

# **Integrating intelligent tutoring systems for differentiated learning in inclusive classrooms**

by

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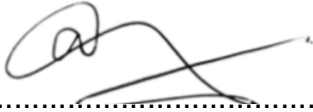
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October 2024

## Declaration

I declare that the dissertation, which I hereby submit for the degree MEd Computer Integrated Education at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.



.....  
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August 2024

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

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## Abstract

This study falls within the field of computer-integrated education (CIE), specifically investigating the integration of Intelligent Tutoring Systems (ITSs) for differentiated learning in inclusive classrooms. An independent school in South Africa has recently implemented an ITS to support Grade 7 Mathematics in their inclusive classroom setting. This innovative technology holds the potential for enhancing differentiated learning, which aims to personalise education and cater to the diverse needs of all learners. While ITSs have established their effectiveness in providing adaptable and individualised instruction, the specific features that best support diverse learners within the South African educational landscape and policy framework require further exploration. Differentiated learning in inclusive classrooms aims to personalise education and cater to diverse learner needs. ITSs offer adaptive, individualised instruction, yet their integration within these settings remains under-researched, particularly in South African contexts.

This study addresses this gap by investigating the potential of ITSs for differentiated learning in inclusive Grade 7 Mathematics classrooms in an independent school in South Africa. While ITSs hold promise for differentiated learning, their integration in inclusive environments presents unique challenges. Limited research explores the specific features of ITSs that effectively support diverse learners within the South African educational landscape and policy framework.

This study aims to fill this gap by examining how ITSs can be tailored to address the individual needs of learners in inclusive classrooms. Employing a case study approach, this study delves into the implementation of an ITS for Grade 7 Mathematics in an inclusive school. Data collection involves teacher interviews, and technological analysis, and policy analysis to gain insights into best practices, challenges, and the role of the ITS in differentiated learning.

This research aims to identify features of the ITS that effectively support differentiated learning in this context. It will explore how the ITS can be adapted to meet the unique needs of learners with diverse learning styles and abilities, while also considering the specific policy and curriculum requirements within South Africa. Ultimately, the study will offer practical recommendations for integrating ITSs into inclusive classrooms to enhance the quality and inclusivity of education for all learners.

## **Key Terms**

Intelligent Tutoring Systems (ITSs), Differentiated Learning, Inclusive Education, Information Communication Technologies (ICTs), Artificial Intelligence (AI), Artificial Intelligence in Education (Aled)

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### CERTIFICATE OF EDITING

To whom it may concern,

This letter confirms that the dissertation for the study titled *Integrating intelligent tutoring systems for differentiated learning in inclusive classrooms* by Andrea Kruger was proofread and edited by All-done Editing Services.

The document was edited for grammar, punctuation, spelling, overall style and consistent use of South African English spelling conventions. All amendments were tracked using Microsoft Word's "Track Changes" feature, and consequently, the authors had the option to accept or reject each change. A complete edited copy was provided, but the final decisions as to which changes to implement, rested with the author.

Sincerely,



Marietjie Schutte

## List of Abbreviations

AI	Artificial Intelligence
AIEd	Artificial Intelligence in Education
CAPS	National Curriculum and Assessment Policy Statement
CIE	Computer-Integrated Education
CK	Content Knowledge
DBE	Department of Basic Education
DoC	Department of Communications
DoE	Department of Education
HESA	Higher Education Statistics Agency
IB	International Baccalaureate
ICT	Information and Communication Technology
ITS	Intelligent Tutoring System
MRQ	Main Research Question
NCS	National Curriculum Statement
NLP	Natural Language Processing
OECD	Organisation for Economic Co-operation and Development
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
PYP	Primary Years Programme
SEN	Special Educational Needs
SRQ	Sub-Research Question
TCK	Technological Content Knowledge
TK	Technological Knowledge
TPACK	Technological Pedagogical and Content Knowledge
TPK	Technological Pedagogical Knowledge

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## Chapter 1: Introduction and Orientation

### 1.1 Introduction

This study explored the role of Intelligent Tutoring Systems (ITSs) as tools for differentiating mathematics in an inclusive Grade 7 classroom within the South African education context. According to Kulik and Fletcher (2016), ITSs are computer-based instructional tools designed to assist learners in navigating problems and solutions. These systems adapt learning experiences to students' individual needs and abilities by recording data on learners performance, such as elapsed time during activities, grades, and any errors made (Katsaris, 2021).

As learners proceed with such adaptive assessments, ITSs can adjust the difficulty level of the activity or provide guidance to support learning (Holmes et al., 2019). This data is then analysed to develop profiles of students' learning preferences and capabilities, allowing for the provision of individualised instruction (Katsaris, 2021). Integrating ITSs in education has brought forward improved academic performance and enhanced areas of knowledge and skills, including mathematics, science, reading, critical thinking and problem-solving (Masri et al., 2019).

This research investigated how ITSs can be integrated within the context of inclusive education to facilitate differentiated learning in a Grade 7 mathematics classroom. The central aim was to examine how these systems can support and enhance an inclusive educational environment, adapting mathematical instruction to meet the diverse needs of learners and promoting equitable learning opportunities.

### 1.2 Background

Tomlinson (2001), who is considered an expert in the field of differentiated learning, explains that in a differentiated classroom, diverse pathways are offered for learners to access content, comprehend concepts, and produce outcomes, ensuring that each learner can achieve effective learning. Differentiation is a pedagogy designed to address the needs, skills, and preferences of learners (Hall et al., 2003). This involves tailoring instruction to meet the cognitive and socio-cultural understandings and practices that learners bring to their learning environments (Louden et al., 2005).

Inclusive classrooms implement differentiated learning to accommodate diversity and ensure educational access for all learners, regardless of their abilities, backgrounds, or learning preferences (Ambrose, 2010). In South Africa's educational context, where classrooms are diverse and inclusive education is a national priority, the application of differentiated instruction becomes even more crucial.

The focus of this study was a Grade 7 classroom in a South African school, where the researcher aimed to explore how ITSs can support the cultivation of an inclusive classroom through means of differentiation. This particular classroom, consisting of learners with a wide range of abilities and backgrounds, provided a relevant environment to investigate the efficacy of an ITS in promoting differentiated learning.

The ITS under investigation, known as MathU, is a tool designed to support the subject matter of Mathematics for primary and high school learners ranging from Grades 7 to 10. MathU's ability to provide personalised instruction and adaptive assessments aligns with the principles of differentiation, making it a suitable candidate for this study. This investigation highlighted the practical realities of a South African classroom, where the diverse needs of learners must be met through innovative and effective teaching strategies. The findings of this study have the potential to contribute to the broader understanding of how ITSs can be leveraged to enhance inclusive education in similar contexts, particularly within South Africa.

### 1.3 Research Focus

#### 1.3.1 Problem Statement

There has been a global policy shift towards inclusive education, driven by a growing consensus that children with special education needs should be integrated into mainstream educational environments (du Plessis, 2013). This shift requires schools to accommodate all learners, so that equal access to quality education is provided and further, to challenge discriminatory stigmas, create inclusive communities and foster a society which values and celebrates diversity (McConkey, 1995). South Africa has specifically committed to the goal of providing equitable and inclusive education for all learners (Walton & Engelbrecht, 2024).

According to Donohue and Bornman (2014), there have been ‘significant changes’ in creating a policy framework to enable an inclusive education system, with the publication of White Paper 6 in 2001 being a cornerstone of these efforts. White Paper 6 asserts that the Department of Education has “a special responsibility ... to ensure that all learners, with or without disabilities, pursue their learning potential to the fullest” (White Paper 6, 2001).

Despite these commitments, an equitable and inclusive education system still remains difficult to achieve (Walton, 2011). Implementing inclusive education poses challenges for many teachers in South Africa (Onyishi & Sefotho, 2020). Challenges such as limited preparation time, large class sizes, heavy workloads, inadequate teaching resources, and insufficient support for teachers in implementing inclusive teaching methods continue to hinder the effective implementation of inclusive education (Scott et al., 1998; Yuen et al., 2005).

To address these challenges, differentiation has emerged as a key teaching pedagogy within inclusive education (Dalton et al., 2012). Differentiation involves tailoring instruction to meet students’ diverse cognitive and socio-cultural needs, ensuring that every learner can access the curriculum, engage with the content, and demonstrate their understanding in ways that reflect their abilities and learning preferences (Tomlinson, 2001). However, differentiation is often viewed as being resource-intensive and time-consuming, making it difficult for teachers to implement in diverse classrooms (de Jager, 2023).

It is suggested that ITSs have the potential to support inclusivity and differentiation in the classroom (Kulik & Fletcher, 2016). Yet, despite their presence since the 1970s, ITSs tend to remain underutilised by teachers as tools for creating inclusive educational environments that feature differentiated learning (Al-Aqbi, 2017). Only recently have teachers begun to recognise the pedagogical advantages that ITSs offer for supporting learning through differentiation (Ali & Abdel-Haq, 2021).

Notably, while there is substantial research on the uses and benefits of ITSs (Craig et al., 2018; Kulik & Fletcher, 2016) and the concept of inclusivity and differentiated learning, even within a South African context (Ambrose et al., 2010; Du Plessis, 2013; Tomlinson, 2001; Walton & Engelbrecht, 2024), the intersection of these areas remains underexplored.

Specifically, the connection of an ITS to support inclusive education within the South African context, as informed by relevant policy documents, is a research area that has not yet been adequately addressed.

The research problem, therefore, was that while teachers are required to provide inclusive education, the process of differentiation is challenging and resource-intensive (Onyishi & Sefotho, 2020). ITSs offer a promising solution to this problem, yet they are not widely adopted or utilised in schools (Craig et al., 2004). This study bridged this gap by investigating how an ITS, known as MathU, can be effectively implemented to support differentiation in an inclusive Grade 7 mathematics classroom in South Africa. By addressing this issue, the study aimed to offer insights and solutions that can enhance the inclusivity and effectiveness of education in diverse classroom settings, especially within the realm of Mathematics Education for in Primary School.

### 1.3.2 Research Questions

Given the challenges associated with implementing inclusive education, particularly the resource-intensive nature of differentiation as a teaching pedagogy for inclusive education, teachers may struggle to create environments that effectively address the needs of their diverse learners (Onyishi & Sefotho, 2020). Although ITSs offer a promising solution to facilitate differentiation and support inclusive education, their adoption and utilisation in classrooms remain limited (Al-Aqbi, 2017).

To address this problem, the main research question (MRQ) guiding this study was:

**MRQ:** How can the implementation of an ITS support the cultivation of a differentiated learning environment in an inclusive classroom setting?

To answer this MRQ and investigate how an ITS can support cultivating a differentiated learning environment in an inclusive classroom setting, the researcher considered it essential to incorporate a framework that integrates the interplay between pedagogy, content, and technology. Therefore, the *Technological Pedagogical and Content Knowledge (TPACK)* model was utilised in the creation of the sub-research questions, as it provides a lens in which to these interactions can be explored (McKenney et al., 2015).

Developed by Mishra and Koehler (2006), TPACK emphasises the integration of technology with pedagogical strategies and content knowledge to create effective teaching and learning environments. This framework was particularly relevant for this study because it allows for a comprehensive analysis of how ITSs can be tailored to address diverse learning needs within an inclusive educational setting.

The TPACK framework served as the foundation for developing data collection methods, such as interviews, policy document analysis, and ITS exploration. It also guided how this data would be analysed. Each component of TPACK was essential, even though only three areas of TPACK were explored in the research questions.

The TPACK framework informed the development of the following sub-research questions (SRQs), each of which aligns with a specific domain of TPACK, as highlighted below:

**SRQ1:** What encompasses differentiated learning in an inclusive classroom setting?  
(*Pedagogical Knowledge*)

This question is rooted in understanding the foundational principles of differentiated instruction and how it can be effectively implemented in classrooms with diverse learners.

**SRQ2:** How do the features of an ITS support differentiated learning?  
(*Technological Pedagogical Knowledge*)

Here, the focus shifts to the technological aspects of ITSs and how they can enhance pedagogical strategies to support differentiation.

**SRQ3:** How is Mathematics addressed through the ITS, MathU?  
(*Technological Content Knowledge*)

This question explores the alignment of ITS features with subject-specific content, particularly how Mathematics is addressed through MathU, ensuring that technology is not only supportive of pedagogy but also of the specific content being taught.

In using the TPACK framework as the guiding lens, this study ensured a holistic examination of the intersections between pedagogy, content, and technology, providing a description for how each of these elements can be leveraged to support differentiated learning in an inclusive classroom setting. *Section 2.9* further elaborates on the TPACK framework and its relevance to this study.

### 1.3.3 Rationale

This study aimed to investigate the extent to which ITSs can be utilised to facilitate differentiation in inclusive classroom settings by examining best practices and potential challenges associated with their use. Specifically, MathU, a mathematics-focused ITS, was chosen due to its potential to address the complex and diverse learning needs inherent in inclusive education environments. Mathematics, as a core subject, often presents significant challenges for differentiation, making it an ideal focus for exploring the practical application of ITSs. The study also explored how the integration of ITSs like MathU can mitigate the challenges of implementing differentiated learning, offering a scalable and data-driven approach to tailor educational experiences to individual learners.

This research is anticipated to benefit teachers, learners, and educational policymakers by providing insights into the application of ITSs to support differentiated learning environments in inclusive classrooms. Furthermore, the study aimed to address a gap in the literature by examining how MathU can align with inclusive policies and educational demands in South Africa, contributing to the broader discourse on equity and technology in education.

### 1.3.4 Purpose Statement

The purpose of this study was to explore how integrating an ITS can support the cultivation of a differentiated learning environment in an inclusive Grade 7 Mathematics classroom in South Africa. Specifically, this study aimed to explore how the MathU ITS can facilitate differentiated instruction to address the diverse needs of learners. By investigating this, the study sought to provide actionable insights into how ITSs can be effectively integrated into educational practices to enhance inclusivity and support varied learning styles.

The objectives of this study include:

- Identifying the ways in which MathU ITS facilitates differentiated learning. This included examining how the ITS's adaptive features, feedback mechanisms, and instructional strategies contribute to personalised learning experiences.
- Exploring teacher perceptions of the MathU ITS's effectiveness in enhancing inclusive education. This involved gathering insights on how the ITS supports their efforts to create a more inclusive and differentiated learning environment.
- Providing recommendations for the integration of ITSs in other educational contexts based on the findings. This aimed to offer practical guidance for implementing similar technologies in diverse classrooms to support inclusive education and differentiated learning.

#### 1.4 Delineations

While this study acknowledges the broader context of Artificial Intelligence in education (AIEd), it specifically focused on the implementation and impact of ITSs within inclusive classroom settings. The study addressed mathematics instruction through the investigation of the ITS known as MathU, a South African ITS designed to align with the CAPS curriculum for Grades 7 to 10. MathU emphasises effective mathematics instruction and supports differentiated learning in an inclusive, independent school environment. By concentrating on MathU and its application in Grade 7 mathematics classrooms, this research aimed to explore how ITSs can be tailored to meet diverse educational needs and enhance inclusivity in the educational setting.

#### 1.5 Overview of Literature Review

The literature in this dissertation provides a comprehensive exploration of pedagogical approaches and the role of technology in mathematics education, particularly focusing on the integration of ITSs, such as MathU. The aim was to contextualise the use of ITSs within the broader landscape of educational technology and mathematics education, with a particular emphasis on their potential to support differentiated learning in inclusive South African classrooms. Mathematics education has long been seen as a cornerstone for developing critical thinking, problem-solving skills, and logical reasoning.

The Curriculum and Assessment Policy Statement (CAPS) in South Africa outlines the importance of Mathematics as a subject that enhances mental processes and advances logical and critical thinking (DoE, 2011). CAPS also emphasises the integration of real-life problems into teaching to enhance these skills, aligning with constructivist pedagogies that advocate for active, learner-centred learning (Mwakapenda, 2008). This pedagogical approach is fundamental to understanding how ITSs like MathU can be effectively integrated into the curriculum to support differentiated learning.

ITSs are adaptive learning technologies designed to provide personalised instruction and feedback to learners. These systems are grounded in theories of AI and cognitive science, and they aim to mimic the one-on-one interaction between a learner and a tutor (VanLehn, 2011).

ITSs are particularly useful in mathematics education, where they can offer targeted support based on the students' individual needs, thus enabling differentiated instruction. The MathU ITS, which is explored in this dissertation, illustrates the capacity of these systems to enhance learning outcomes by providing real-time feedback and personalised learning pathways for learners.

Differentiated instruction is an instructional strategy aimed at meeting the diverse learning needs of learners by modifying the content, process, and products of their learning (Tomlinson, 2001). ITSs, like MathU, are particularly well-suited to supporting differentiated instruction, as they can dynamically modify the level of difficulty, offer different types of exercises, and provide instant feedback based on the student's performance. This aligns with Tomlinson's (2001) principles of differentiation, which emphasise the need to provide multiple pathways to learning and tailor instruction to meet the needs of all learners.

Inclusion in education refers to the practice of teaching all learners, regardless of their abilities or disabilities, within the same classroom setting (Walton & Engelbrecht, 2024). Differentiation within this context is critical, as it allows teachers to meet the diverse needs of all learners.

South African classrooms, characterised by diversity in terms of language, socio-economic background, and learning abilities, present unique challenges for differentiation (Walton, 2013).

The integration of ITSs like MathU can provide teachers with the tools to offer personalised learning experiences that accommodate these diverse needs, thus supporting the goals of inclusive education (Ainscow, 2005).

The MathU ITS represents a practical application of TPACK and differentiated instruction principles within the South African context. Aligned with both the CAPS curriculum for Mathematics in the Senior Phase and the British International Mathematics Year curriculum, MathU provides a structured, curriculum-aligned platform that covers all key content areas specified in the CAPS curriculum. It offers resources on fundamental mathematical concepts, analytical thinking, spatial reasoning, practical application, and data handling skills, all of which are essential for developing mathematical proficiency (DoE, 2011).

The digital format of MathU allows for flexible time management, adapting to individual learner needs while ensuring comprehensive skill development. This flexibility is crucial in diverse South African classrooms, where students' learning needs can vary widely. MathU supports the implementation of CAPS guidelines in a digital learning environment, enhancing the quality of mathematics education in South Africa by providing a personalised learning experience (Mogari, 2014).

Studies examining the effects of ITSs on learning outcomes have demonstrated that these systems can significantly improve students' academic performance, especially in mathematics (Kulik & Fletcher, 2016). ITSs like MathU have the potential to close the gap between learners with different abilities by providing personalised support that is sometimes challenging to achieve in traditional classrooms. This is particularly important in South African classrooms, where resource constraints and large class sizes can hinder the implementation of differentiated instruction (Howie, 2003). By offering tailored instruction and immediate feedback, MathU and similar ITSs can help to address these challenges, ultimately leading to improved learning outcomes for all learners.

## 1.6 Overview of Theoretical Framework

This study is grounded in the TPACK model, a theoretical framework that provides a lens for understanding the complex interplay between technology, pedagogy, and content in the context of education (Koehler et al., 2013).

The TPACK model, as conceptualised by Mishra and Koehler (2006), builds upon Shulman's (1987) framework of Pedagogical Content Knowledge (PCK) and incorporates Technological Knowledge (TK), expanding the scope of effective teaching practices to include the integration of digital tools and resources.

The TPACK model's inclusion in this study was driven by its comprehensive nature, which allowed for a detailed examination of how MathU as an ITS can be integrated in a Grade 7 Mathematics classroom to support differentiated learning in an inclusive South African educational context.

Therefore, the TPACK model was utilised in the creation of the sub-research questions, highlighted in *Section 1.3.2*, and later in *Section 4.2* as it provides a lens through which to explore these interactions. Furthermore, the TPACK framework also served as the basis for creating the semi-structured interview questions used in this study.

The questions the researcher asked were carefully designed to align with the TPACK model's components, ensuring that the interviews would elicit responses relevant to the study's focus on the integration of technology, pedagogy, and content knowledge in an inclusive educational setting.

To offer a clear understanding of the TPACK model and its application within this study, Figure 1.1 is included to represent the model's components and their interrelations.

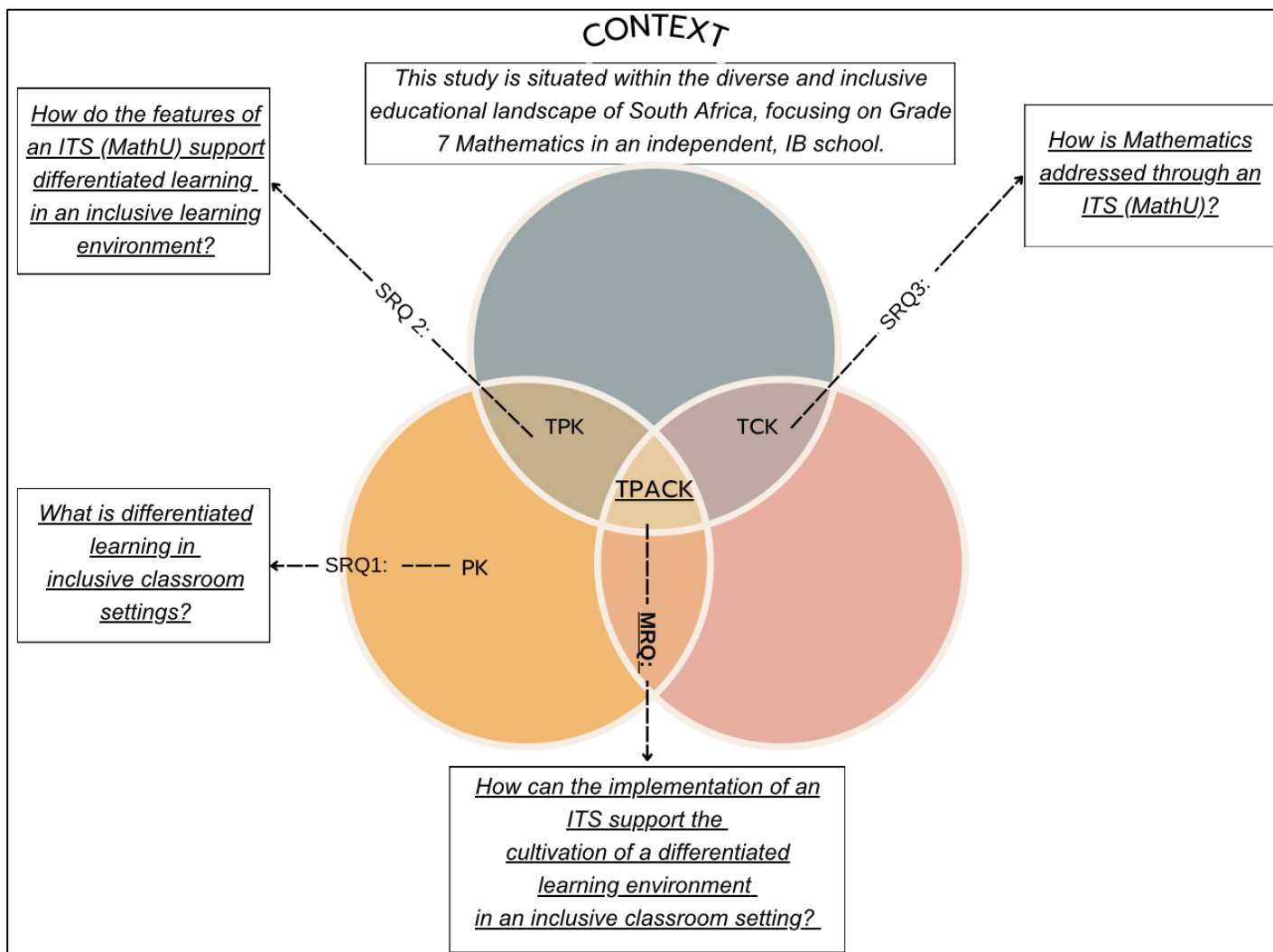


Figure 1.1 Technological Pedagogical Content Knowledge Relevant to This Study (Adapted from Koehler & Mishra, 2008)

## 1.7 Research Design

This study employed a structured approach to research design, guided by the research onion model conceptualised by Saunders et al. (2007).

The research onion provides a framework for making informed decisions at the different levels within the research process, from the overarching philosophical stance to the specific techniques and procedures employed for data collection and analysis.

Figure 1.2 summarises the research design choices made for this study, whereafter each layer is discussed in the context of this study. Note that each level of the research design has been colour-coded to correspond with the colours shown in Figure 1.2. Further elaboration on the research design is provided in Chapter 3, specifically within the Methodology section of this study.

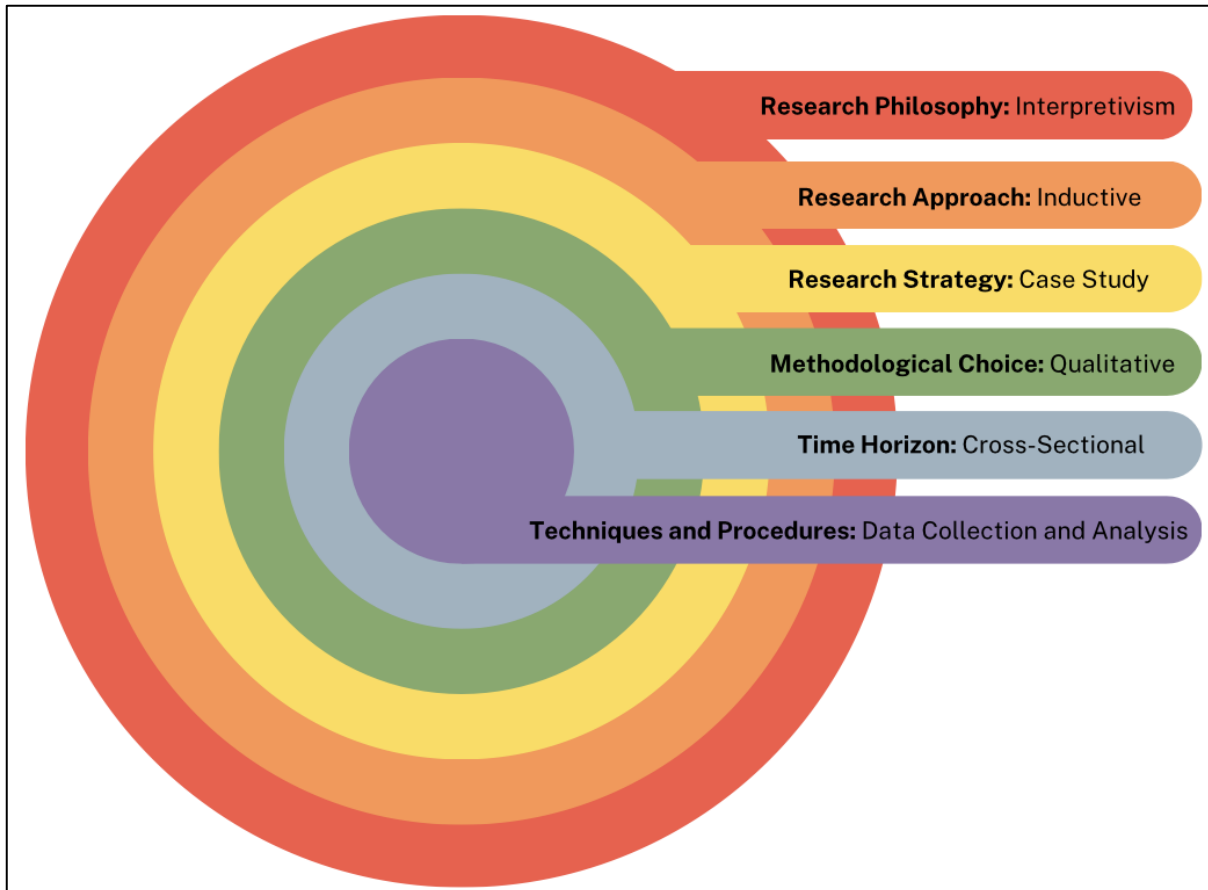


Figure 1.2: Research Onion  
(Adapted from Saunders et al. 2007)

### 1.7.1 Research Philosophy: Interpretivism

The research philosophy underpinning this study is interpretivism, which seeks to understand participants' complex, socially constructed realities (Ryan, 2018). This paradigm is grounded in the processes of observation and interpretation through which the researcher first gathers information about phenomena, and then makes sense of the information by drawing inferences (Aikenhead, 2003).

This philosophy aligns with the study's aim to explore the ways in which an ITS like MathU is implemented and experienced within inclusive classroom settings. By adopting an interpretivist approach, the study sought to uncover the deeper meanings and implications of ITS integration from teachers' perspectives.

### 1.7.2 Research Approach: Inductive

The study adopted an inductive research approach, typically suited for qualitative studies where the goal is to develop theory or insights based on the data collected (Gay & Airasian, 2007).

This approach was ideal for this study, as it sought to build an understanding of how the MathU ITS supports differentiated learning in an inclusive classroom environment. The findings from this study may contribute to the development of a broader theoretical framework for ITS implementation in similar educational contexts.

### 1.7.3 Research Strategy: Case Study

The research strategy employed in this study was a case study, which allows for a comprehensive exploration of a particular phenomenon within its real-life context (Yin, 2014). In this study, the case under investigation was the implementation of the MathU ITS in a Grade 7 inclusive, Mathematics classroom.

### 1.7.4 Methodological Choice: Qualitative

This study employed a qualitative methodological approach. In the context of this study, qualitative methods, such as interviews, policy document analysis and ITS exploration were used to gather in-depth data on teachers' experiences with the MathU ITS. This approach allowed the researcher to capture the subtleties of how the ITS is perceived, utilised, and integrated into classroom practices.

### 1.7.5 Time Horizon: Cross-Sectional

The study adopted a cross-sectional time horizon, indicating that data was collected at a specific point in time (Wang & Cheng, 2020). This design choice was appropriate for the study's aim to capture a snapshot of the current implementation and impact of the MathU ITS within a specific Grade 7 inclusive classroom. In this study, data was collected during the final term of the school year when learners were preparing for examinations using MathU.

During this time frame, the use of MathU by both learners and teachers was at its peak, providing an ideal period to observe and analyse the system's effectiveness and integration in the classroom.

### 1.7.6 Techniques and Procedures: Data Collection and Analysis

The final layer of the research onion highlights the techniques and procedures used for data collection and analysis. In this study, data was collected through a combination of qualitative methods, including semi-structured interviews with teachers, policy document analysis, and an exploration of the ITS, MathU.

Thematic analysis, a method used in the identifying, analysing, and reporting of patterns within qualitative data (Braun & Clarke, 2006), was used.

## 1.8 Ethical Considerations

In research, ethics refers to the principles that delineate right from wrong within a particular group (Bogdan & Biklen, 1997). The ethical considerations ensure that research study participants within research studies are protected from harm or malpractice (Barrow et al., 2024). The researcher made sure to address all relevant ethical considerations within this study, including informed consent, voluntary participation, anonymity and confidentiality. Further, the researcher adhered to the University of Pretoria's ethical guidelines at all times.

