen, 2009). Padayachee and Campbell (2021) reported that supporting rural and under-resourced schools by providing low-tech resources alongside online platforms, is found to be an effective way to bridge the resources gap and minimise cognitive load (Garrison & Vaughan, 2008).

Promoting engagement through practical application (Cleveland-Innes & Wilton, 2018), enhances the learning process (Sweller, 2011, 2020). Hence, applying new knowledge guided by manipulatives, examples, and collaborative reasoning during F2F workshops promotes engagement. Cognitive Load Theory initially failed to include the social nature of learning. However, the theory evolved to include notions of social agency in technology-enabled learning (Mayer, 2014, 2017; Kirschner et al., 2018; Sweller, 2020) and collaborative cognitive load in collective environments (Kirschner et al., 2011; Kirschner et al., 2018). Collaborative cognitive load is the '*joint-working*' of long-term memories in complex problem-solving (Kirschner et al., 2018), on the premise that the small size of working memory is the most significant limitation to learning (Sweller, 2011). This results in increased engagement, autonomy, and competence (Ryan & Deci, 2017).

In this study, teachers in my workshops could describe ways to apply their newly acquired knowledge (see 5.4.4, 5.4.5 & 5.5.2). Furthermore, teachers developed solutions to relevant problems they applied to their classroom practice and proudly showed off by posting a photo of the WA group (see Figures 5.9 & 5.15).

6.1.4 Sense of Puzzlement Fostering Engagement

According to the literature, triggering events include identifying needs that ignite the process of engaging with MKT content (Garrison et al., 2001; Garrison & Arbaugh, 2007; Akyol & Garrison, 2011). However, establishing deep and meaningful learning requires activity in all four of these cognitive presence energies. Evidence reported by Akyol and Garrison (2011), shows that cognitive presence requires a balance of cognitive, social and teaching presence. In other words, the facilitator's role extends beyond the delivery of content to guiding inquiry and stimulating teachers' reflective thinking (see 3.1.2), by linking current problems to prior knowledge, demonstrated during the workshop (see 3.2.2). Facilitators must actively engage all teachers in discussions, acknowledge their points of view, and foster a sense of belonging and value, ensuring meaningful contributions from all participants (see 3.1.2 & 3.3.3). This aligns with Archibald's (2010) findings, as cited by Cleveland-Innes and Wilton (2018), which state that social and teaching presence accounts for 69% of the impact on cognitive presence.

Interesting, concrete resources, e.g. LEGO bricks (see 5.7.2), effectively sparked conversation in this study (see 5.4.4 & 5.5.2). Inspired by Mosimege and Ismael (2004), I integrated traditional manipulatives such as beadwork and basket weaving to explore geometry and symmetry. His work encourages me to view culture as 'prior knowledge' and align it with the CAPS curriculum. These applications sparked interest and curiosity among teachers (see 5.4.4). Similarly, the provocative question posed by the facilitator or one of the teachers, as seen in the 'jelly sweets and toothpicks' (see 5.4.4), created a situation where a challenging mathematics problem presented for discussion, was resolved.

From this, it would appear that triggering events or an unexpected piece of information could prompt further inquiry (see 5.4.4), resulting in engagement and discussion. Unexpected information triggers already acquired knowledge, and the two pieces of 'schema' contrast each other, creating an inquiry within the teacher (see 3.2.2). This could motivate teachers from within to ask questions and participate in collaborative problem-solving (see 3.3). The teachers in this programme responded better to F2F training sessions than online sessions (see 5.8). Although teachers seemed hesitant to engage and actively participate in online sessions (5.4.2), the exposure due to F2F workshops might have broadened their instructional toolkit by hearing first-hand how others approach activities or challenges (see 5.8). After establishing trusting relationships and acquiring basic ICT skills, teachers' level of engagement increased. Therefore, I can conclude that F2F workshop activities piqued teachers' curiosity, which led to increased engagement with MKT content in a blended technology-enabled programme.

6.2 SOCIAL PRESENCE

Assertion 2: Providing structured, curriculum-aligned, printed resources and a collaborative low-tech electronic platform, improved teachers' risk-free expression, collaboration, and self-projection, effectively motivating engagement.

6.2.1 Low-tech collaborative electronic platform for risk-free expression

Risk-free expression in a positive, supportive environment enhances engagement (Akyol & Garrison, 2011). Garrison and Vaughan (2008) discuss the importance of professional development for teachers to implement blended learning successfully. One of their suggestions is incorporating activities requiring teachers to participate actively in discussions and problem-solving tasks. They argue that it helps maintain engagement and promotes deeper learning. Risk-free expression in a positive learning climate also encourages engagement, according to Cleveland-Innes and Wilton (2018). In this study, as mentioned previously, in this chapter, I provided structured, curriculum-aligned, printed resources that improved teachers' risk-free discussions (see 5.5.2). During the workshops, I encouraged participation in discussions and guided conversations to stay focused on the learning outcome (5.4.2). This seemed to make the teachers feel more confident about expressing their ideas without fear of judgement when provided with well-structured resources, thus reducing uncertainty and promoting inclusivity (see 5.4.4). This approach enables social presence, which is crucial for creating a meaningful educational experience (Cleveland-Innes & Wilton, 2018; Akyol et al., 2011). Social presence involves the ability of participants to connect, express emotions, and establish interpersonal relationships in a learning environment (Cleveland-Innes & Wilton, 2018).

In this study, F2F workshops set the stage for much more engaging online discussions as the programme evolved (see 5.8). However, during the two years of this study, I did not fully succeed in empowering all the teachers to autonomously and independently engage with online resources (see 5.4.4). I created online forums that acted as a virtual gathering space for teachers, promoting interaction, risk-free expression, collaboration, and a sense of community (see 5.4.6, 5.7.2 & 5.8), and critical components for successful blended learning. The "*Mathematics Professional Support"*- WhatsApp group served as a virtual gathering space in some ways. According to Moss (2021), WhatsApp serves as a platform that allows teachers to engage in discussions, ask questions, and receive feedback from facilitators or colleagues.

6.2.2 Collaboration

The engaging manipulatives (see 6.1) elicited group discussions that quickly resulted in collaboration during F2F workshops. Teachers worked together to find methods and ways to solve their self-identified problem (see 5.4.4). The literature confirms that the 'joint-working' of long-term memories in complex problem-solving can reduce cognitive load (Kirschner et al., 2018; Stott, 2021). This collaborative work also enhances relationship building and sets a feeling of trust and belonging amongst teachers. Engagement and participation increase when teachers feel they have the skills required to do the activities (Ryan & Deci, 2017; Hann et al., 2007).

Concrete resources were standard tools that fostered peer collaboration, enabling teachers to work cohesively toward shared learning goals (see 5.4.4). According to Cleveland-Innes and Wilton (2018), collaboration with peers could enhance understanding of the content. Furthermore, the collaboration fosters a sense of belonging and group identity that might lead to effective engagement (Ford et al., 2014). In this study, I needed to create a meaningful learning experience for the teachers participating in this programme. Social presence involves the ability of participants to connect, express emotions, and establish interpersonal relationships in a learning environment (Garrison & Vaughan, 2008). Even though it seemed as if I did not fully succeed in creating online forums, teachers seemed to enjoy the F2F workshops (see 5.4.4 & 5.8). They used them as an opportunity to communicate in meaningful discussions (see 5.4.4). As a result, we created a sense of community with some discussions that continued afterwards on the WA group (see 5.4.3). As Akyol, Vaughan and Garrison (2011) reported, developing a blended community of inquiry takes time. As reported in section 5.8, as the blended mathematics teacher development programme evolved, teacher engagement on the BeeLine LMS with MKT content did increase. The blended mathematics teacher development programme is sure to continue after this research study, with the prospect of creating a technology-enabled learning environment.

6.2.3 Self-projection and personal expression

Self-projection and personal expression gave teachers a sense of ownership and fostered connection in the programme. According to Rayn and Deci (2017), when teachers are encouraged to express their personal beliefs and project their perspectives, they feel more engaged in the programme. This sense of autonomy leads to greater engagement and an enhanced connection to the programme. Padayachee and Campbell (2021) noted in their article on supporting mathematics teachers in a community of inquiry, is that it is crucial for creating a meaningful educational experience. They also state that it is essential for teachers to connect, express emotions, and establish interpersonal relationships in a learning environment. Kirschner and colleagues (2018) report that collaborative cognitive load is the 'joint-working' of long-term memories in complex problem-solving. Hence, teachers pool their mental resources when collaborating, practically, creating a collective working memory. This shared cognitive load allows teachers to distribute it more effectively, making it easier to solve complex problems (Kirschner et al., 2018; Sweller, 2011). This joint working of long-term memories was observable in this study during F2F workshop activities where teachers and I worked together to solve problems (see 5.1, 5.2, 5.3 & 5.4). Moreover, during class observations, I noticed what the teacher did and had a conversation reflecting on and guiding the teacher's practices and MKT (see 5.5.3). This allowed teachers to engage in meaningful discussions, leading to possible professional growth.

In this study, I encouraged teachers during F2F workshops to project their unique teaching styles and methodologies using their own manipulatives or other resources (see 5.5.2). This enhanced their sense of agency and ownership, motivating them to engage in the programme activities (see 5.4.4). After conducting F2F workshops, teachers enjoyed sharing photos (see 6.1.3) to showcase how they implemented their newly learnt knowledge. One teacher requested my assistance with installing WhatsApp on her laptop after observing me, when I shared documents with her from my laptop via WhatsApp (C2 Cayla: OR).

6.3 TEACHING PRESENCE

Assertion 3: The facilitator needs to start with individual face-to-face (F2F) sessions focused on participant-paced Mathematics Knowledge for Teaching (MKT) and Information Communication Technologies (ICT) skills development, with opportunities to showcase development. As confidence and competence grow, transition to group and blended sessions. Key priorities include curriculum design, practical methodologies, fostering constructive exchange, and addressing and resolving core issues.

6.3.1 Setting Curriculum and Methods

McCarthy and Oliphant (2013) found variable levels of ICT skills among a group of mathematics teachers who took part in their study, and only some could demonstrate the integration of technology and content knowledge. This was also the case in this study, where teachers could not always effectively access online resources (see 5.4.5). Therefore, I found it compelling to begin with individual F2F teacher-paced MKT and ICT skills development sessions (see 5.8). Furthermore, I ensured that all instructional material and online resources were CAPS-aligned (see 5.4.2 & 5.8). I structured the programme starting with F2F workshops and, when teachers indicated that they were ready, online workshops for those who signed up for it. This contextually responsive pacing approach allowed the teachers to participate in training sessions that they felt they could manage. According to Murayama and colleagues (2013), teacher engagement and the management of intrinsic cognitive load, are critical factors for learning. When teachers are willing to tolerate a small amount of extra extraneous cognitive load to learn a new concept or skill, the space left for germane cognitive load can support deep learning. Therefore, teachers need to set their personal goals within the programme. The freedom to choose creates autonomy, which, in turn, enhances engagement (Bandura, 1997).

Similar to cognitive presence discussed in 6.1, instructional materials that are aligned with the CAPS curriculum and utilise worked examples for MKT, reduce the cognitive load on the working memory and increase performance (Brunstein et al., 2009; Kalyuga & Sweller, 2004; Rey & Buchwald, 2011). Researchers found that, given the abstract nature of mathematics and ICT usage, it is crucial to be sensitive to the cognitive load of the teacher's minds (Setayesh, 2018; Hannula et al., 2019). This, I believe, is a contributing factor to why teachers are hesitant to engage in online workshops (see 5.4.2). However, as Akyol, Vaughan, and Garrison (2011) found, over time, a community of inquiry evolves and establishes a teaching presence coinciding with a cognitive and social presence that enhances engagement.

In this study, I clearly communicated important dates and times for the school visits and the workshops (see 5.4.2 & 5.4.4). I offered F2F workshop training MKT and ICT skills development in a personalised and paced environment (see 5.8). I supported the development of group dynamics and ensured that discussions remained productive and aligned with learning goals (see 5.4.4). Rooted in Ryan and Deci’s (2000, 2012, 2020) self-determination theory, the authors emphasise fostering intrinsic motivation by supporting autonomy, competence, and relatedness. This study fostered autonomy by allowing teachers to create and follow personalised learning plans aligned with their needs (see 5.4). Competence provides opportunities for teachers to attend F2F or online workshops that enhance their MKT and ICT skills (see 5.7) and relatedness by encouraging teachers to participate in F2F and online workshops (see 5.8).

6.3.2 Shaping Constructive Exchange

The facilitator plays a central role in moderating the learning process, offering clear guidance, and tailoring content to the teachers’ individual needs (Cleveland-Innes & Wilton, 2018). In this study, I facilitated F2F workshops and gradually shifted from a directive to a supportive role, allowing teachers to take greater control of their learning processes (see 5.4.4 & 5.6.2). I led the F2F workshops, encouraging engagement by providing constructive feedback and fostering a sense of accomplishment and competence (see 5.4.4 & 5.7.1). According to Guiffrida and colleagues (2013), teachers motivated by their intrinsic needs for autonomy, connection, and competence, are more likely to show continuous persistence in professional development activities and master job satisfaction and psychological wellness.