### 1.8.1 Informed Consent and Voluntary Participation

Informed consent is the principle that ensures participants in a research study are completely aware of the nature and purpose of the study, as well as their rights as participants (Flick, 2004). This involves communicating the study's goals, procedures, and expected duration, as well as the researcher's credibility, to enable participants to make informed decisions about whether or not to participate (De Vos et al., 2011).

In this study, informed consent was upheld by ensuring that all participants were informed about the nature, purpose, and procedures of the research. The objectives and expected duration of the study were also communicated to each participant, enabling them to make an informed decision about their participation.

During this process, letters of participation were provided and signed by each participant, affirming their voluntary consent to participate in the study. These signed letters are included in Appendix D of this study.

### 1.8.2 Anonymity and Confidentiality

In research, anonymity involves the collection of data without obtaining any personal information, whereas confidentiality refers to the protection of data and by removing any personal information so that results cannot be traced back to participants (Coffelt, 2017). In this study, while the participants were not anonymous – since the researcher knew their identities – confidentiality measures were implemented.

All identifying information was removed from the study, with participants' real names being replaced by pseudonyms. Additionally, AI-generated avatars were created to represent the participants, capturing their essence without revealing their true identities. This approach safeguarded participants' privacy and ensured that their identities could not be recognised, thereby upholding the principle of confidentiality throughout the study.

### 1.9 Dissertation Outline

This dissertation is structured into six chapters. The organisation of these chapters reflects a logical progression from the initial introduction and theoretical foundation to the methodological framework, data presentation, analysis of findings, and finally, the conclusions drawn from the research. Figure 1.3 represents these chapters, illustrating the relationships between the chapters and highlighting how they inform and support one another.

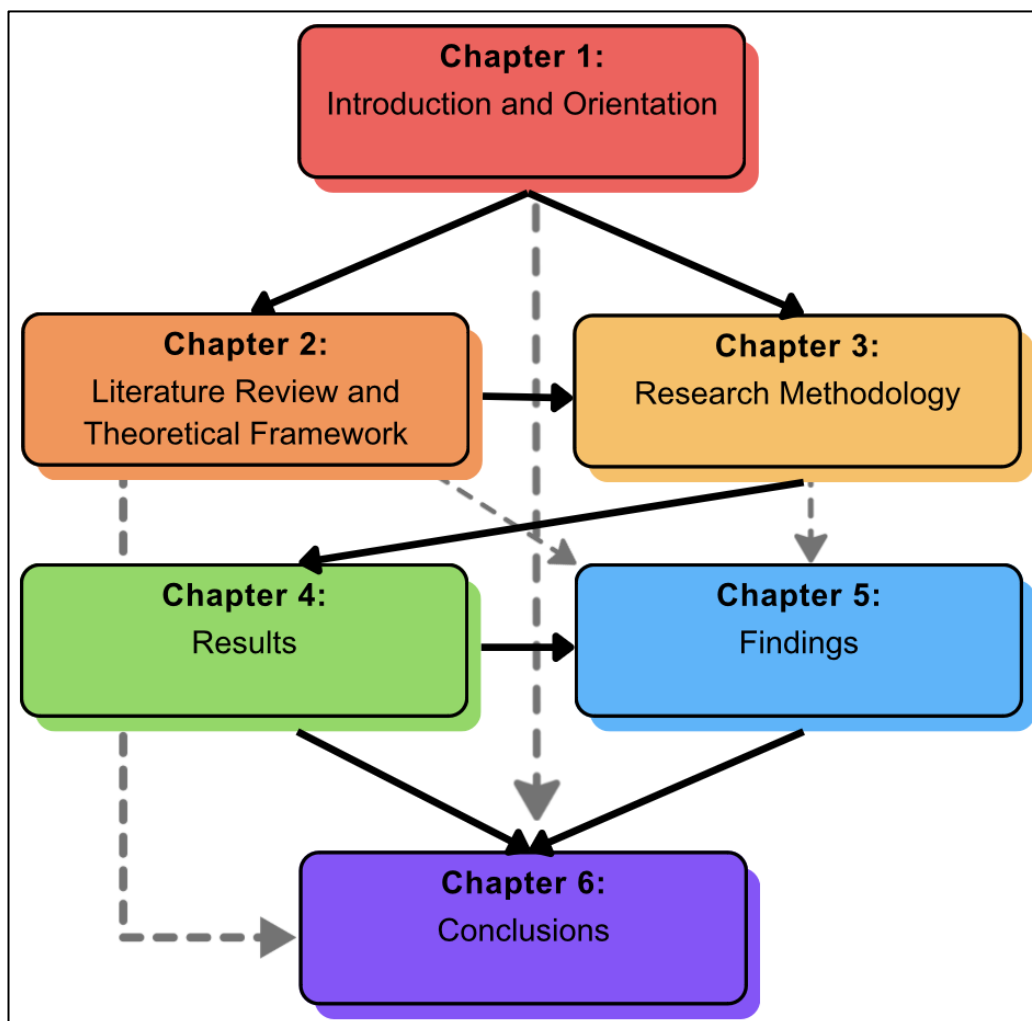


Figure 1.3: Dissertation Outline

### 1.9.1 Chapter 1: Introduction and Orientation

Chapter 1 lays the groundwork for the dissertation by introducing the research topic, articulating the problem statement and highlighting the significance and objectives of the study. This chapter also presents an overview of the research questions and the rationale for the investigation. Furthermore, it outlines the researcher's methodology and reasoning for conducting the research, thereby establishing the context and guiding the direction for the subsequent chapters.

### 1.9.2 Chapter 2: Literature Review and Theoretical Framework

Chapter 2 discusses existing literature related to research on inclusive education, differentiated learning, and ITSs, thereby offering a review of relevant studies. Additionally, Chapter 2 introduces and discusses the theoretical framework that underpins the research, providing the conceptual lens through which the study was conducted. The theoretical framework guided the research design, data collection, and analysis, ensuring that the study was grounded in established academic principles.

### 1.9.3 Chapter 3: Research Methodology

Chapter 3 further expands on the research methodology used in the study, drawing on the Research Onion model conceptualised by Saunders et al. (2007). This chapter details the research philosophy, approach, strategy, and methods employed to collect and analyse data. The methodological choices made in this chapter were directly informed by the theoretical framework discussed in Chapter 2, ensuring coherence between theory and practice. This chapter also discusses the ethical considerations of the study, the data collection process, and the techniques used for data analysis.

### 1.9.4 Chapter 4: Results

Chapter 4 presents the research results, detailing the data collected during the study from semi-structured interviews, school policy documents on inclusion and the ITS exploration. This chapter focuses on the raw data and the initial findings that emerged from the analysis. The results presented in this chapter served as the basis for the analysis and interpretation in Chapter 5.

#### 1.9.5 Chapter 5: Findings

Chapter 5 offers a deeper analysis and interpretation of the findings, initially presented in Chapter 4. This chapter addresses each of the sub-research questions in detail, linking them back to the overarching research question. The analysis was conducted in light of the theoretical framework and the literature reviewed in Chapter 2.

#### 1.9.6 Chapter 6: Conclusions

Chapter 6 concludes the dissertation by summarising the key findings and drawing final conclusions. This chapter revisits the research questions and objectives outlined in Chapter 1, assessing the extent to which they have been addressed.

The conclusions drawn in this chapter are based on the analysis conducted in Chapter 5 and are linked back to the broader literature discussed in Chapter 2. This chapter also offers recommendations for future research and practical applications, emphasising the contribution of the study to the academic field and its potential impact on practice.

#### 1.10 Conclusion

Chapter 1 introduced the research on integrating ITSs for differentiated learning in inclusive South African classrooms. It discussed the role of ITSs in personalising instruction based on students' needs, enhancing skills in various subjects, and supporting differentiated instruction. The background highlighted the importance of catering to diverse learner needs in inclusive settings and the challenges teachers face in implementing differentiation. The research focus outlined the study's aim to investigate how ITSs can facilitate differentiated learning, presenting the problem statement, research questions, and rationale. The chapter also previewed the literature review, theoretical framework based on the TPACK model, research design, ethical considerations, and dissertation outline, setting the stage for the detailed exploration in the subsequent chapters.

## Chapter 2: Literature Review

### 2.1 Introduction

In Chapter 1, the researcher provided an overview of the study, where the research problem was stated, followed by research questions, methods used to conduct the research, sample selection as well as a summary of data analysis. The purpose of Chapter 2 is to embark on an exploration of the existing body of literature concerning the utilisation of ITSs for the facilitation of differentiated learning within the inclusive education context of South Africa.

Chapter 2 begins with an overview of the South African educational landscape, setting the context for the study by highlighting the complexities of inclusive education within this environment. The review then explores pedagogical strategies, with a focus on differentiation as a means to foster inclusivity in the classroom. Building on this foundation, the discussion shifts to the integration of Artificial Intelligence in Education (AIEd), particularly the role of ITSs in supporting differentiated learning. The literature review is organised to lead the reader from a broad understanding of education in South Africa to a detailed analysis of how ITSs can facilitate inclusive practices. This progression is represented in Figure 2.1, which outlines the flow of the main headings, and thereafter, culminates in a discussion of the TPACK model, the theoretical framework guiding the study.

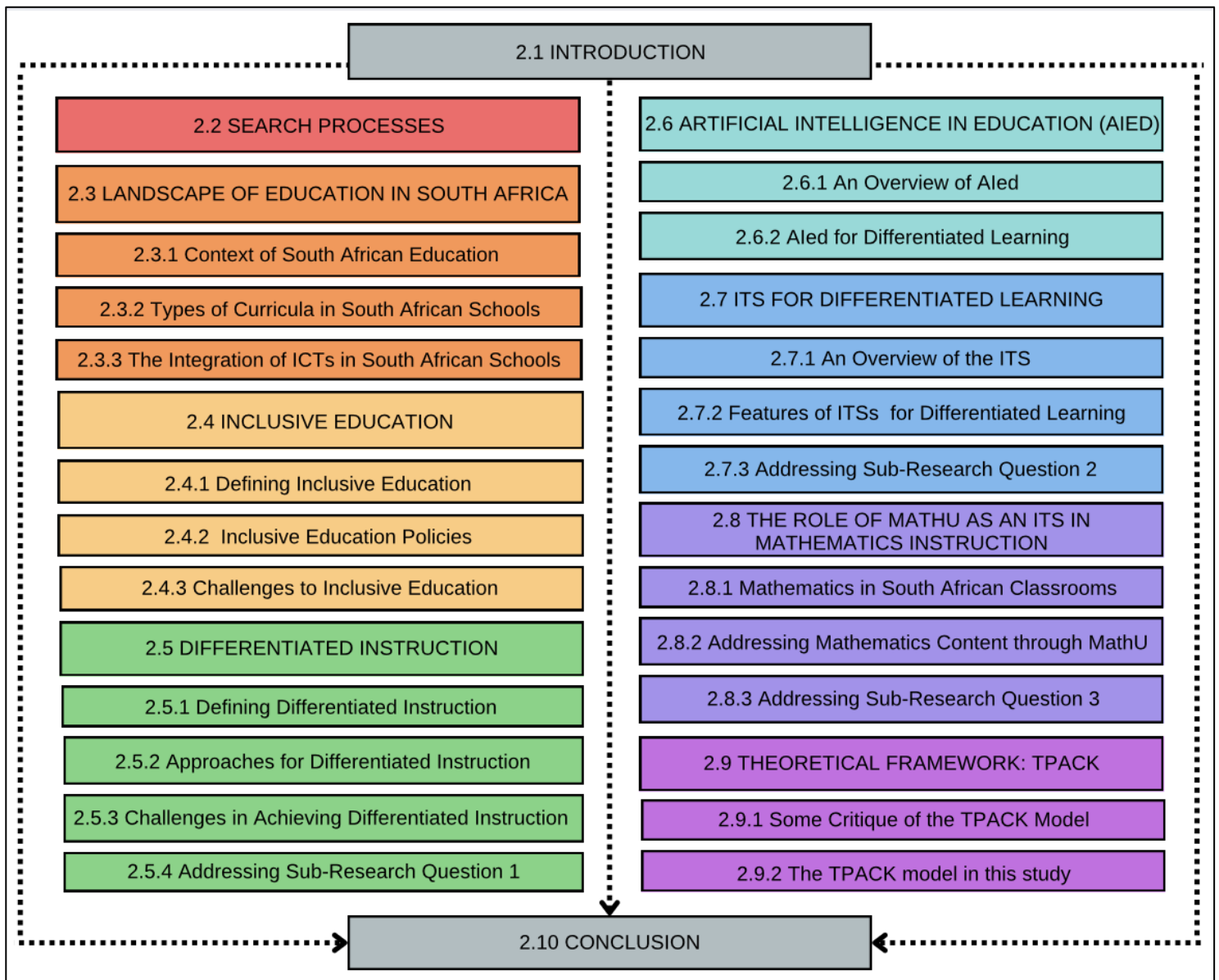


Figure 2.1: Outline of Literature Review

Figure 2.1 highlights how the review transitions from a broad overview of South African education to a more focused discussion on the application of ITSs in educational settings. This structured approach culminates in a discussion of the TPACK model, previously mentioned in *Section 1.6*, which serves as the theoretical framework guiding the study.

## 2.2 Search Processes

The following outlines the approach undertaken to identify, evaluate, and synthesise relevant literature, ensuring the process is explicit, thorough, and rigorous. This is in line with the principles of Blunden et al. (2000), who emphasise the importance of a well-documented and methodical search strategy.

The first step in the literature review involved conducting an extensive search of published scientific literature across multiple databases to ensure the identification of a broad range of relevant studies. In this step, it is important to determine the inclusion/exclusion criteria, including relevant dates, locations (and languages), methods, and conflicting points of view (Fink, 2019). The databases used for this study included ERIC (ProQuest), Education Research Complete (EBSCO) and JSTOR, which were chosen for their comprehensive indexing of educational technology and inclusive education literature. This multi-database approach aimed to capture a wide array of studies relevant to the research focus on ITSs and differentiated learning.

The next step involved entering appropriate keywords, as they enabled the discovery of relevant studies indexed under these terms (Sukhera, 2022). Initial relevant articles were examined to extract their keywords, which then guided the search process. The primary keywords used included “*intelligent tutoring systems*”, “*differentiated learning*”, “*inclusive education*”, “*adaptive learning technologies*”, and “*South African education*”. Various combinations of these keywords were iteratively applied to ensure a comprehensive retrieval of pertinent literature.

Step 3 involved reviewing abstracts and articles (Fink, 2019). After completing the search, the abstracts of articles were reviewed to determine their relevance to the research questions. This step involved a critical evaluation of abstracts to ensure that the selected studies directly addressed the integration of ITSs in differentiated learning or inclusive education. Only those abstracts that were clearly pertinent were chosen for a full-text review.

The final step involved documenting the literature search results and synthesising the findings (Paré et al., 2015). The key insights and data from the selected articles were integrated into the narrative of the literature review. This synthesis provided a cohesive overview of existing research, identifying both established knowledge and gaps in the literature.

The reviewed articles were referenced throughout the dissertation to support the theoretical framework, methodology, and analysis, ensuring a well-substantiated research foundation.

## 2.3 Landscape of Education in South Africa

In this section, the researcher provides an initial exploration of three crucial dimensions within South African education, namely, the present context of South African education, types of curricula within South African education settings, and the integration of ICTs in South African schools. These three areas play a large role in contextualising this study within the South African educational landscape, offering the context for this research study. This contextualisation ensures that the research findings are relevant, and that any recommendations provided are specifically designed to address the unique needs and circumstances of South African education.

### 2.3.1 Context of South African Education

The current state of South African education has been influenced by a significant historical backdrop (Dube, 2020). The South African Schools Act 84 of 1996 formalised the desegregation of schools, resulting in significant transformation in the educational system (DoE, 1996b). Vandeyar (2010) mentions that one of these changes aims to offer learners from diverse backgrounds the opportunity to attend any school of their choice, creating what is known as an inclusive education system. However, Badat and Sayed (2014) argue that despite these transformative efforts, achieving a fully inclusive education system in South Africa remains a complex and ongoing challenge.

Thus, in the endeavour of fostering a more inclusive educational environment within South African schools, a series of policies and initiatives were put into place (Dalton et al., 2012). White Paper 6 (DoE, 2001) and the South African Schools Act of 1996 (DoE, 1996b) were key policies in creating inclusivity within South African classroom settings (du Plessis, 2013).

Engelbrecht et al. (2015) explain that this paradigm shift moved away from a medical deficit model of difference toward a social model of difference. The medical-deficit model was seen in pre-1994 South African education, where disability was viewed as an individual issue (Hodkinson, 2010).

The medical-deficit model placed the responsibility for addressing learning barriers on the individual, rather than the education system, thereby resulting in exclusive practices that hindered access for all to mainstream education (Naicker, 2007).

However, with the advent of democracy in South Africa and movements in global disability rights, a shift began towards the social model of disability, rooted in principles of social justice (Meltz et al., 2014). Unlike the medical-deficit model, the social-model acknowledges that disability is not only an individual's problem but also a product of exclusionary social and economic practices (Naicker, 2007).

Thus, it aimed to remove disabling barriers created by inclusion-based attitudes and institutions. In the context of education, the social-model promoted inclusive schooling as a means to combat prejudicial attitudes toward disabled individuals in society (Winzer & Mazurek, 2010). This shift necessitated significant changes in curriculum, classroom management, and stakeholder attitudes to break free from stereotypes and discrimination (Hodkinson, 2010).

However, despite these policies and attempts at transformation, research has revealed some complexities in the implementation of inclusive education in South Africa (Donohue & Bornman, 2014; Walton, 2011). These complexities include challenges related to limited funding, overcrowded classrooms, and negative school cultures that influence attitudes toward diversity and disability (Walton, 2017). As a result, this has contributed to the stagnation in the implementation of inclusive education in some South African classrooms.

### 2.3.2 Types of Curricula in South African Schools

The South African Schools Act (No. 84 of 1996) categorises schools into two main types: public and independent schools (DoE, 1996a). Franklin (2017) notes that public schools and independent schools feature clear demarcations in the curricula they employ, each reflecting distinct approaches to pedagogy and educational objectives.

South African public schools are guided by the national curriculum framework known as the Curriculum and Assessment Policy Statement (CAPS), administered by the Department of Basic Education (DBE) (DoE, 1996a). The CAPS curriculum highlights a comprehensive and standardised educational strategy, tailored to ensure that learners across the nation acquire fundamental knowledge and skills across various academic disciplines (Maharajh et al., 2016).

Whilst Olivier and Kruger (2022) argue that this curriculum places an emphasis on teaching subjects, such as mathematics, science, language studies, and social sciences, Shabangu (2021) maintains that the underlying mission of CAPS transcends pedagogical strategies for these subjects; and instead aspires to rectify historical inequities in South African education, advocating for the principles of equality and inclusivity. Thus, CAPS represents an effort to bridge historical disparities and offer learners a uniform and substantial educational foundation (Khoza, 2015).

In contrast to the public school curriculum, independent schools in South Africa display a diversified landscape of curriculum choices (Gous et al., 2014). Whilst some independent schools in South Africa still choose to adhere to the national CAPS curriculum, others follow alternative curricula (Gous et al., 2014). In fact, many independent schools tend to gravitate toward international curricula, such as the Cambridge International Curriculum or the International Baccalaureate (IB) programme (Booyse, 2010). These alternative curricula prioritise the cultivation of critical thinking skills, concept-driven learning experiences, creativity, and a more holistic approach to education (Cambridge, 2010; Hill & Saxton, 2014).

Interestingly, in 2009, Umalusi initiated an equivalence-setting research project in collaboration with the Higher Education Statistics Agency (HESA) to benchmark the CAPS curriculum against the IB curriculum, followed in many South African independent schools (Booyse, 2010). This is a valuable research project as it illuminates the equivalence of various curricula within the South African educational landscape. The study revealed differences and similarities between different focus areas, including: curriculum organisation, sequencing and pacing, content coverage, the depth of content, teaching pedagogies and assessment guidance.

In terms of curriculum organisation, the CAPS curriculum features explicit organising principles structured around learning outcomes and knowledge areas. In contrast, the IB curriculum lacks explicit organising principles, and rather focuses on assessment objectives, providing teachers with flexibility. When looking at sequencing and pacing, CAPS emphasises clear sequencing and pacing in content progression for teachers, however, it is considered strenuous to follow. IB allows teachers more freedom and discretion in the sequencing and pacing of content.

Notably, CAPS shares a substantial content overlap with IB, especially in core topics. Thus, there is an alignment in content coverage with both curricula. The depth of content covered is also closely aligned in both curricula.

The teaching approach of CAPS promotes outcomes-based, learner-centred, and activity-based teaching, moving away from rote learning. IB also emphasises learner-centred approaches with a big focus on enquiry-based learning. Lastly, in terms of assessment guidance, CAPS offers comprehensive assessment guidance for teachers and learners, with detailed structures and weightings. While the IB provides clear assessment objectives, the guidelines are less detailed (Booyse, 2010).

Table 2.1 provides a summary of the comparisons between the CAPS curriculum and the IB curriculum.

*Table 2.1: A Comparison Between CAPS and IB (Booyse, 2010)*

<b>Aspects</b>	<b>CAPS Curriculum</b>	<b>IB Curriculum</b>
1. Curriculum Organisation	<ul style="list-style-type: none"> <li>• Explicit organising principles focused on learning outcomes and knowledge areas</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of explicit organising principles, emphasis on assessment objectives providing flexibility</li> </ul>
2. Sequencing and Pacing	<ul style="list-style-type: none"> <li>• Emphasises clear sequencing and pacing, strenuous for teachers</li> </ul>	<ul style="list-style-type: none"> <li>• Allows teachers more freedom and discretion in sequencing and pacing</li> </ul>
3. Content Coverage	<ul style="list-style-type: none"> <li>• Substantial content overlap, especially in core topics</li> </ul>	<ul style="list-style-type: none"> <li>• Substantial content overlap, particularly in core areas</li> </ul>
4. Depth of Content	<ul style="list-style-type: none"> <li>• Closely aligned in terms of depth of content coverage</li> </ul>	<ul style="list-style-type: none"> <li>• Closely aligned in terms of depth of content coverage</li> </ul>
5. Teaching Approach	<ul style="list-style-type: none"> <li>• Promotes outcomes-based, learner-centred, and activity-based teaching, moving away from rote learning</li> </ul>	<ul style="list-style-type: none"> <li>• Emphasises learner-centred approaches with a focus on enquiry-based learning</li> </ul>
6. Assessment Guidance	<ul style="list-style-type: none"> <li>• Offers comprehensive assessment guidance with detailed structures and weightings</li> </ul>	<ul style="list-style-type: none"> <li>• Offers comprehensive assessment guidance with detailed structures and weightings</li> </ul>

Within this study, the researcher is focusing on the IB curriculum (highlighted in blue) followed by an independent school in Gauteng. Table 2.1 above below indicates the comparison between these two curricula found in South African schools.

### 2.3.3 The Integration of Information and Communication Technologies in South African Schools

Information and Communication Technologies (ICTs) encompass a wide arrange of tools and technologies that play a pivotal role in education, offering teachers and learners with resources to enrich teaching and learning through digital platforms and online connectivity (Mwapwele et al., 2019).

In the context of this study, ICTs refer to technologies, such as the Internet, wireless networks and mobile devices (Ratheeswari, 2018). The integration ICTs within South African schools holds significant potential for enhancing the quality of education, as recognised by the South African Government (DoE, 2004). The South African Education ICT White paper underscores the transformative power of ICTs in education, emphasising its capacity to support learner-centric learning experiences aligned with national curriculum goals (DoE, 2004).

Moreover, Hove and Grobbelaar (2020) mention that ICTs have the potential to promote inclusion by addressing diverse educational needs within the education system. Barakabitze et al. (2019) agree with Hove and Grobbelaar, stating that one of the primary advantages of ICT integration in South African classrooms is its capacity to promote inclusive, learner-centred learning approaches (Barakabitze et al., 2019).

The *South Africa Connect National Broadband Policy* of 2013 by the Department of Communications and overseen by the Department of Communications and Digital Technologies, envisions widespread ICT knowledge and usage across individuals, communities, organisations, and society (DoC, 2013). Within the educational landscape, this policy emphasises the role of ICTs as vehicles for advancing social development and inclusive practices (Mwapwele et al., 2019). Evidently, the integration of ICTs necessitates a profound transformation in the roles of teachers and learners in South African classrooms (Samarakoon et al., 2017). Teachers now evolve into facilitators of learning, monitoring ICT-based learning functions, and learners transition from passive recipients to active initiators of their learning experiences (Barakabitze et al., 2019).

## 2.4 Inclusive Education

In this section, the focus now shifts from the broader educational field of South Africa to inclusive education, directly addressing SRQ 1: *What encompasses differentiated learning in an inclusive classroom setting?* This discussion aligns with the pedagogical knowledge component of the TPACK model, offering insights into the strategies and approaches that underpin effective differentiation in inclusive educational environments.

### 2.4.1 Defining Inclusive Education

The inclusive education philosophy gained significance since the 1994 Salamanca Declaration, which advocated for the global adoption of inclusive education policies, aimed at eradicating discriminatory practices against learners facing barriers to learning and development (UNESCO, 1994). According to UNICEF (2017), inclusive education refers to an educational system that ensures the participation and support of all learners, regardless of their background, abilities or specific needs. This includes ensuring that teaching methods and curricula are suitable for each learner, regardless of ability level. Inclusive education fosters a sense of belonging and encourages active participation in the school culture for all learners (Booth, 1996).

The general principle for inclusive education emphasises the right of learners with disabilities to be full members of regular classes alongside their peers within their community (Haug, 2017). However, Magnússon (2019) interestingly notes that the concept of inclusive education can exhibit variations within implementation, interpretation, and definition both in research and application. Prevalent scholars in the field of inclusive education emphasise the diverse range of perspectives surrounding inclusive education (Amor et al., 2019; Artiles et al., 2006; Göransson & Nilholm, 2014).

In response to the uncertainty surrounding the achievement of inclusive education, Finkelstein et al. (2021) identified five key domains within that are pivotal in creating effective learning experiences designed to reduce educational barriers for all learners. The first domain, collaboration and teamwork, highlights the importance of cooperative efforts amongst teachers and other stakeholders of the school community.

This collaboration involves teachers, language specialists, psychologists, physiotherapists and family members and learners,

The domain highlights the significance of a collective approach to education, where diverse expertise is key to supporting learning (Lindner & Schwab, 2020).

The second domain, instructional practices, centres on how teachers plan and organise their teaching and learning methods to enhance learner's engagement and understanding. This domain encompasses the methodologies employed to effectively teach content to learners, which according to Sanger (2020), include strategies, such as differentiated instruction. These practices are vital in ensuring that instruction is accessible and engaging for all learners (Louden et al., 2005).

Organisational practices form the third domain, which focuses on the modification of the learning environment and classroom setup (Finkelstein et al., 2021). According to Darling-Hammond et al. (2020), the primary aim here is to eliminate barriers to learning and to create an engaging and motivating atmosphere that is conducive to learning for all learners. This domain highlights the importance of the physical and structural aspects of the learning environment in fostering inclusivity (Lindner & Schwab, 2020).

The fourth domain, social, emotional, and behavioural practices, is concerned with the creation of a positive learning environment where learners experience social and emotional inclusion (Heyder et al., 2020). This domain addresses the need for practices that promote a sense of belonging and emotional well-being among learners, which are critical components of an inclusive educational setting (Lindner & Schwab, 2020).

The fifth domain emphasises the individualised assessment and ongoing monitoring of students' achievements, ensuring that progress is tracked and support is tailored to each student's personal needs. This domain advocates for the use of diverse assessment methods to accurately gauge and support each student's progress, recognising that traditional assessment practices may not fully capture the learning and development of diverse learners (Tai et al., 2024).

According to Finkelstein et al. (2021), together, these five domains define what an inclusive learning environment is, where all learners have an equal opportunity to succeed. Figure 2.2 illustrates these five essential domains – collaboration and teamwork; instructional practices; organisational practices; social, emotional and behavioural practices; and determining progress.

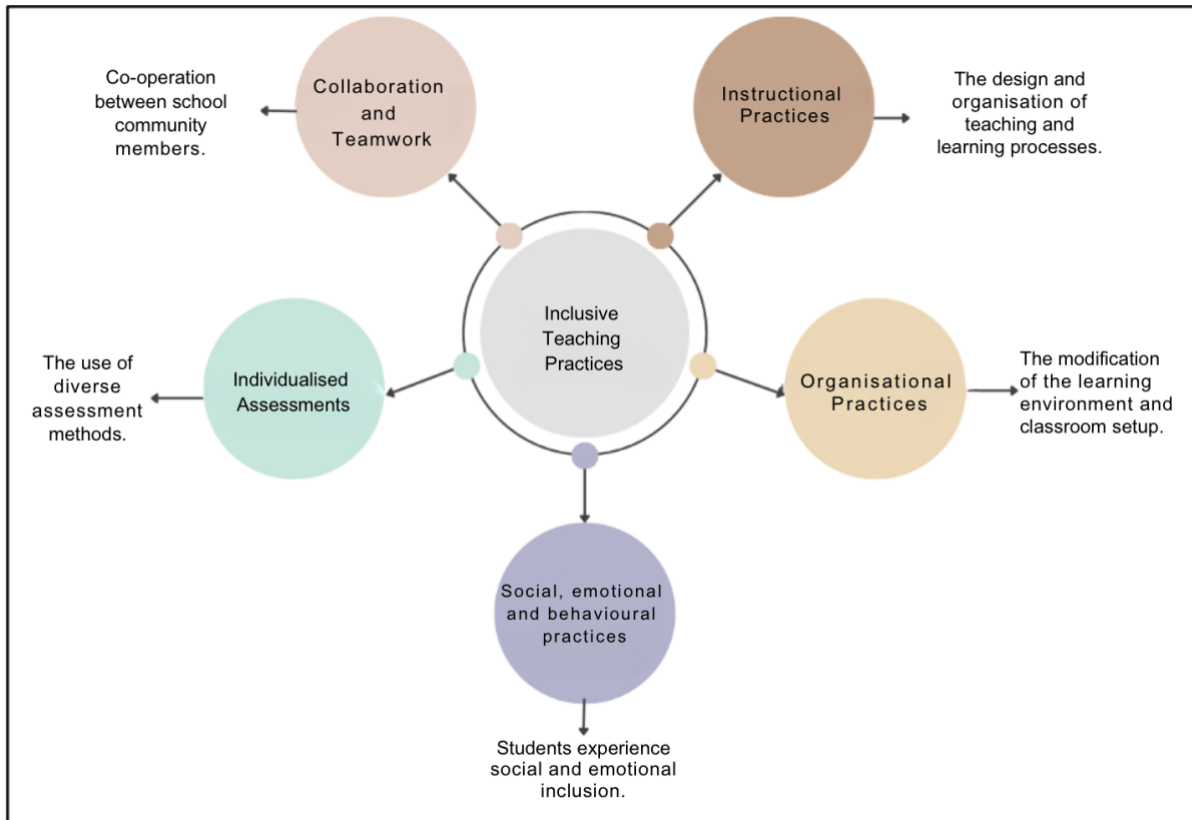


Figure 2.2: Domains of Inclusive Teaching Practice  
(Adapted from Finkelstein et al., 2021)

#### 2.4.2 Inclusive Education Policies

As mentioned in *Section 2.4.1*, the Salamanca Statement, introduced by UNESCO in 1994, constitutes a seminal international policy initiative in the field of inclusive education (UNESCO, 1994). Haug (2017) explains that this policy document has gained significant recognition from various European countries.