In this study, I found that allowing teachers to set their learning goals and progress at their own pace empowers them to take ownership of their development (see 5.6.2). I offered synchronous and asynchronous support and provided feedback in a timely manner (see 5.4.2 & 5.4.4). This resulted in more teachers exploring the online resources as the programme evolved (see 5.8). As teachers gain confidence and skills, they transition into collaborative, group-based learning and blended learning environments (combining F2F and online sessions) (see 5.8). This transition requires guidance and scaffolding (see 3.2.2), and I supported the development of group dynamics and ensured that discussions remained productive and aligned with learning goals.

6.3.3 Focusing and Resolving Issues

According to Cleveland-Innes and Wilton (2018), at the beginning of the programme, the facilitator most often does direct instruction. However, as the programme evolves and the community of inquiry grows stronger, teachers will support one another (Cleveland-Innes & Wilton, 2018; Sweeney, 2022). The facilitation of learning refers particularly to cognitive support but can include all kinds of learning support and encouragement. Both the facilitator and teachers themselves can do this.

In this study, I found that starting with individual F2F, participant-paced MKT and ICT training ensured productive discussions, maintained engagement, and helped teachers navigate challenges (see 5.4.4 & 5.5.2). Strategies, such as prompt feedback, setting clear expectations, and creating a safe learning environment, ensured consistent and meaningful engagement (see 5.7.1). Furthermore, I encouraged teachers to apply and demonstrate their newly learnt skills in practice in their classroom environments (see 5.4.4). From this, teachers would demonstrate how they resolved their self-identified issues. Collaborative tasks and discussions effectively strengthened social presence within the programme, while ensuring engagement and productive interaction (see 5.4.2 & 5.4.4).

Teaching presence binds all the energies together, as its effectiveness improves cognitive and social presence, ‘sparking’ an exceptional learning experience (Cleveland-Innes &

Wilton, 2018). Similarly, my actions aimed at reinforcing the development of a sense of community among teachers in the F2F and online workshops (5.42). Asking questions such as, *"How could online resources help you prepare for varying skilled classes?" (C1 Maryke: Online)* and encouraging teachers to share their practical experiences, allowed the teachers to take the 'facilitator' role. It appeared from the F2F workshops that teachers understood the MKT that was presented in a way that they could internalise and apply it in their own classrooms (see 5.4.4).

6.4 CONCLUSION

I made several assertions to the study's research questions in this chapter. I have supported each assertion by reference to the data of the study. I assert that the following are informative in creating a framework for blended mathematics teacher development programmes in the context of rural South African schools:

- Assertion 1: Concrete resources (e.g. manipulatives and printed, structured curriculum instructional material) effectively motivate teachers' engagement with Mathematics Knowledge for Teaching content in a blended technology-enabled environment. Key strategies include: Information Exchange with Hands-on Guidance; Connecting Ideas through Manipulatives; Applying Concepts via Practical Activities Supported by Online Resources, and Fostering Engagement through a Sense of Puzzlement.
- Assertion 2: Providing structured, curriculum-aligned, printed resources and a collaborative low-tech electronic platform, improved teachers' risk-free expression, collaboration, and self-projection, effectively motivating engagement.
- Assertion 3: The facilitator needs to start with individual face-to-face (F2F) sessions, focused on participant-paced Mathematics Knowledge for Teaching (MKT) and Information Communication Technologies (ICT) skills development, with opportunities to showcase development. As confidence and competence grow, transition to group and blended sessions. Key priorities include curriculum design, practical methodologies, fostering constructive exchange, and addressing and resolving core issues.

These assertions are grounded in the data of this study and are seen as valuable in aiding practice improvement (Torrisi-Steele & Drew, 2013). It is hoped that educational project and programme leaders who read this script, have been able to conceptualise elements relevant to their environments, so that the impact of this study will extend beyond the confines of this programme (Ghimire, 2022). I end this thesis by concluding my study and suggesting its implications for research and practice in the final chapter.

CHAPTER 7 : CONCLUSION

"I know it's a rare privilege, but if one can really tackle

something in adult life that means that much to you,

then it's more rewarding than anything I can imagine."

Andrew Wiles

This action research study aimed at creating a framework for blended mathematics teacher development programmes in rural South African schools. Unlike some positivistic approaches to research, in which variables are controlled from without, a study such as this, is situated within actual practice to understand, from within, the complexity of an actual situation (Reason & Bradbury, 2008). While the study's primary purpose was to investigate and improve the localised case, numerous authorities in education research suggest that storytelling by practitioner-researchers is potentially the most effective way to enhance practice. It provides alternative perspectives and enables personal and professional transformation through collaborative learning and growth, allowing readers to extract relevant aspects for their localised settings (Zuber-Skerritt & Wood, 2019; Herselman & Botha, 2014; Jit & Dhliwayo, 2024; Reason & Bradbury, 2008).

Taking a pragmatic approach to research (Onwuegbuzie & Leech, 2005; McBeath, 2022) and guided by realist leanings (Lebow, 2024; Maxwell, 2022), qualitative data was gathered through participant observations and reflective discussions, aimed at sensing the complexities of the situation (Padayachee & Campbell, 2021; Sweeney, 2022). The accumulated data corpus spans two years and comprises quantitative and qualitative data, namely participant questionnaires; interviews; reflective journaling; evaluation forms; my field notes/monthly reports, and LMS data tracking participants' engagement. Data collection, analysis and interpretation were done in a reflective, cyclical manner through triangulation. Data triangulation aimed at comparing inductive insights with deductive categories. This iterative process involved cycles of reflection, planning, and interpretation (Sweeney, 2022). These cycles were guided by research questions focusing on design and implementation features to promote and optimise teacher engagement.

In Chapter Five I described, and in Chapter Six discussed the details of my participatory action research cycles and how I aimed to create an exceptional learning experience within the mathematics teacher development programme. My action, evaluation, and reflection endeavour spanned two years. This enables readers to understand my viewpoints and form naturalistic generalisations (Merriam, 1988; Melrose, 2009; Guenther & Falk, 2021). The process of analysis, interpretation, and construction of assertions was done while considering the constraints of working within rural South African schools. This was guided by both the theoretical and conceptual frameworks, as well as the research questions. The knowledge claims from this study are given below, followed by a more detailed exposition of the Blended Mathematics Teacher Development framework. I then comment on the recommendations, limitations, and implications for further research and practice.

7.1 KNOWLEDGE CLAIMS

Looking back over the two years of this study, I am convinced that various design and implementation features should be considered to create a blended mathematics teacher development framework in rural South African schools. The design and implementation of such a framework takes time, effort, persistence, and resilience, and it is likely to be accompanied by problems and challenges. This view evolves from synthesising this study's findings, summarised in the following assertions, which answer the research questions.

> ***Assertion 1:*** *Concrete resources (e.g. manipulatives and printed structured curriculum instructional material) effectively motivate teachers' engagement with Mathematics Knowledge for Teaching content in a blended technology-enabled environment. Key strategies include: Information Exchange with Hands-on Guidance; Connecting Ideas through Manipulatives; Applying Concepts via Practical Activities Supported by Online Resources, and Fostering Engagement through a Sense of Puzzlement.*

Assertion 2: *Providing structured, curriculum-aligned, printed resources and a collaborative low-tech electronic platform improved teachers' risk-free expression, collaboration, and self-projection, effectively motivating engagement.*

Assertion 3: *The facilitator needs to start with individual face-to-face (F2F) sessions focused on participant-paced Mathematics Knowledge for Teaching (MKT) and Information Communication Technologies (ICT) skills development, with opportunities to showcase development. As confidence and competence grow, there is transition to group and blended sessions. Key priorities include curriculum design; practical methodologies; fostering constructive exchange, and addressing and resolving core issues.*

These assertions are summarised in the two theoretical contributions arising from this study: the Camping Approach, and the Blended Mathematics Teacher Development framework. The Camping Approach demonstrates the design and implementation features of the programme. The Blended Mathematics Teacher Development framework proposes the blended learning educational method for rural South African schools. For clarification, I describe these in the following sections.

7.2 THE CAMPING APPROACH

The Camping Approach, which emerged from this study, demonstrates the programme's design and implementation features. Hence, the '*going camping*' metaphor helps describe the cognitive, social, and teaching presence features that promote effective engagement. In Figure 7-1, I demonstrate a typical South African Campsite, representing the teaching and learning environment. Similar to a campsite that requires a needs analysis to ensure clean water, enough shade, and wood for a campfire, the blended learning programme begins with an orientation and teachers' needs inquiry. Best practices must be adapted to the school contexts where the programme will be delivered, involving thoughtful planning and customisation (see 5.1). Understanding the school environment and each teacher's unique needs, challenges, and resources is crucial (see 5.2). In addition, teachers' demographics, expertise, and available time must be considered (see 4.4.2).

The teachers' existing Mathematics Knowledge for Teaching (MKT) must be evaluated, as well as their ICT skills (see 5.4.1).

To set up camp, preparation needs to be done, such as arranging for the food and beverages, and if there is a need, the fishing gear too. Effective teacher development depends on the pre-workshop preparation stage (see 5.4.1). Consideration should be given to the specific needs and challenges of rural teaching and learning environments, including infrastructure and internet access. Collaboration with teachers is paramount in this teacher-centred programme. Teachers must be involved in the planning of the curriculum by seeking their input and encouraging them to share their needs and professional development goals for the programme. The latter will inform the learning outcomes of the training sessions.

What is a camp without a campfire, ‘braaivleis’, and conversation? Once the environment is set up, much like "*setting up camp*," the focus shifts to creating a "campfire," symbolising an enriching educational experience where quality learning occurs. Using the teacher's inputs obtained during the pre-workshop preparation phase, inform the planning, design and delivery of F2F and online workshops, tailored to their identified needs (see 5.4). I designed and created instructional material on these MKT needs and gathered the necessary concrete resources to conduct creative and interactive workshops addressing the learning outcomes identified by the teachers.

A campfire requires three energies, as illustrated in Figure 7-1: *fuel* (cognitive presence); *oxygen* (social presence), and a *spark* (teaching presence). The synergy of these three energies creates a warm and resourceful campfire. The campfire is a metaphor for the F2F and online workshops.

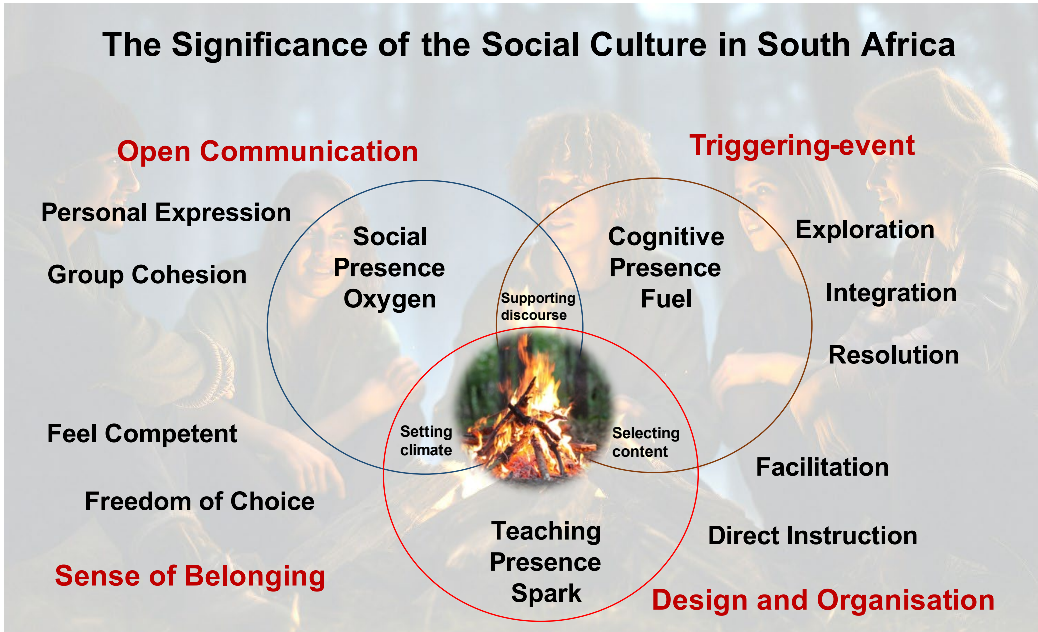

Figure 7.1: ***Effective facilitation requires intensive F2F sessions and continuous support to encourage knowledge implementation.***

Cognitive presence, or *fuel*, encompasses the mathematics information, instructional material, and resources that form the programme's core content, as it focuses on mathematics teacher development (see 5.4.2 & 5.4.4). From this study, I found that providing structured, curriculum-aligned, and quality printed resources, supported discourse and engaged teachers. These resources were designed to assist the teachers in preparing for teaching by compiling mathematics worksheets, assessments, and classroom activities. Furthermore, I encouraged teachers to integrate printed materials with digital content shared via ICTs, enhancing their online engagement and leading to professional development.

Social presence, the *oxygen*, involved the social activities and interactions within the programme (see 5.4.2 & 5.4.4). Therefore, I ensured that all teachers had access to content and resources, regardless of their abilities. For example, I provided printed material to teachers in hard copies for their planning (see 5.4.4). This approach motivated teachers to engage and set a favourable climate for the programme. As the programme developed, teachers realised its value and potential benefits. Hence, the facilitator should start with individual F2F, participant-paced MKT and ICT development sessions and gradually move towards group, online, and blended sessions as confidence and skills develop. Synchronous and asynchronous discussions, classes, and study sessions fostered connections among teachers, enabling teacher-to-teacher interactions. Virtual platforms, such as WhatsApp groups, can facilitate informal discussions and enhance social presence, which is particularly significant in the South African cultural context.

Teaching presence, the *spark* is vital for igniting and maintaining teacher engagement (see 5.4.2 & 5.4.4). Facilitators must inspire and motivate teachers, transforming the learning experience into an active and authentic one. In this study, I found that concrete resources (e.g., manipulatives and printed, structured curriculum instructional materials) effectively motivated teachers to participate actively. For example, I conducted a workshop using toothpicks and jelly sweets to explain 3D mathematics concepts, such as vertices, edges, and faces (see 5.4.4). Teachers actively participated in the workshop by building (and later eating) the 3D shapes. This enjoyable event sparked their interest in online instructional material and resources, after realising the usefulness of the concrete resources and printed material during the workshop. Therefore, facilitators should adopt a guiding role, encouraging investigation, discovery, and knowledge creation. Meeting teachers where they are and modifying instruction to suit their needs is crucial for fostering a positive learning environment.

As can be seen, the campfire metaphor highlights the importance of integrating cognitive, social, and teaching presences to create a powerful and unique educational experience. Content is essential, but it must be accessible and engaging. Social interactions are essential for a lively learning environment, and teaching presence is necessary to inspire and ignite the learning process. I have realised from this study that, in the context of rural South African schools, effective facilitation requires intensive F2F sessions to establish trust and relationships, followed by the introduction of ICTs. This approach must be supported by continuous communication and tailored support to maintain teacher engagement and promote continuous teacher professional development.

Subsequently, the bridge period (see 5.4.3) and sharing online resources (see 5.4.2 & 5.4.5), like a '*campfire conversation*' that continues long after supper, with a cup of hot chocolate, social communication fosters trust, provides opportunities to share experiences and builds relationships (see Figure 7-1). During these two stages, I supported teachers synchronously and asynchronously, providing timely feedback and guidance as needed. This teacher-centred approach can be conducted in a balanced blended approach, F2F and online, to offer a blend of structured guidance and support.

Creating a continuous and collaborative learning culture is essential, as it is where teachers learn from one another and share their ideas. Professional development should be embedded within daily routines, such as mathematics department meetings, standard planning periods, or brief sessions during breaks or free periods.

Prioritising content knowledge and pedagogy is also critical. I addressed subject-specific needs, such as mathematics topics identified by the teachers, relevant to their immediate situations. Feedback and reflection form the most essential part of the initial phase. Through this study, I have realised that teachers sometimes '*do not know what they do not know*' until we engage in reflective conversations. I provided regular feedback to teachers and sought their input on implementation, encouraging them to reflect on their practice and make necessary adjustments.

Respecting teachers' time is crucial, so I encouraged them to allocate dedicated time for professional development, without extending the school day unnecessarily. However, if and when teachers agree to extend the school day, I created structured collaboration blocks. During these blocks, teachers would attend F2F discussions and workshops. I made sure to recognise teachers as professionals during engagement sessions. For example, I celebrated their achievements, acknowledged their expertise, and encouraged ongoing learning and growth. In addition, customisation is critical; therefore, I adapted these practices to fit each school's context and involved all stakeholders for successful implementation. This phase also consists of setting up the necessary technological infrastructure (e.g., learning management systems and communication tools) and training teachers on using ICTs effectively.

7.3 BLENDED MATHEMATICS TEACHER DEVELOPMENT FRAMEWORK

The Camping Approach informed the Blended Mathematics Teacher Development framework presented in Figure 7-2. The Blended Mathematics Teacher Development framework is an instructional model which can be effective in CPTD programmes. The framework for a blended mathematics teacher development programme is the end product of this study and answers the main research question repeated here:

> **What design and implementation features could comprise a framework for blended mathematics teacher development programmes in rural South African schools?**

A comprehensive framework for blended mathematics teacher development programmes in rural South African schools should include several essential design and implementation features (Figure 7.2).

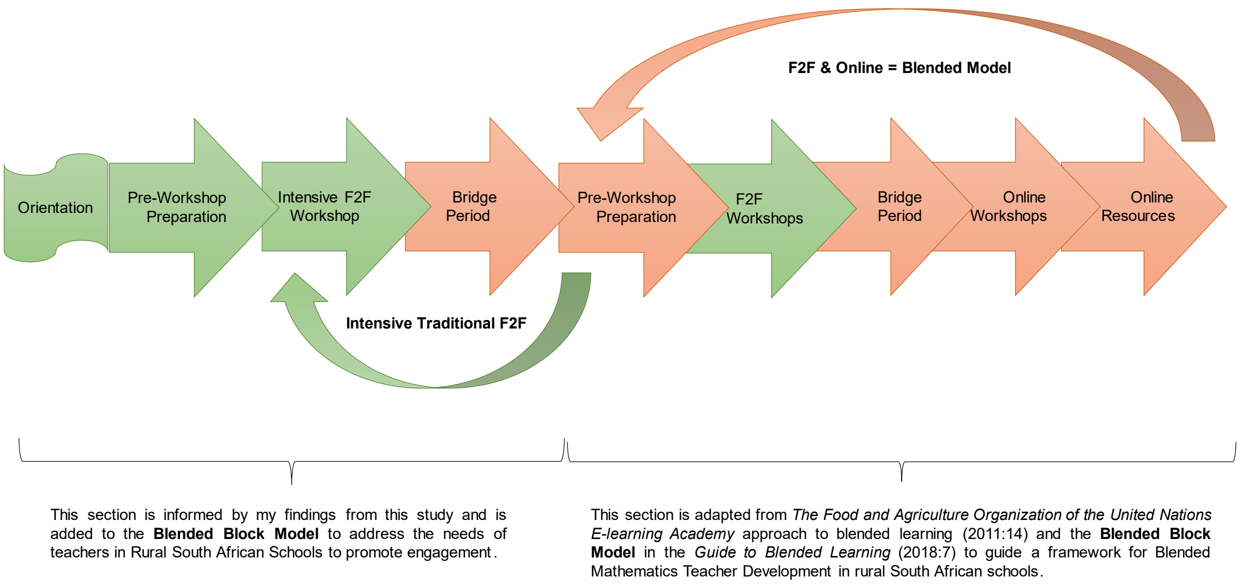

Figure 7.2: *The South African Blended Block Model for Blended Mathematics Teacher Development in Rural South African Schools*.

1. *Orientation phase is crucial to understanding the local context, building relationships, and establishing clear communication and expectations with stakeholders.*
2. *Pre-workshop preparation involves collaboratively designing the programme, ensuring that it aligns with the teachers' needs and available resources.*

3. *Intensive F2F workshops focus on intensive engagement, facilitator presence and collaborative learning.*
4. *Bridge period provides ongoing support and encourages application and reflective practice.*
5. *Second pre-workshop preparation: reflect and analyse previous interventions followed by personalised planning.*
6. *Second F2F workshops characterised by intensive follow-up; reflect with teachers for further action.*
7. *Second bridge period prepare for differentiated support and progressive transition. During this step, teachers can transition to technology-enabled learning or attend F2F workshops.*
8. *Online workshops characterised by reflective preparation. Personalised approach, interactive learning, and flexible delivery.*
9. *Online resources for continuous support, reflective transition, and sustainable development.*

This iterative process fosters engagement, enabling teachers to transition gradually to a fully blended approach as they become more proficient and confident. Following this structured approach, the framework aims to empower mathematics teachers and improve educational outcomes in rural South African schools.

Table 7.1: ***Framework for Designing and Implementing a Blended Mathematics Teacher Development Programme in Rural South African Schools.***

Blended Mathematics Teacher Development Framework		
Steps	**Guiding Principles**	**Activities**
1: Orientation	● **Understand Context:** Develop a comprehensive understanding of the school, local community, and environmental context. ● **Build Relationships:** Establish strong relationships with stakeholders, respecting the school culture and hierarchy. ● **Clear Communication:** Communicate the programme's purpose, participants, expectations, and benefits. ● **Collaborative Design:** Co-design the programme with stakeholders, ensuring mutual agreement on logistics and expectations. ● **Promote Professional Identity:** Foster autonomy, competence, and relatedness to enhance teachers' professional identities. ● **Assess Technology:** Evaluate technology	● Conduct initial meetings to understand the context and build relationships. ● Communicate the programme's purpose, teachers' expectations, and benefits. ● Collaborate with stakeholders to design the programme and schedule sessions. ● Visit the site for assessment and provide necessary technology infrastructure and connectivity. ● Set individual appointments to get to know participating mathematics teachers.

	infrastructure and skills, providing necessary support for online aspects of the programme.	
2: Pre-Workshop Preparation	• **Reflective Design:** Base the programme design on insights gained during the orientation step. • **Materials:** Develop explicit, concise, straightforward instructional materials to avoid cognitive overload. • **Collaborative Reflection:** Engage teachers in reflecting on and agreeing to the programme components.	• Design the instructional programme based on teachers' needs identified in Step 1. • Develop explicit, concise instructional materials. • Plan F2F workshops focusing on developing MKT and ICT skills. • Confirm the programme design with teachers to ensure it meets their needs.
3: Intensive F2F Workshops	• **Intensive Engagement:** Conduct hands-on workshops to develop skills and knowledge. • **Facilitator Presence:** A strong teaching presence motivates and engages teachers. • **Collaborative**	• Conduct F2F workshops at each school, focusing on hands-on activities and practical exercises. • Provide printed materials and concrete resources to motivate

	Learning: Facilitate interaction and collaboration among teachers.	and engage teachers. ● Encourage interaction and collaboration during workshops.
4: Bridge Period	● **Ongoing Support:** Provide continuous support through online platforms and regular communication. ● **Encourage Application:** Motivate teachers to apply workshop learnings in their classrooms. ● **Reflective Practice:** Collect feedback and reflect on the first intervention cycle to inform future planning.	● Offer ongoing support via discussion forums, webinars, and virtual office hours. ● Encourage teachers to complete reflective questionnaires. ● Use feedback to plan subsequent site visits and tailor support to individual needs.
5: Pre-Workshop Preparation	● **Reflective Analysis:** Analyse and reflect on observations and feedback from previous interventions. ● **Personalised Planning:** Plan the next cycle of interventions based on teachers' motivational levels and needs.	● Plan site visits and MKT workshops tailored to the needs of different teacher categories. ● Prepare for individual meetings with teachers.

6: F2F Workshop	● **Intensive Follow-Up:** Conduct a second round of intensive, hands-on workshops to develop skills and knowledge further. ● **Facilitated Reflection:** Reflect with teachers after each intervention to analyse effectiveness and plan next steps.	● Conduct second F2F workshops, focusing on hands-on activities and collaborative learning. ● Reflect with teachers' post-workshop to gather insights and feedback. ● Analyse each workshop to inform bridge period planning.
7: Bridge Period	● **Tailored Support:** Prepare for differentiated support based on teachers' skill levels and interests. ● **Progressive Transition:** Move skilled and interested teachers to the bridge period for more advanced development.	● Assess which teachers need further pre-workshop preparation and which are ready for the bridge period. ● Plan for continued mentoring and support for teachers needing additional help. ● Prepare advanced resources and support for teachers entering the bridge period.

8: Online Workshop	• **Reflective Preparation:** Review previous workshops and site visits to plan the next F2F / online workshop. • **Personalised Approach:** Tailor the F2F / online workshop to the teachers' needs and skill levels.	• Reflect on the outcomes of previous workshops and site visits. • Design and prepare materials for the F2F /online workshop. • Ensure the F2F / online workshop meets the needs and expectations of the participants.
	• **Interactive Learning:** Conduct online workshops that promote interaction and active learning. • **Flexible Delivery:** Provide flexible access to online workshop materials and sessions.	• Conduct online workshops using interactive tools and methods. • Provide recorded sessions and resources for flexible access. • Facilitate discussions and collaborations through online platforms.

9: Online Resources	**Continuous Support:** Maintain ongoing online support and mentorship for all teachers. **Reflective Transition:** Reflect on the effectiveness of the blended approach and make necessary adjustments. **Sustainable Development:** Ensure the programme is sustainable and can be maintained with reduced site visits.	- Continue providing online support and mentorship. - Reflect on the blended approach's effectiveness and gather feedback from teachers. - Adjust the programme as needed to ensure sustainability and effectiveness. - Gradually reduce site visits as teachers become more skilled and self-reliant, increasing the focus on online training and support.

Following these steps and principles, the programme aims to create a sustainable, effective, blended mathematics teacher development programme that enhances teachers' skills and improves mathematics education in rural South African schools.