The Salamanca Statement's paramount objective is to advocate for equal educational rights and access to high-quality education for all learners, irrespective of their diverse abilities or specific educational needs. Emphasising the principles of inclusivity, the Salamanca Statement signifies a pivotal shift away from segregated educational settings (Magnússon, 2019).

Pather (2019) agrees with Haug (2017) and Magnússon (2019), indicating that the Salamanca Statement underscores the commitment to fostering inclusive educational environments and promoting educational equity on a global scale. In the years following the Salamanca Declaration, global discourse surrounding inclusive education broadened to encompass a more holistic and comprehensive approach, reflecting a profound paradigm shift (Pather, 2019).

Now shifting from a global context to a South African context, the introduction of democracy marked a profound turning point in government policy (Sisk, 2017). Phasha et al. (2017) emphasizes that inclusive education in an African context must critically address questions of power, equity, and social difference, acknowledging learners' diverse identities, histories, and cultural backgrounds as integral to the schooling process.

This transformation signified a departure from the apartheid system, bringing in an era of inclusion for all citizens. Central to this transformative journey was the development of an inclusive education system, aligning with the principles within the Constitution of the Republic of South Africa (Act 108 of 1996). This constitution firmly upholds the values of dignity, equality, and access to education as fundamental rights for every South African citizen, regardless of their background or abilities (Motala & Pampallis, 2020).

The Education White Paper No. 6, entitled 'Special Needs Education: Building an Inclusive Education and Training System' (DoE, 2001) emerged as a pivotal policy document in the world of inclusive education. This document outlined a comprehensive blueprint for establishing an inclusive education system in South Africa (Pather, 2019). According to Murungi (2015), the White Paper articulated the principles and goals of inclusive education and provided a roadmap for the practical implementation of inclusive practices within the country's educational landscape.

While the concept of inclusive education holds the promise of providing equitable educational opportunities to all learners, it is important to recognise that its practical implementation is not without its challenges (Donohue & Bornman, 2014). These challenges are discussed in the following section.

### 2.4.3 Challenges to Inclusive Education

The implementation of an inclusive education poses challenges globally in their efforts to provide a quality education for all learners, including those with special educational needs (SEN) (Nel et al., 2010). Furthermore, inclusive education also confronts numerous challenges within the context of South Africa (Seedat, 2018).

Allan and Slee (2008) highlight a notable level of teachers' uncertainty surrounding the creation of inclusive environments in schools and the effective implementation of inclusive teaching practices and pedagogies.

This uncertainty highlights the fact that whilst there may be a consensus on the definition of inclusive education and its underlying principles, the practicality of achieving it remains a challenge (Ramberg, 2018).

One of the significant challenges in achieving inclusive education in South African classrooms, as mentioned by Haug (2017), is the resistance to change among teachers. The transition from traditional, mainstream teaching practices to inclusive education requires a fundamental shift in pedagogical approaches and attitudes (Somma & Bennett, 2020). Somma and Bennett (2020) further explain that whilst teachers do express positive attitudes towards inclusive teaching practices, they also report a lack of confidence in implementing these practices for SEN learners in their classrooms.

As a result, teachers may harbour negative sentiments regarding the inclusion of SEN learners in their own classrooms (MacFarlane & Woolfson, 2013). Research suggests that the key to challenging and reshaping teachers' negative sentiments with regard to inclusive education is to provide them with opportunities to actively engage in and achieve success through the use of inclusive practices in their classrooms (Forlin et al., 2009; Grierson & Gallagher, 2009; Sharma et al., 2012). Somma and Bennett (2020) agree by arguing that these experiences of success with inclusion will empower teachers to undergo a positive transformation in their attitudes and perceptions regarding inclusive education.

Another hurdle to implementing inclusive education in South Africa lies in the lack of training and insufficient skills of teachers to adapt the curriculum to meet the diverse learning needs of learners (de Jager, 2013).

As Chataika et al. (2012) note, this challenge is further exacerbated by the historical disparities in education, which have left a legacy of unequal access to quality teacher training. Many teachers express feelings of unpreparedness to effectively teach SEN learners in their classrooms (Suprayogi et al., 2017).

To substantiate this statement, researchers have revealed that teachers have consistently showcased deficiencies in their readiness to effectively cater to SEN learners (DeSimone & Parmar, 2006; Maccini & Gagnon, 2006). As a solution, Mangope and Mukhopadhyay (2015) believe that offering appropriate professional development in managing diverse learners will ultimately lead to the enhancement the quality of teaching and learning for inclusive learning environments.

A further challenge to attaining successful inclusive education environments, especially in a South African context, is students' diverse linguistic and cultural backgrounds, adding an additional layer of complexity (Gay, 2015). Stofile (2008) agrees with this challenge and states that adapting teaching materials and strategies to cater to this diversity is a considerable challenge. Therefore, the need for culturally responsive pedagogies and the recognition of indigenous knowledge systems further complicates the task of ensuring an inclusive educational environment (Cocks et al., 2012).

Indeed, South Africa's journey to inclusive education is confronted by numerous challenges, from resistance to change among teachers to the pressing need for comprehensive teacher training and support. Amidst these challenges, one pedagogical approach that emerges as a promising means for the attainment of inclusive education is differentiation (Ainscow et al., 2013). This is discussed in the following sections.

## 2.5 Differentiated Instruction

In this section, the discussion moves to differentiated instruction, continuing the exploration of SRQ 1: What encompasses differentiated learning in an inclusive classroom setting? This section delves deeper into the principles, approaches and challenges surrounding differentiation, thereby further contributing to the pedagogical knowledge component of the TPACK model, emphasising the importance of adaptable teaching methods in fostering an inclusive and effective learning environment.

The conclusion of this section synthesises the literature findings to address SRQ 1 effectively.

#### 2.5.1 Defining Differentiated Instruction

According to de Jager (2017), differentiated learning is an educational method employed to educate learners with varying skill levels within one single, inclusive classroom setting. Differentiated instruction, as a key component of pedagogy, is essential for addressing the diverse needs of learners in an inclusive classroom (Mills et al., 2014).

Muthukrishna and Schoeman (2000) explain differentiation as a pedagogical approach that fundamentally acknowledges and addresses various dimensions of learners' diversity, including unique talents, learning styles, readiness levels, interests, and learning profiles.

Achieving differentiation necessitates teachers' readiness to modify the subject matter, assessment methods, and teaching and learning strategies, thereby fostering an inclusive classroom environment (Muthukrishna & Schoeman, 2000).

Thus, in the context of an inclusive classroom, differentiated instruction endeavours to align students' preferred learning approaches with appropriate pedagogical techniques, desired learning outcomes, and authentic opportunities for demonstrating acquired knowledge (Spencer-Waterman, 2014). Armstrong et al. (2009) argue that differentiated instruction acknowledges the diverse needs of learners by seeking to create an equitable educational landscape where inclusivity is realised through tailored instructional practices. In this study, differentiated instruction is defined as an approach that accommodates individual differences and needs, offering learners diverse opportunities for learning.

According to Tomlinson (2014), differentiation is an approach that aligns each student's learning with their readiness level, interests and preferred learning style. This approach involves acknowledging and building upon students' similarities, whilst also embracing their individual differences (Tomlinson, 2001). Interestingly, differentiation is also at times referred to as responsive instruction because differentiation emphasises a proactive planning approach to accommodate and respond to learners' diversity (Roy et al., 2013). This approach is discussed in the following section.

### 2.5.2 Approaches for Differentiated Instruction

Tomlinson (2004) provided a comprehensive explanation to achieve differentiation through a differentiation model, which serves as the theoretical foundation for differentiation in this study. In this model, Tomlinson (2004) mentions four principles to consider when creating a differentiated learning context. These principles include content, process, product, and learning environments (Tomlinson, 2001).

Content differentiation involves adapting what is learnt and the materials or resources through which learners access this learning (Stavrou & Koutselini, 2016). With content differentiation, the goal is to present alternative content so that all learners can engage meaningfully with the curriculum (Tomlinson, 2008).

According to Tomlinson (2001), content can be differentiated by varying the complexity of the material, offering different resources, or providing multiple formats to accommodate diverse learning and accessibility needs. In practice, differentiating content may involve using tiered assignments where learners work on different tasks that target the same understanding but vary in complexity (Gentry et al., 2013). This approach ensures that all learners are working towards the same learning objectives but at a level that is appropriate for their current readiness.

Process differentiation, on the other hand, focuses on the instructional methods used to engage learners with the content (Tomlinson, 2001). This emphasises the use of varied instructional tasks and grouping strategies to meet the diverse learning needs of learners. The goal is to ensure that all learners have opportunities to develop key skills regardless of their learning style or pace (Tomlinson, 2008). Process differentiation might include flexible grouping, providing learners with choices in how they learn, or by incorporating technology, such as using multimedia resources or e-tools, to enhance engagement and accommodate different learning preferences (Tomlinson, 2001).

Through means of product differentiation, learners can demonstrate their understanding and mastery of content via a variety of assessment methods (Tomlinson, 2001). Each assessment method should be aligned to assess the same learning objectives but in ways that align with different learners' strengths and interests (Blecker & Boakes, 2010; Wormeli, 2006).

The learning environment in a differentiated classroom is structured to promote a safe, supportive, and inclusive atmosphere where high expectations are set for all learners. This principle involves creating a classroom culture that values respect, caring, and a sense of community among all participants (Tomlinson, 2001),

Moreover, a differentiated learning environment is characterised by ongoing assessment and adjustment, where teachers continuously monitor learners progress and make necessary changes to the environment to support learning better (Blecker & Boakes, 2010).

Table 2.2 presents a summary of these four principles mentioned above in creating a differentiated learning environment (Tomlinson, 2001).

*Table 2.2: Principles to Create a Differentiated Learning Environment*  
 Source: (Tomlinson, 2001)

<b>Principles of Differentiated Learning</b>	<b>Description</b>
1. Content	Present alternative subject matter to ensure accessibility for all learners, accommodating diverse learning preferences.
2. Process	Varying instructional tasks, resources, and grouping strategies to meet the diverse learning needs of learners.
3. Product	Encouraging learners to demonstrate their learning through a range of options, promoting learners voice and choice.
4. Learning Environment	Fostering a safe and supportive atmosphere, setting high expectations for all learners within the classroom setting.

Table 2.2 highlights that to achieve success in the implementation of differentiated instruction, teachers require a deep understanding of their students' learning and thinking processes, a wide range of teaching options, motivation, and an awareness of the classroom climate (Munro, 2012). Although this is a clear and comprehensive model for differentiation, there are certain challenges associated with its implementation, which are discussed in the next section.

### 2.5.3 Challenges in Achieving Differentiated Instruction

Whilst the above literature reveals that differentiated instruction can support SEN learners, teachers tend to face challenges in dedicating time to providing differentiated instruction, ensuring understanding, and tracking individual learners progress (Barua et al., 2022). This is due to the fact that the demands of creating and delivering differentiated instruction for each learner can be time-consuming and resource-intensive (Mills et al., 2014). Moreover, Prensky (2010) maintains that teachers could be resistant to change their pedagogies from traditional instructional methods. Ultimately, the successful implementation of differentiated learning activities in inclusive classrooms relies heavily on teacher training and professional development (Prensky, 2010).

Lavania and Nor (2020) indicate that the absence of adequate training and professional development opportunities for teachers constitutes a substantial barrier to the successful implementation of differentiated instruction. de Jager (2011) concurs with this statement and further states that teachers require support and guidance to acquire the knowledge, skills, and strategies necessary for differentiated learning.

A potential solution to the challenges mentioned above lies in the integration of Artificial Intelligence in education (AIEd) tools and technologies (Wadhwa, 2017). According to Ilkka (2018), AIEd systems have the ability to customise educational content and methods to meet the needs and preferences of individual learners, aligning closely with the principles of differentiated instruction.

### 2.5.4 Addressing Sub-Research Question 1

The literature highlights differentiated instruction as a key strategy for creating inclusive classrooms by addressing diverse learners needs through tailored teaching methods, content, and assessments. Tomlinson's (2001) model outlines the core principles of differentiation: content, process, product, and learning environment, all aimed at making learning accessible and meaningful for all learners.

However, challenges, such as time constraints, resource demands, and resistance to change impede its implementation (Mills et al., 2014; Tomlinson, 2001). Professional development and the integration of AIEd are suggested solutions to enhance the effectiveness of differentiated instruction (Lavania & Nor, 2020; Wadhwa, 2017).

Differentiated learning in an inclusive classroom involves adapting teaching methods, content, and assessments to meet individual learner needs. Guided by principles like content, process, product, and learning environment, this approach ensures that all learners can engage meaningfully with the curriculum (Tomlinson, 2001). However, its success depends on overcoming challenges related to time, resources, and teacher training (Mills et al., 2014), with AIEd offering promising support to personalise learning and enhance differentiation (Ilkka, 2018).

In the following paragraphs, the various AIEd tools and technologies, and their potential impact on addressing the challenges of differentiated learning in inclusive classrooms are explored.

## 2.6 Artificial Intelligence in Education

In this section, the focus now shifts to exploring AIEd. This discussion addresses SRQ 2: How do the features of an ITS support differentiated learning? By examining the integration of AI in educational contexts, this section aligns with the TPK component of the TPACK model, providing insights into how technology can enhance and personalise learning experiences in inclusive classroom settings.

### 2.6.1 An Overview of Artificial Intelligence in Education

In some classrooms, teachers tend to treat their learners as a homogeneous group, delivering the same content by using uniform teaching methods and expecting uniform responses (Onyishi & Sefotho, 2020). This approach illustrates a notable lack of differentiation, and highlights the aforementioned literature regarding teachers' lack of knowledge, skills, and strategies required for implementing differentiated instruction (Shareefa et al., 2019). In contrast to this homogenised teaching approach, differentiated learning places learners at the centre of their educational journeys, entrusting learners with the responsibility for their own learning (de Jager, 2017).

Recently, the integration of AIEd has emerged as a valuable technological tool for both teachers and learners in addressing the challenges and requirements of differentiation (Ahmad et al., 2022).

In fact, Pennington (2009) goes so far as to argue that any challenge associated with implementing differentiated instruction could in fact be addressed through the utilisation of AI technology. By leveraging AIEd, learners can resolve their learning barriers by engaging in tailored learning activities (de Jager, 2017).

AI encompasses a range of definitions within the literature. According to Nabiye (2012), AI refers to the ability of computer-controlled systems to perform tasks in a way that mimics typical human behaviour. These tasks include mental processes, such as reasoning, meaning-making, generalisations and learning from past experiences (Nabiye, 2012). Nilsson (2014) further explains that AI is the construction of an algorithmic system that can emulate human intelligence.

It involves transforming data received from users into processed, meaningful information through filtering and processing mechanisms (Nilsson, 2014). Similarly, Sharma et al. (2019) characterise AI as a field of study within computer science that aims to address cognitive problems related to human intelligence, such as learning, problem-solving, and pattern recognition, whilst also adapting to new situations.

AIEd has gained increasing attention due to the potential to support learning in diverse contexts (Chen et al., 2020). One such key area of application is the development of intelligent tutoring systems (ITSs), which employ AI technology to deliver learning content, provide immediate feedback, and monitor individual learners progress (Bayne, 2015). With the integration of AI software and technologies, inclusive education stands to benefit from improved differentiated learning experiences, adaptive instruction, and enhanced educational decision-making processes (Hwang et al., 2020).

#### 2.6.2 Artificial Intelligence in Education for Differentiated Learning

Integrating AIEd technologies and tools into learning environments holds significant potential for supporting inclusive education (Wadhwa, 2017). Within inclusive education, AIEd aims to achieve the objective of delivering differentiated learning, taking into account students' unique learning approaches, preferences, and personal characteristics (Hwang, 2014).

Collins and Halverson (2018) argue that AIEd technologies can offer benefits towards inclusive education in terms of learner engagement, learning environments, the scaffolding of learners, inclusion of SEN learners, support for collaborative learning, and the reinforcement of positive social behaviour.

Further, Hwang et al. (2020) explain that the use of AI in education truly enables differentiated and adaptive learning experiences tailored to meet the individual needs of diverse learners.

Hwang et al. (2020) suggest that the use of AI tools and techniques can assist teachers in addressing the challenges associated with traditional methods of teaching a group of learners with diverse needs, as described by Onyishi and Sefotho (2020). However, it is crucial to note that the beneficial impacts of these technologies do not unfold automatically; rather, their effectiveness relies on strategic integration and thoughtful application within the learning process, as emphasised by Collins and Halverson (2018).

The successful integration of AIEd into learning experiences requires a thoughtful and pedagogically sound approach from teachers (Kasneci et al., 2023). Such a pedagogically sound approach prioritises personalisation, real-time feedback, adaptability, ethical considerations, inclusivity, and ongoing improvement.

Notably, in the field of AIEd, intelligent tutoring systems (ITSs) are being recognised as one of the most prevalent applications (Hwang et al., 2020). ITSs harness AI technologies to deliver adaptive learning experiences tailored to each student's cognitive levels and abilities, a concept well-articulated by Ouyang and Jiao (2021). This process begins with an initial baseline assessment of a learner, collecting data on their prior and existing knowledge, skills, and learning preferences (Bouchet et al., 2013). Based on this profile, the ITS then customises learning materials and activities. Continuous monitoring of the student's progress allows for real-time adaptive feedback, offering hints, explanations, or additional challenges as needed (Holstein et al., 2017).

The system keeps a record of the student's performance and progress, offering data-driven insights for both learners and teachers (Arroyo et al., 2014). When engaging with an ITS, learners make progress in their personalised pathways, advancing at their own pace and interacting with content that aligns precisely with their understanding (Sundararajan & Nitta, 2015). This ensures that as learners advance and demonstrate mastery, the ITS will introduce more advanced content, while also offering support and reinforcement for challenging areas (Hwang et al., 2020).

## 2.7 Intelligent Tutoring Systems for Differentiated Learning

Now, this section delves into the specific role of ITSs in supporting differentiated learning, directly addressing SRQ 2. By focusing on ITSs' capabilities, this discussion highlights how these advanced AI technologies can adapt to students' diverse needs, thereby enhancing personalised learning experiences. This section also contributes to the TPK component of the TPACK model, emphasising the intersection of technology and pedagogy in creating effective differentiated learning environments. The conclusion of this section synthesises the literature findings to effectively address Sub-Research Question 2.

### 2.7.1 An Overview of the Intelligent Tutoring System

According to Castro-Schez et al. (2021) an ITS is an automated, computer-based tool that provides adaptive learning experiences by modelling students' cognitive and emotional states. Dašić et al. (2016) further elaborate that an ITS is a sophisticated software system that integrates AI principles and methods to address the challenges of teaching and learning.

Niño et al. (2023) explain that ITSs function as virtual tutors by presenting content, assigning tasks, providing feedback, and answering questions. They offer prompts designed to stimulate cognitive, motivational, or metacognitive growth, all within self-paced, learners-led, adaptive, and interactive learning environments (VanLehn, 2011).

These systems guide learners through activities and problems, offering tailored hints based on real-time assessments of each student's progress (Ma et al., 2014; Steenbergen-Hu & Cooper, 2014). ITS researchers and developers, such as VanLehn (2011) and Graesser et al. (2018) have recognised the value of incorporating problem-solving activities that allow for multiple solution strategies within ITS systems. This approach to differentiation is believed to have a positive impact on students' academic achievements and motivation (Mitrovic et al., 2001). Moreover, ITSs integrate a range of educational tools, such as tests, exercises, activities, and lessons, which cater to diverse learner preferences (Ramírez-Noriega et al., 2017).

ITSs serve as valuable tools to enhance learning inclusivity and differentiation by catering to a diverse set of learners (Ma et al., 2014). This is particularly vital in learning environments where challenges to differentiation are encountered, such as when teacher-led, one-on-one time is limited (Barua et al., 2022).

Through integrating an ITS, learners receive personalised attention and support that would be otherwise challenging to achieve through conventional instruction methods (Nye, 2015).

In an analysis encompassing 248 studies, VanLehn (2011) compared the efficacy of human tutoring to ITS tutoring. Results indicated that learning environments had advanced to a point where ITSs emerged as a viable alternative to human tutoring, particularly within STEM subjects (del Olmo-Muñoz et al., 2023).

The study further revealed that the impact of ITSs appeared to be more pronounced when applied to general groups, rather than only targeting low-achieving learners, and the positive effects of ITS interventions were more substantial when their duration was limited to shorter periods, such as one term, as opposed to more extended interventions spanning an entire school year (VanLehn, 2011).

These observations underscore the potential of ITSs as valuable tools in supporting inclusive education and optimising differentiation for all learners. However, whilst VanLehn (2011) indicates that ITSs have evolved to a point where they can be considered as effective as one-on-one human tutoring, it is important to note that these tools should not be seen as replacements for the entire classroom eco-system (del Olmo-Muñoz et al., 2023).

### 2.7.2 Features of Intelligent Tutoring Systems for Differentiated Learning

ITSs have emerged as innovative educational tools that can be instrumental in supporting learners across various subject areas (Almasri et al., 2019). A culmination of meta-analyses and evaluatory studies have shown that ITSs can yield moderate to large improvements compared to traditional teacher-led instruction, non-ITS computer-based learning, and printed materials (Ma et al., 2014; Nesbit et al., 2014).

Waalkens et al. (2013) point out that one of the distinguishing features of an ITS is the comprehensive guidance offered throughout problem-solving processes, and not just the focus on the final answers. This *step-level* guidance has been identified as a key feature contributing to the success of ITSs in facilitating learning outcomes (VanLehn, 2011). Ultimately, the primary objective of all ITSs remains the same – that is, to deliver advanced instructional guidance on a personalised level, mirroring a human tutor (del Olmo-Muñoz et al., 2023).

According to Santhi et al. (2013), successful ITSs should perform three key functions, namely, to accurately diagnose a student's knowledge level through principled assessments, to decide on appropriate instructional strategies for individual learners, and adapt them accordingly, and, to provide timely and constructive feedback to users. Yet, above and beyond these three key functions, ITSs include various features aimed at improving the learning experience by personalising it to meet the unique needs of individual learners (Graesser et al., 2018).

The main feature of ITSs is that of adaptive learning (Steenbergen-Hu & Cooper, 2013). Within an ITS, the adaptive nature involves several key categories of adaptation, including the adaptation of the user environment, learning content, search functionalities, and the facilitation of communication and cooperation amongst learners in group activities (Brusilovsky, 2007; Paramythis & Loidl-Reisinger, 2003). The adaptive learning capabilities of ITSs enable them to modify the content and pace of instruction according to a student's current skills, knowledge, and progress.

Further, ITSs are grounded in content-specific knowledge across various disciplines, such as mathematics, physics, language studies, and programming (Graesser et al., 2018). Additionally, ITSs offer immediate and constructive feedback to learners, helping them to identify errors and guiding them toward correct solutions (Perikos et al., 2017).

Data analytics play a crucial role in ITSs, as these systems collect and analyse data on all individual learner interactions, performance, and academic progress (VanLehn, 2011). This information is used to identify patterns, diagnose challenges, and refine the instructional approach (Perikos et al., 2017).

According to Boonthum et al. (2008), some ITSs can also incorporate Natural Language Processing (NLP) techniques, enabling them to understand and generate human-like language. This capability allows for interactive conversations with learners, addressing questions, clarifying doubts, and providing explanations in a more engaging and conversational manner.

### 2.7.3 Addressing Sub-Research Question 2

ITSs are advanced, AI-driven educational tools designed to provide personalised learning experiences by adapting to students' cognitive and emotional states (Castro-Schez et al., 2021). They serve as virtual tutors, offering content, assignments, feedback, and guidance tailored to individual learners needs (Niño et al., 2023). ITSs are distinguished by their ability to deliver step-level guidance throughout problem-solving activities, rather than merely focusing on final answers (Waalkens et al., 2013). These systems enhance learning inclusivity and differentiation by offering adaptive learning environments that modify content and pacing based on a student's skills and progress (Steenbergen-Hu & Cooper, 2013).

Key features of ITSs include adaptive learning, immediate feedback, data analytics, and in some cases, NLP for interactive communication (Boonthum et al., 2008; Graesser et al., 2018; Perikos et al., 2017). These tools have shown to be particularly effective in STEM subjects, offering an alternative to human tutoring, especially in environments where teacher-led instruction time is limited (VanLehn, 2011).

The features of ITSs support differentiated learning by leveraging adaptive learning mechanisms that modify instructional content and pace according to each student's unique abilities and progress (Steenbergen-Hu & Cooper, 2013). These systems provide personalised feedback, offer multiple solution strategies for problem-solving, and integrate various educational tools to accommodate diverse learning preferences (Graesser et al., 2018; Ramírez-Noriega et al., 2017). By collecting and analysing data on user interactions, ITSs are able to refine instructional approaches in real time, thus enhancing the learning experience (Perikos et al., 2017; VanLehn, 2011). Furthermore, ITSs' ability to incorporate NLP allows for more engaging, conversational interactions, making the learning process more interactive (Boonthum et al., 2008).

Overall, ITSs facilitate a differentiated teaching approach, ensuring that all learners, regardless of their learning needs, receive the appropriate level of support and challenges, thereby optimising their academic outcomes and motivation (Barua et al., 2022; Mitrovic et al., 2001).

## 2.8 The Role of MathU as an ITS in Mathematics Instruction

This section focuses on the integration of ITSs, specifically focusing on MathU, in the context of Mathematics education. The discussion explores how ITSs, as a component of Technological Content Knowledge (TCK), can enhance mathematical learning. This section aims to address Sub-Research Question 3: How is Mathematics addressed through the ITS, MathU?

### 2.8.1 Mathematics in South African Classrooms

The Department of Basic Education (2011) asserts that mathematics is a human activity that encompasses the observation, representation, and investigation of patterns and qualitative relationships. This subject fosters mental processes that enhance logical and critical thinking, improve accuracy, develop and problem-solving skills (DoE, 2011, p. 8).

Mathematics is crucial for societal and economic development (Mogari, 2014). The National Curriculum Statement (NCS) Curriculum and Assessment Policy Statement (CAPS) describes Mathematics as a language that encompasses symbols, numeracy, geometry, and visual representations (DoE, 2011, p. 8). The policy aims to integrate real-life problems into teaching to enhance problem-solving and critical thinking skills (Mwakapenda, 2008). Molefe and Brodie (2010) note that while Mathematics involves structured procedures, it also requires skills, such as reasoning and communication. Mathematics education requires attention to contextual language, signifiers, rules, and graphs (Bansilal et al., 2015).

The CAPS Document outlines the structure and focus of mathematics instruction for the Senior Phase, encompassing Grades 7 to 9. According to CAPS, the mathematics curriculum is organised into five primary content areas: Numbers, Operations and Relationships; Patterns, Functions and Algebra; Space and Shape (Geometry); Measurement; and, Data Handling. Each of these content areas is designed to develop specific mathematical skills critical to students' overall mathematical proficiency (DoE, 2011b).

The CAPS document specifies that instructional time is allocated as follows: each term consists of 10 weeks, with a total of 4.5 hours per week dedicated to mathematics, amounting to 180 hours of teaching time annually (10 weeks  $\times$  4.5 hours/week  $\times$  4 terms = 180 hours/year).

In addition to teaching, between six and 12 hours per term are set aside for revision and assessment, resulting in a total of 24 to 48 hours annually. This allocation ensures that approximately 150 hours of direct teaching are available for the content areas. The distribution of time among these areas is guided by the weightings provided in the CAPS, which represent notional hours. This framework allows for some flexibility in the distribution of teaching time across grades, accommodating the diverse needs and contexts of different educational settings (Department of Basic Education, 2011).

### 2.8.2 Addressing Mathematics Content through MathU

The MathU ITS for Grade 7 demonstrates a robust alignment with both the CAPS curriculum for Mathematics in the Senior Phase, as well as the British International Mathematics Year curriculum.

MathU's homepage is meticulously designed to align with the Grade 7 maths CAPS topics by providing an organised framework that covers all necessary areas of study. The inclusion of chapters on Numbers, Operations, and Relationships ensures that learners gain proficiency in fundamental mathematical concepts, such as whole numbers, exponents, fractions, percentages, ratios, rates, and integers. These foundational elements are crucial for developing numerical literacy.

The Patterns, Functions and Algebra section offers resources on functions and relationships through graphs as well as algebraic expressions and equations. This encourages analytical thinking by teaching learners how to discern patterns and understand algebraic manipulation. Space and Shape (Geometry) is addressed through chapters dedicated to two-dimensional shapes' geometry alongside three-dimensional figures. This helps learners visualise mathematical concepts in space, which is essential for spatial reasoning. Measurement principles are explored within chapters focusing on construction techniques as well as perimeter and area calculations. This practical application of mathematics reinforces understanding through real-world contexts.

Lastly, Data Handling capabilities are fostered through statistics chapters that empower learners to collect, analyse, and interpret data effectively – a skill increasingly valuable in our data-driven world.

While the system does not explicitly display time allocations, its digital format presumably allows for flexible time management, potentially adapting to individual learners needs while adhering to the CAPS-specified curriculum framework and time distributions. The breakdown of topics, as evidenced by the inclusion of specific subtopics, suggests a comprehensive approach to skills development within each content area. This aligns with CAPS’ emphasis on fostering overall mathematical proficiency. The MathU ITS thus appears to offer a well-structured, curriculum-aligned platform for Grade 7 mathematics instruction, potentially enhancing the implementation of the CAPS guidelines in a digital learning environment.

Figure 2.3 illustrates a screenshot of the MathU ITS interface for Grade 7 CAPS Mathematics, displaying the curriculum aligned with the South African CAPS framework. The interface presents 15 main chapters covering key mathematical content areas, alongside additional subtopics, providing a comprehensive and structured approach to the Grade 7 mathematics curriculum.