7.4 RECOMMENDATIONS

To design and implement a blended mathematics teacher development programme in rural South African schools, the following recommendations are made:

7.4.1 Mathematics Teacher Development

The study demonstrated that the engagement of most of the teachers involved in the blended mathematics teacher development programme increased throughout the programme. The teachers' active engagement became more evident as their confidence and skills developed in mathematics content knowledge, pedagogy, classroom management, and ICT skills (see 5.7.3 & 5.8). Therefore, the study recommends that teachers be involved in tailor-made blended mathematics teacher development programmes that promote active engagement. The blended mathematics teacher development programme aims to offer professional development opportunities to teachers in rural South African schools. Rural school teachers do not have equal opportunities for professional development as urban schools, which are situated closer to educational institutions (Padayachee & Campbell, 2021; Jita & Dhliwayo, 2024). Furthermore, limited access to resources, internet access (Ghimire, 2022; Ford et al., 2014) and the high cost of educational opportunities, such as workshops, conferences or breakfast or dinner sessions with professional bodies (see SACE (n.d.)) are some of the problems these teachers face (Padayachee & Campbell, 2021).

7.4.2 School management

The study noted that the support of the principal, deputy principal and the school management team is crucial for the blended mathematics teacher development programme to be initiated and successfully implemented. In this study, the involvement of the school leadership that supported the blended mathematics teacher development programme contributed to its successful implementation. Therefore, the study emphasises the necessity for the commitment and participation of the principal, deputy principal, and school management team, so that teachers can benefit optimally from this blended mathematics teacher development programme.

The poor ICT infrastructure in some schools where the teachers work, negatively impacted the implementation of ICTs. The ICT infrastructure was there in some schools, but it appeared to be accessible only to the management and administrative staff. This created conflict and tension among teachers and other non-teaching staff members. Therefore, the study recommends that principals as ICT leaders must lead the process of drawing up an ICT policy. The ICT policy would prevent favouring certain employees, minimise tensions in the schools, and advance a sense of shared ownership of ICT resources.

7.4.3 Department of Education

The study revealed that despite establishing frameworks, the implementation of CPTD faced challenges such as resource constraints, varying levels of teacher engagement, and the need for more effective monitoring and evaluation (see 2.1). In addition, there is no guiding framework to date, for rural South African schools on how CPTD should be designed and implemented. This absence of a practical CPTD framework, especially for the professional development of mathematics teachers in South Africa, has resulted in inconsistent and ineffective training (see 2.1). There is an urgent need to guide schools in developing tailor-made, blended mathematics teacher development programmes and realistic and pragmatic implementation plans. The following could be included in the guidelines for schools and other stakeholders:

- Schools and stakeholders should clarify the teachers' needs before implementing the blended mathematics teacher development programme.
- The blended mathematics teacher development programme should not be imposed but collaboratively developed by all stakeholders, including the mathematics teachers.

- Schools should establish CPTD committees and designate a competent and enthusiastic mathematics teacher overseeing all matters related to blended mathematics teacher development programmes. The ICT component of the blended mathematics teacher development programme might need a member of the school's IT team to manage the technicalities concerning online workshops, material, LMS, etc., and act as a leader to motivate and assist teachers in using ICT.
- Collaboration between Mathematics teachers and ICT leaders from neighbouring schools could provide a space for support and capacity building.

7.5 LIMITATIONS

The blended mathematics teacher development programme I investigated represents only seven South African rural area schools. This programme is tailor-made for the project schools where I facilitate and mentor mathematics in-service teachers. However, in some senses, it represents many typical mathematics in-service teachers because the blended mathematics teacher development programme involves teachers of various backgrounds, experience, qualifications, skills, and cultures. In addition, the Eastern Cape is viewed as one of South Africa’s poorest provinces with limited resources, and the very rural areas experience intense connectivity problems, especially during load shedding and power cuts. Nevertheless, my study gives insight into potentially effective ways to design and implement a framework for blended mathematics teacher development programmes. It is hoped that readers can extract those aspects of the narrative presented in these pages that are relevant to their local situation and construct an understanding of the framework that would work for them.

In this way, it is hoped that this study will help inform practice. The likelihood of this has increased because the suggestions made from this study, have emerged from a participatory action-based research process within the complexities of actual practice. This increases the likelihood that practitioners will view the findings as applicable to their situations. On the other hand, the process I suggest requires considerable effort, time, and skill from the facilitator or programme manager. I fulfilled both roles, which was not desirable. When the blended mathematics teacher development programme is implemented on a bigger scale, it reveals the importance of the facilitator as a co-inquirer in the struggle involved in sense-making. It requires the facilitator to monitor work in contexts where quality is unlikely to be produced without considerable effort, time, and guidance. It also suggests the importance of the facilitator's modelling and encouraging engagement daily. Further, it indicates the input from individual teachers and a tailor-made blended mathematics teacher development programme, which can be time-consuming and challenging to set up and implement. This process also requires the facilitator to have an in-depth conceptual understanding to make appropriate decisions, when designing instructional material and planning F2F or online workshops. These findings show that hard work and risk on the part of the facilitator are required by the more complex, interactive facilitator-teacher relationship associated with a constructivist teaching-learning scenario, relative to a traditional view of transmission and absorption (Driscoll, 2002; Gresalfi et al., 2009). These aspects seem to reduce the likelihood that the framework emerging from this study will be employed widely by many practitioners. Research shows that the effectiveness of these programmes depends on their design, implementation, and the support provided to teachers (Cleveland-Innes & Wilton, 2018; Padayachee & Campbell, 2021; Moss, 2021).

As mentioned, CPTD initiatives such as QMS and SACE PDP, school management and teachers tend to simplify tasks to reduce insecurity and confrontation (SACE (n.d.); Simelane & Mutambara, 2022; Badaru & Adu, 2022). The descriptions given in this study show that the Camping Approach, emerging from this study, often leads to feelings of insecurity and should, at least for some activities, involve a long-term, struggle-filled process. Should facilitators adapt and change this framework to remove the need for this struggle and make implementation more manageable, the framework is unlikely to promote active engagement. The simplification process is the main reason for the failure of the process-oriented instructional strategies developed by scientists and implemented in the US after World War II (Reason & Bradbury, 2005).

On the other hand, South African teachers seem to be willing to change. A lack of clarity on how to do this in practice, questioning the nature of workshops conducted by SACE and the DBE, as well as the need for better support structures for teachers to enhance their professional development seem to be the limiting factors (Ndaba et al., 2023; Simelane & Mutambara, 2022). My experience through interaction with principals, teachers, and other stakeholders is consistent with this viewpoint. This increases the likelihood that some stakeholders would embrace the Framework for Blended Mathematics Teacher Development, which has shown promise and is grounded in actual practice.

7.6 IMPLICATIONS

Blended learning is a relatively young teaching and learning approach, especially in the South African context. While CPTD had been studied to an extent in South Africa, these studies focused on traditional teacher training approaches (see 2.1). In addition, the blended learning models that best fit the rural South African context were from *The Food and Agriculture Organization of the United Nations E-learning Academy* approach to blended learning (2011:14) and the Blended Block Model in the *Guide to Blended Learning* (Cleveland-Innes & Wilton, 2018, p. 7) (see 2.2).

The results of these studies have already been discussed. They show practices for an ideal internet access and connectivity environment, and where resources are available. I concluded from this that there was a need to understand how to design and implement blended learning in the rural environment of some South African schools. However, an extensive study of the literature at the beginning of this study did not reveal much practical advice on achieving blended learning successfully, and there were limited discussions within the context of rural South African schools. There are also no empirically tested exemplars to guide programme designers and facilitators into the setting of a culture that does not value initiatives where technology integration in education is attempted. This creates a barrier to accepting and utilising blended learning. Some teachers also resisted adopting new teaching methodologies and professional development practices, particularly those related to ICTs and LMS. From my findings, addressing these challenges involves extensive planning, training, and ongoing support. Therefore, balancing F2F, online and mentoring phases, required careful planning. Teachers need clear guidance and the opportunity to share their thoughts and ideas on how this programme could address their needs. This could also lead to self-directed learning and participation when teachers feel they are part of the programme design. The programme design and implementation involve collective planning, communication, and adaptability. The Camping Approach forms the pillars of the Framework, which can be seen as a guideline for blended mathematics teacher development programmes. I see it as distinct from the current models and approaches which fall into the CPTD category. Through this new framework proposal, I believe this study could contribute to understanding beneficial CPTD. This is particularly so in the context of promoting mathematics teachers' professional development within rural South African schools, but not limited to this area. I believe this framework is similar to Cleveland-Innes and Wilton (2018), who describe blended learning as the ideal approach to teaching and learning.

Furthermore, this study will hopefully contribute to the participatory action research methodology (PAR). I suggest that the framework in Figure 4-2 is valuable for investigating what design and implementation features could comprise a framework for blended mathematics teacher development programmes. I found this to be both feasible to use and appropriate. This study has some implications for further investigations. Research on implementing the Camping Approach in alignment with the HRDS Quadrant in other environments in South Africa or other countries, and for teaching disciplines other than mathematics, would enhance an understanding of its applicability to contexts different from my programme. It would also be interesting to investigate whether attempts to design and implement a framework like this one, have value beyond the rural environment and technologically impaired settings. This could be done in a more advantaged environment, where teachers can access resources and connectivity with more ease. It would also be interesting to see how the teachers who participated in this blended mathematics teacher development programme continue to participate in professional development activities, and thus, keep their campfire burning, now that they have firewood and have been sparked.

7.7 CONCLUSION

In this chapter, I have summarised the knowledge claims I have made in this study, focusing on the assertions made in Chapter Six, in answer to the study's research questions. I have also expounded on the Camping Approach and Blended Mathematics

Teacher Development framework to comprehend these assertions. The Camping Approach highlights the importance of integrating cognitive, social, and teaching presences to create a powerful and unique educational experience.

The framework for a blended mathematics teacher development programme is the end product of this study. By understanding and addressing the unique needs of each participant, I aimed to create a supportive and motivating environment that fosters active participation and professional development. This tailored approach ensures that all teachers, regardless of their initial motivation or skill level, can benefit from the blended mathematics teacher development programme and enhance their teaching practices. In summary, strengthening competence, autonomy, and relatedness in the facilitation process, creates a conducive environment for teachers to motivate themselves, improving engagement and participation and realising their professional identity.

I entered this study enthusiastically and optimistically, hoping that I could spark teachers' interest and create a campsite where teaching and learning would take place and conversations would be long-lasting. While my campfire is still burning and conversations are continuing, I listen with heightened attention and a good deal of respect for the effort required for professional development, especially for in-service teachers with limited resources and time. Here follows the words of one teacher, who appreciated my efforts and energy, during a LEGO training workshop:

> *"Thank you for letting our kids play again." (C3 Bella: OR)*

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APPENDIX A: BIOGRAPHICAL QUESTIONNAIRE: BLENDED MATHEMATICS TEACHER DEVELOPMENT PROGRAMME

Biographical Questionnaire: Blended Mathematics teacher development programme

Please help me to improve our blended mathematics teacher development programme in the future by filling out this anonymous questionnaire.

* Indicates required question

1. Email *

____

2. Do you give permission for your answers to this questionnaire to be used for research purposes? *

This will not harm you in any way, but will help us in improving our blended mathematics teacher development programme in the future. Since this is an anonymous questionnaire, your answers cannot be traced back to you.

Mark only one oval.

- Yes
- No

3. What is your age? *

____

4. What is your gender? *

Mark only one oval.

- Female
- Male
- Prefer not to say
- Other: ______________________

5. What is your highest qualification? *

Mark only one oval.

- ⬭ Four-year Bachelor of Education degree (B. Ed.)
- ⬭ Three-or four-year Bachelor's degree
- ⬭ One-year Postgraduate Certificate in Education (PGCE)
- ⬭ Bachelor of Education Honours
- ⬭ Masters in Education
- ⬭ Doctoral in Education
- ⬭ Honours degree (other field)
- ⬭ Masters degree (other field)
- ⬭ Doctoral degree (other field)
- ⬭ Other: ____________________

6. If you selected other, list your qualifications here.

____

____

____

____

____

7. What kind of school do you teach at? *

Mark only one oval.

- ⬭ Quintile 1-3 (schools serving poor communities)
- ⬭ Quintile 4 (schools serving emerging communities)
- ⬭ Quintile 5 (generally X-Model-C schools)
- ⬭ Independent
- ⬭ Other: ____________________

8. At which school do you teach? (Write your school's name) *

____

9. Did you register on BeeLine? *

Mark only one oval.

- ◯ Yes
- ◯ No

10. If you did not register on BeeLine, please tell us what prevented you from registering on BeeLine. *

If you did register on BeeLine, write n/a or not applicable.

11. How much time did you spend on BeeLine? *

Mark only one oval.

- ◯ less than 5 hours
- ◯ 5-10 hours
- ◯ 10-15 hours
- ◯ 15-20 hours
- ◯ More than 20 hours
- ◯ Other: ________________

12. How much time do you think you should have spent on BeeLine to get the most out of it? *

Mark only one oval.