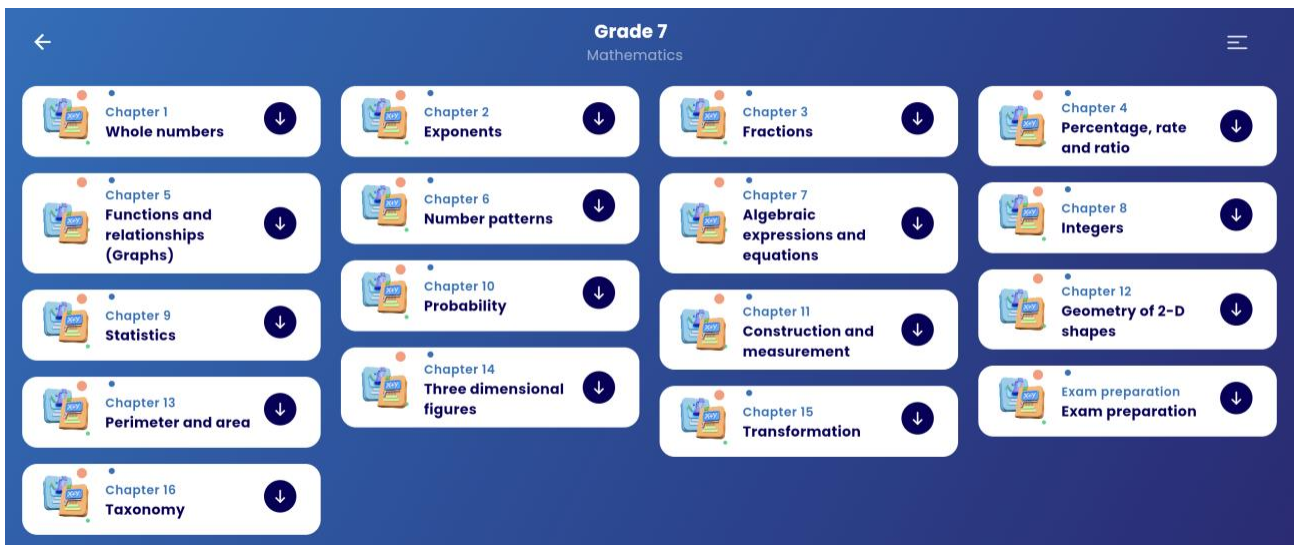


Figure 2.3: Screenshot of MathU’s Grade 7 CAPS Alignment

### 2.8.3 Addressing Sub-Research Question 3

MathU is able to address Mathematics through a structured, curriculum-aligned platform that covers all key content areas specified in the CAPS curriculum. It provides resources and chapters on fundamental mathematical concepts, encouraging analytical thinking, spatial reasoning, practical application, and data handling skills.

The digital format allows for flexible time management, adapting to individual learners needs, while ensuring comprehensive skills development in alignment with CAPS guidelines.

## 2.9 Theoretical Framework: Technological, Pedagogical and Content Knowledge Model

A theoretical framework guides the exploration of complex phenomena and provides a lens through which to analyse relationships between data (Collins & Halverson, 2018). The present study makes use of the Technological, Pedagogical and Content Knowledge (TPACK) model as the theoretical framework. The TPACK model has been approached from four main perspectives.

Firstly, Pierson (2001) describes TPACK as a novel definition of technology integration. Secondly, Niess (2011) describes TPACK as the amalgamation of content, pedagogy, and technology knowledge, representing the means to achieve technology integration. Thirdly, Mishra and Koehler (2006) refer to TPACK as the knowledge base essential for effective technology-infused teaching, emphasising the intersections of content, pedagogy, and technology; and lastly, Angeli et al. (2016) define TPACK as a distinctive body of knowledge with its own development and assessment criteria.

In the theoretical framework of this study, these varied perspectives collectively enhance the understanding of the TPACK model and its significance in the context of technology integration in South African education.

The TPACK model (Mishra & Koehler, 2006) gained much prominence in academia around 2006 (Graham, 2011). Rooted in Shulman's framework on pedagogical content knowledge (PCK) (Shulman, 1987), TPACK has since evolved to include technological knowledge (Graham, 2011).

The TPACK model is depicted as a Venn diagram featuring three overlapping circles that represent three fundamental knowledge areas: Pedagogical Knowledge (PK), Content Knowledge (CK), and Technological Knowledge (TK). The intersections of these knowledge areas yield four additional forms of knowledge: Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and the overarching Technological Pedagogical and Content Knowledge (TPACK).

Additionally, the TPACK model often considers the context, making it a comprehensive framework for understanding how technology can be effectively integrated into pedagogical practices across various content domains (Mishra & Koehler, 2006).

Table 2.3 represents the seven interconnected knowledge constructs within the TPACK framework, as well as the context.

*Table 2.3: The Seven Knowledge Constructs and Context in TPACK*

<b>Knowledge Area</b>	<b>Description</b>
Technological Knowledge (TK)	Knowledge of technology use, hardware, software, and applications (Hilton, 2016; Mishra & Koehler, 2006).
Pedagogical Knowledge (PK)	Knowledge of teaching, including instructional methods, assessment, and evaluation (Chai et al., 2013; Shulman, 1986).
Content Knowledge (CK)	Knowledge of a particular academic or subject area taught in the instructional process (Padmavathi, 2017; Shulman, 1986).
Pedagogical Content Knowledge (PCK)	Knowledge of teaching a particular subject area (Padmavathi, 2017). It is the intersection of pedagogical knowledge and content knowledge (Mishra & Koehler, 2006).
Technological Pedagogical Knowledge (TPK)	Knowledge of technology use to support teaching and learning (Marich & Greenhow, 2016). It is the intersection of technological knowledge and pedagogical knowledge (Mishra & Koehler, 2006).
Technological Content Knowledge (TCK)	Knowledge of technology use to teach a particular subject area (Hilton, 2016). It is the intersection of technological knowledge and content knowledge. (Mishra & Koehler, 2006)
Technological Pedagogical and Content Knowledge (TPACK)	Knowledge of technology use to teach a subject area effectively (Chai et al., 2013). It is the intersection of technological knowledge, pedagogical knowledge, and content knowledge. (Mishra & Koehler, 2006).
Context	The always-changing context refers to physical elements, such as the design of the learning environment, characteristics of the school, grade level, learners background, and the types of available technologies (Mishra & Koehler, 2006).

### 2.9.1 Some Critique of the Technological Pedagogical and Content Knowledge Model

The TPACK model has been a prominent theory within the realm of educational technology research (Hew et al., 2019). Yet, despite its popularity, the TPACK framework has in fact received some critique, with scholars engaging in ongoing discussions regarding critical aspects of the model (Angeli et al., 2016; Kessler & Phillips, 2019).

One significant area of critique within the TPACK model lies in the actual definition of the seven different components forming TPACK (Saubern et al., 2020). There are concerns over how to precisely define the components of TPACK and how they interact with each other (Angeli et al., 2016).

Cox (2008) conducted a conceptual analysis of the TPACK model and highlighted that there are, in fact, 89 different interpretations of TPACK, featuring variances in the definitions of each component. The lack of clarity and fuzzy boundaries surrounding the TPACK model underscores the need for greater clarity and consensus in its conceptualisation within educational research (Graham, 2011).

To address this, the researcher has clearly defined and delineated each TPACK component based on established scholarly interpretations (Mishra & Koehler, 2006). These definitions can be seen in Table 2.3 above. By defining the components in a transparent manner, this research aims to provide a solid foundation for examining the integration of ITS within the context of Inclusive South African Education.

#### 2.9.2 The Technological Pedagogical and Content Knowledge model in This Study

Whilst there are some critique relating to the TPACK model, as mentioned above, adopting the TPACK model as the theoretical foundation for this study holds merit due to its profound impact on the understanding of successful technology integration in education (Rosenberg & Koehler, 2015). The development of the TPACK model came about as a response to the absence of theory guiding the integration of technology into education (Mishra & Koehler, 2006). As a result, researchers worldwide have increasingly turned to TPACK to address critical issues concerning effective technology integration in education (Graham, 2011).

TPACK has also become a framework for investigating teacher professional development in the context of technology integration (Chai et al., 2013; Voogt et al., 2012). This is crucial in a rapidly evolving digital age where teachers must continuously adapt their skills to effectively leverage technology for teaching. By grounding this study in the TPACK framework, it becomes aligned with a well-established and recognised model that facilitates a deeper understanding of the complex interplay between pedagogy, content, and technology in the educational landscape.

The TPACK model has played a pivotal role in shaping the formulation of the researcher's sub-research questions, ensuring a systematic exploration of the integration of ITSs in an Inclusive South African Education context. These sub-research questions were carefully created to align with the distinct facets of the TPACK framework:

*SRQ1: What encompasses differentiated learning in an inclusive classroom setting?*

This sub-research question delves into the Pedagogical Knowledge component of TPACK. It aims to elucidate the fundamental principles and practices of differentiated learning within the inclusive classroom context, reflecting the pedagogical expertise required for effective teaching in this environment.

*SRQ2: How do the features of an ITS support differentiated learning?*

This sub-research question addresses the technological pedagogical knowledge of TPACK. It focuses on understanding the technological features and capabilities of ITSs that facilitate and enhance differentiated learning.

*SRQ3: How is Mathematics matter addressed through the ITS, MathU?*

This sub-research question underscores the importance of content knowledge within the TPACK framework. It examines how ITSs address specific subject matter, emphasising the need for a deep understanding of the content being taught and how technology can be harnessed effectively to convey this content within an inclusive education context.

The TPACK model, which emphasises the interplay between technology, pedagogy, and content knowledge, provides a valuable theoretical framework for understanding the potential of an ITS to support differentiated instruction in an inclusive classroom setting (Celik, 2023). By using the TPACK model as a the guiding framework, teachers who make use of ITSs can develop an understanding of how this tool can support the cultivation of a differentiated learning environment. Teachers can gain insights into how to integrate the ITS effectively into their pedagogical practices and content knowledge, as well as how to use the technology to support differentiated instruction in an inclusive classroom setting (Glaze et al., 2021).

Figure 2.4 illustrates the TPACK model, highlighting the interplay between each knowledge area, as well as the context in which the TPACK model takes place.

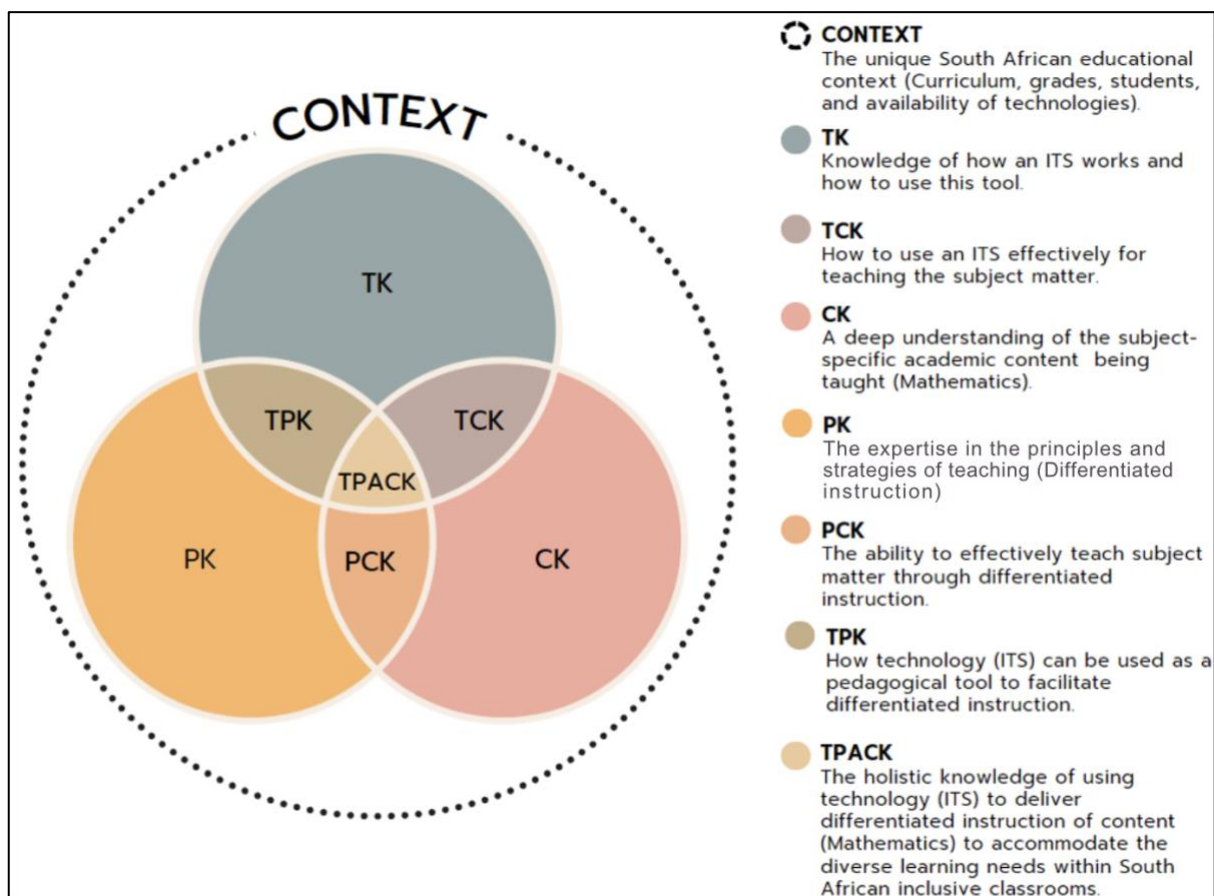


Figure 2.4: Technological Pedagogical and Content Knowledge Model  
Source: Mishra and Koehler (2006)

The sections below delve into the application of the TPACK model within this study, by focusing on each component within the model.

### 2.9.2.1 Technological Knowledge (TK)

TK, defined as the understanding of how to effectively use emerging technologies, according to Cox and Graham (2009), is of paramount importance in the context of employing an ITS. It equips teachers with the knowledge to comprehend the technical infrastructure of ITS, enabling the seamless integration of these systems into the classroom environment. Such knowledge empowers teachers to adapt to the ever-evolving technological landscape, making the most of new features and updates within ITS. It also enables them to harness the full potential of ITS tools, manage and analyse data, and personalise the learning experience for all learners.

TK is the linchpin for the successful implementation and utilisation of ITS, facilitating differentiated and effective learning experiences.

### *2.9.2.2 Pedagogical Knowledge (PK)*

PK encompasses a teacher's understanding of effective teaching and learning practices (Chai et al., 2013). Differentiated instruction is a pedagogy deeply rooted in pedagogical expertise (Suprayogi et al., 2017). De Jager (2017) defined differentiated instruction as an educational approach to address diverse learner skill levels within inclusive classrooms. This pedagogical method, central to effective teaching (Mills et al., 2014), entails ongoing individual progress monitoring, recognising unique learning needs, and adapting instruction accordingly.

### *2.9.2.3 Content Knowledge (CK)*

Within this study, CK is defined as a comprehensive understanding of the subject of mathematics in the context of an IB school. As explained by Shulman (1986), CK encompasses the teacher's expertise in deciding on the content that should be imparted to each learners. It is important to note that the nature of CK required to teach a subject differs from subject to subject (Odajima, 2019).

### *2.9.2.4 Technological Pedagogical Knowledge (TPK)*

Mishra and Koehler (2006) define TPK as the understanding of the various technologies used in teaching and learning, including awareness of their components and capabilities for teaching and learning pedagogies. Moreover, it involves an insightful comprehension of how teaching pedagogies might be transformed by the integration of specific technologies (Odajima, 2019).

In this study, TPK pertains to the understanding and utilisation of ITS technology to facilitate differentiated instruction. TPK encompasses the proficiency to harness the capabilities of ITS technology to cater to the diverse learning needs of learners. This incorporates an awareness of best practices and strategies in teaching and the adept use of ITS tools to effectively implement these strategies.

### *2.9.2.5 Technological Content Knowledge (TCK)*

Mishra and Koehler (2006) define TCK as the interplay between technology and subject-specific content, emphasising knowledge of topic-specific representations that harness emerging technologies. In this study, TCK refers to the comprehension of how an ITS can effectively teach diverse knowledge domains within the field of mathematics.

TCK underscores the imperative connection between technology and the specific mathematical content being conveyed, thereby enriching the content knowledge of mathematics education (Hilton, 2016).

#### *2.9.2.6 Pedagogical Content Knowledge (PCK)*

Shulman's seminal work in 1986 united the domains of pedagogy and content knowledge and posited that these two facets should not function in isolation (Shulman, 1986). PCK explores diverse approaches to presenting subject matter, ensuring it becomes accessible to learners with varying needs (Glaze et al., 2021). In the context of this study, PCK signifies the integration of differentiated instruction to effectively teach mathematics.

#### *2.9.2.7 Technological Pedagogical and Content Knowledge (TPACK)*

As described by Mishra and Koehler (2006), TPACK extends beyond the realms of technology, pedagogy, and content knowledge, representing a holistic form of knowledge that integrates all seven components. In the context of this study, TPACK encapsulates the comprehensive utilisation of an ITS to effectively teach mathematics through the pedagogy of differentiated instruction.

#### *2.9.2.8 Context*

The context, which is often overlooked when exploring the TPACK model (Chai et al., 2013), encompasses the dynamic physical elements of the learning environment, encompassing school characteristics, grade level, learner backgrounds, and available technologies (Mishra & Koehler, 2006). The context of this study is situated within an inclusive, independent school located in Pretoria, South Africa. This school aligns its educational framework with the IB curriculum, which emphasises a holistic approach to education, intercultural understanding, and developing globally aware citizens.

### *2.10 Conclusion*

The literature in this dissertation has provided an examination of pedagogical approaches, particularly focusing on the integration of ITSs like MathU in Mathematics education. The review has emphasised the role of ITSs in facilitating differentiated instruction within inclusive South African classrooms, highlighting their potential to support diverse learners needs through personalised, adaptive learning experiences.

The discussion has shown that the integration of ITSs aligns well with contemporary pedagogical theories, including constructivist approaches and the principles of differentiated instruction as outlined by Tomlinson (2001). Furthermore, the literature underscores the relevance of the ITS, MathU, in the context of the Grade 7-9 CAPS syllabus for Mathematics in South Africa. By addressing the unique challenges of diverse South African classrooms, ITSs like MathU offer a promising solution for bridging educational gaps and improving overall learning outcomes. As the researcher transitioned to the methodological framework in Chapter 3, the insights gained from the literature review informed the research design and methods used to investigate the effectiveness of MathU in supporting differentiated learning.

## Chapter 3: Methodology

### 3.1 Introduction

Chapter 3 commences by delineating the research design that underpins the investigation of the integration of ITSs for facilitating differentiated learning within inclusive South African classrooms. This chapter delves into the philosophical assumptions, approach, strategy, and specific techniques employed for data collection, analysis and dissemination.

According to Leedy and Ormrod (2016), research design serves as an extensive framework that guides the research process. Research design encompasses the selection of participants, research sites, and the methodologies employed for data collection in the pursuit of investigating research questions (McMillan & Schumacher, 2010). This design functions as a plan that establishes a connection between the research questions and the strategies to be employed (Leedy & Ormrod, 2016). The researcher makes use of the Research Onion conceptualised by Saunders et al. (2015) to explain the research design in this study.

This model posits that research is conducted by making choices at six hierarchical levels, ranging from abstract philosophical choices to more practical considerations. Saunders' research onion provides a comprehensive framework for research design by breaking down the research process into smaller, more manageable stages.

Figure 3.1 provides a summary of the research design used within this study.

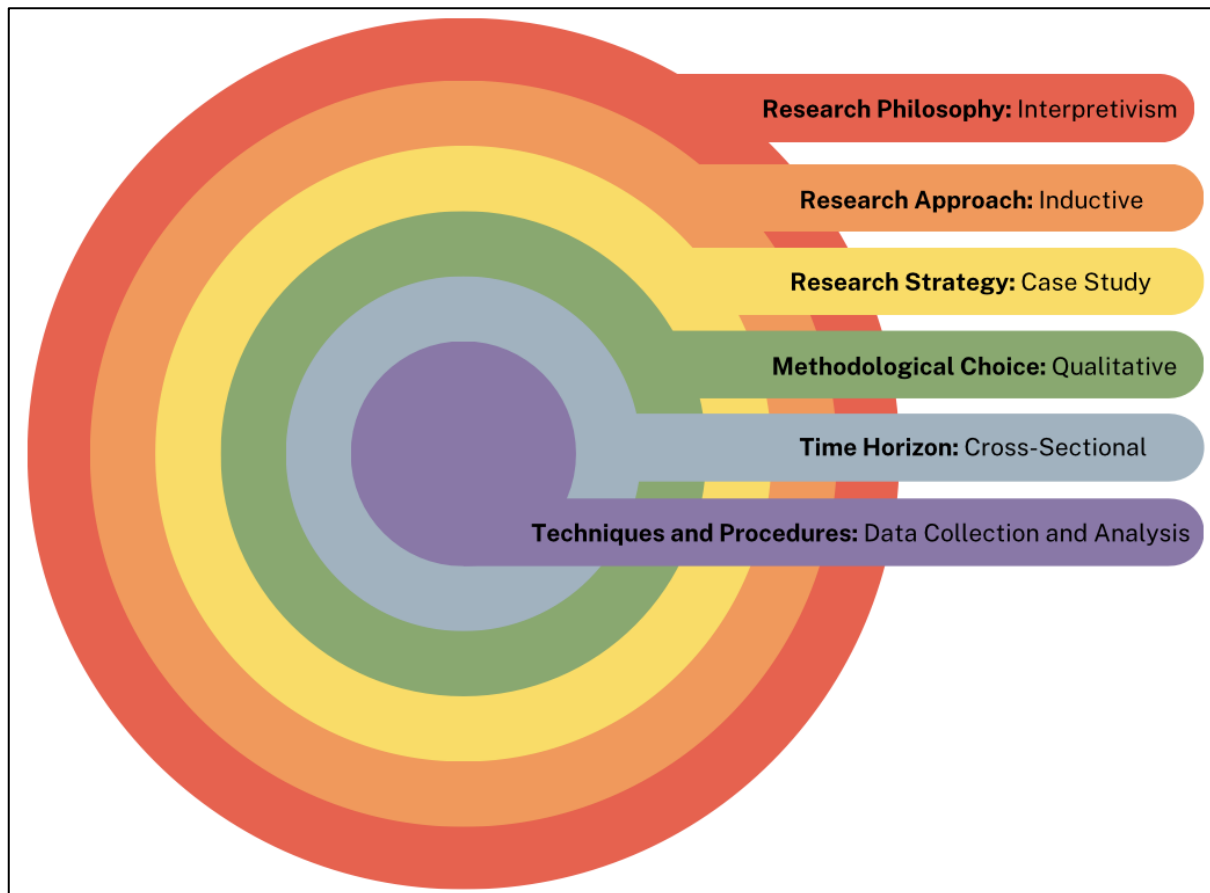


Figure 3.1: Research Onion  
(Adapted from Saunders et al. 2007)

In accordance with Figure 3.1, the discussion commences with an examination of the **research philosophy**, interpretivism, in conjunction with its associated constructivist ontology. Subsequently, the study's **research approach** to theory development, characterised by an inductive methodology with elements of deduction, is delineated. The subsequent section delves into the explication of the **research strategy**, identified as an exploratory case study. Thereafter, the **mono-method qualitative** choice is discussed, followed by the **time horizon** which indicates that data collection was conducted cross-sectionally employing three distinct **techniques and procedures**: semi-structured interviews, policy document analysis, and the technological tool exploration of MathU.

This chapter concludes by revealing the research's alignment with theoretical frameworks, considerations regarding quality assurance, and ethical considerations inherent in the study's design and implementation.

## 3.2 Philosophy

The research philosophy encompasses the fundamental beliefs and assumptions about how knowledge is developed and understood within a specific research context (Saunders et al., 2009). This concept of knowledge development is closely related to what Creswell (2009) describes as a *philosophical worldview*, which reflects the broader perspective that researchers bring to their studies, shaping their approach to research design and methodology.

The discussion focuses on the research philosophy that guides this study, linking it to the researcher's chosen paradigm. This connection is vital, as the selected research philosophy influences the design decisions and methodological approaches employed throughout the study, ensuring consistency and rigour in addressing the research questions. *Section 3.2* comprises two key elements, namely, the ontology, and epistemology (Engle, 2008).

### 3.2.1 Ontology

The ontology of this study, which pertains to the nature of reality (Saunders, Lewis, & Thornhill, 2019), is grounded in constructivism. This philosophical perspective posits that reality is not an objective entity but a social construct influenced by the experiences and interactions of individuals or groups (Cupchik, 2001).

Within the context of this research, constructivism implies that the realities uncovered are inherently subjective, emerging from the lived experiences and perspectives of the study's participants. These constructed realities are particularly relevant in exploring the integration and impact of the ITS, MathU, in educational settings, as they reflect the nuanced and diverse ways in which stakeholders – such as teachers, learners, and policymakers – perceive and engage with the technology. The study adopts a qualitative approach, utilising semi-structured interviews, policy document analysis, and a technological examination of MathU to uncover these multiple realities.

Through this lens, the research aims to capture the complex, context-dependent nature of the phenomenon under investigation, providing a deeper understanding of how MathU functions within the broader landscape of educational technology and differentiated learning in inclusive classrooms.

### 3.2.2 Epistemology

The epistemology of this study, which concerns the nature of knowledge and the methodologies employed in its acquisition (Cohen, Manion & Morrison, 2007), is rooted in interpretivism.

Interpretivism is a philosophical approach that goes beyond merely identifying the existence or absence of relationships between elements; it delves into the intricate ways these relationships are manifested and the specific contexts in which they unfold (Lin, 1998).

In the context of this research, an interpretivist epistemology is relevant as it prioritises a deep understanding of the subjective realities and meanings constructed by individuals within their social environments (Myers, 2019). Therefore, this study embraces an interpretivist philosophy to explore teachers' nuanced perceptions and experiences regarding the integration of the ITS in inclusive educational settings.

By focusing on the subjective and context-dependent nature of knowledge, this approach allows the research to capture the rich, diverse interpretations that participants bring to their interactions with MathU, thereby providing a comprehensive understanding of its impact and effectiveness within the specific educational milieu.

This epistemological stance aligns with the broader constructivist ontology of the study, reinforcing the idea that knowledge is co-constructed through social interactions and experiences (Thanh & Thanh, 2015).

### 3.3 Research Approaches

In this study, the approach to theory development is guided by principles that direct the organisation of data, the identification of themes, and the creation of meaning (Salmons, 2016). The researcher included inductive reasoning within this study, however, there were instances where deductive reasoning was also employed, thereby allowing for a comprehensive analysis of the data collected. This discussion is elaborated on in the *Sub-sections* 3.3.1 and 3.3.2 below.

### 3.3.1 Deductive Reasoning

The initial phase of the research employed deductive reasoning. The TPACK model was used as a guiding framework to create the semi-structured interview schedule, evaluate policy documents, and explore the MathU ITS. This approach allowed the researcher to structure the investigation around specific, theoretically-grounded hypotheses. For instance, the interview questions were designed to probe the integration of technology in teaching based on the key components of the TPACK framework. Similarly, the analysis of policy documents and the MathU ITS was conducted with a focus on how these elements align with the principles of TPACK, ensuring that the research remained anchored in established theoretical constructs.

### 3.3.2 Inductive Reasoning

Following the deductive phase, the research adopted an inductive approach to data analysis. After collecting data through interviews, policy document evaluations, and ITS exploration, the researcher broadened their focus to identify patterns and emerging themes within the data. This inductive process involved looking beyond the predefined TPACK framework to uncover new insights and connections that might not have been anticipated during the initial deductive analysis. The findings were then synthesised and incorporated back into the TPACK model, allowing for a more nuanced and contextually relevant interpretation of the data. This iterative process of moving from specific observations to broader generalisations enabled the researcher to draw meaningful conclusions about integrating ITSs in Grade 7 mathematics teaching within inclusive South African classrooms.

## 3.4 Research Strategy: Case study

Yin (2009) defines a case study as an investigation that examines a certain phenomenon within its authentic real-life context. Creswell and Creswell (2017) explain that case studies constitute a qualitative design through which the researcher conducts an in-depth exploration of a programme, event, activity, or process, of one or more individuals. These cases are delimited by both time and activity.

Case studies are valuable for obtaining a comprehensive understanding of a specific concept within a real-world context (Crowe et al., 2011b). Yin (2014) further highlights that selecting a case study as a research strategy can be based on factors, such as the unusual nature of the case.

In this study's case, the integration of technology-enhanced learning tools like ITSs presents itself as a relatively novel and innovative approach to instruction, warranting an in-depth examination to elucidate its efficacy, challenges, and potential for promoting inclusive education practices (Shute & Zapata-Rivera, 2010).

Thus, the choice of a case study methodology aligns with the need for a nuanced and contextually rich exploration of the complex dynamics inherent in integrating ITSs in Grade 7 Mathematics instruction within inclusive educational settings. An exploratory case study was employed as the chosen case study method.

#### 3.4.1 Exploratory Case Study

According to Yin (2014), case studies are appropriate when asking “how”, “why”, “what”, and “who” questions. In the exploratory case study approach, the focus is on answering “how” and “what” questions, which aligns with the research objectives of this study (Lucas et al., 2018). Specifically, the study sought to understand how teachers utilised MathU to differentiate instruction and what factors influenced the successful integration of this technology in inclusive classrooms.

The exploratory case study approach was employed in this study as it aligns with the nature of the research enquiry and the aim of gaining an extensive and in-depth understanding of the phenomenon under investigation (Crowe et al., 2011a). Exploratory case studies are especially appropriate when there is no predetermined outcome, and the research seeks to explore assumed causal relationships that are too intricate for a survey or experimental design (Yin, 2014). Additionally, exploratory case studies are particularly beneficial for gaining an in-depth understanding of a social phenomenon (Yin, 2014).

In this study, the exploratory case study approach facilitated a comprehensive examination of the complex interplay between teachers' pedagogical practices, students' diverse needs, and the affordances of the ITS within the specific context of inclusive classrooms in South Africa. By immersing in the natural educational setting and employing various data collection methods, such as observations, interviews, and document analysis, the researcher was able to obtain rich, detailed insights into the perspectives and experiences of the participants, thereby contributing to a deeper understanding of the phenomenon under study.

Table 3.1 outlines the key characteristics of an exploratory case study, discussed above, demonstrating how each aspect was adhered to within this research.

*Table 3.1: Characteristics of an Exploratory Case Study*

<b>Characteristic</b>	<b>Description</b>	<b>How This Study Adhered to Characteristics</b>
Research Questions	Focuses on “how” and “what” questions to explore the phenomenon in-depth.	The study sought to understand how teachers utilised MathU to differentiate instruction and what factors influenced its integration.
Purpose	Aims to explore and understand a relatively unknown or complex phenomenon.	The study aimed to explore the novel integration of ITSs in Grade 7 Mathematics instruction within inclusive classrooms.
Contextual Focus	Conducted within the real-life context of the phenomenon, allowing for a deep understanding of the environment and its impact.	The research was embedded in the real-world context of South African inclusive classrooms.
Flexibility	Maintains flexibility in the research design to adapt to emerging findings and themes.	The study allowed for adjustments in focus and design as new themes emerged during data collection and analysis.
Data Collection Methods	Utilises multiple data collection methods for a comprehensive understanding of the phenomenon.	The study employed semi-structured interviews, observations, and document analysis to gather rich and varied data.
Outcome	Produces detailed descriptions and insights into the phenomenon, contributing to a broader understanding.	The study provided detailed insights into the integration of ITSs, highlighting challenges and benefits in inclusive education.
Suitability	Suitable for exploring complex phenomena where existing theories are insufficient or non-existent.	The exploratory case study was appropriate given the limited existing research on ITS integration in inclusive classrooms.
Scope	Bounded by time and activity, focusing on a specific case or instance of the phenomenon.	The study was delimited by focusing on the integration of ITS within a specific time frame and educational setting.

### 3.4.2 The Case

The case in this study centres on Grade 7 Mathematics teachers within an independent, inclusive school following the IB curriculum who have adopted the ITS known as MathU to facilitate differentiated learning. The parameters chosen to define the case were carefully considered to ensure a comprehensive exploration of the research phenomenon and to align with the study's objectives and theoretical underpinnings. The focus on Grade 7 Mathematics teachers was intentional, as this grade level represents a critical juncture in the students' educational journey, where the mastery of foundational mathematical concepts is essential for future academic success.

Additionally, the subject of Mathematics was chosen as MathU is specifically designed for mathematics instruction. The decision to concentrate on an independent, inclusive school was driven by the recognition that such institutions often prioritise the integration of innovative pedagogical approaches and technologies to support learners with varying abilities and needs. By situating the study within this context, valuable insights could be gained into the practical implementation of differentiated learning strategies and the potential role of technology in fostering an inclusive learning environment. Furthermore, the selection of the ITS MathU as the ITS was based on its specific design and capabilities to support differentiated instruction by tailoring content, feedback, and learning pathways to each student's unique strengths, weaknesses, and preferences.

To provide clarity on the subsequent sections, it is important to note that *Sections 3.2.4.1 and 3.2.4.2* delve into the specifics of the case study, focusing on two critical aspects: the educational setting and the use of technology within that setting.

#### *3.4.2.1 Educational Setting*

This exploratory case study focuses on one independent school in Pretoria, Gauteng, where the International Baccalaureate Primary Years Programme (IB PYP) curriculum is followed from grades 0000 to 7. The IB PYP is an enquiry-based and transdisciplinary curriculum that encourages learners to engage in independent thinking and assume accountability for their own educational journeys (IBO, 2023). The school strongly emphasise inclusivity, particularly in accommodating neurodiversity within its learners body.

IB schools, such as the school under investigation, adhere to an Inclusion Policy. This policy is designed to facilitate the participation of all learners in the processes of teaching, learning, and assessment. This is achieved by identifying and subsequently reducing or eliminating barriers through thoughtful and appropriate arrangements (IBO, 2023).

Another cornerstone of the school's educational philosophy is the integration of technology to enhance teaching and learning experiences. Notably, Grades 4 to 7 learners are equipped with iPads, fostering a digital learning environment and enabling personalized learning experiences. The school boasts a diverse learner population comprising a significant number of foreign nationals and non-native English speakers. Over the past 25 years, the school has established itself as a leading independent educational institution known for its commitment to academic excellence, innovation, and inclusivity.

#### 3.4.2.2 *Technology Use and MathU*

The school under investigation features an extensive array of technological resources and tools. This institution has four 'academic pillars' upon which a dynamic, personalised learning journey can be created for each learner.

One significant pillar is *future-focused skills*, which places a significant emphasis on technology integration throughout its educational programmes. A notable aspect of the school's technological landscape is the provision of iPads to all learners, from grades 4 to 7. These iPads serve as indispensable e-tools, especially in the context of assessments. They provide learners with a digital platform for completing their assessments, enhancing the overall educational experience.

The use of technology has become a distinguishing feature in maintaining the school's competitive edge. The MathU ITS software specialises in the fields of AI and adaptive assessments to map, monitor, and assess learner progress. MathU's technology enables educational institutions to access a comprehensive set of tools. These tools empower teachers to efficiently allocate relevant assignments and homework to learners devices, instantly retrieve performance and achievement data, and effortlessly identify areas in which learners may require additional instruction and review.

MathU aims to enhance learning in subjects like Mathematics, Physical Sciences, and Mathematical Literacy for learners in Grades 7 to 12. It showcases a significant step toward providing learners with a unique and data-driven learning experience, improving their understanding of core subject areas while supporting the educational goals of both learners and teachers (MathU, 2023).

### 3.5 Methodological Choice: Qualitative

This study followed a mono-method, qualitative method (Saunders et al., 2015). Qualitative research can be defined as a research approach that seeks to gather in-depth, descriptive data within a particular context or situation (Ormston et al., 2014). It aims to delve into how individuals perceive their world and how they conceptualise and reflect upon their life experiences.

This method is concerned with providing insights into the complexity of human behaviour, thoughts, and emotions (Maree, 2007). The qualitative research methodology was employed in this study to align with the interpretivist philosophy and facilitate an in-depth exploration of how teachers employed an ITS called MathU within inclusive classrooms for teaching and learning purposes.

Qualitative research focuses on developing explanations of social phenomena (Hancock et al., 2001), thus allowing the researcher to gather detailed data that focuses on the participants' feelings, opinions, and experiences (Ahmad et al., 2022).

A specific advantage of the qualitative methodology in this study was its capacity to provide access to a Grade 7 Mathematics classroom environment where a select group of participants had been deliberately chosen due to their usage of the ITS, MathU, for Grade 7 mathematics instruction (Family Health et al., 2005). This educational setting served as the backdrop in which teachers incorporated the ITS into their daily teaching and learning routines, enabling a detailed analysis of this particular scenario. Moreover, it facilitated investigations into how the inclusive school integrated MathU to enhance differentiation.

As Maree (2007) indicates, this approach is useful in exploring a precise phenomenon within its natural educational setting, enabling investigations into how the inclusive school integrated this technological tool to enhance differentiation.

### 3.6 Time horizon: Cross-sectional

A cross-sectional time horizon was selected for this study primarily due to time constraints inherent in the research process. The implementation of the ITS software, MathU, during final examinations in the fourth school term necessitated a focused data collection window limited to that specific time period. Given these circumstances a cross-sectional study, characterised by its examination of data at a single point in time, was deemed appropriate (Setia, 2016).

Therefore, this study's adoption of a cross-sectional time horizon allowed for the efficient collection of data within the specified timeframe, facilitating an initial exploration of the integration of ITS technology in Grade 7 mathematics education within inclusive school settings.

### 3.7 Techniques and Procedures

This section outlines the techniques and procedures employed in the study, detailing the data collection methods, sampling approach, criteria for participant selection, and the participation process. These elements are critical in ensuring the reliability and validity of the research findings, as they provide a structured and systematic approach to gathering and analysing data relevant to the research questions (Garg, 2016).

#### 3.7.1 Sampling Approach and Criteria

The term "population" is defined as the comprehensive group of individuals possessing specific characteristics as outlined by the researcher, intending to be generalised in a study (McMillan & Schumacher, 2010). A comprehensive set of individuals with predetermined characteristics forms the basis of a population (Thacker, 2020).

On the other hand, a "sample" is a subset of this population selected for detailed examination (De Vos, 2002).

This study's population and sample revolve around one single independent international school located in Pretoria, within the Gauteng province.

The choice of Pretoria for data collection is due to its proximity to the researcher's institution, facilitating more accessible data collection. Further, the selection of this specific school was based on its recent implementation of ITSs, particularly for Grade 7 Mathematics assessments.

This study employed purposive sampling, a non-probability sampling method based on the assumption that the sample sufficiently represents the broader population (Lavrakas, 2008). By utilising a purposive sampling approach, the researcher specifically chose individuals that offered valuable insights into the research topic (Maree, 2007). It is imperative for researchers to justify their purposive sampling strategy in relation to the specific case under investigation (Bloomberg, 2018).

Thus, the researcher deliberately sought participants with specific characteristics (Lewis-Beck et al., 2004). These characteristics included:

- **Teaching Grade 7-9 Mathematics:** Participants needed to be teachers who instruct Mathematics for Grades 7 through 9, ensuring that their insights were relevant to the grade level of interest in the study.
- **Utilising the ITS, MathU, in their classrooms:** Teachers had to be actively using the MathU ITS in their classrooms. This criterion was essential to obtain data on the practical application and impact of the ITS within the context of differentiated learning.
- **Inclusive School Environment:** Participants were required to teach in an inclusive school setting. This was important to understand how MathU supports differentiated instruction in diverse classrooms with varied learner needs.





Therefore, the sample comprised four participants who are Grade 7 Mathematics teachers, all employed at the same independent, inclusive IB school in Pretoria. The participants included three males and one female, who were chosen purposively due to their shared responsibility for teaching Mathematics and their regular utilisation of the MathU software as a pedagogical tool.

To maintain confidentiality, pseudonyms were assigned to each participant: Pam, Jim, Michael, and Toby. Pam, aged 30, has ten years of teaching experience, with this being her second year at the school. Jim, aged 35, brings fifteen years of teaching experience, having transitioned from teaching high school mathematics to Grade 7 mathematics, and this marks his fifth year at the school. Michael serves as the head of the Mathematics department and is recognised as the MathU “champion”- an expert in MathU, whose role encompasses providing training to staff, facilitating software implementation, and supporting ongoing usage.

Additionally, champions may engage learners by organising maths competitions and other activities. With thirty years of teaching experience, Michael provides valuable insight into the integration of ITSs within mathematics instruction. Toby, aged 26, is the youngest member of the team, bringing five years of teaching experience to his role as a Grade 7 mathematics teacher, having recently joined the school.

The table below presents an overview of the four participants involved in this study. To ensure confidentiality and provide a clear representation of the participants to the readers, avatars were created using AI software known as *Fotor*. These avatars serve as visual representations of the participants and are associated with their pseudonyms. The table includes details on their age, years of teaching experience, years at their current school, and their role within the school.

*Table 3.2: Participants' Demographic Information, Teaching Experience, Years at Current School, and Role at School*

Participant	Age	Years of Teaching Experience	Years at Current School	Role at School
Pam 	30	10	2	Grade 7 Mathematics Teacher
Jim 	35	15	5	Grade 7 Mathematics Teacher
Michael 	50	30	15	Head of Mathematics Department, MathU Champion
Toby 	26	5	1	Grade 7 Mathematics Teacher

### 3.7.2 Participation Process

In selecting participants for the study, potential participants were approached by the researcher and invited to take part in the research.

Upon gaining their consent, the researcher proceeded to schedule individual interviews with each participant. For those participants willing to engage in semi-structured interviews, they were presented with a letter explaining the study's purpose and procedures. This letter is included in Appendix D.

Participants were given the opportunity to review this letter and provide written consent before the interviews commenced. Additionally, documents and access to the ITS, MathU, were gathered from the school administration, ensuring comprehensive data collection for the study.

Table 3.3 below highlights the selection criteria for this study's participants.

*Table 3.3: Inclusion Criteria for Sample Selection*

Criteria	Description
School Selection	<ul style="list-style-type: none"> <li>• Independent school located in Pretoria</li> <li>• Inclusive Education Policy</li> <li>• Significant use of ICTs</li> </ul>
ITS Implementation	<ul style="list-style-type: none"> <li>• Recent integration of ITS (MathU) specifically for Grade 7 Mathematics</li> </ul>
Inclusivity	<ul style="list-style-type: none"> <li>• School embraces an inclusive educational environment</li> </ul>
Teacher	<ul style="list-style-type: none"> <li>• Experience in teaching mathematics</li> <li>• Understanding of ITS technology</li> </ul>

### 3.8 Data Collection

Qualitative research methods require contact with participants, allowing for the observation, interviewing, and recording of natural processes (McMillan & Schumacher, 2014). Case studies incorporate multiple sources of data collection, such as interviews, observations or document analysis (Shanks & Bekmamedova, 2018;





Yin, 2014). The use of multiple data collection techniques strengthens the overall credibility of a case study by allowing for multiple perspectives to be incorporated into the analysis (Flick, 2004).

The data collection strategies for this study are outlined in Table 3.4. This table delineates the alignment between research questions, data collection methods, and corresponding TPACK components. The MRQ investigates how ITS implementation can support differentiated learning in inclusive classroom environments, complemented by three SRQs that explore specific aspects of differentiated learning, ITS features, and mathematics instruction through ITS.

For each research question, the primary data collection method consisted of semi-structured interviews with four participants, ensuring a qualitative depth to the inquiry. This is supplemented by document analysis of school policy documents for the MRQ and SRQ 1, and technological exploration or evaluation of the MathU ITS for the MRQ, SRQ 2, and SRQ 3. The TPACK framework is utilised to contextualise each research question, with the MRQ addressing overall TPACK, SRQ 1 focusing on PK, SRQ 2 on TPK, and SRQ 3 on TCK.

*Table 3.4: Data Collection Strategies*

### Integrating intelligent tutoring systems for differentiated learning in inclusive classrooms

RESEARCH QUESTIONS	DATA COLLECTION	TPACK COMPONENT
<p><b>MRQ:</b> How can the implementation of an ITS support the cultivation of a differentiated learning environment in an inclusive classroom setting?</p>	<ul style="list-style-type: none"> <li>Semi-structured interviews with four participants.</li> <li>Document analysis of school policy document.</li> <li>Technological exploration of the ITS, MathU.</li> </ul>	<p><b>TPACK:</b> Knowledge of how to use the ITS, MathU, to differentiate Grade 7 Mathematics in an inclusive, South African classroom.</p> 
<p><b>SRQ 1:</b> What encompasses differentiated learning in an inclusive classroom setting?</p>	<ul style="list-style-type: none"> <li>Semi-structured interviews with four participants</li> <li>Document analysis of school policy document.</li> </ul>	<p><b>PK:</b> Knowledge of what differentiation looks like and is perceived in an inclusive South African classroom.</p> 
<p><b>SRQ 2:</b> How do the features of an ITS support differentiated learning?</p>	<ul style="list-style-type: none"> <li>Semi-structured interviews with four participants</li> <li>Technological evaluation of the ITS, MathU.</li> </ul>	<p><b>TPK:</b> Knowledge of an ITS, the features of a good ITS, and how this supports the pedagogy of differentiation.</p> 
<p><b>SRQ 3:</b> How is Mathematics addressed through the ITS, MathU?</p>	<ul style="list-style-type: none"> <li>Semi-structured interviews with four participants</li> <li>Technological exploration of the ITS, MathU.</li> </ul>	<p><b>TCK:</b> Knowledge of the ITS, MathU, and how Grade 7 Mathematics is delivered and differentiated for an inclusive classroom.</p> 

The sub-sections below explore each data collection technique and procedure presented in the table above in greater detail.

#### 3.8.1 Document Analysis

The researcher made use of the document analysis component to complement the research questions and further elaborate on the insights gleaned from interviews (Frey, 2018). Often integrated as an additional supplementary method in qualitative research, documentary analysis enhances the study's rigor through triangulation, a multi-method approach (Owen, 2014).

The policy document on inclusion was essential to this study, serving as a foundational element that provided crucial context for understanding inclusive education within the specific school setting under investigation. The analysis of this policy document was integral to the study, underpinning the examination of how inclusion is defined and implemented in the South African independent, inclusive school context. The data from the document also further corroborated the interview data, as suggested by Yanow (2007). The school's policy document on inclusion is found in Appendix B.

Flick (2022) suggests that when selecting documents for the document analysis, purposive sampling may be employed by the researcher.

Researchers are to assess authenticity, credibility, representativeness, and meaning during the selection process (Flick, 2022). In adhering to Flick’s guidelines regarding document sampling, the researcher observed the following characteristics in the policy documents analysed. The document demonstrated authenticity, with the school policy document sourced directly from the school under investigation. The document served as a primary source of information. Credibility was established by the reliability of the document producers (Flick, 2018). Additionally, the document was representative, showcasing typical scenarios and cases of inclusive education. Lastly, it was deemed meaningful, being significant, clear, and easily understandable by all parties involved within the educational context.

The researcher thoroughly analysed the policy to understand its definitions of inclusive education and the application of differentiated learning. This analysis aimed to elucidate what inclusive education and differentiation entail in the specific context of the case study and provided a basis for triangulating the data.

Additionally, the researcher created a checklist based on the TPACK framework to evaluate how well the policy addresses inclusive education from this theoretical perspective (Appendix B). This checklist served as a tool for assessing the alignment between the TPACK components and the policy guidelines, highlighting how the framework supports inclusive education within the studied setting.

Table 3.5 below illustrates the alignment between the TPACK components and the document analysis findings, demonstrating the integration of the TPACK framework into the assessment of inclusive education practices.

*Table 3.5: Analysis of the Inclusion Policy Linked to TPACK*

TPACK	Analysis
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PK	<ul style="list-style-type: none"> <li>• Differentiation strategies according to students' needs.</li> <li>• Collaboration among stakeholders highlights shared responsibility for learning.</li> </ul>
CK	<ul style="list-style-type: none"> <li>• Emphasis on providing equal opportunities for all learners</li> <li>• Curriculum content designed to be inclusive and accessible.</li> </ul>
TK	<ul style="list-style-type: none"> <li>• Acknowledgment of technological resource allocation</li> <li>• Use of data-driven decision-making reflects awareness of technology's role in assessment and evaluation.</li> <li>• Integration of various technological tools to support differentiated instruction.</li> </ul>
TCK	<ul style="list-style-type: none"> <li>• Incorporation of technology to facilitate access to content for all learners.</li> </ul>
TPK	<ul style="list-style-type: none"> <li>• Integration of technology in a way that aligns with pedagogical goals for inclusion.</li> </ul>
PCK	<ul style="list-style-type: none"> <li>• Strategies for adapting content to diverse learning needs.</li> </ul>
TPACK	<ul style="list-style-type: none"> <li>• Coherence and alignment with inclusive education principles reflect comprehensive integration of technological, pedagogical, and content knowledge.</li> </ul>

### 3.8.2 ITS Exploration

In addition to the qualitative data gathered through the semi-structured interviews with teachers and the review of the school's inclusion policy, the study also examined the technological capabilities of the ITS known as MathU. This analysis was guided by the TPACK framework and conducted prior to the semi-structured interviews.

The initial evaluation of MathU was essential for the researcher to gain a comprehensive understanding of how the ITS functioned and how it could be applied in the context of this study.

According to Firat et al. (2020), technological analysis as a data collection method has gained significant importance in contemporary research methodologies. The use of digital technologies as a means to collect data has proven to be pivotal for researchers, facilitating access to a wealth of data (Topp & Pawloski, 2002).

From an educational context, Wishart and Thomas (2015) argue that the analysis of E-tools for data collection creates multimodal data analysis opportunities in research.

McKenney et al. (2015) also suggest that an analysis of technological tools holds the potential to offer novel insights into complex educational challenges. In this study, a technological analysis was particularly fitting as it allowed for the exploration of how an ITS can influence the educational landscape.

Analysing the technological aspects and tools embedded within the MathU ITS can provide an understanding of its impact on teaching methods, the learning environment, and the overall efficacy of its integration in the South African educational context.

Therefore, before engaging with the interview data, the researcher conducted an exploratory analysis of MathU by making observational notes in a journal. These notes were then integrated into the thematic analysis, discussed in *Section 3.9*. Following this initial exploration, MathU was evaluated using a checklist aligned with the TPACK model. The checklist was designed with criteria rooted in both the TPACK framework and the relevant literature ITSs, highlighted in *Section 2.7.2*.

The literature provided additional guidance in identifying key features of ITSs, which were incorporated into the checklist alongside TPACK components. This assessment involved examining features of MathU, such as content customisation, adaptive feedback mechanisms, progress monitoring tools, system stability, data security measures, user-friendliness, integration capabilities, and differentiation-specific functionalities. Table 3.6 illustrates the checklist that was used in the evaluation of MathU.

*Table 3.6: Evaluation of MathU*

Feature Category	Key Features	Description	TPACK Component
Adaptive Learning Capabilities	User Environment Adaptation	Adjusts learning environment based on student needs.	TK
	Content Adaptation	Modifies learning content according to the student's current skills, knowledge, and progress.	TCK
	Pace Adaptation	Adjusts the speed of instruction to match the student's learning pace.	TPK
	Search Functionality Adaptation	Customizes search functions to align with students' preferences and needs.	TK
	Facilitation of Communication and Cooperation	Supports group activities by enabling communication and collaboration among students.	TPK, TCK
Step-Level Guidance	Problem-Solving Support	Provides detailed assistance throughout problem-solving processes.	PCK
Personalized Instructional Guidance	Tailored Learning Experiences	Delivers advanced, personalized instructional guidance tailored to individual student needs, mirroring the support a human tutor would provide.	PCK, TCK, TPK
Diagnostic Capabilities	Knowledge Level Assessment	Accurately diagnoses a student's current knowledge level through diagnostic assessments.	CK
	Instructional Strategy Selection	Decides on appropriate instructional strategies based on individual student data.	TPK, TCK
	Strategy Adaptation	Continuously adapts instructional strategies as the student progresses.	TPK, TCK
Feedback Mechanisms	Timely and Constructive Feedback	Provides immediate feedback to help students identify and correct errors during the learning process.	TCK
Content-Specific Knowledge	Discipline-Specific Instructional Content	Grounded in discipline-specific knowledge (e.g., mathematics, physics, language studies, programming) to offer relevant and accurate instructional content.	CK
Data Analytics	Student Interaction and Performance Data	Collects and analyzes data on individual student interactions, performance, and academic progress to refine instructional approaches.	PK
Natural Language Processing	Interactive Conversations	Incorporates NLP techniques to understand and generate human-like language, enabling engaging and interactive conversations with learners.	TPK
Integration and Interoperability	System Integration	Ensures seamless integration with other educational technologies and platforms.	TK
	User-Friendliness	Provides an intuitive and accessible user interface for both students and educators.	TK
	System Stability	Maintains high levels of system reliability and stability during use.	TK
	Data Security Measures	Implements robust data security protocols to protect student information.	TK
Additional Considerations	Cultural and Contextual Sensitivity	Tailors learning content and interactions to be culturally relevant and contextually appropriate.	Context
	Scalability	The system should be scalable to accommodate varying numbers of users and diverse educational settings.	Context

### 3.8.3 Semi-Structured Interviews

According to Adams (2015), a semi-structured interview is a type of qualitative interview carried out in a conversational style, typically involving one respondent at a time. Both closed-ended and open-ended questions are asked, often being accompanied by follow-up questions aimed at understanding the “why” or “how” behind the respondent’s answers (Maree, 2007). Semi-structured interviews have the potential to yield comprehensive data, particularly in the semi-structured format employed in this research (Hamilton & Corbett-Whittier, 2013).

In this research, semi-structured interviews were conducted in one independent school with four Grade 7 Mathematics teachers using the ITS MathU to facilitate differentiated learning in an inclusive classroom setting. The conceptual framework, highlighted in Chapter 2 served as the basis upon which the semi-structured interview questions were posed, as seen in Appendix C. The following sub-sections delineate the content of the semi-structured interviews, as well as how these interviews were conducted, recorded and transcribed.

#### a) Interview Content

The researcher wrote up a collection of 12 broad, highly open-ended questions to steer the interviews within a semi-structured framework. This sequence commenced with a foundational set of enquiries directly correlated with the three secondary research questions, as per the TPACK framework. It concluded with three additional questions addressing the integration of technology, content, and pedagogical knowledge to establish the TPACK intersection. The complete list of questions is provided in Appendix C, with each question’s relevance to the research elucidated in *Section 3.10*.

#### b) Interview Conduct

The semi-structured interviews were conducted with an emphasis on fostering conversational dynamics, facilitating a comfortable environment conducive to open dialogue and reflective sharing of insights.

Approaching the interviews as conversations rather than formal interrogations allowed for a more natural exchange of ideas, promoting rapport between the researcher and participants. However, as the primary instrument in the interviews, the researcher remained mindful of personal biases and maintained a receptive stance towards any information provided by the participants (Kvale, 2018; Yin, 2014).

Throughout the interviews, careful attention was paid to non-verbal cues, such as pauses and silences, which often signalled deep reflection or contemplation on the part of participants. Notably, instances where participants exhibited reticence or provided concise responses were regarded as valuable contributions, indicative of a direct and focused communication style that eschewed unnecessary verbosity. These nuanced aspects of the interview process were integral to capturing the participants' authentic perspectives and experiences, contributing to the depth and authenticity of the study's findings. Lastly, to mitigate potential subjectivity, the researcher consistently sought clarification of participants' statements, fostering a deeper understanding of their perspectives (Kvale, 2018).

#### c) Interview Recordings

All of the interviews took place after school hours, providing a conducive environment in the quiet classrooms of the teachers. These sessions typically ranged from one to two hours in duration, allowing for thorough exploration of topics while accommodating participants' schedules. Each interview was recorded using both the researcher's mobile phone and tablet, to safeguard against potential loss or damage of valuable audio recordings. This served as a precautionary measure, ensuring the preservation of data integrity. Prior to commencement, participants were required to provide explicit consent for the recording of the interviews, adhering to ethical standards and respecting participants' autonomy in the research process.

#### d) Interview Transcripts

The transcriptions were completed by using an automatic transcription software named Otter.ai. While this method generally produced transcripts of satisfactory quality, it was noted that certain accents posed challenges for the software, resulting in occasional inaccuracies. To ensure the reliability of the transcriptions, the researcher subsequently reviewed and corrected any errors. Additionally, the researcher followed a naturalised method of transcription, in which transcripts were enriched with subtextual cues, such as indications of laughter, pauses, and other non-verbal expressions, to enhance the contextual understanding of the dialogue.

According to Oliver et al. (2005) naturalised transcription aims to capture speech in its entirety, retaining as much detail as possible to present a faithful representation of real-world communication. By preserving the interviews in their unaltered form, the researcher aims to maintain transparency with readers and allow participants' voices to resonate authentically (Schegloff, 1997).

### 3.9 Data Analysis

The researcher employed Braun and Clarke's (2006) six-phase method of thematic analysis in an iterative manner to analyse the collected data. This is discussed in detail below, as the researcher elaborates on how the thematic analysis was applied to the four semi-structured interviews, as well as to the policy document analysis and the ITS exploration. The analysis was guided by the theoretical lens of the TPACK framework, ensuring a rigorous and cohesive examination of all evidence. This approach facilitated a thorough understanding of key aspects of the case study, as emphasised by Yin (2014).

Figure 3.2 depicts the researcher's engagement with the six phases, illustrating how this method combines a rigorous process with adaptability (Braun & Clarke, 2022). Each phase is elaborated upon in the discussion. It is important to note that the aim of the analysis was not to ascertain accuracy but to present findings as either strong or weak, with a focus on being compelling, thoughtful, rich, and nuanced (Braun & Clarke, 2022).

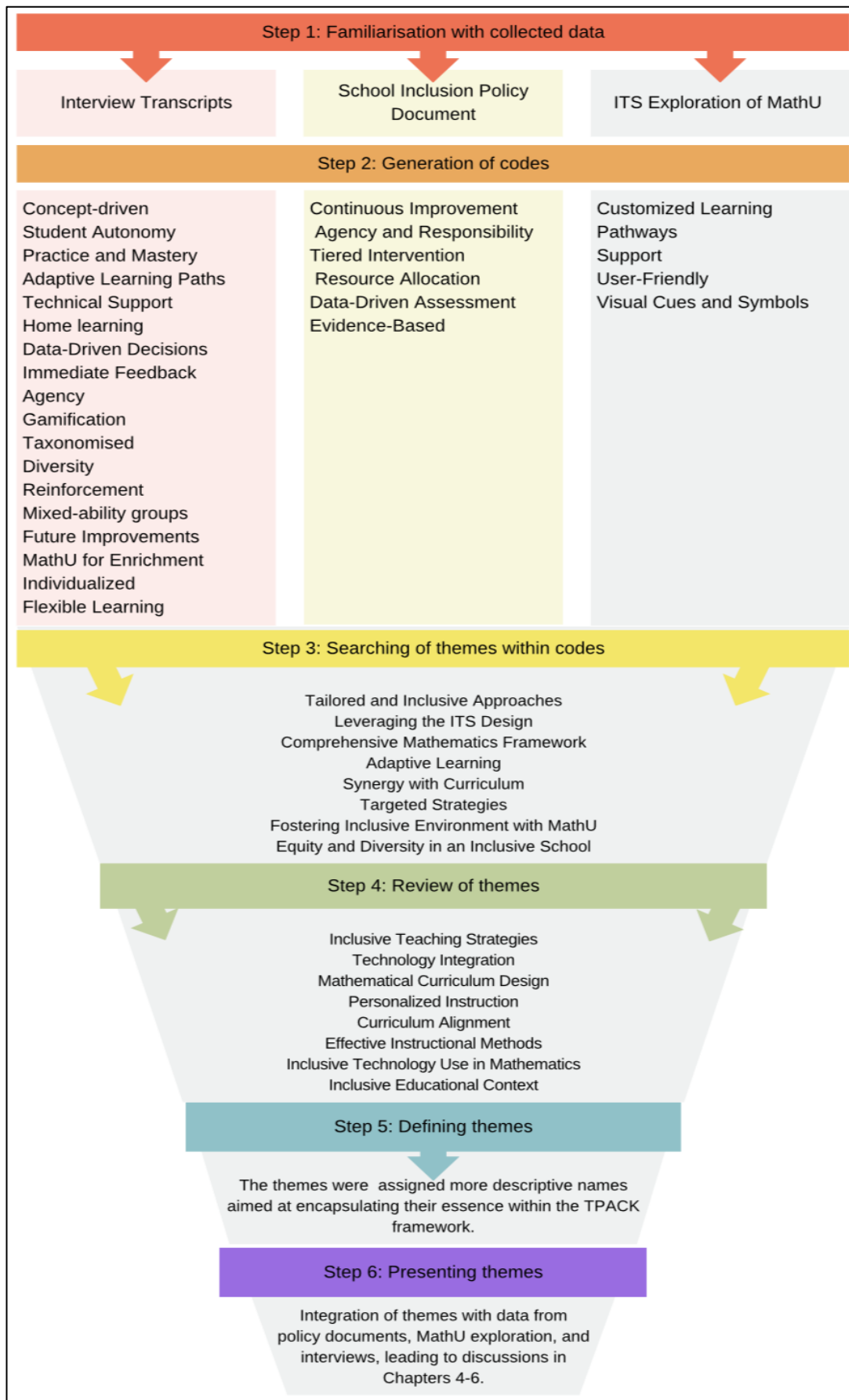


Figure 3.2: The Process of Data Analysis (Adapted from Braun and Clarke (2006))

## Step 1: Familiarisation with collected data

Prior to conducting the interviews, the researcher engaged in a thorough review of the school's policy document on inclusion. This initial examination involved noting reflections and key passages that were particularly significant. The insights gained from this pre-interview analysis were instrumental in developing a nuanced understanding of the policy context. These observations subsequently informed the analysis of the interview data and the exploration of MathU, ensuring a well-rounded approach to understanding the intersection of policy, inclusion, differentiation, and technology within the study.