- Much more than I did
- A little more than I did
- I think I spent the right amount of time on it
- A little less than I did
- Much less than I did
- Other: ______________________

13. Did you download the Monyetla App. *

Mark only one oval.

- Yes
- No

14. If you did not download the Monyetla App, please tell us what prevented you from downloading the Monyetla App. *

If you did download the Monyetla App, write n/a or not applicable.

15. How much time did you spend on the Monyetla App? *

Mark only one oval.

- less than 5 hours
- 5-10 hours
- 10-15 hours
- 15-20 hours
- More than 20 hours
- Other: ______________________

16. How much time do you think you should have spent on the Monyetla App to get the most out of it? *

Mark only one oval.

- Much more than I did
- A little more than I did
- I think I spent the right amount of time on it
- A little less than I did
- Much less than I did
- Other: ______________________

17. What other Applications or ICT resources do you make use of? (For example: Telegram, Teacha, Department of Education Websites) Name them all here. *

18. What access do you have to ICTs? *

Check all the blocks that are applicable

Check all that apply.

	I own at least one of these, so I can use it at home or at school	Someone at home owns one of these, so I can use theirs at home	My school lets me use one of these and I can take it home with me too	My school lets me use one of these, but only at school	I don't have access to one of these at any time - home or school	I have access to one of these, but I don't use it because I don't know how to use it / I don't feel confident at using it	I have access to one of these, but I don't use it because of another reason that I will explain below
Smart phone (a cell phone that can go onto the internet - not just make phone calls and send SMSs)	☐	☐	☐	☐	☐	☐	☐
Tablet	☐	☐	☐	☐	☐	☐	☐
Computer (laptop / desktop)	☐	☐	☐	☐	☐	☐	☐

19. Optional: Clarify your answers to any of the questions above, if necessary

20. What access do you have to the internet? *

Mark only one oval per row.

	very little to none because of the high cost	very little to none because of poor coverage in the area	fair to good speed, but limited data	data is unlimited or enough for my needs, but speed stops me from being able to do what I need	excellent: unlimited or enough for my needs, and the speed is sufficient for my needs	other (which I will explain below)
At home	⬭	⬭	⬭	⬭	⬭	⬭
At school	⬭	⬭	⬭	⬭	⬭	⬭

21. Optional: Clarify your answers to any of the questions above, if necessary

Thank you for your time and input. It is much appreciated.
Have a nice day!

APPENDIX B: COLLECTIVE IDENTIFICATION OF MATHEMATICS TRAINING AND DEVELOPMENT NEEDS

Collective Identification of Mathematics Training and Development Needs

Demographic Information

* Indicates required question

1. Email *

2. Name and Surname: *

3. School Name: *

4. Grade Taught: *

5. Years of Teaching Experience: *

6. Do you have internet access? *

   Check all that apply.

   - [ ] Yes
   - [ ] No
   - [ ] Other: __________

General Professional Development Needs

7. How often do you participate in professional development activities? *

Check all that apply.

- [ ] Never
- [ ] Occasionally
- [ ] Sometimes
- [ ] Often
- [ ] Always

8. What types of professional development activities have you found most beneficial in the past?
(Select all that apply) *

Check all that apply.

- [ ] Face-to-face workshops
- [ ] Online workshops
- [ ] Peer collaboration
- [ ] Conferences
- [ ] In-service training
- [ ] Other (please specify)

9. What are the barriers to your participation in professional development activities? (Select all that apply) *

Check all that apply.

- [ ] Time constraints
- [ ] Lack of access to quality programmes
- [ ] Cost
- [ ] Lack of support from management
- [ ] Lack of internet and ICTs
- [ ] Other (please specify)

Specific Mathematics Training Needs

Complete this section with as much detail as possible.

10. Please rate your confidence in teaching the following mathematics topics: *

Mark only one oval per row.

	Very Confident	Confident	Neutral	Not Confident	Not at all Confident
Number Theories	⬭	⬭	⬭	⬭	⬭
Patterns	⬭	⬭	⬭	⬭	⬭
Functions	⬭	⬭	⬭	⬭	⬭
Trigonometry	⬭	⬭	⬭	⬭	⬭
Financial Mathematics	⬭	⬭	⬭	⬭	⬭
Algebra	⬭	⬭	⬭	⬭	⬭
Calculus	⬭	⬭	⬭	⬭	⬭
Geometry	⬭	⬭	⬭	⬭	⬭
Statistics	⬭	⬭	⬭	⬭	⬭
Probability	⬭	⬭	⬭	⬭	⬭

11. Which mathematics topics do you feel you need most training on? (Select up to 3): *

Check all that apply.

- [ ] Number Theory
- [ ] Algebra
- [ ] Geometry
- [ ] Calculus
- [ ] Statistics
- [ ] Probability
- [ ] Functions
- [ ] Other (please specify)
- [ ] Other: ______________________

12. What specific challenges do you face in teaching the mathematics topics you selected above? *

13. Have you previously received training on any of these topics? If yes, please specify the type and provider of the training. *

Preferred Training Formats and Resources

Please give as much detail as possible.

14. Which training formats do you prefer? *
(Select all that apply)

Check all that apply.

- [ ] Face-to-face, traditional workshops
- [ ] Online workshops
- [ ] Webinars
- [ ] Peer mentoring
- [ ] Self-paced modules
- [ ] Other (please specify)
- [ ] Other: ______________________

15. What resources do you believe would help you improve your teaching of mathematics topics? *
(Select all that apply)

Check all that apply.

- [ ] Lesson plans
- [ ] Teaching guides
- [ ] Classroom activities
- [ ] Assessment tools
- [ ] Technology tools and apps
- [ ] Other (please specify)
- [ ] Other: ______________________

16. Are there any additional resources or supports you need to effectively teach mathematics? Please explain. *

____
____
____
____
____

17. What additional topics or areas do you think should be included in professional development for mathematics teachers?

____
____
____
____
____

18. How can professional development programmes be improved to better meet your needs?

19. Any other comments or suggestions regarding professional development and training needs?

Thank you for completing this questionnaire. I am looking forward meeting with you during our next training session.

Maryke la Grange-Taylor
Contact information:
079 514 4140
marykelgt@gmail.com

APPENDIX C: COMMUNITY OF INQUIRY BLENDED LEARNING EVALUATION

COMMUNITY OF INQUIRY
BLENDED LEARNING EVALUATION

SCHOOL / SESSION NAME:

____

DATE:

____

LEARNING OUTCOME:

____

SP: SOCIAL PRESENCE CP: COGNITIVE PRESENCE TP: TEACHING PRESENCE EP: EMOTIONAL PRESENCE

	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE	
1. Teachers can describe ways to test and apply the knowledge learnt.	1	2	3	4	5	**CP:** *Resolution*
2. My actions reinforce the development of a sense of community among workshop participants.	1	2	3	4	5	**TP:** *Facilitation*
3. Teachers in my workshop are motivated to explore content-related questions.	1	2	3	4	5	**CP:** *Triggering Event*
4. Workshop activities pique teachers' curiosity.	1	2	3	4	5	**CP:** *Triggering Event*

5. I acknowledge emotion expressed by the teachers in my workshop.	1	2	3	4	5	**EP:** *(Teaching Presence)*
6. I communicate important dates/time frames for learning activities.	1	2	3	4	5	**TP:** *Design and Organisation*
7. Teachers in my workshop can form distinct impressions of other participants.	1	2	3	4	5	**SP:** *Personal Expression*
8. I communicate essential goals.	1	2	3	4	5	**TP:** *Design and Organisation*
9. I provide feedback in a timely fashion.	1	2	3	4	5	**TP:** *Direct Instruction*
10. I provide feedback that helps teachers understand their strengths and weaknesses relative to the goals and objectives.	1	2	3	4	5	**TP:** *Direct Instruction*
11. I help to identify areas of agreement and disagreement on topics in a way that allows teachers to learn.	1	2	3	4	5	**TP:** *Facilitation*
12. Teachers feel comfortable disagreeing with other participants while still maintaining a sense of trust.	1	2	3	4	5	**SP:** *Group Cohesion*
13. Reflection on content and discussions helps teachers understand fundamental concepts.	1	2	3	4	5	**CP:** *Integration*
14. Expressing emotion in relation to sharing ideas is acceptable in my workshop.	1	2	3	4	5	**EP:** *(Cognitive Presence)*
15. Discussions are facilitated in a valuable way to help teachers appreciate different perspectives.	1	2	3	4	5	**CP:** *Exploration*

16. I encourage participants to explore new concepts.	1	2	3	4	5	**TP:** *Facilitation*
17. I communicate essential topics.	1	2	3	4	5	**TP:** *Design and Organisation*
18. Combining new information helps teachers answer questions raised in activities.	1	2	3	4	5	**CP:** *Integration*
19. Brainstorming and finding relevant information helps teachers resolve content-related questions.	1	2	3	4	5	**CP:** *Exploration*
20. In my role as instructor is to demonstrate emotion in my presentations and/or when facilitating discussions.	1	2	3	4	5	**EP:** *(Teaching Presence)*
21. Learning activities help teachers construct explanations/solutions.	1	2	3	4	5	**CP:** *Integration*
22. Teachers feel their point of view is acknowledged by other participants.	1	2	3	4	5	**SP:** *Group Cohesion*
23. Participants feel comfortable taking on the role of teacher when the opportunity arises.	1	2	3	4	5	**TP:** *Facilitation*
24. Teachers utilise a variety of information sources to explore problems posed in my workshop.	1	2	3	4	5	**CP:** *Exploration*
25. I keep teachers engaged and participating in productive dialogue.	1	2	3	4	5	**TP:** *Facilitation*
26. Teachers feel comfortable interacting with other participants.	1	2	3	4	5	**SP:** *Open Communication*
27. I provide clear instructions on how to participate in learning activities.	1	2	3	4	5	**TP:** *Design and Organisation*

28. I find myself responding emotionally to ideas or learning activities.	1	2	3	4	5	**EP:** *(Cognitive Presence)*
29. Knowing other participants gives teachers a sense of belonging.	1	2	3	4	5	**SP:** *Personal Expression*
30. Teachers feel comfortable conversing.	1	2	3	4	5	**SP:** *Open Communication*
31. Online or web-based communication is an excellent medium for interaction with and among teachers.	1	2	3	4	5	**SP:** *Personal Expression*
32. Problems posed increase teacher interest in content.	1	2	3	4	5	**CP:** *Triggering Event*
33. Teachers can apply the knowledge created to their work or other non-class-related activities.	1	2	3	4	5	**EP:** *(Social Presence)*
34. I help to focus discussion on relevant issues in a way that allows teachers to learn.	1	2	3	4	5	**TP:** *Direct Instruction*
35. Teachers can apply the knowledge created to their work or other non-class-related activities.	1	2	3	4	5	**CP:** *Exploration*
36. Teachers feel comfortable participating in discussions.	1	2	3	4	5	**SP:** *Open Communication*
37. Teachers develop solutions to relevant problems that can be applied in practice.	1	2	3	4	5	**CP:** *Resolution*
38. I help guide teachers towards understanding topics in a way that allows them to clarify their thinking.	1	2	3	4	5	**TP:** *Facilitation*
39. Discussions can help teachers to develop a sense of collaboration.	1	2	3	4	5	**SP:** *Group Cohesion*
40. Emotion is expressed, f2f or online, among the teachers in my course.	1	2	3	4	5	**EP:** *(Social Presence)*

APPENDIX D: REFLECTIVE JOURNAL

Reflective Journal

School:		Date:	
Workshop title:		Facilitator(s):	
Workshop description: [Write a brief description of the course]			
Learning objectives: The teachers in this course are expected to be able to: [Use action verbs, provide a bulleted list of what the teachers will be able to do after going through this course.]			
<u>Course structure</u>			
Title			
Learning Outcomes			
Learning activities: F2F / Online			
Learning content: F2F / Online		Self-created / Web resources	
Facilitating: F2F / Online		Mentoring: F2F / online	
Number of Participants:			

Community of Inquiry Blended Learning

Elements	Categories	Indicators	Presence	Research Cycle _____	
				F2F	Online
Social Presence	Open Communication	Risk-Free Expression	Build trusting relationships and express the safety of the teacher-facilitator and teacher-teacher platform where we discuss our mathematics needs and abilities and identify the areas where we need support and personal growth and where our strengths lie.		
	Group Cohesion	Encourage Collaboration	Create a sense of belonging in the programme and interactions among teachers. Share ideas with mathematics teachers on how to work with and connect with other teachers via digital platforms such as BeeLine, WhatsApp, email, etc. Encourage teachers to share mathematics lessons, work together, and support each other in achieving common goals.		
	Personal Expression	Design and compile their own lessons on topics that they feel comfortable with.	Teachers are to share mathematics lessons/resources. Effective collaboration and coordination enhance task cohesion. Feel comfortable disagreeing/interacting with others. Converse freely F2F / online.		