Figure 3.3 highlights the initial observations the researcher recorded upon her first reading of the school's policy document on inclusion.

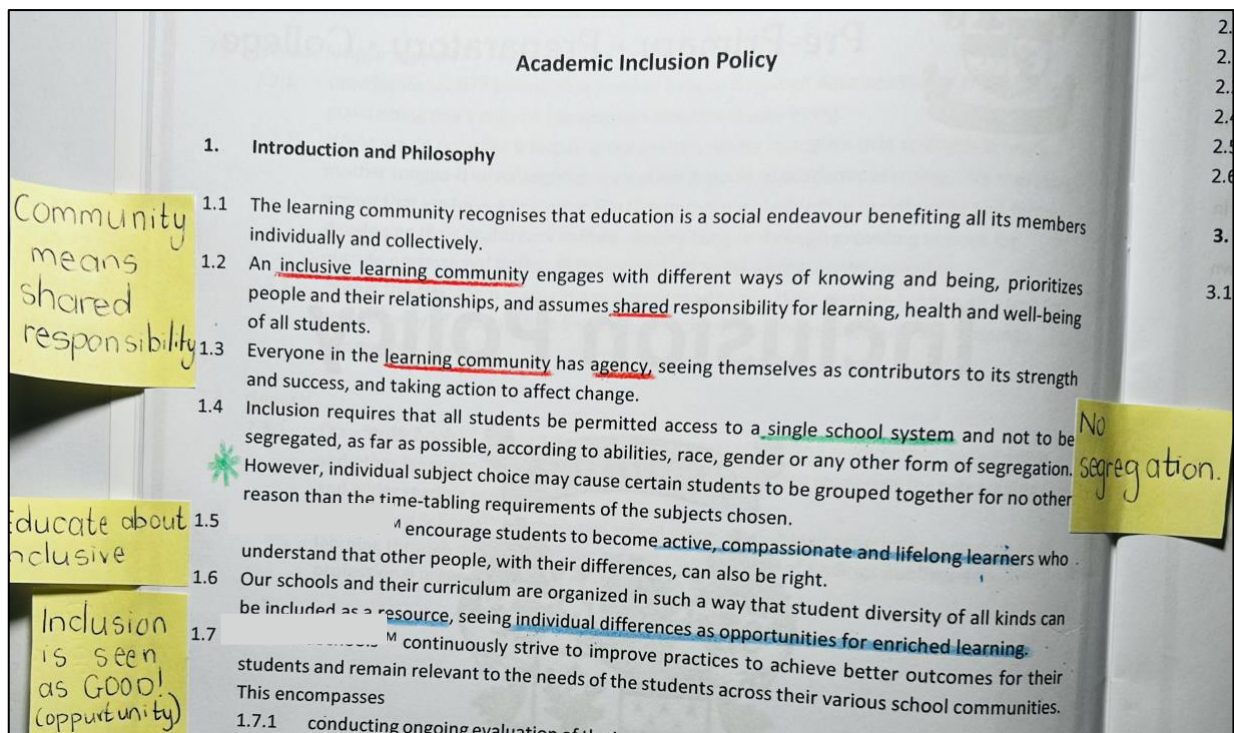


Figure 3.3: An Example of the Researcher's Observations on the School Policy Document

Additionally, before conducting the interviews, the researcher engaged in an in-depth exploration of the MathU ITS. This investigation involved navigating the application from the teacher's perspective on the teacher platform. The researcher examined the various functionalities of the ITS and recorded detailed observations in a journal about her experiences with MathU. Figure 3.4 shows an example of these journal observations.

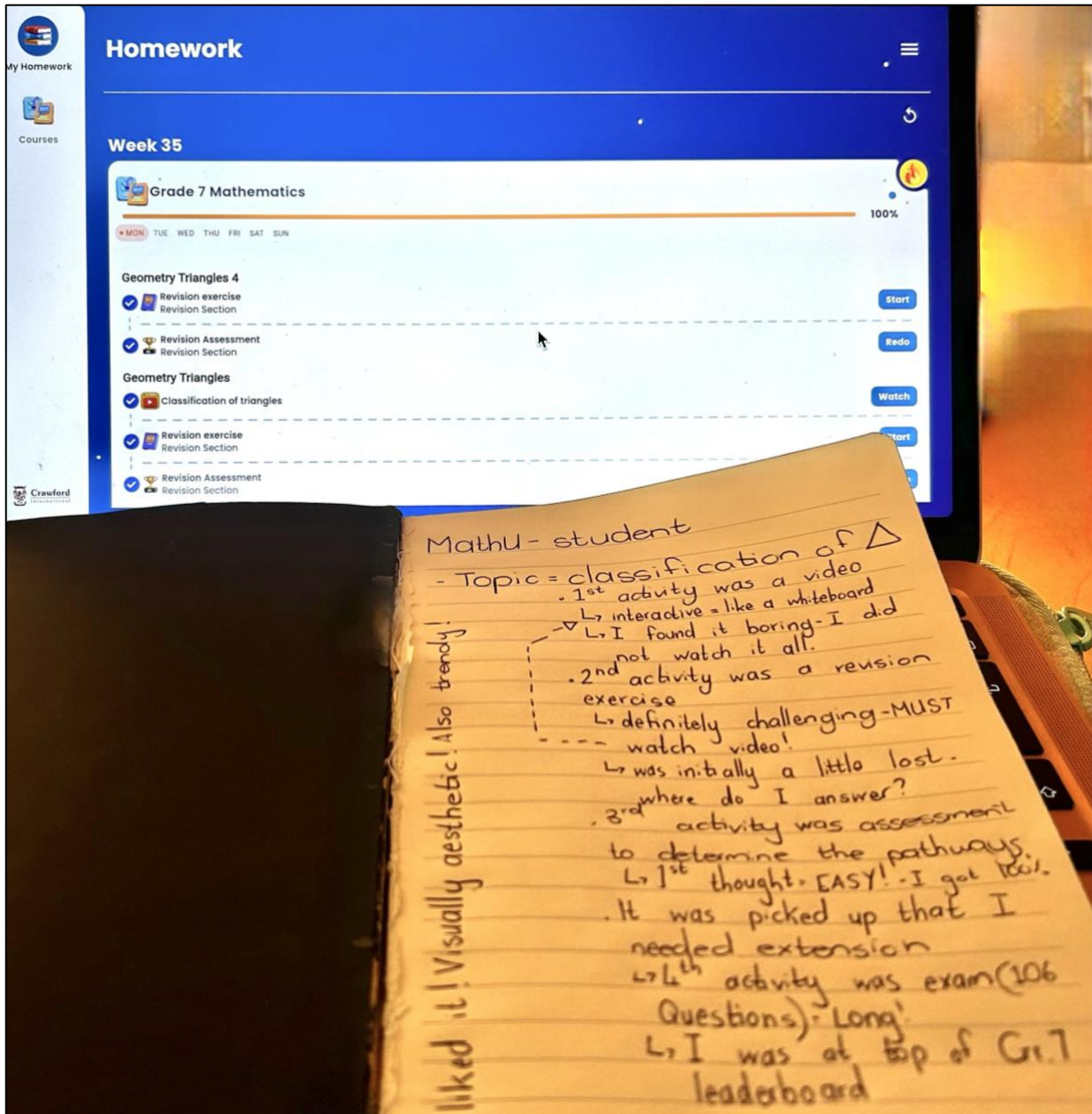


Figure 3.4: Researcher's Journal Observations from MathU Exploration

During the analysis of the interview data, the researcher engaged in active listening by initially playing each interview recording without taking notes. Active listening enabled the recall of non-verbal cues and gestures, contributing to a deeper understanding of the interview dynamics (Tennant et al., 2024).

Subsequently, the researcher made use of Otter.ai to transcribe each interview after the initial playback. Once all interviews were transcribed, the researcher carefully read through each transcript multiple times. During this process, notes were made of any initial trends or noteworthy passages in the data.

Figure 3.5 shows an example of these notes. Additionally, the researcher recorded her reflections on the data. This practice of documenting thoughts and observations was maintained throughout the analysis to ensure transparency (Bowen, 2009). Preliminary notes, captured during the initial familiarisation with the data, provided valuable insights that later informed the interpretation of the data. These early observations served as the foundation for identifying recurring themes and patterns within the dataset at a later stage.

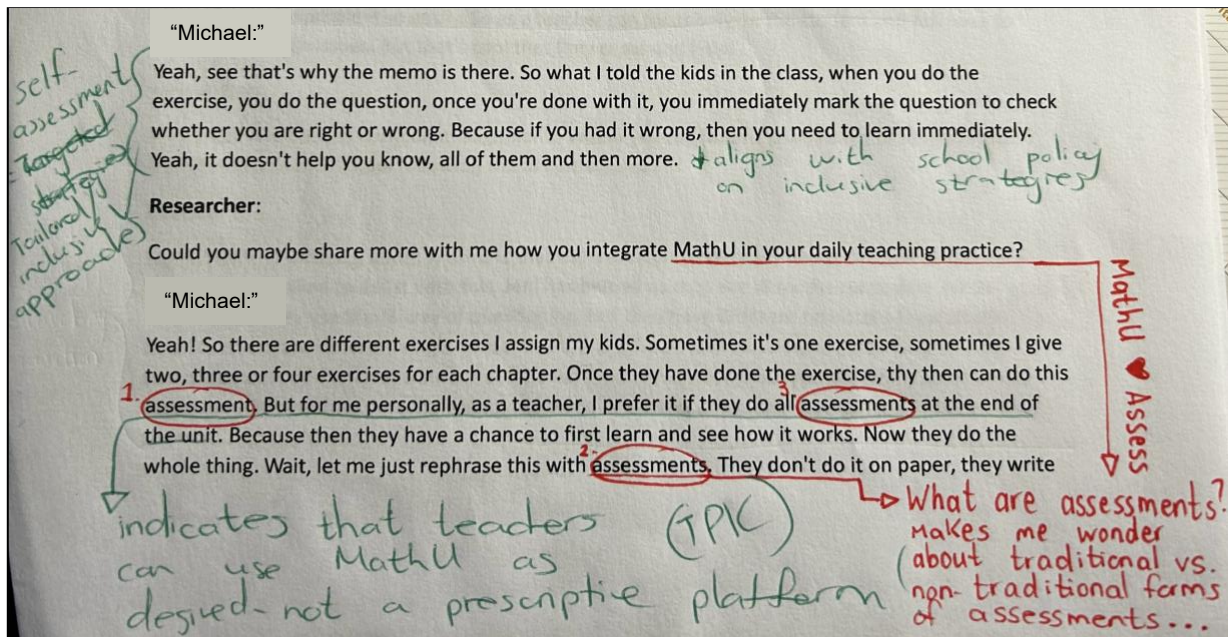


Figure 3.5: An Example of the Researcher's Reflections in the Dataset

## Step 2: Generation of codes

In the second phase of the thematic analysis, researchers immerse themselves within their data, gaining insights into its contents and identifying points of interest (Braun & Clarke, 2006). This stage consists of the initial coding process, which serves as a reflective method of interacting with and interpreting the data (Savage, 2000).

Coding enables researchers to distil the data into manageable units and develop conceptual understandings of the phenomena under investigation (Morse & Richards, 2002).

In this study, the researcher generated her own codes based on the inclusion policy, observations from the MathU exploration, and the interview data. This approach ensured a nuanced and comprehensive analysis, allowing for the development of a robust conceptual framework that integrates insights from multiple data sources.

As mentioned in *Section 3.3.2*, the TPACK model played a crucial role in the creation of the interview schedule. The questions were loosely based on all components of the TPACK model to ensure comprehensive coverage of the content. Following the analysis of the interviews, the researcher identified commonly emerging themes, which are highlighted below.

Throughout the coding process, researchers systematically identify significant sections of text and assign labels to them based on emerging themes or issues (King, 2004). The researcher read through each interview transcript individually. During this close reading, she carefully examined the text line-by-line. As significant phrases, concepts or issues of interest emerged, the researcher assigned codes to label and categorise those notable excerpts or passages. To keep track of the evolving codes systematically, the researcher used a colour-coding technique. Different colour highlights were assigned to represent the various codes identified across the data.

This allowed the researcher to visually distinguish and organise the coded segments based on their respective themes or topics. These colour-coded excerpts provided manageable conceptual units that enabled deeper reflection on the underlying meanings and patterns within the collected data sources.

Figure 3.6 illustrates an excerpt of the transcripts featuring the researcher’s manually written, colour-coded annotations.

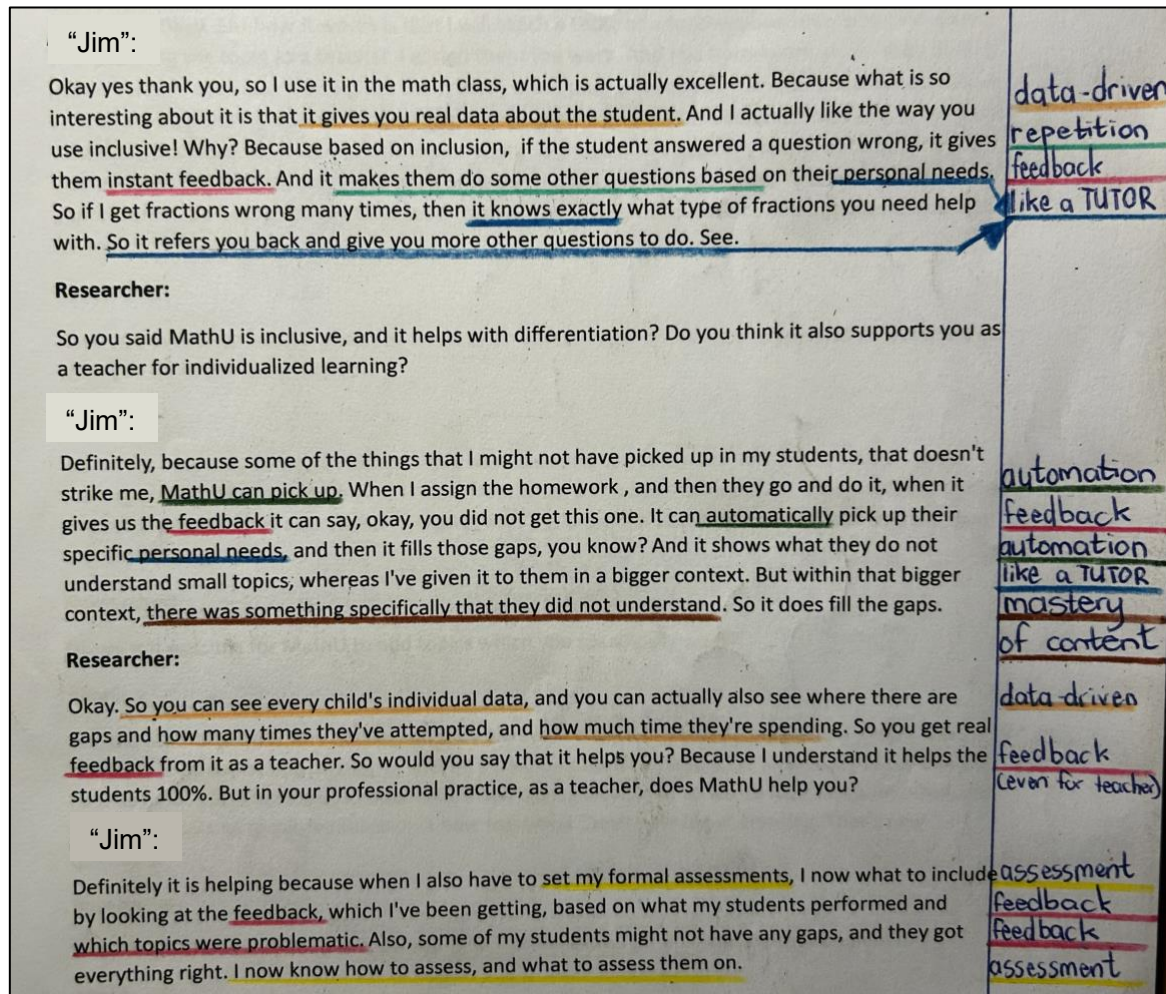


Figure 3.6: Excerpt of Codes in an Interview Transcript

After the initial coding and assigning of colour-coded labels to significant excerpts from the transcripts, the researcher created a Microsoft Excel spreadsheet to define each code category and consolidate the coded data.

Under each code column, the researcher placed a "1" mark corresponding to the specific quote or response from the participant that mentioned or exemplified that particular coded concept. This table helped the researcher clearly define the meaning of each code, while also allowing her to neatly map and reference which coded concepts were discussed by the participant for a given interview question.

The table facilitated organising the coded qualitative data in a structured manner for further analysis and identification of broader themes spanning the coded content. Figure 3.7 illustrates an excerpt of the Microsoft Excel spreadsheet for one of the interview questions.

Question:	Code 1	Code 2	Code 3
Would you say that MathU identifies gaps in learning?	Immediate Feedback	Additional Resources	Individualized Instruction
<i>So if they struggle with it, and they don't understand, they can go to the memo and see oh, wait, this is how it was meant to be done. If they still don't understand it, the video explains only this question, not in general, the topic, but this question specifically on how you would go about answering that question."</i>			1
<i>If the kids don't do so well in the quizzes or activities, there's like a reroute in questioning, like very similar, questions, but with more steps so that they are able to actually do better. Oh, it's got the memo feature on the iPad, so kids can write down the answer and then flip it to check.</i>	1	1	1
<i>it works with an individual, and ensure that it caters for your specific needs."</i>			1
<i>It offers immediate feedback and provides additional resources to address specific learning gaps."</i>	1	1	
<b>Potential Code</b>	<b>Potential Definition</b>		
Immediate Feedback	Timely provision of feedback on student performance		
Additional Resources	To enrich learning beyond the standard curriculum		
Individualized Instruction	Tailoring teaching methods, content, and pace to meet the specific learning needs and preferences of individual students.		

Figure 3.7: An Example of Coded Data in a Microsoft Excel Spreadsheet

Figure 3.8 below illustrates all the codes identified during the initial coding phase of the semi-structured interviews, policy document, and ITS exploration. These codes emerged as key themes in the data, reflecting various aspects of the research phenomena.

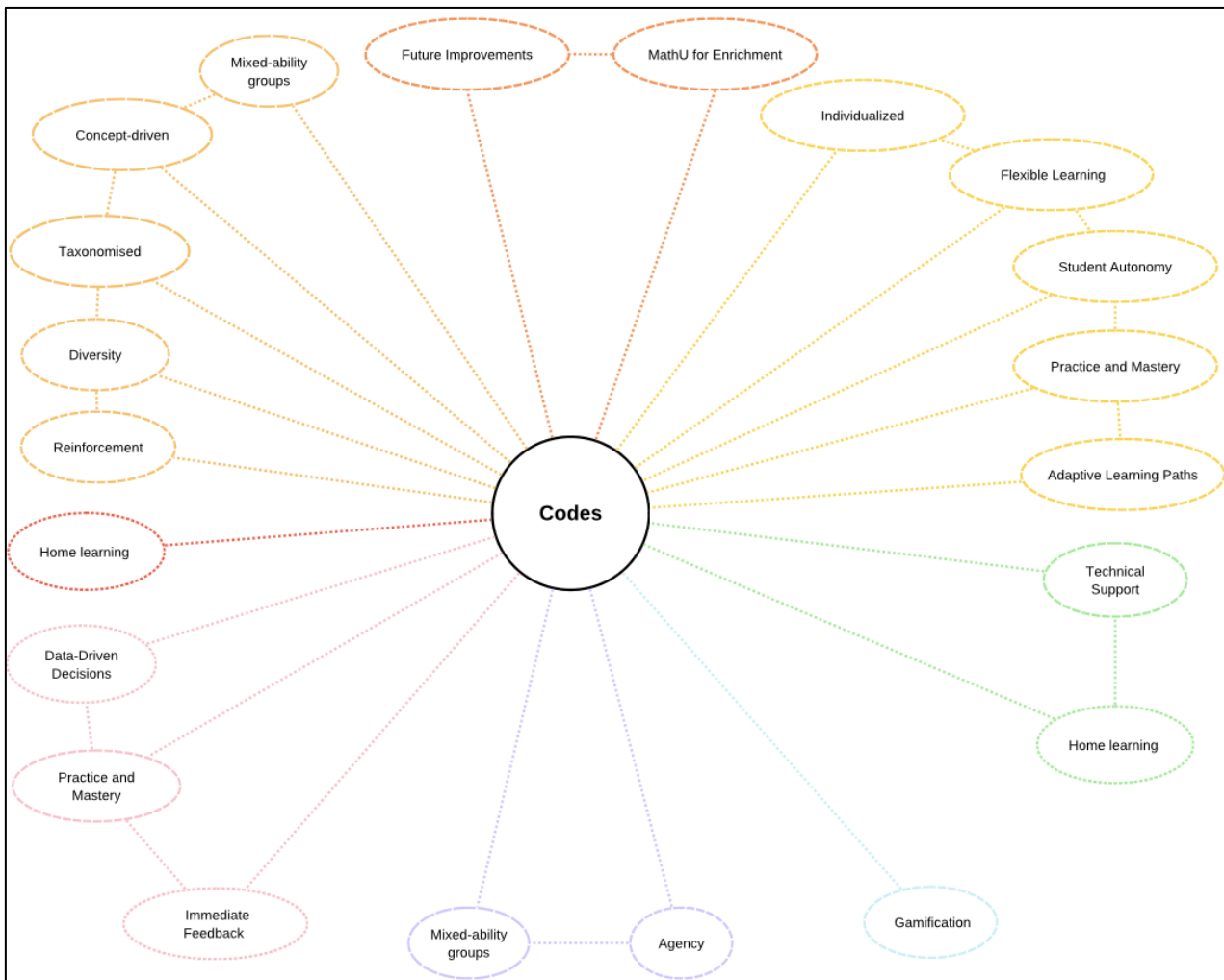


Figure 3.8 Codes Identified From Semi-Structured Interviews, Policy Document and ITS Exploration

**Step 3: Searching of themes within codes**

Now, the focus shifts from interpreting individual data items within the dataset to interpreting the holistic meaning across the entire interview dataset (Braun & Clarke, 2012).

Thus, coded data is reviewed and analysed to determine how different codes may be combined according to shared meanings, forming themes or sub-themes. It is important that the pattern of codes communicate something meaningful that will help answer the research question (Braun & Clarke, 2013).

In Step 3, which focused on developing themes, the researcher conducted her first round of theme development. This involved an inductive analysis in which the researcher identified the emergent themes and patterns directly from the policy document, ITS exploration, and interview data. The themes emerged organically, taking shape based on the codes mentioned in Step 2, which surfaced through careful analysis of the interview transcripts.

The researcher examined the coded data segments, looking for commonalities, relationships, and recurring ideas or perspectives across the participants' responses. At the end of this stage, it was possible for the researcher to produce a thematic map that collates codes relative to their respective themes (Braun & Clarke, 2012). Figure 3.9 indicates the thematic map that the researcher created after developing the initial themes from the dataset. These codes and themes are further discussed in Chapters 4, 5 and 6.

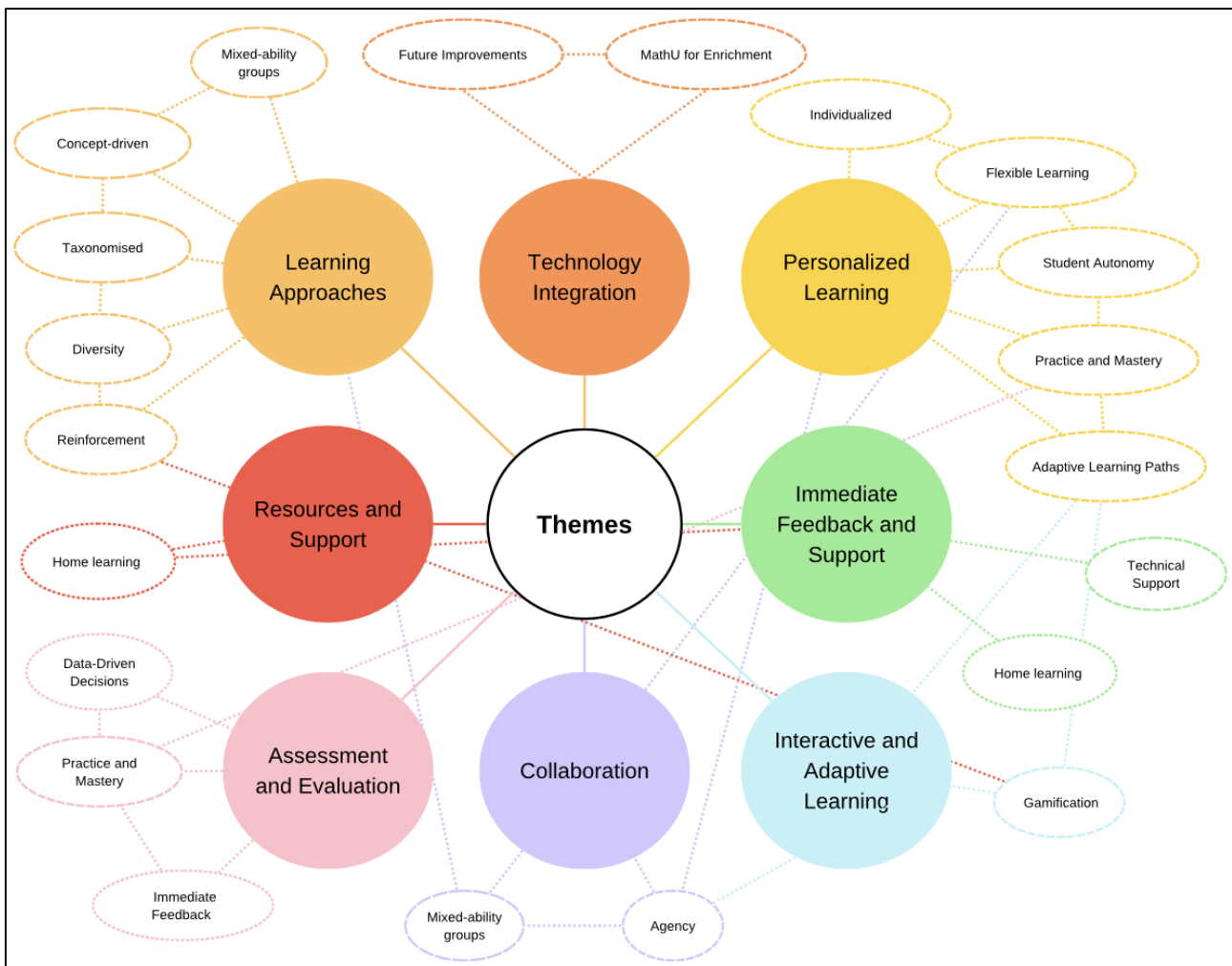


Figure 3.9: Thematic Map Indicating Potential Themes and Corresponding Codes

#### Step 4: Review of themes

In Step Four, the researcher again engaged with all the quotations and the entire data set (Braun & Clarke, 2022).

Here, the researcher utilised Microsoft Excel to align the initial themes from Step 3 with the TPACK framework, and revise them accordingly. During this recursive phase, the researcher revisited the coded data and preliminary themes, carefully examining how they related to and could be mapped onto the components of the TPACK framework.

This involved an iterative process of reviewing the themes, refining their scope and definitions, and positioning them within the conceptual lens of the TPACK model.

Now, the researcher employed a deductive approach by assigning codes from the TPACK framework to the themes initially identified in phase three. This deductive coding process facilitated the alignment and integration of the emergent themes with the established TPACK conceptual model.

#### Step 5: Defining themes

This step commenced with the objective of enhancing the clarity of the themes (Braun & Clarke, 2006). The themes were also assigned more descriptive names aimed at encapsulating their essence within the TPACK framework (Braun & Clarke, 2022). During this stage, deductive reasoning came into play once again, as the theoretical framework assisted the researcher in aligning the themes with the study's objectives. In this step, the researcher redefined the themes to ensure easy comprehension and summarised each theme to be more concise. The researcher ensured that the themes were redefined to align with the TPACK framework that guides this study. This alignment ensures that the themes are fitting for the study and adequately address the research questions, which were also created from the TPACK framework.

Table 3.7 demonstrates the initial themes undergoing a process of refinement and redefinition.

Table 3.7: Researcher's Process of Theme Refinement and Redefinition

<b>Initial Theme Name</b>	<b>Refined Theme Name</b>	<b>Redefinition and TPACK Alignment</b>
Tailored and Inclusive Approaches	Inclusive Teaching Strategies	<i>Application of effective teaching methods for diverse learners needs.</i> <b>(Pedagogical Knowledge)</b>
Leveraging the ITS Design	Technology Integration	<i>Utilisation of technology, specifically ITS, in educational settings.</i> <b>(Technological Knowledge)</b>
Comprehensive Mathematics Framework	Mathematical Curriculum Design	<i>Organisation and delivery of mathematical content.</i> <b>(Content Knowledge)</b>
Adaptive Learning	Personalised Instruction	<i>Use of technology to tailor instruction to individual learners needs.</i> <b>(Technological Pedagogical Knowledge)</b>
Synergy with Curriculum	Curriculum Alignment	<i>Aligning technology-enhanced teaching practices with curriculum goals.</i> <b>(Technological Content Knowledge)</b>
Targeted Strategies	Effective Instructional Methods	<i>Application of specific teaching methods to convey content effectively.</i> <b>(Pedagogical Content Knowledge)</b>
Fostering Inclusive Environment with MathU	Inclusive Technology Use in Mathematics	<i>Using MathU to create an inclusive learning environment to teach Mathematics</i> <b>(Technological, pedagogical and content knowledge)</b>
Equity and Diversity in an Inclusive School	Inclusive Educational Context	<i>Consideration of equity and diversity in an inclusive educational setting</i> <b>(Context)</b>

Figure 3.10 illustrates how the themes took shape and were mapped within the TPACK framework. The themes were reorganised and structured to align with the intersecting domains of technological knowledge, pedagogical knowledge, and content knowledge, as well as the context that comprise the TPACK model. This figure is revisited in Chapters 4 and 5, where a discussion follows on these themes.

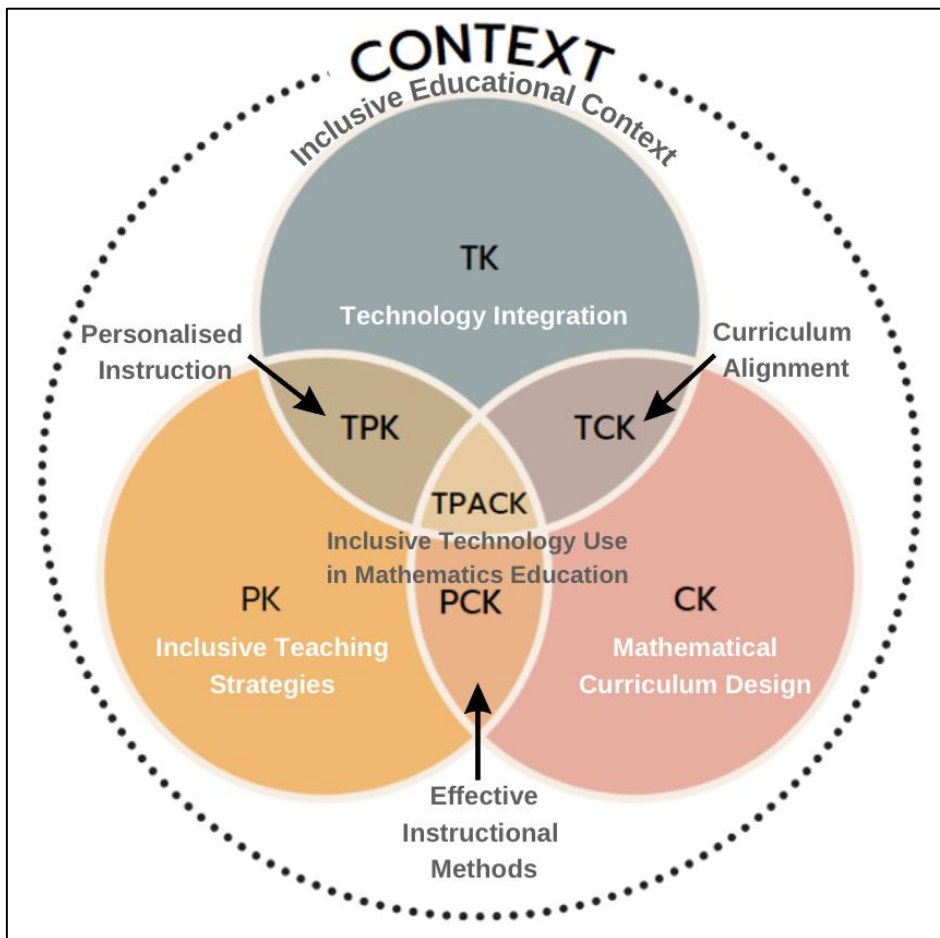


Figure 3.10: Redefinition and TPACK Alignment of Themes

**Step 6: Presenting the themes**

Step Six, following Braun and Clarke’s model (2022), represents the culmination of all writing activities undertaken throughout the research process, including the literature review. At this stage, the researcher synthesises the identified themes in Chapter 4, where an integrated discussion of the results derived from policy documents, the exploration of MathU, and the interviews is presented. The seven themes that emerged – Inclusive Teaching Strategies, Technology Integration, Mathematical Curriculum Design, Personalised Instruction, Curriculum Alignment, Effective Instructional Methods, and Inclusive Technology Use in Mathematics – are thoroughly explored. This integration continues in Chapter 5, where these themes are subjected to deeper analysis and discussion, and it culminates in Chapter 6, where final conclusions are drawn within the broader context of Inclusive Educational Practices.

### 3.10 Trustworthiness and Quality Assurance

This section highlights the criteria for establishing the trustworthiness of this study, with particular emphasis on credibility, transferability, dependability, and confirmability. These criteria, as described by Mathison (2005), are vital for evaluating the rigour and reliability of qualitative research. By adhering to these standards, the researcher has sought to enhance the integrity and quality of the study, thereby ensuring that the findings are robust, reliable, and applicable within the context of ITSs in inclusive education. This approach strengthens the validity and relevance of this research for teachers, policymakers, and researchers in the field of educational technology.

#### 3.10.1 Credibility

Credibility refers to the accuracy and authenticity of the data and the researcher's interpretations of that data (Polit & Beck, 2010). In the context of this study, credibility is achieved by ensuring that the descriptions and interpretations of the ITSs impact align closely with the lived experiences of teachers in the inclusive classroom setting. To enhance credibility, the researcher has engaged in member checking by allowing participants to review and provide feedback on the findings. Additionally, the researcher has sought input from stakeholders, including teachers and policymakers, to validate the study's results and interpretations (Shenton, 2004). This rigorous approach helps ensure that the study's conclusions are reflective of and relevant to the participants' real-world experiences and contexts.

#### 3.10.2 Transferability

Transferability refers to the extent to which the findings and results of a study can be applied to diverse contexts or groups of participants (Lincoln & Guba, 1990). The researcher can employ a 'thick' description to enable users to make informed judgments regarding the transferability of research outcomes (Korstjens & Moser, 2018). A 'thick' description involves providing comprehensive and detailed accounts of the research context, participants, methods, and results. This approach enhances the potential for users to assess the relevance and applicability of the research findings to their specific settings. By utilising a thick description, the researcher can promote the transferability of research outcomes and support their utilisation in diverse contexts (Korstjens & Moser, 2018). In this study, the researcher provides ample information about the context as well as participants so that readers can apply the findings to their own contexts and experiences.

### 3.10.3 Dependability

Dependability refers to the consistency and stability of research findings over time, reflecting how well the results are supported by the data collected from participants (Lincoln & Guba, 1990). To ensure dependability, it is important to gather participants' assessments of the study's findings, interpretations, and recommendations, ensuring that these elements are grounded in the data collected from participants throughout the study. The use of participant feedback can help ensure the accuracy and reliability of research findings, which can enhance the credibility and validity of the study's conclusions (Korstjens & Moser, 2018). To achieve dependability, the researcher includes the overall research design so that the study can be replicated to achieve the same results.

### 3.10.4 Confirmability

Confirmability is concerned with the extent to which the findings of a study can be verified or confirmed by other researchers (Korstjens & Moser, 2018). In this study, the researcher demonstrates confirmability by stating how the findings and conclusions are established through means of quotes and narratives from each participant.

## 3.11 Ethical Considerations

In research, ethics refers to the principles of what is right and wrong within a particular group (Bogdan & Biklen, 1997). The ethical considerations ensure that research study participants are protected from harm or malpractice. The researcher made sure that all ethical considerations within this study, including informed consent, voluntary participation, anonymity and confidentiality, were adhered to. Further, the researcher complied with the University of Pretoria's ethical guidelines at all times.

### 3.11.1 Informed Consent and Voluntary Participation

Informed consent is a fundamental ethical principle in research, guaranteeing that participants are fully informed about the study's nature, purpose, and procedures, as well as their rights as participants (Flick, 2004). This study followed the ethical guidelines set by the University of Pretoria, ensuring that all research activities were conducted in accordance with established ethical standards (Code of Ethics for Research, 2019).

Prior to the commencement of the study, the researcher provided comprehensive information to all potential participants. This information outlined the study's goals, procedures, expected duration, and the researcher's credibility, thereby enabling participants to make well-informed decisions about their involvement (De Vos et al., 2011). Participants were made aware that their participation was entirely voluntary and that they had the right to withdraw from the study at any point without any negative consequences. This letter can be seen in Appendix D.

Consent was obtained from multiple stakeholders: the teachers directly involved in the study, the school board, and the principal. This multi-layered consent process ensured that all parties were fully informed and agreed to participate willingly (Kadam, 2017). The consent forms, which are included in Appendix D, serve as formal documentation of this agreement.

#### 3.11.2 Confidentiality

Confidentiality pertains to participants' privacy, ensuring that their identities cannot be recognised by readers or other participants (Giordano et al., 2007). While the participants in this study were not anonymous to the researcher due to purposive sampling, their identities were carefully concealed at all times. Confidentiality was rigorously maintained throughout the study, ensuring that all private information provided by participants remained secure and could not be traced back to them in any reports or publications of the study's results and findings (Wiles et al., 2019). Participants were assured that their identities would be protected, and their responses would remain entirely anonymous in the dissemination of the research, fostering a high level of trust and upholding the study's ethical standards.

#### 3.12 Conclusion

This section of the study served as a blueprint, delineating the comprehensive research design guided by the Research Onion framework (Saunders et al., 2007). The chapter situated the research within an interpretivist philosophy, discussing its relativist ontology and subjective epistemology. It then outlined the inductive approach, complemented by a deductive element during the coding phase. Following this, the qualitative nature of the research was examined, and the justification for its exploratory case study strategy was provided.

The chapter proceeded to discuss the sampling methods and data collection processes, including the analysis of a policy document, the ITS exploration, and the semi-structured interviews, which were conducted, recorded, and transcribed. A detailed and illustrated explanation of the six steps of reflective thematic analysis (Braun & Clarke, 2022) was then presented, followed by the analysis methods of the policy documents and ITS tool, MathU. The chapter concluded by addressing the criteria for quality assurance and the ethical considerations involved in the study.

## Chapter 4: Results

### 4.1 Introduction

Chapter 3 delved into the details of the data collection methodology employed in this study. It elucidated the interpretive paradigm, qualitative research approach, and its relevance to the research at hand. Additionally, the chapter shed light on the case study research strategy and its application within the context of this investigation. The data collection strategy, data analysis techniques, population, and sample were also explained. Further, potential limitations, trustworthiness, and ethical considerations were explored.

This chapter now presents and discusses the study's results from the three data sources: the exploration of the MathU ITS, the analysis of the school policy documents, and the insights gained from semi-structured interviews with four Grade 7 Mathematics teachers using MathU in their classrooms. This was guided by the main research question: How can implementing an ITS support differentiated learning in an inclusive classroom?

To answer the sub-research questions, the following data collection methods were employed:

#### 1. *Exploration of the MathU ITS (Appendix A):*

This technological analysis was undertaken to examine how an ITS like MathU can influence the inclusive educational landscape. Analysing the technological aspects and tools embedded within MathU provides an understanding of its potential impact on teaching methods, the learning environment, and the overall efficacy of its integration within the South African educational context.

#### 2. *Analysis of school policy document on inclusion (Appendix B):*

The analysis of the school policy document was conducted to offer insights into contemporary educational issues and further corroborate the interview data, as suggested by Yanow (2007). This document analysis helps to contextualise the use of MathU within the broader framework of inclusive education policies.

### 3. Interviews with four Grade 7 Mathematics teachers who use MathU (Appendix C):

The interviews consisted of a set of 11 broad, open-ended questions designed to guide semi-structured discussions. The interviews aimed to gather information regarding differentiation techniques, challenges experienced, scenarios of MathU usage, curriculum alignment, MathU challenges, accessibility features, and enquiry-based learning.

Each of the TPACK components played a significant role in the investigation of the ITS, MathU and how it is used to support differentiation within an inclusive Grade 7 Mathematics classroom. Figure 4.1 below represents each component of TPACK, aligned with the research questions, and the relevant codes identified within the three datasets.

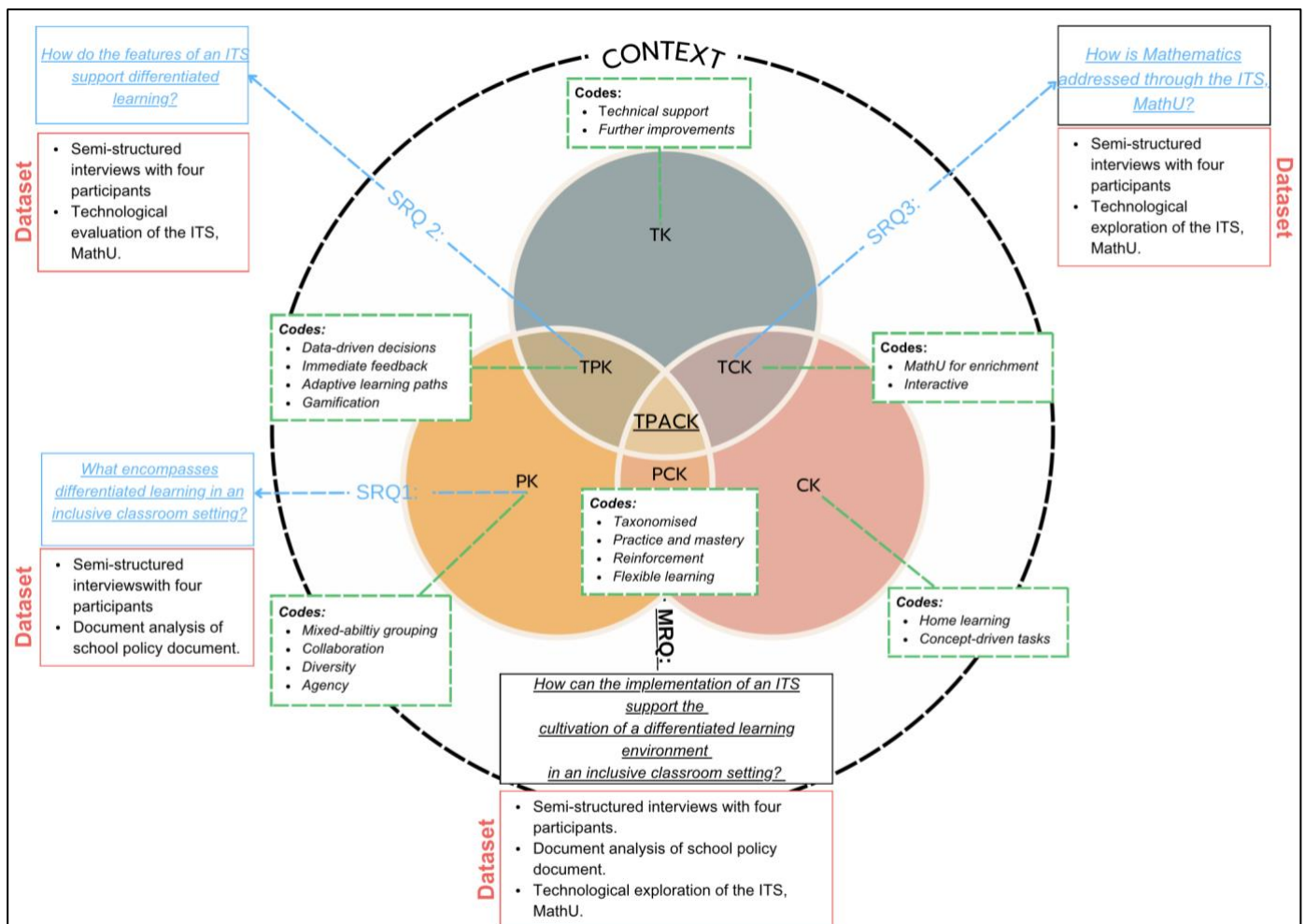


Figure 4.1: Data Collection Strategies and Relevant Codes Aligned to the TPACK Model (Adapted from Mishra and Koehler (2006))

## 4.2 Presentation of Results

The following sections present the findings, represented in Figure 4.1 above. The researcher begins by presenting the results from the ITS exploration, and School Policy Document on Inclusion. Thereafter, the researcher summarises the interview responses for each participant.

### 4.2.1 Results from ITS Exploration

Prior to conducting the research interviews, the researcher engaged in an exploration of the MathU ITS to gain comprehensive knowledge and familiarity with its functionalities. This preliminary investigation aimed to establish a foundational understanding of the tool's capabilities and operational dynamics. As the researcher familiarised herself with MathU through hands-on interaction and exploration, she sought to acquire insight that would inform subsequent qualitative data collection. The researcher kept an observational journal throughout this process, noting her experiences, thoughts and feelings regarding MathU's usage.

This approach ensured that during the interviews, the researcher could effectively contextualise discussions regarding MathU's technological features and its potential to support differentiated instruction in inclusive classroom settings. This analysis was guided by the TPACK framework, which emphasises the importance of effectively integrating technology into teaching and learning practices (Koehler & Mishra, 2009).

The researcher presents a checklist that demonstrates how MathU aligns with the key features of an ITS as identified in the literature (Boonthum et al., 2008; Graesser et al., 2018; Perikos et al., 2017). Additionally, these key ITS features have been mapped to the components of the TPACK model, making this analysis relevant to the study's framework. By assessing MathU against these criteria, the discussion offers a comprehensive understanding of its technological capabilities and its potential impact on differentiated learning in an inclusive educational setting. To enhance this analysis, relevant screenshots of the MathU platform have been included, showcasing the specific features and user experiences discussed.

Table 4.1: Checklist of MathU

Feature Category	Key Features	Description	TPACK Component
Adaptive Learning Capabilities	User Environment Adaptation	Adjusts learning environment based on student needs.	TK
	Content Adaptation	Modifies learning content according to the student's current skills, knowledge, and progress.	TCK
	Pace Adaptation	Adjusts the speed of instruction to match the student's learning pace.	TPK
	Search Functionality Adaptation	Customizes search functions to align with students' preferences and needs.	TK
	Facilitation of Communication and Cooperation	Supports group activities by enabling communication and collaboration among students.	TPK, TCK
Step-Level Guidance	Problem-Solving Support	Provides detailed assistance throughout problem-solving processes.	PCK
Personalized Instructional Guidance	Tailored Learning Experiences	Delivers advanced, personalized instructional guidance tailored to individual student needs, mirroring the support a human tutor would provide.	PCK, TCK, TPK
Diagnostic Capabilities	Knowledge Level Assessment	Accurately diagnoses a student's current knowledge level through diagnostic assessments.	CK
	Instructional Strategy Selection	Decides on appropriate instructional strategies based on individual student data.	TPK, TCK
	Strategy Adaptation	Continuously adapts instructional strategies as the student progresses.	TPK, TCK
Feedback Mechanisms	Timely and Constructive Feedback	Provides immediate feedback to help students identify and correct errors during the learning process.	TCK
Content-Specific Knowledge	Discipline-Specific Instructional Content	Grounded in discipline-specific knowledge (e.g., mathematics, physics, language studies, programming) to offer relevant and accurate instructional content.	CK
Data Analytics	Student Interaction and Performance Data	Collects and analyzes data on individual student interactions, performance, and academic progress to refine instructional approaches.	PK
Natural Language Processing	Interactive Conversations	Incorporates NLP techniques to understand and generate human-like language, enabling engaging and interactive conversations with learners.	TPK
Integration and Interoperability	System Integration	Ensures seamless integration with other educational technologies and platforms.	TK
	User-Friendliness	Provides an intuitive and accessible user interface for both students and educators.	TK
	System Stability	Maintains high levels of system reliability and stability during use.	TK
	Data Security Measures	Implements robust data security protocols to protect student information.	TK
Additional Considerations	Cultural and Contextual Sensitivity	Tailors learning content and interactions to be culturally relevant and contextually appropriate.	Context
	Scalability	The system should be scalable to accommodate varying numbers of users and diverse educational settings.	Context

#### *4.2.1.1 Adaptive Learning Capabilities*

The researcher noted that MathU demonstrates strong adaptive capabilities in content adaptation and pace adaptation, aligning with the TCK and TPK components of the TPACK framework, respectively. The system's ability to modify learning content based on students' current skills and progress, as well as adjust instruction speed to match individual learning paces, showcases its potential for personalised learning experiences. However, the absence of user environment adaptation and search functionality adaptation suggests areas for potential improvement. Enhancing these features could further tailor the learning experience to individual learner needs and preferences, potentially increasing engagement and effectiveness.

#### *4.2.1.2 Step-Level Guidance*

According to VanLehn (2011), effective ITSs offer ample step-by-step guidance across all adaptive assessments. MathU offers step-level guidance by providing targeted support at various stages of problem-solving. The researcher observed that when she struggled with a problem, she could click on a hint button to access a video or series of clues that broke down the problem into manageable steps and explained the underlying concepts. This immediate, context-specific help aids in understanding by addressing common misconceptions and guiding learners through the solution process. The system adapts its feedback based on the student's performance, offering additional hints or remedial content as needed.

However, it was noted that during adaptive assessments, this real-time assistance is not available, requiring users to apply their knowledge independently to accurately gauge their understanding and problem-solving skills.

The screenshot below highlights the activity with the step-by-step guidance for each question that the researcher completed in her exploration of the tool. The hints are seen at the top-right corner of the screen, with the icon of the open book. It is important to note that when a learner seeks a hint, the teacher is notified, and this affects the student's performance on the leaderboard.

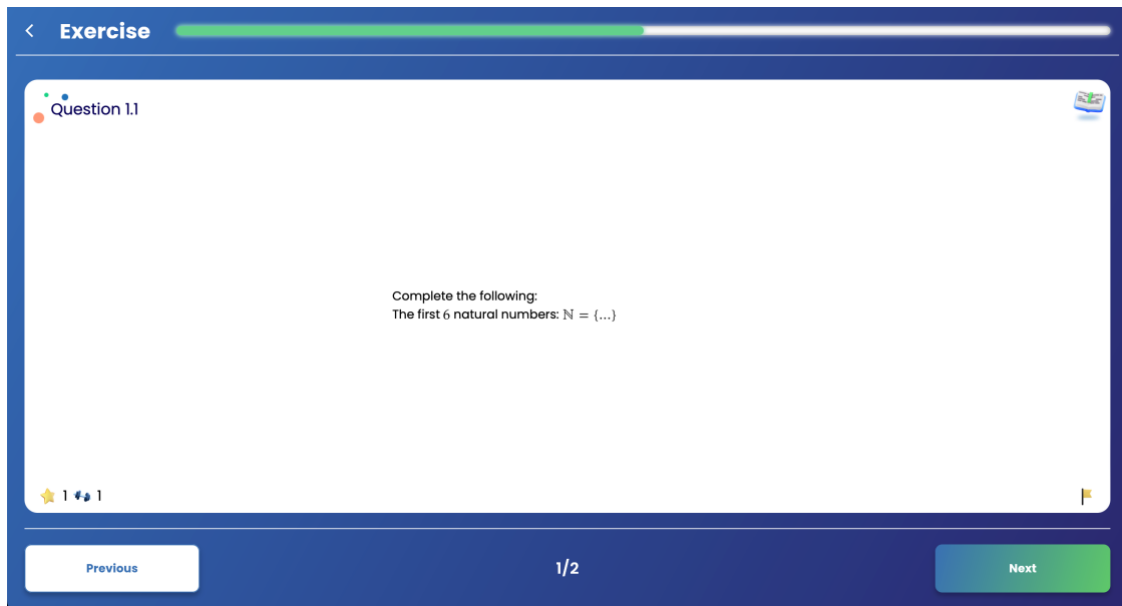


Figure 4.2: A Question in Question 1.1 for a MathU Activity

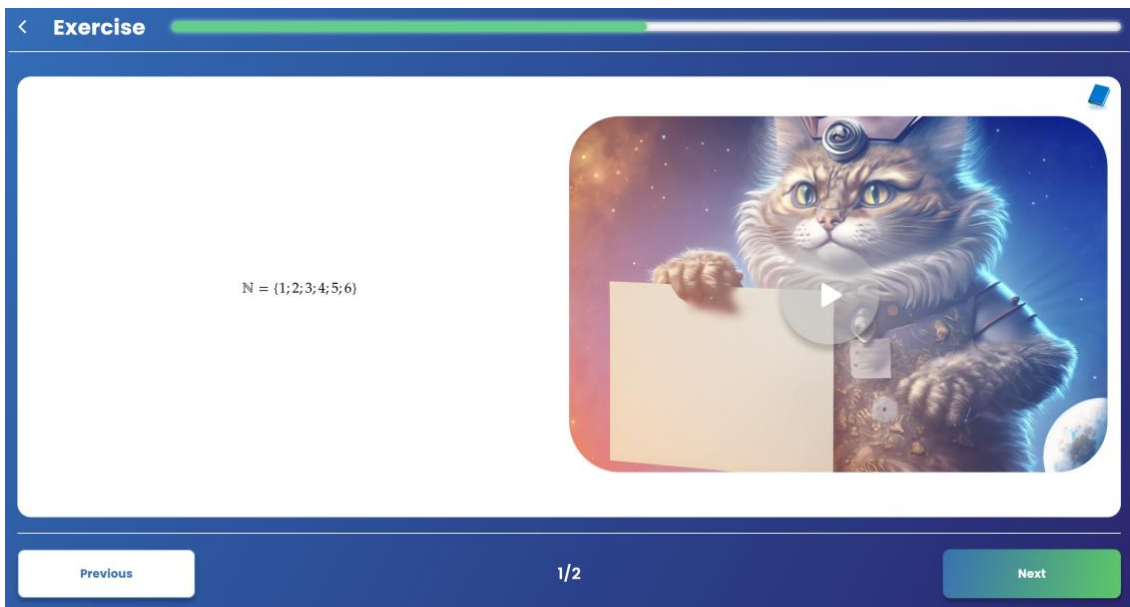


Figure 4.3: The Relevant Hint for Question 1.1 in a MathU Activity

#### 4.2.1.3 Personalised Instructional Guidance

One significant outcome of ITSs is their ability to offer personalised learning experiences tailored to individual students' learning styles and preferences (VanLehn, 2011). In the case of MathU, this personalisation becomes more effective as learners use the program over time. MathU builds a comprehensive database of each student's performance, which allows it to track their progress and identify their strengths and areas for improvement.

Based on this data, the system can recommend activities and resources that are well-suited to each student's current maths level, thereby enhancing their learning experience and helping them progress at their own pace.

MathU allows for a high degree of customisation and personalisation to meet the diverse needs of learners in an inclusive classroom setting. Through MathU, teachers have the flexibility to either select pre-designed chapter tests and lesson plans for all learners within a class, or to assign individual learners with more targeted extension and enrichment activities based on their specific learning requirements.

During the analysis, the researcher noted that MathU's user interface provides teachers with intuitive tools to customise and adapt the content and learning pathways for their learners. For example, after learners complete the initial chapter test or activity within MathU, the system automatically creates personalised "Pathways" for each learner based on the questions they answered incorrectly. These Pathways trigger the generation of additional, individualised practice exercises and examples tailored to the specific concepts or skills that each learners needs more reinforcement on, rather than providing a one-size-fits-all approach.

The screenshot in Figure 4.4 shows the results of a quiz the researcher completed. The researcher scored 67% on the quiz, and the system has identified areas for improvement, presenting the learners with a "Continue to pathway" option to receive personalised content and practice to address those gaps.

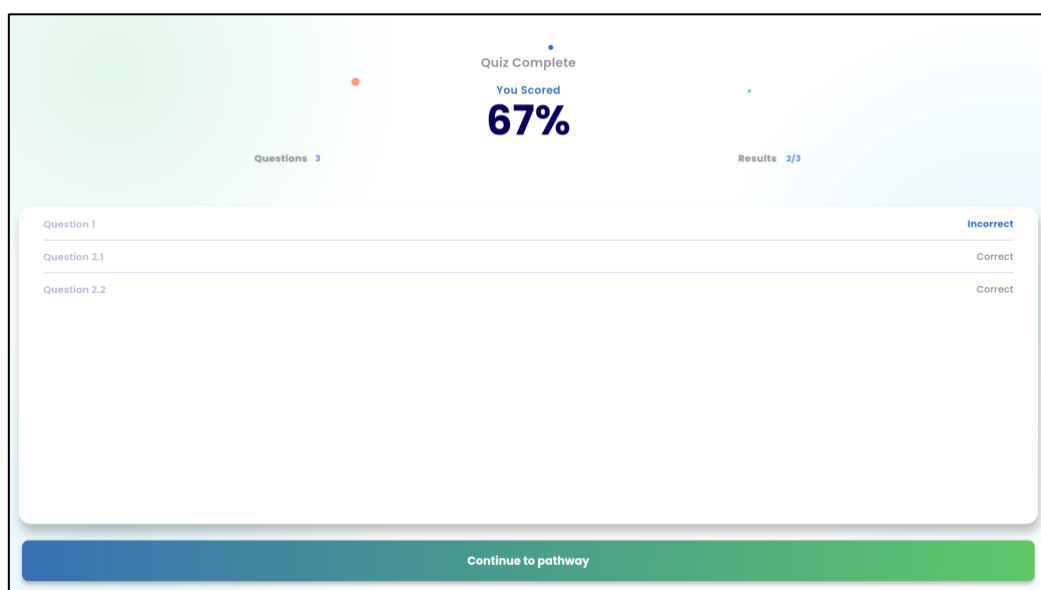


Figure 4.4: Personalised Pathway Based on Quiz Performance

The next screenshot in Figure 4.5 shows the researcher working through the personalised pathway generated by the MathU system based on her previous quiz performance. This tailored pathway aims to address the users' learning needs and helps them to progress in their understanding of the subject matter.

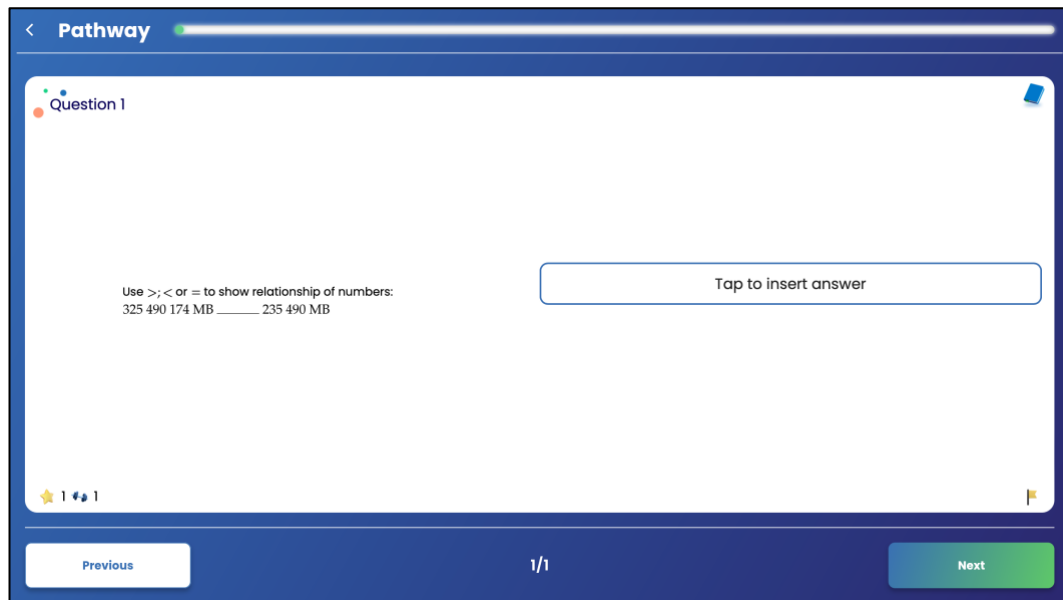


Figure 4.5: Personalised Practice in the MathU Pathway

#### 4.2.1.4 Diagnostic Capabilities

All three features in this category are ticked on the checklist, indicating the diagnostic capabilities of MathU. MathU's ability to accurately diagnose a student's current knowledge level through diagnostic assessments and subsequently select appropriate instructional strategies based on individual data demonstrates a sophisticated approach to personalised learning. The inclusion of strategy adaptation further enhances this capability, allowing for continuous refinement of instructional approaches as learners progress.