Cognitive Presence	Exploration	Information Exchange	Mathematics Teacher Development Workshops [F2F and online] share various information on topics in mathematics and show how to use ICTs to access lessons, resources, and other material.		
	Triggering-events	Conflicting Ideas / Puzzlement	This creates a sense of curiosity and prompts the teacher to investigate further. Teachers generate unintended but productive ideas around mathematics teaching and learning. The goal is to fully engage teachers to ensure engagement in learning.		
	Integration	Connecting Ideas	By showing the teachers practical [Worked Examples], teachers relate different pieces of mathematics knowledge, bridging gaps between concepts. Teachers combine mathematics information from various sources to form a coherent whole. The teacher applies their understanding to real-world contexts or problem-solving.		
	Resolution	Apply Ideas for Problem Solving & New Scenarios	Q&A to help and support teachers in their learning journey, form coherent understandings and consolidate insights. The resolution phase provides closure to the inquiry process.		

Cognitive Presence	Exploration	Information Exchange	Mathematics Teacher Development Workshops [F2F and online] share various information on topics in mathematics and show how to use ICTs to access lessons, resources, and other material.		
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	Resolution	Apply Ideas for Problem Solving & New Scenarios	Q&A to help and support teachers in their learning journey, form coherent understandings and consolidate insights. The resolution phase provides closure to the inquiry process.		

Self-determination Theory

Self-determination Continuum			Notes / Observations / Reflections
Amotivation	Non-regulation	The individual lacks any intention to act. Complete absence of autonomous motivation. Lack of a sense of purpose or interest in activities. Do not see any meaningful connection between activity and results. This can also stem from a perceived lack of competence, feeling incapable or ineffective.	
Extrinsic Motivation	External Regulation	Motivation is driven by external factors (rewards, punishments, social pressure). Actions are not inherently satisfying; they serve an external purpose. Focus on obtaining a reward / avoiding negative consequences. Participate in the mathematics teacher development programme to prevent possible negative comments.	
	Introjected Regulation	Act due to a sense of obligation rather than internal desire/enjoyment. Behaviour is driven by avoiding shame, guilt or seeking pride. Teachers participate in the mathematics teacher development programme to avoid feeling guilty about not participating.	
	Identified Regulation	Individuals attribute personal importance and conscious value to a specific regulation. Behaviour is willing engagement. Teachers participate for better mathematics understanding, believe it is important to better self-development, and it confirms self-image.	

	Integrated Regulation	Teachers fully assimilate an external regulation into their sense of self. Act because it aligns with individual core values, even though they may have originated externally. Teachers who consistently engage in the mathematics teacher development programme because they deeply value self-development and want to learn more about mathematics and ICT skills.	
Intrinsic Motivation	Intrinsic Regulation	Individuals are self-determined and driven by interest, enjoyment, and the inherent satisfaction derived from their activity. Mathematics teachers enjoy engaging in the content of the teacher development programme. The internal drive is where individuals find fulfilment in activities for their own sake.	

APPENDIX E: BLENDED LEARNING EVALUATION: ICT SKILLS

Blended Learning Evaluation: ICT Skills

Please rate your agreement with the following statements regarding your ICT skills:

* Indicates required question

1. Email *

2. School Name *

3. Participant Name *

4. Basic Computer Skills *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can effectively use essential computer functions (e.g., turning on/off, using the keyboard and mouse).	⬭	⬭	⬭	⬭	⬭

5. Word Processing *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can create, edit, and format documents using word processing software (e.g., Microsoft Word, Google Docs).	⬭	⬭	⬭	⬭	⬭

6. Spreadsheets *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can create, edit, and analyse data using spreadsheet software (e.g., Microsoft Excel, Google Sheets).	⬭	⬭	⬭	⬭	⬭

7. Presentation Software *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can create and deliver presentations using software (e.g., Microsoft PowerPoint, Google Slides).	⬭	⬭	⬭	⬭	⬭

8. Internet and Email *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can effectively use the internet to search for information and communicate via email.	⬭	⬭	⬭	⬭	⬭

9. Learning Management Systems (LMS) *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can use an LMS (e.g., BeeLine) to access course materials and for self-study.	⬭	⬭	⬭	⬭	⬭

10. Online Collaboration Tools *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can use online collaboration tools (e.g., Google Drive and Microsoft Teams) to collaborate with the facilitator and colleagues.	⬭	⬭	⬭	⬭	⬭

11. Educational Software and Tools *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can integrate educational software and tools (e.g., educational apps) into my teaching and learning.	⬭	⬭	⬭	⬭	⬭

12. Troubleshooting *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I can troubleshoot common technical issues (e.g., printer problems and software crashes) that arise during a workshop or when I access resources and material online.	⬭	⬭	⬭	⬭	⬭

13. Continuous Professional Development *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
- I actively seek opportunities to improve my ICT skills through professional development.	⬭	⬭	⬭	⬭	⬭

Thank you for completing this document. The information you provided will assist me in designing the blended mathematics teacher development programme more effectively.

Maryke
la Grange-Taylor

Contact details:

0795144140

marykelgt@gmail.com

APPENDIX F: SEMI-STRUCTURED INTERVIEW

Semi-structured Interview

1. Cognitive Presence:

    - How do you utilise this programme's mathematics resources and information in your teaching?
    - Describe how you applied mathematics knowledge learnt from this programme in your teaching or preparation.
    - How did discussions during workshops influence your perspective on teaching mathematics?
    - Describe how you applied ideas and solutions shared during workshops in practice.
    - Reflect on the programme; tell me how the mathematics content covered in the workshop changed your understanding of mathematics.
    - Thinking of our discussions on ____ mathematics topics in the workshop, tell me how it influences your understanding.
    - How did brainstorming and finding new ideas for teaching and learning mathematics change your understanding of the topic?
    - Tell me how the learning activities and resources shared during the workshop influenced your understanding of the topic.
    - Does the mathematics content covered in the workshop interest you and make you curious to learn more about the topic?

2. Teaching Presence:

    - How would you describe the facilitator's method of communication?
    - Does the facilitator ensure that her teaching methods encourage participants to discuss and exchange ideas with their peers?
    - Was the topics covered during the workshop communicated?
    - Was the workshop organised to ensure participants understand what is expected of them and how to participate effectively?
    - Describe how the facilitator interacts with participants to establish a sense of community and social presence in the classroom.
    - How does the facilitator provide feedback to participants to help them understand the presented mathematics concepts?
    - Can you describe a direct teaching intervention you have used in your practice to reach a consensus on a complex issue?
    - How does the facilitator support participants who may have difficulty understanding the mathematics content presented in the workshop?
    - Explain how the facilitator encourages participants to explore new concepts in mathematics.
    - How and when did the facilitator provide feedback to participants?

APPENDIX G: LESSON OBSERVATION TOOL FOR MATHEMATICS

Lesson Observation Tool for Mathematics

School Name:	
Date:	
Lesson Title:	
Teacher Observed:	
Grade Level:	

Lesson Content and Planning	
Objective(s) of the Lesson:	1.
	2.
	3.
Lesson Alignment	
1. Is the lesson aligned with curriculum standards and learning objectives?	
2. How does the teacher demonstrate alignment with the content?	

Instructional Strategies and Techniques	
Teaching Methods Used:	1.
	2.
	3.
Engagement	
3. How does the teacher engage in learning activities?	
4. Are the teacher actively participating in the learning process?	

Classroom Environment	
Classroom Management	
5. How effectively does the teacher manage the classroom and transitions?	
6. How does the teacher communicate expectations/learning outcomes?	

Teaching and Learning	
Teacher Understanding	
7. Does the teacher show an understanding of the topic being taught?	
8. If not, identify the part where an inability to understand could be noted.	

Collaborative Reflection and Next Steps	
Reflection	
9. What are the teacher's reflections on the lesson?	
10. What worked well, and what could be improved?	
Next Steps	
11. Recommendations for the teacher moving forward?	
12. How can the teacher continue to improve instructional practices?	

Overall Observations	
Strengths Observed	Areas of Growth
Additional Notes	

Maryke la Grange-Taylor

Contact details:

0795144140

marykelgt@gmail.com

APPENDIX H: BLENDED MATHEMATICS TEACHERDEVELOPMENT PROGRAMME

Questionnaire: Blended Mathematics teacher development programme

Please help us to improve our blended mathematics teacher development programmes in the future by filling out this anonymous questionnaire.

* Indicates required question

1. Email *

2. Do you give permission for your answers to this questionnaire to be used for research purposes? *

This will not harm you in any way, but will help us in improving our blended mathematics teacher development programme in the future. Since this is an anonymous questionnaire, your answers cannot be traced back to you.

Mark only one oval.

- Yes
- No

3. Did you register on BeeLine? *

Mark only one oval.

- Yes
- No

4. If you did not register on BeeLine, please tell us what prevented you from registering on BeeLine. *

If you did register on BeeLine, write n/a or not applicable.

5. How much time did you spend on BeeLine? *

Mark only one oval.

- less than 5 hours
- 5-10 hours
- 10-15 hours
- 15-20 hours
- More than 20 hours
- Other: ______________________

6. How much time do you think you should have spent on BeeLine to get the most out of it? *

Mark only one oval.

- Much more than I did
- A little more than I did
- I think I spent the right amount of time on it
- A little less than I did
- Much less than I did
- Other: ______________________

7. What other Applications do you use. Name them here. *

If you do not use any other apps, write n/a or not applicable.

8. How much time did you spend on the other Apps? *

Mark only one oval.

- less than 5 hours
- 5-10 hours
- 10-15 hours
- 15-20 hours
- More than 20 hours
- Other: ______

9. How much time do you think you should have spent on the other Apps to get the most out of it? *

Mark only one oval.

- Much more than I did
- A little more than I did
- I think I spent the right amount of time on it
- A little less than I did
- Much less than I did
- Other: ____________________

10. What access do you have to ICTs? *

Check all the blocks that are applicable

Check all that apply.

	I own at least one of these, so I can use it at home or at school	Someone at home owns one of these, so I can use theirs at home	My school lets me use one of these and I can take it home with me too	My school lets me use one of these, but only at school	I don't have access to one of these at any time - home or school	I have access to one of these, but I don't use it because I don't know how to use it / I don't feel confident at using it	I have access to one of these, but I don't use it because of another reason that I will explain below
Smart phone (a cell phone that can go onto the internet - not just make phone calls and	☐	☐	☐	☐	☐	☐	☐

send SMSs)							
Tablet	☐	☐	☐	☐	☐	☐	☐
Computer (laptop / desktop)	☐	☐	☐	☐	☐	☐	☐

11. Optional: Clarify your answers to any of the questions above, if necessary

12. What access do you have to the internet? *

Mark only one oval per row.

	very little to none because of the high cost	very little to none because of poor coverage in the area	fair to good speed, but limited data	data is unlimited or enough for my needs, but speed stops me from being able to do what I need	excellent: unlimited or enough for my needs, and the speed is sufficient for my needs	other (which I will explain below)
At home	◯	◯	◯	◯	◯	◯
At school	◯	◯	◯	◯	◯	◯

13. Optional: Clarify your answers to any of the questions above, if necessary

Section A

This instrument is designed to assess your experiences in online learning. The following questions will assist us in assessing your perceptions with regard to learning in an online environment. Your responses will be held in strict confidence and your identity will not be revealed to anyone other than the researchers in the project. Please complete all pages of this questionnaire. This will take approximately 20 minutes.

14. Compared to previous face-to-face learning experiences, how would you rate your online learning experiences or using online resources with the following? *

Please answer the following questions by placing an 'X' in the appropriate response box.

Check all that apply.

	1: Much better	2: Better	3: Same	4: Worse	5: Much worse
Identify key issues?	☐	☐	☐	☐	☐
Stimulating your curiosity?	☐	☐	☐	☐	☐
Identifying relevant new information?	☐	☐	☐	☐	☐
Engaging in exchange of ideas?	☐	☐	☐	☐	☐
Synthesising ideas?	☐	☐	☐	☐	☐
Resolve problems?	☐	☐	☐	☐	☐
Understand concepts?	☐	☐	☐	☐	☐

Applying ideas or concepts?	☐	☐	☐	☐	☐
Expressing your emotions?	☐	☐	☐	☐	☐
Being open? (i.e. ask for assistance)	☐	☐	☐	☐	☐
Asking questions?	☐	☐	☐	☐	☐
Responding to others' comments?	☐	☐	☐	☐	☐
Sustaining discussion?	☐	☐	☐	☐	☐
Feeling part of the facilitation community?	☐	☐	☐	☐	☐
Referring to others by name?	☐	☐	☐	☐	☐
Expectations are communicated clearly?	☐	☐	☐	☐	☐

Activities are well designed?	☐	☐	☐	☐	☐
Taking responsibility?	☐	☐	☐	☐	☐
Set climate for learning and design?	☐	☐	☐	☐	☐
Summarise discussion?	☐	☐	☐	☐	☐
Feeling comfortable engaging in discussion?	☐	☐	☐	☐	☐
Feeling comfortable with facilitation methods?	☐	☐	☐	☐	☐
Understanding organisation of the facilitation?	☐	☐	☐	☐	☐
Feeling satisfied with facilitator interaction (questions,	☐	☐	☐	☐	☐

comments, facilitation)?					
Receiving facilitator assistance in reaching consensus?	☐	☐	☐	☐	☐
Receiving facilitation intervention?	☐	☐	☐	☐	☐
Assess learning outcomes?	☐	☐	☐	☐	☐
Accepting facilitator feedback?	☐	☐	☐	☐	☐

15. Optional: Explain any of your answers, above, if you feel you need to. OR if you do not use any online platform to collect resources or to design your own material. I would really like to know more about your online ICT usage.

16. Section B *

BeeLine Online Digital Platform

For each item check the description that best describes your engagement in this particular online digital platform. HOW CHARACTERISTIC is each description of you in this particular online digital platform?

Mark only one oval per row.

	1: Not at all	2: Not really	3: Moderately	4: Characteristic	5: Very characteristic
I designed resources on BeeLine on a regular basis	⬭	⬭	⬭	⬭	⬭
I put in effort understanding and working on BeeLine	⬭	⬭	⬭	⬭	⬭
I regularly read/watch/ use the relevant resources on BeeLine	⬭	⬭	⬭	⬭	⬭
I revisited BeeLine as needed to access online resources	⬭	⬭	⬭	⬭	⬭
I planned and	⬭	⬭	⬭	⬭	⬭

designed resources in an organised manner on BeeLine					
I took notes for myself when working on BeeLine	◯	◯	◯	◯	◯
I listened/ watched/read carefully in BeeLine	◯	◯	◯	◯	◯
I found ways to make the BeeLine material relevant to the grade I teach mathematics	◯	◯	◯	◯	◯
I applied the BeeLine material to my lesson plans and way I teach	◯	◯	◯	◯	◯
I found ways to make BeeLine	◯	◯	◯	◯	◯

interesting to me					
I really wanted to learn the material in this BeeLine	◯	◯	◯	◯	◯
I enjoyed the online chats / discussions on platforms such as Zoom sessions / emails / Whatsapps with the facilitator and / or other teachers	◯	◯	◯	◯	◯
I participated actively in discussion forums (e.g. Whatsapp / Zoom / any other platform) in BeeLine	◯	◯	◯	◯	◯
I helped fellow	◯	◯	◯	◯	◯

teachers to design in BeeLine and to use the available resources					
I designed good resources on BeeLine even though it took time and effort and I know that it was not compulsory	◯	◯	◯	◯	◯
I engaged in conversations (back-and-forth dialogues) about designing in BeeLine and using resources from BeeLine, e.g. verbally / online in discussion forums or on Whatsapp or	◯	◯	◯	◯	◯

on Zoom, with fellow teachers and / or the facilitator(s)					
I regularly posted in the discussion forums (e.g. Whatsapp group)	◯	◯	◯	◯	◯
I got to know other teachers also using BaseLine as a resource in their mathematics classrooms and a method of teaching or planning a lesson	◯	◯	◯	◯	◯

17. Optional: Explain any of your answers, above, if you feel you need to. OR if you have not use BeeLine as a specific online digital platform please let me know in this question.

15. Section C *

ANY Online Digital Platform

For each item check the description that best describes your engagement in any other online digital platform. HOW CHARACTERISTIC is each description of you in this particular online digital platform?

Mark only one oval per row.

	1: Not at all	2: Not really	3: Moderately	4: Characteristic	5: Very characteristic
I put in effort understanding and working with this online digital platform	⬭	⬭	⬭	⬭	⬭
I regularly read/watch/ use the relevant resources on this online digital platform	⬭	⬭	⬭	⬭	⬭
I revisited this online digital platform as needed to access online resources	⬭	⬭	⬭	⬭	⬭
I took notes	⬭	⬭	⬭	⬭	⬭

for myself when visiting this online digital platform					
I listened/ watched/read carefully in this online digital platform	◯	◯	◯	◯	◯
I found ways to make the material on this online digital platform relevant to the mathematics I teach	◯	◯	◯	◯	◯
I applied the material found on this online digital platform to my lesson plans and way I teach	◯	◯	◯	◯	◯
I really wanted to use	◯	◯	◯	◯	◯

the material on this online digital platform					
I participated actively in discussion forums (e.g. Whatsapp / Zoom / any other platform) about this online digital platform	◯	◯	◯	◯	◯
I helped fellow teachers to use the available resources on this online digital platform	◯	◯	◯	◯	◯
I engaged in conversations (back-and-forth dialogues) about using resources	◯	◯	◯	◯	◯

from this online digital platform e.g. verbally / online in discussion forums or on Whatsapp or on Zoom, with fellow teachers and / or the facilitator(s)					
I regularly posted in the discussion forums (e.g. Whatsapp group) about this online digital platform					
I encouraged my mathematics learners in my classroom to download and to use this online digital platform					

I assisted my learners to download this online digital platform	⬭	⬭	⬭	⬭	⬭
I assisted my learners on how to use this online digital platform and how to access mathematics lessons and resources	⬭	⬭	⬭	⬭	⬭

19. Optional: Explain any of your answers, above, if you feel you need to.

20. Optional: Name any other digital information platform (e.g. Telegram, Teacha) that you regularly use to access resources and other material to use in your mathematics classroom.

Thank you for your time and input. It is much appreciated.
Have a nice day!

APPENDIX I: QUESTIONNAIRE: BLENDED MATHEMATICSTEACHER DEVELOPMENT PROGRAMME

Questionnaire: Blended Mathematics teacher development programme

Please help me to improve our blended mathematics teacher development programmes in the future by filling out this anonymous questionnaire.

* Indicates required question

1. Email *

   ____

2. Do you give permission for your answers to this questionnaire to be used for research purposes? *

   This will not harm you in any way, but will help us in improving our blended mathematics teacher development programme in the future. Since this is an anonymous questionnaire, your answers cannot be traced back to you.

   Mark only one oval.

   ◯ Yes
   ◯ No

3. Do you have a Laptop (or other device) that you can use to design / create your own teaching material / resources / teaching aids? *

   Mark only one oval.

   ◯ Yes
   ◯ No

4. If YES, please tell me how you use your device to design / create your own teaching material / resources / teaching aids? *

5. Can you connect to the school WiFi? *

Mark only one oval.

- Yea
- No

6. Do you have a Laptop (or other device) that you can use to attend / conduct online meetings or workshops via Zoom / Google Meets or any other digital platform? *

Mark only one oval.

- Yes
- No

7. If YES, please tell me about the digital platforms (e.g Zoom) that you use or have used. *

8. Are you a member of the WhatsApp Mathematics group created by Maryke from Infundo? *

Mark only one oval.

- Yes
- No

9. If YES, do you take actively part in conversations / discussions on the WhatsApp group? *

Mark only one oval.

- Yes
- No

10. If NO, please give a reason why you are not part of the group OR why you do not take actively part in the conversations / discussions on the group. *

11. Are you a member of any other Mathematics WhatsApp groups? *

Mark only one oval.

- Yes
- No

\

12. If YES, please tell me more about the Mathematics WhatsApp group that you are part of and how active you are on that group. *

13. Please describe how you use technology in your OWN mathematics learning and preparation time. *

14. Do you design your own mathematics lesson plans, question papers, assignments etc.? *

Mark only one oval.

- Yes
- No
- Sometimes
- Other: ______________

15. If YES, please tell me how you design / create / compile your own mathematics lesson plans, question papers, assignments etc. *

16. If NO, please tell me why you do not design / create / compile your own mathematics lesson plans, question papers, assignments etc. *

17. Do you share your mathematics resources with other mathematics teachers in your school? *

Mark only one oval.

- Yes
- No
- Sometimes

18. Do you share your mathematics resources with other mathematics teachers in other schools? *

Mark only one oval.

- Yes
- No
- Sometimes

19. If YES, to the above question, please tell me more about your practice of sharing mathematics resources and why it is important to you. *

20. If NO, to the above question, please tell me more about your practice of NOT mathematics sharing resources and why you do not share your resources. *

21. Do you or did you ever co-created mathematics e-content like videos or PowerPoint MP4? *

Mark only one oval.

- Yes
- No
- Sometimes

22. If YES, please tell me more about you co-creating e-content e.g. when, where, why? *

23. Did you ever enroll yourself in an online course to learn about teaching with technology? *

Mark only one oval.

- Yes
- No

24. If YES, please tell me about the course e.g. the institution, when etc. *

25. If NO, please give a reason or tell me why not. *

26. How confident are you in using technology? *

Mark only one oval.

	1	2	3	4	5	
not :	◯	◯	◯	◯	◯	very confident

27. Please tell me what technology you are using to improve your teaching and learning, to design your lessons, to create your worksheets etc. *

28. Do you use BeeLine for self-development? *

Mark only one oval.

- Yes
- No
- Sometimes

29. How much time did you spend on BeeLine? *

Mark only one oval.

- less than 1 hours
- 1-2 hours
- 3-5 hours
- 5-10 hours
- More than 10 hours
- Other: ______________________

30. If you are not using Beeline, please tell me why you are not using BeeLine. *

31. Why did you not reach out to Maryke to assist you with BeeLine? *

32. What other Applications or Websites do you use when you plan and prepare for mathematics teaching and learning. Name them here. *

If you do not use any other apps, write n/a or not applicable.

33. Optional: Clarify your answers to any of the questions above, if necessary

Professional Development

Please complete all pages of this questionnaire. This will take approximately 10 minutes.

34. What motivates you / drive you to be better at your job? *

35. What do you think you need to be better at your job? *

36. Are you satisfied with your job performance? Why? *

37. Are you satisfied with your mathematics content knowledge? *

Mark only one oval.

- Yes
- No
- Sometimes

38. Explain your answer to the previous question. *

39. Are you satisfied with your classroom management skills? *

Mark only one oval.

- Yes
- No
- Sometimes

40. Explain your answer to the previous question. Please provide an example to support your answer. *

41. Are you satisfied with the way you teach mathematics to your learners? *

Mark only one oval.

- Yes
- No
- Sometimes

42. Explain your answer to the previous question. Please provide an example to support your answer. *

43. What do you think you can do different in teaching mathematics? *

44. Explain your answer to the previous question. Please provide an example to support your answer. *

45. What do you want to do different when you teach mathematics? *

46. Explain your answer to the previous question. Please provide an example to support your answer. *

47. Please give me your opinion on 'self-development'? *

48. How do you think one can develop oneself? *

49. Who do you think is responsible for teacher development? *

Mark only one oval.

- ⬭ I am responsible
- ⬭ DBE
- ⬭ Principal
- ⬭ Other

50. Explain your answer to the previous question. Please provide an example to support your answer. *

51. Optional: Clarify your answers to any of the questions above, if necessary.

Thank you for your time and input. It is much appreciated.
Have a nice day!

APPENDIX J: BLENDED MATHEMATICS TEACHERDEVELOPMENT PROGRAMME

Blended Mathematics teacher development programme

Please help me to improve our blended mathematics teacher development programmes in the future by filling out this anonymous questionnaire.

* Indicates required question

1. Email *

____

2. Do you give permission for your answers to this questionnaire to be used for research purposes? *

This will not harm you in any way, but will help us in improving our blended mathematics teacher development programme in the future. Since this is an anonymous questionnaire, your answers cannot be traced back to you.

Mark only one oval.

◯ Yes

◯ No

3. What is your gender? *

Mark only one oval.

◯ Female

◯ Male

◯ Prefer not to say

◯ Other: _______________________

4. What is your highest qualification? *

Mark only one oval.

- ( ) Bachelor of Education degree (B. Ed.)
- ( ) Bachelor's degree (other field)
- ( ) Postgraduate Certificate in Education (PGCE)
- ( ) Bachelor of Education Honours
- ( ) Masters in Education
- ( ) Doctoral in Education
- ( ) Honours degree (other field)
- ( ) Masters degree (other field)
- ( ) Doctoral degree (other field)
- ( ) ACE
- ( ) Other: ____________________

5. If you selected other, list your qualifications here.

____
____
____
____
____

6. At which institution did you graduate? (e.g. University of the Free State)

____
____
____
____
____

7. What is your age? *

Check all that apply.

- [ ] 21 - 35
- [ ] 36 - 50
- [ ] 51 and older

8. What kind of school do you teach at? *

Mark only one oval.

- ◯ Quintile 1-3 (schools serving poor communities)
- ◯ Quintile 4 (schools serving emerging communities)
- ◯ Quintile 5 (generally X-Model-C schools)
- ◯ Other: ____________________

9. At which school do you teach? (Write the school's name) *

____

10. How many years teaching experience do you have? *

Mark only one oval.

- ◯ 1 - 5 years
- ◯ 6 - 10 years
- ◯ 11 - 20 years
- ◯ 21 and more years
- ◯ Other: ____________________

11. Do you enjoy teaching? *

Mark only one oval.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Yes, love it

12. What do you like about your job as a mathematics educator?

____
____
____
____
____

13. What do you not like about your job as a mathematics educator?

____
____
____
____
____

14. Why did you choose to become a mathematics teacher?

____
____
____
____
____

15. What motivates you to go to school everyday?

Check all that apply.

- [ ] Teaching and learning
- [ ] Educate the learners
- [ ] I have to be at school
- [ ] To receive a salary
- [ ] It is my job
- [ ] Other: ____________________

16. What motivates you to prepare for your mathematics lessons and to teach every day?

____
____
____
____
____

Thank you for your time and input. It is much appreciated.
Have a nice day!

APPENDIX K: CYCLE 4: FOCUS: "TEACHING PARTICIPANTS HOW TO LEARN MATHEMATICS"

SEMI-STRUCTURED QUESTIONS

Cycle 4: Focus: "Teaching participants how to learn mathematics"

Semi-Structured Questions

1. Are you connected to the internet? WiFi? Data?

2. What devices do you use?

3. I did/did not receive your request form that lists your mathematical needs or mathematics topics before my site visit. Can you tell me more about that?

4. I conducted the online mathematics workshop on ___. You logged on / did not log on for the workshop. Can you tell me more?

5. I gave your school a mathematics file consisting of resources and materials that you can use when preparing to teach mathematics. Did you use the material during the term? Give an example.

6. The mathematics resources that I shared with you on the WA group/email / BeeLine, did you manage to access it? Download / print/use/file? Give an example.

7. Last week, I conducted the LEGO workshop at your school, where we collectively shared ideas on using LEGOs in teaching mathematics. You attended/did not attend. Tell me more.

8. Today, I visited your school and mathematics classroom and had a reflective discussion with you to identify your mathematics training and development needs collectively. You were available / not available when you confirmed with me. Tell me more. Your experience/ideas.

9. How can I better my communication or mathematics teaching/facilitation / educational support? (Setting the curriculum, focusing on discussions, sharing personal meaning).

10. We are discussing your personal development today, and the programme is about professional development for mathematics teachers. How do you feel about the programme and the discussion around the expectations and activities of the programme?

11. What can I do better to support you with resources, material, and ideas for teaching mathematics?

12. Can I support you in teaching mathematics with new ideas and methods? Do you want to learn new content?

13. Do you find the resources and material useful that I share with you? How do you apply it in your planning and preparation?

14. How and when do you plan your mathematics lessons/prepare for teaching?

15. Who is responsible for your personal development? Why do you think [you] are responsible for your own learning and development?

16. When I conduct a mathematics workshop [F2F or online], what can I do better when presenting/addressing the curriculum?

17. How can I better drive the discussions in the mathematics workshop [F2F or online]?

18. What can I do better in this mathematics teacher development programme so that you will participate/engage more actively? What is your specific need?

Thank you for your time, honest reflection, and feedback. I appreciate it.

APPENDIX L: REQUEST FOR PERMISSION – PRINCIPALS

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS
UV

REQUEST FOR PERMISSION TO CONDUCT RESEARCH

Dear ____

I am doing research and would like to request permission to conduct my research in your school,

____, *Joe Gqabi district, Eastern Cape province.*

DATE
May 2023 - October 2024

TITLE OF THE RESEARCH PROJECT
Creating an Action Research-Based Framework for Blended Mathematics Teacher Development in Rural South African Schools

PRINCIPLE INVESTIGATOR / RESEARCHER(S) NAME(S) AND CONTACT NUMBER(S):

Maryke la Grange-Taylor 1999 205 360 079 514 4140

FACULTY AND DEPARTMENT:
University of the Free State, Bloemfontein Campus
Faculty of Education (Higher Education Studies)
Department: *School of Mathematics, Natural Sciences and Technology Education*

STUDYLEADER(S) NAME AND CONTACT NUMBER:

Dr Angela Stott *Staff nr. 0874058* *078 508 0848*

WHAT IS THE AIM / PURPOSE OF THE STUDY?
The aim of this study is to investigate the components of a framework that could be utilised for a blended mathematics teacher development programme in low quintile rural South African schools.

WHO IS DOING THE RESEARCH?
This research is conducted by Maryke la Grange, a PhD student, Mathematics facilitator, and Associate of Infundo Consulting sponsored by PG Bison.

205 Nelson Mandela Drive/Rylaan, Park West/Parkwes, Bloemfontein 9301, South Africa/Suid-Afrika
P.O. Box/Posbus 339, Bloemfontein 9300, South Africa/Suid-Afrika, T: +27(0)51 401 9111, www.ufs.ac.za

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

This study has received approval from the

- Research Ethics Committee of UFS

(**Approval number:** UFS-HSD 2023/0653)

- Eastern Cape, Department of Basic Education
- Infundo Consulting / PG Bison

A copy of approval letters can be obtained from the researcher.

WHY ARE YOUR INSTITUTION/ORGANISATION/COMPANY INVITED TO TAKE PART IN THIS RESEARCH PROJECT?

Maryke la Grange, Associate of Infundo Consulting is running an in-service teacher development programme for Mathematics teachers in the PG Bison Project Schools (Ugie and Maclear), Joe Gqabi district, Eastern Cape province.

WHAT IS THE NATURE OF PARTICIPATION IN THIS STUDY?

The teachers who agree to participate in this study will: 1. Answer an online questionnaire about their experiences with the digital learning platform, BeeLine. 2. Participate in an interview about their experiences with the digital learning platform, BeeLine (only selected participants), 3. Participate in an online group interview to reflect on their use of the digital learning platform, BeeLine, 4. Answer an online post-reflection questionnaire at the end of the group interview. 5. Allow the interviews and group interviews to be audio/screen recorded.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

The blended mathematics teacher development programme aims to guide mathematics teachers of any grade to learn from, use, design and develop quality online lessons. This blended programme consists of 1) in-service teacher professional development where the facilitator (myself) supports teachers with mathematics content (self-study) online and face-to-face facilitation, 2) encourages teachers to design, develop and use their mathematics content in their classrooms and on digital platforms of which their learners have access to, and 3) encourage teachers to form mathematics communities of practice (COP) based on the grades they teach where they can share lessons plans, content, resources and success stories. Co-creation occurs with teachers as they apply different teaching strategies in their own classrooms and provide evidence of how they have applied it.

WHAT ARE THE POTENTIAL RISKS TAKING PART IN THIS STUDY?

Answering the questionnaire and interview will take some of the teachers' time.

WILL THE INFORMATION BE KEPT CONFIDENTIAL?

Yes. Anonymous reporting will be used so that participants will not be identifiable.

Province of the
EASTERN CAPE
EDUCATION

CORPORATE PLANNING, MONITORING, POLICY AND RESEARCH COORDINATION
Steve Vukile Tshwete Complex, Zone 6 Zwelitsha, 5608, Private Bag X0032, Bhisho, 5605 REPUBLIC OF SOUTH AFRICA:
Enquiries: Ms. F. Pakade Tel: 040 608 7170/4001 . Fax :040 608 4372. Email: fundiswa.pakade@ecdoe.gov.za
Website: www.ecdoe.gov.za **Date: 31July 2023**

Ms. Maryke La Grange -Taylor

Gowanlea 61

Reynecke Ave

Heuwelsig

Bloemfontein

9301

Dear Ms La Grange -Taylor

PERMISSION TO UNDERTAKE A DOCTORAL RESEARCH: CREATING AN ACTION RESEARCH-BASED FRAMEWORK FOR BLENDED MATHEMATICS TEACHER DEVELOPMENT IN RURAL SOUTH AFRICAN SCHOOLS

1. Your application to conduct the above-mentioned research involving teachers participating in a blended mathematics teacher development programme under the jurisdiction of the of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:

a. there will be no financial implications for the Department;

b. institutions and respondents must not be identifiable in any way from the results of the investigation;

c. you seek parent's consent for minors;

d. it is not going to interrupt educators' time and task;

e. the research may not be conducted during official contact time;

f. the research may not be conducted during official contact time, provided that an arrangement to do research at the school including getting inside a classroom has been arranged and agreed upon in writing with the Principal and the affected teacher/s;

g. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district;

[Type here]
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Customer care line: 086 063 8636
Website: www.ecdoe.gov.za

APPENDIX M: TEACHER CONSENT FORM

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RESEARCH STUDY INFORMATION LEAFLET AND CONSENT FORM

DATE
August 2023 - August 2024

TITLE OF THE RESEARCH PROJECT
Creating an Action Research-Based Framework for Blended Mathematics Teacher Development in Rural South African Schools

PRINCIPLE INVESTIGATOR / RESEARCHER(S) NAME(S) AND CONTACT NUMBER(S):
Maryke la Grange-Taylor 1999 205 360 079 514 4140

FACULTY AND DEPARTMENT:
University of the Free State, Bloemfontein Campus
Faculty of Education (Higher Education Studies)

STUDYLEADER(S) NAME AND CONTACT NUMBER:
Dr Angela Stott
078 508 0848

WHAT IS RESEARCH?
Research is something we do to find new knowledge about the way things and people work. We use research projects or studies to help us find out more about children and teenagers and the things that affect their lives, their schools, their families, and their health. Research also helps us to find better ways of helping, or treating children who are sick. We do this to try and make the world a better place!

WHAT IS THE AIM / PURPOSE OF THE STUDY?
The aim of this study is to investigate the components of a framework that could be utilised for a blended mathematics teacher development programme in low quintile rural South African schools.

WHO IS DOING THE RESEARCH?
This research is conducted by Maryke la Grange, a PhD student, Mathematics facilitator, and Associate of Infundo Consulting.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?
This study has received approval from the Research Ethics Committee of UFS. A copy of the approval letter can be obtained from the researcher.

Approval number: UFS-HSD 2023/0653

WHY ARE YOU INVITED TO TAKE PART IN THIS RESEARCH PROJECT?

You are a participant in the in-service teacher development programme for Mathematics teachers conducted by Maryke la Grange, supported by Infundo, PG Bison, BeeLine and Monyetla. I believe that you can contribute to the research project and that you will benefit from it.

WHAT IS THE NATURE OF PARTICIPATION IN THIS STUDY?

1. Answer an online questionnaire about your experiences with the digital learning platform (BeeLine and Monyetla App), 2. Participate in an interview about your experiences with the digital learning platform (only selected participants), 3. Participate in an online group interview to reflect on your use of the digital learning platform, 4. Answer an online post-reflection questionnaire at the end of the group interview. 5. Allow the interviews and group interviews to be audio/screen recorded.

CAN THE PARTICIPANT WITHDRAW FROM THE STUDY?

Participation is voluntary and there is no penalty or loss of benefit for non-participation. Being in this study is voluntary and you are under no obligation to consent to participate. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time without giving a reason.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

By participating, you will help me to improve the way that I help you and other teachers in blended in-service teacher development programmes in the future.

WHAT IS THE ANTICIPATED INCONVENIENCE OF TAKING PART IN THIS STUDY?

Completion of the questionnaire and interviews will take some of your time.

WILL WHAT I SAY BE KEPT CONFIDENTIAL?

Your answers will be given a fictitious code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings. Your answers may be reviewed by people responsible for making sure that research is done properly, including the members of the Research Ethics Committee. Otherwise, records that identify you will be available only to Maryke la Grange, unless you give permission for other people to see the records. Your anonymous data may be used for journal articles and conference presentations. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report. While every effort will be made by the researcher to ensure that you will not be connected to the information that you share during the focus group, I cannot guarantee that other participants in the focus group will treat information confidentially. I shall, however, encourage all participants to do so. For this reason, I advise you not to disclose personally sensitive information in the focus group. You may stop being in the study at any time without getting in trouble.

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HOW WILL THE INFORMATION BE STORED AND ULTIMATELY DESTROYED?

Electronic information will be stored on a password protected computer or online storage space. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. After this period written information will be burned.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICPATING IN THIS STUDY?

No payment will be given, but it is hoped that participation will lead to enhanced learning and teaching effectiveness.

HOW WILL THE PARTICIPANT BE INFORMED OF THE FINDINGS / RESULTS OF THE STUDY?

If you would like to be informed of the final research findings, please contact Dr Angela Stott on 0785080848 or stottae@ufs.ac.za, or Maryke la Grange on 079 514 4140 or 1999205360@ufs4life.ac.za.

Thank you for taking time to read this information sheet and for participating in this study.

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CONSENT TO PARTICIPATE IN THIS STUDY

I, ______________________________________ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits, and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet. I have had sufficient opportunity to ask questions and am prepared to participate in the study. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable). I am aware that the findings of this study will be anonymously processed into a research report, journal publications and/or conference proceedings.

I agree to the recording of the *insert specific data collection method*.

I have received a signed copy of the informed consent agreement.

Full Name of Participant: ____

Signature of Participant: _____________________________________ Date: ____________________

Full Name(s) of Researcher(s): ____

Signature of Researcher: _____________________________________ Date: ____________________

APPENDIX N: TURNITIN REPORT

TurnItIn.docx

ORIGINALITY REPORT

10%	6%	7%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.tandfonline.com Internet Source	<1%
2	Submitted to Pennsylvania State System of Higher Education Student Paper	<1%
3	www.ncbi.nlm.nih.gov Internet Source	<1%
4	cris.maastrichtuniversity.nl Internet Source	<1%
5	pdfcoffee.com Internet Source	<1%
6	Mundy, Christine Elizabeth. "Exploring the Effectiveness of Pogil and Chemorganisers in Foundation Chemistry : A Mixed Methods Study", University of Pretoria (South Africa), 2023 Publication	<1%
7	Submitted to University of West Florida Student Paper	<1%