It is important to highlight that MathU leverages AI technology to detect learner performance and create a diagnostic assessment for each individual learner. This AI-driven approach enables the system to analyse complex patterns in learners' responses and behaviours, providing a more nuanced and accurate understanding of each learner's strengths, weaknesses, and learning styles.

By utilising AI in its diagnostic processes, MathU can create highly personalised learning pathways for each learner. These pathways are dynamically generated based on the AI's analysis of the student's performance, adapting in real time to the student's progress and changing needs. This level of individualisation goes beyond traditional one-size-fits-all approaches, offering adaptive learning experiences.

#### 4.2.1.5 Feedback Mechanisms

The timely and constructive feedback feature is ticked, indicating that MathU provides immediate feedback to help learners identify and correct errors during the learning process. This real-time support is crucial for maintaining learner engagement and promoting active learning. A key aspect of MathU's feedback mechanism is its integration within the personalised pathway assessment. Importantly, MathU immediately provides feedback after a learner inputs their answer in their individualised pathway assessment.

The screenshot in Figure 4.6 below indicates how MathU offers immediate feedback after inputting an answer within a user's personalised pathway assessment.

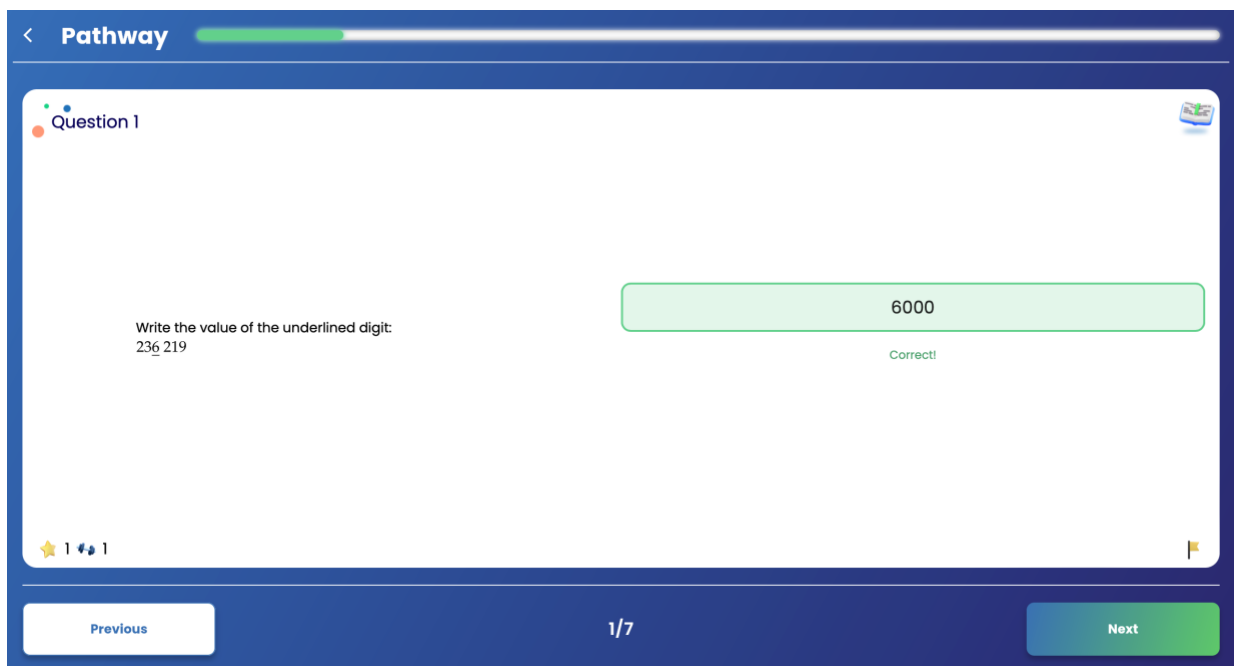


Figure 4.6: Immediate Feedback in a Pathway Assessment

#### 4.2.1.6 Content-Specific Knowledge

MathU demonstrates strong content-specific knowledge as indicated by the ticked box in the checklist. MathU is grounded in discipline-specific knowledge for mathematics, offering relevant and accurate instructional content. This feature is essential for maintaining the quality and relevance of the educational material presented to learners.

The screenshot in Figure 4.7 below highlights the content covered within MathU, it is aligned to the CAPS standards of Grade 7 Mathematics.

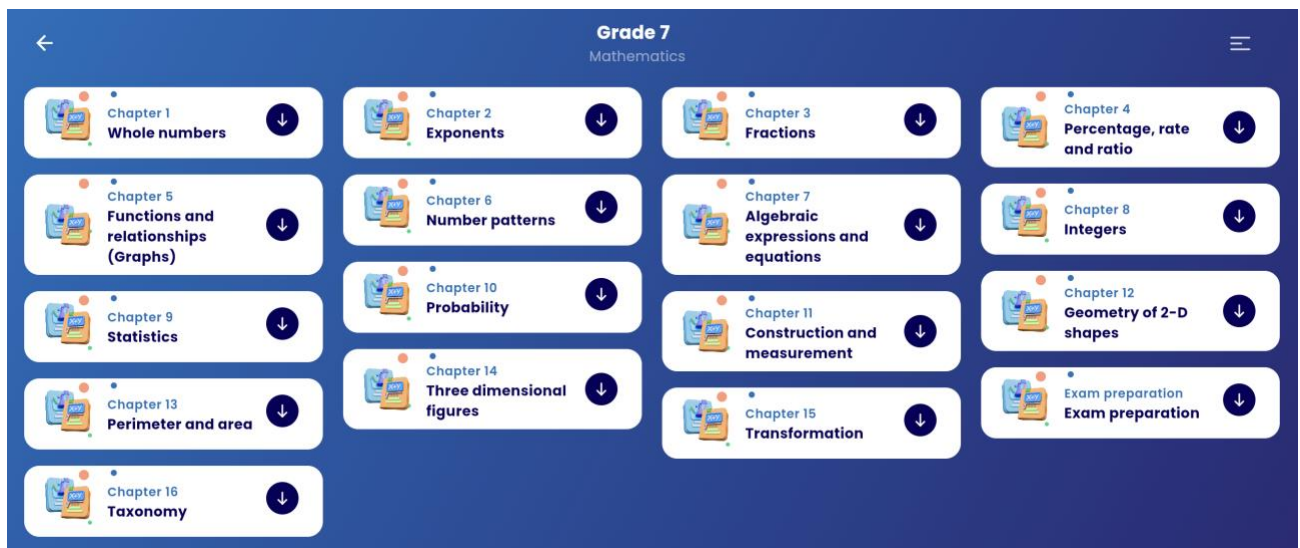


Figure 4.7: Grade 7 Mathematics Content in MathU

#### 4.2.1.7 Data Analytics

The learner interaction and performance data feature is ticked, indicating that MathU collects and analyses data on individual learner interactions, performance, and academic progress. The inclusion of a teacher dashboard highlights how MathU serves as a comprehensive educational technology solution, supporting both individual learning and broader classroom management and assessment needs. The screenshot in Figure 4.8 below highlights the teacher dashboard, where a student's data is displayed.

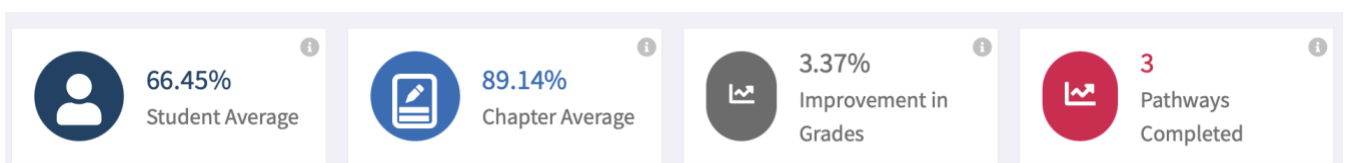


Figure 4.8: Data Analytics in MathU

#### 4.2.1.8 Natural Language Processing

The interactive conversations feature is not ticked, suggesting that MathU may not incorporate advanced NLP techniques for engaging in human-like conversations with learners. This could be an area for future development to enhance learners' engagement and provide more interactive learning experiences.

#### 4.2.1.9 Integration and Interoperability

The platform's reliability is an essential factor in evaluating the suitability of MathU for use in inclusive classroom settings. This encompasses both the system stability and the measures in place to ensure the security and confidentiality of learners' data. Based on the information gathered during the analysis, the MathU platform has demonstrated a high degree of consistency and uptime. The system is designed to provide uninterrupted access and functionality, which is critical for supporting seamless learning experiences for all learners in the inclusive classroom. Whilst teachers reported a few technical glitches during their use of the platform, the MathU platform offers dedicated IT support services, as indicated by the information in the screenshot in Figure 4.9. Teachers and learners can log support tickets to address any technical issues or concerns, including those related to data security and privacy. This 24/7 support availability further reinforces the platform's commitment to reliability and responsiveness in serving the needs of its users.

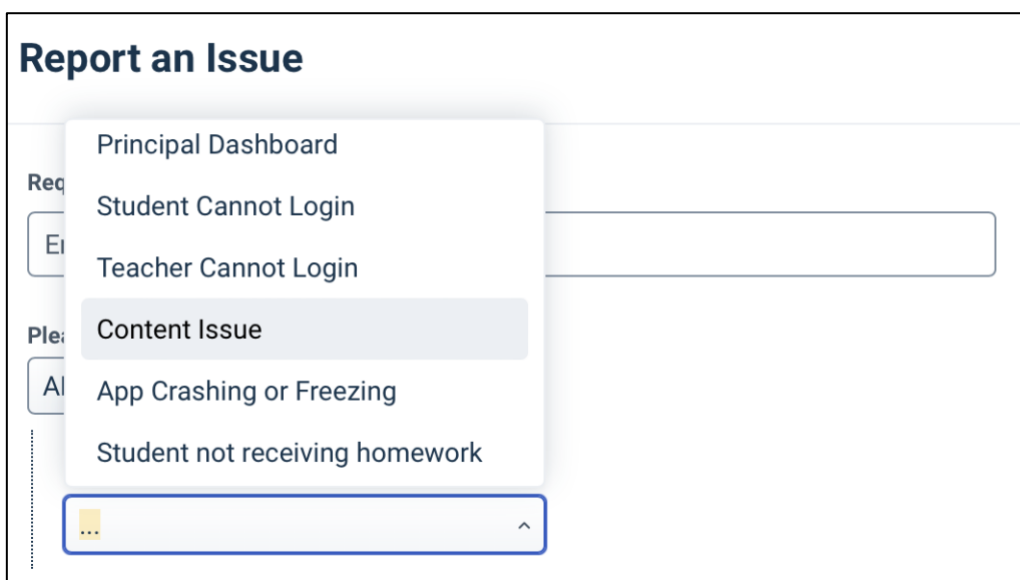


Figure 4.9: Support Services for MathU

The MathU platform also places a strong emphasis on data privacy and security, as evidenced by the detailed Terms of Use policy provided in Figure 4.10. This policy outlines the platform’s compliance with the Creative Commons Attribution 3.0 License, ensuring the appropriate attribution and use of the original course materials. Additionally, the policy highlights the specific measures in place to protect learners data, such as encryption, access controls, and adherence to relevant data protection regulations.

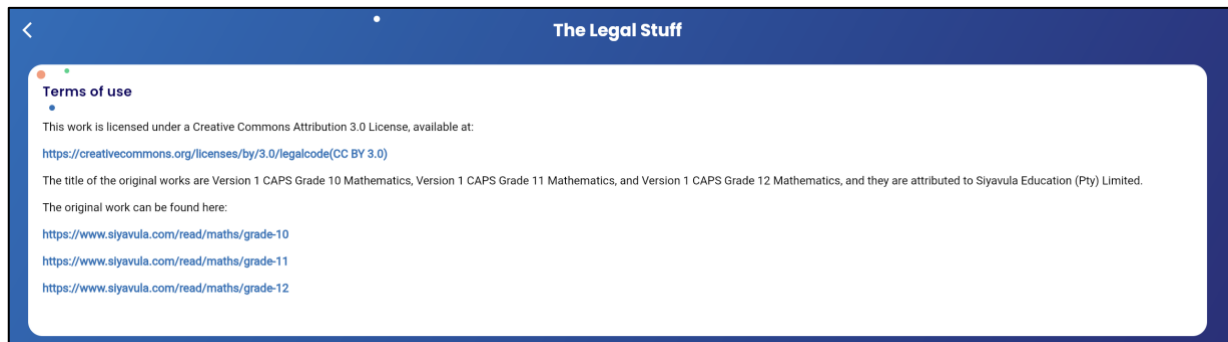


Figure 4.10: MathU's Commitment to Transparency and Data Protection

#### 4.2.1.10 Additional Considerations

The MathU platform is designed with a strong focus on user-friendliness and accessibility. The platform features numerous visual cues and symbols, catering to the needs of learners who may have challenges with reading. While advanced accessibility features like captions and text-to-speech are not yet available, the developers have indicated that they are actively working on incorporating these capabilities to enhance the user experience further.

The screenshot in Figure 4.11 showcases the accessibility-focused design elements incorporated into the “Whole Numbers” chapter. The interface prominently features visual icons and symbols, catering to learners who may benefit from non-text-based cues. This inclusive approach aligns with the platform’s commitment to supporting diverse learner needs within the inclusive classroom setting. The clear organisation of content and interactive exercises, along with the availability of assistive features, demonstrate MathU's emphasis on creating an efficient and engaging learning experience for all learners.

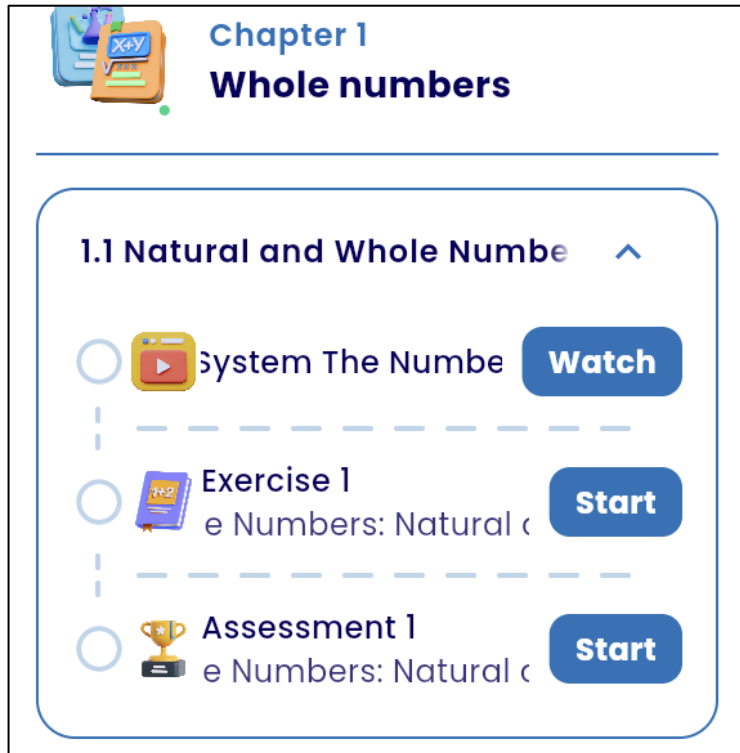


Figure 4.11: Accessibility-Focused Design in MathU

The platform's integration with learning management systems and learner information systems is a strength. As seen in the screenshot in Figure 4.12, learners can easily log in using their Microsoft or Google accounts, as well as their mobile phone numbers.



Figure 4.12: The Login Dashboard for Learners and Teachers

#### 4.2.1.11 Summary of Findings

The evaluation of MathU reveals that it exhibits strong adaptive learning capabilities, particularly in content and pace adaptation, aligning well with the TPACK framework's TCK and TPK components. It offers effective step-level guidance and personalised instructional pathways based on individual performance, facilitating tailored learning experiences. MathU's diagnostic capabilities and real-time feedback mechanisms further enhance personalised learning, while its content-specific knowledge aligns with Grade 7 CAPS standards. The platform also demonstrates robust data analytics, though it lacks advanced NLP features. Additionally, MathU prioritises reliability, data security, and accessibility, with ongoing efforts to improve its user interface and integration with learning management systems, making it a valuable tool in inclusive educational settings.

The evaluation identified several areas where MathU could improve. Specifically, it lacks user environment adaptation and search functionality adaptation, which could enhance personalised learning experiences. Additionally, while MathU provides step-level guidance during problem-solving, this support is not available during adaptive assessments, requiring users to work independently. The platform also lacks advanced NLP features for interactive conversations, which could further engage learners. Furthermore, advanced accessibility features, such as captions and text-to-speech are not yet implemented, although they are reportedly in development. These missing elements suggest potential areas for future enhancement to better meet diverse learning needs.

#### 4.2.2 Results from School Policy Document on Inclusion

The document analysis of the school's inclusion policy was conducted as an essential component of the research, providing critical insights that complemented the data obtained from interviews. The inclusion policy, examined within the framework of TPACK, offered a foundational perspective on how inclusive education is conceptualised and implemented within the South African independent school context. The analysis aimed to understand the policy's definitions of inclusive education and differentiated learning, and to assess the alignment of these practices with the TPACK components. Table 4.2 below presents a checklist for evaluating the results of the school policy document in relation to the TPACK framework.

Table 4.2: Checklist of School Policy Document

TPACK	Checklist Criteria	Comments
TK	Does the policy recognize the role of technology in supporting inclusive education?	<i>Emphasis on the importance of using technology to support inclusive education, particularly in data-driven decision-making and differentiated instruction (section 1.7.3 and 3.1.1.2.)</i>
	Is there mention of the allocation of technological resources to support students with diverse needs?	<i>Acknowledges continuous improvement and innovation (section 1.7.4), but could more explicitly discuss the allocation of technological resources for inclusive practices.</i>
	Does the policy emphasize the use of technology for continuous assessment and progress monitoring?	<i>Highlights the importance of using data to evaluate the success of interventions (section 1.7.3) and drive educational decisions</i>
	Are various technological tools mentioned or implied to support differentiated instruction?	<i>Supports the use of technological tools in differentiated instruction through its emphasis on innovative practices and continuous monitoring of student progress ( sections 1.7.3, 3.1.1.3).</i>
CK	Does the policy ensure that curriculum content is designed to be inclusive and accessible to all students?	<i>Underlines the need for a curriculum that includes student diversity as a resource (section 1.6)</i>
	Is there an emphasis on providing equal learning opportunities for all students regardless of their background or abilities?	<i>Promotes equal learning opportunities by rejecting segregation and encouraging an inclusive environment (section 1.4), ensuring that all students can achieve their personal potential (section 2.5).</i>
PK	Does the policy outline specific strategies for differentiating instruction according to students' needs?	<i>Differentiation is central to the policy, with clear guidelines on tiered interventions to meet diverse student needs (sections 3.1.1 - 3.1.3).</i>
	Does the policy highlight the importance of collaboration among teachers, staff, and other stakeholders in supporting student learning?	<i>Advocates for collaborative approaches among teachers and other stakeholders in identifying and supporting students requiring additional assistance (sections 3.1.1.5, 1.7.5).</i>
	Is there a provision for regular professional development for teachers to help them meet the needs of all students?	<i>The policy ensures continuous professional development for teachers to empower them in meeting diverse student needs (sections 1.7.5)</i>
TCK	Does the policy discuss how technology is integrated to facilitate access to educational content for all learners?	<i>Implies the use of technology to enhance access to educational content, particularly through its focus on innovation and data-driven interventions (sections 1.7.3, 1.7.4).</i>
	Are innovative technological practices encouraged to enhance the Learner Support Programme?	<i>Innovative technological practices are encouraged to enhance the Learner Support Programme, ensuring that it meets the evolving needs of students (1.7.4).</i>
TPK	Does the policy ensure that technology use aligns with pedagogical goals for inclusion?	<i>Aligns the use of technology with pedagogical goals by focusing on differentiated instruction and continuous assessment (section 3.1.1.3), ensuring that technology supports effective teaching practices.</i>
	Is there mention of how technology can be used to support differentiated instruction and interventions?	<i>The policy supports the use of technology for differentiated instruction, particularly through its structured approach to tiered interventions (section 3.1.1 - 3.1.3).</i>
PCK	Does the policy include strategies for adapting curriculum content to meet the diverse learning needs of students?	<i>Emphasis on the adaptation of content to meet diverse learning needs (section 1.6), ensuring that all students can access and benefit from the curriculum.</i>
	Is there a focus on seeing student diversity as a resource for enriched learning and not a barrier?	<i>The policy views student diversity as a resource, not a barrier, fostering an environment where individual differences are seen as opportunities for enriched learning (section 1.6).</i>
TPACK	Does the policy reflect a comprehensive integration of technological, pedagogical, and content knowledge to support inclusive education?	<i>Comprehensive integration of technological, pedagogical, and content knowledge, particularly in its structured approach to differentiated instruction and tiered interventions (section 3.1.1 - 3.1.3).</i>
Context	Does the policy recognize and address the importance of context in shaping instructional practices?	<i>Acknowledges the situated nature of instruction by emphasizing the need to adapt practices to the specific needs and contexts of the school community (sections 1.7.4, 2.6).</i>
	Is there consideration of the cultural, social, and community contexts in which learning takes place?	<i>The policy is sensitive to the cultural and social contexts in which learning occurs, ensuring that all students are included and supported (sections 1.2, 2.5).</i>

#### *4.2.2.1 Technological Knowledge*

The policy emphasises “resource allocation to support inclusive education practices, including funding, technology infrastructure, and professional development opportunities for teachers.” This commitment ensures that the school’s technological needs are adequately addressed, reflecting a situated approach where technology is integrated based on the specific context and requirements of the educational environment. By focusing on “ongoing evaluation of the impact of support programs and the allocation of resources”, the policy aligns with the TPACK framework’s technological component, ensuring that technology is effectively used and adapted to meet the unique needs of the school’s diverse learner population.

#### *4.2.2.2 Pedagogical Knowledge*

The policy’s tiered intervention approach, which “provides increasingly intensive instruction and support based on students’ individual needs”, highlights its commitment to differentiated instruction. This approach reflects a context-specific understanding of pedagogical strategies, adapting teaching methods to students’ varying needs within the school’s unique learning environment. The focus on “formative and summative assessments” to identify and address learning difficulties further demonstrates the policy’s alignment with pedagogical best practices, ensuring that instructional strategies are tailored to the specific context of the school.

#### *4.2.2.3 Content Knowledge*

The policy’s emphasis on “engaging with different ways of knowing and being” and ensuring “all learners are afforded the opportunity to achieve to their personal potential” demonstrates its commitment to integrating diverse content knowledge into the curriculum. By promoting an inclusive approach that recognises and values the diverse content and students’ perspectives, the policy supports the effective delivery of educational content within the specific context of the school’s diverse learner population. This approach aligns with the TPACK framework’s content knowledge component, ensuring that content remains relevant and accessible to all learners.

#### *4.2.2.4 Pedagogical Content Knowledge*

Integrating “differentiated instruction” and “continuous teacher formative and summative assessments” within the policy highlights its focus on pedagogical content knowledge. The policy’s approach to providing “intensive instruction and support based on students’ individual needs” ensures that instructional strategies are effectively matched with content to address diverse learning needs. This focus on adapting pedagogical strategies to the content being taught reflects the policy’s context-specific approach, ensuring that teaching methods are aligned with the unique needs and challenges of the school’s educational setting.

#### *4.2.2.5 Technological Pedagogical Knowledge*

The policy’s emphasis on “ongoing professional development for teachers” and “the introduction of innovative practices to enhance the match between the Learner Support Programme and the evolving needs of the school” demonstrates its commitment to technological pedagogical knowledge. By providing teachers with the tools and training needed to integrate technology into their teaching practices, the policy ensures that technological advancements are effectively utilised to support pedagogical strategies. This alignment with TPACK’s technological pedagogical knowledge component reflects the policy’s context-specific approach, ensuring that technology is used in ways that enhance teaching and learning within the school’s unique educational environment.

#### *4.2.2.6 Technological Content Knowledge*

The policy’s focus on “technology infrastructure” and “the importance of resource allocation” to support inclusive education practices reflects a strong understanding of technological content knowledge. By addressing the need for “funding and technology infrastructure” to support educational practices, the policy ensures that technological resources are appropriately integrated into the content being taught. This context-specific approach aligns with TPACK’s technological content knowledge component, ensuring that technology supports and enhances the content delivered within the school’s curriculum.

#### *4.2.2.7 Technological Pedagogical Content Knowledge*

The school's inclusion policy demonstrates a strong commitment to fostering an inclusive learning environment. This is evident in the statement that the institution "continuously strive[s] to improve practices to achieve better outcomes for their learners and remain relevant to the needs of the learners across their various school communities." At the core of the policy is the emphasis on inclusivity in education, promoting equal access to learning opportunities for all learners. The policy aims to create an inclusive learning community where everyone has agency and shares responsibility for learning, health, and well-being. Furthermore, the policy advocates against segregation based on abilities, race, gender, or any other form of differentiation, underscoring the institution's firm stance on equity and non-discrimination. Crucially, the policy outlines goals for the continuous improvement of inclusive practices to achieve better learner outcomes and ensure the learning environment remains relevant and responsive to their evolving needs.

#### *4.2.2.8 Context*

The focus on differentiated instruction and continuous assessment reflects the school's commitment to addressing the unique needs of its learner population. By adapting pedagogical strategies to the school's context, the policy ensures that teaching methods are relevant and responsive to the diverse learning needs of all learners.

#### *4.2.2.9 Summary of Findings*

The policy document reflects a strong commitment to inclusive education through effective integration of technology, pedagogy, and content. It highlights the school's dedication to providing a supportive and adaptive learning environment that addresses the diverse needs of all learners. However, further detail on the practical implementation and evaluation of these components could enhance understanding and ensure the ongoing effectiveness of inclusive practices.

### 4.2.3 Results from Semi-Structured Interviews

Following an in-depth exploration and analysis of MathU and a thorough examination of the school's inclusion policy documents, the researcher conducted four semi-structured interviews with Grade 7 mathematics teachers. These interviews were informed by a comprehensive understanding of MathU's capabilities and the inclusive educational context of the research site. The interviews were analysed through the lens of the TPACK framework, which guided the investigation into how technological, pedagogical, and content knowledge intersect in the use of MathU within an inclusive setting. The findings from these interviews are organised according to the TPACK components. Each section includes a detailed discussion of the results, supported by relevant codes developed during the thematic analysis outlined in *Section 3.9*.

#### 4.2.3.1 Pam



Pam (a pseudonym used for confidentiality purposes) is an experienced mathematics teacher with a decade of teaching experience under her belt. Although she has been a teacher for 10 years, the current academic year marks only her second year at the present school, which has adopted the use of the MathU in classroom instruction. In addition to her regular mathematics classes, Pam also teaches an optional mathematics class for Grade 7 learners who struggle with the subject. Prior to joining this institution, Pam did not have any experience utilising an ITS like MathU in her teaching practice. Despite being relatively new to the integration of this technology-enabled learning platform, Pam has been actively incorporating MathU into her mathematics lessons and navigating the process of leveraging its capabilities to support her students' diverse learning needs.

Pam's responses to Questions 1 and 2 are summarised in Table 4.3 below.

Table 4.3: Pam's Interview Responses to Questions 1 and 2

TPACK Component	Question	Answer
TK	(1) Can you describe the key features of <i>MathU</i> that you mostly use in the classroom?	<i>I enjoy the 'generate chapter test' feature on MathU, it creates a personalised test for my learners based on their performance on their preceding MathU activities.</i>
TK	(2) Can you discuss any challenges or opportunities you have faced while integrating <i>MathU</i> within your classroom?	<i>Coming from a school that never used MathU is challenging to integrate into my daily lessons.</i>

Pam's comments highlight several key codes related to her use of MathU and the challenges she faces. Firstly, she appreciates the "generate chapter test" tool for its immediate feedback and support, which aids in personalised learning by providing customised chapter tests tailored to each student's performance.

This feature significantly saves her time compared to creating tests manually, aligning with the codes of *immediate feedback*, *individual performance insights*, and *customised curriculum implementation*.

However, Pam also faces challenges in integrating MathU into her Grade 7 mathematics class. Coming from a school that never used MathU, she finds it difficult to adapt and integrate this new technology effectively, reflecting the codes of *technology infrastructure* and *adaptation to new tools*. She also struggles with *time management*, expressing a need to find a routine that includes a dedicated "MathU day" for learners to ask questions and work independently. Additionally, her concerns point to the necessity of *technical support* to better utilise MathU in her teaching.

Pam's responses underscore the benefits of the ITS technology and the challenges of adapting to and integrating new educational technologies into existing teaching practices.

Table 4.4: Pam's Interview Response to Question 3

TPACK Component	Question	Answer
PK	(3) How do you incorporate differentiation strategies to meet the diverse learning needs of learners in your classroom?	<i>For differentiation, I prefer using collaborative group work with mixed ability levels.</i>

Pam's response indicates that she prefers implementing collaborative groupings in her classroom to foster differentiation. She finds that mixing learners of varying ability levels into small groups allows for effective differentiation. In these mixed groups, higher-performing learners can support their peers by explaining concepts, while struggling learners benefit from the additional guidance from both Pam and their classmates.

This approach aligns with several key codes, such as *collaborative learning opportunities*, which foster an environment where learners can learn from each other and work together to solve problems. It also aligns with the code of *learner agency and learner autonomy and ownership* as learners take initiative, contribute their strengths, and develop responsibility for their own learning. Another code highlighted is that of *mixed-abilities groups*, where learners with varying skills can collaborate, allowing higher-achieving learners to assist their peers, while those needing more support benefit from their classmates' guidance.

Table 4.5: Pam's Interview Responses to Questions 4 to 9

TPACK Component	Question	Answer
TPK	(4) Can you describe the key features of <i>MathU</i> that you mostly use in the classroom?	<i>I enjoy the 'generate chapter test' feature on MathU, it creates a personalised test for my learners based on their performance on their preceding MathU activities.</i>
TPK	(5) How does <i>MathU</i> support your pedagogical approaches in promoting differentiated learning?	<i>MathU doesn't offer collaboration opportunities because my kids work on their own iPads when they use MathU.</i>
TPK	(6) Can you share any examples of how you use <i>MathU</i> to address students' varying abilities, interests, and learning styles?	<i>I set activities that they need to complete, and I have the leaderboard on my board, the kids motivate each other.</i>
TPK	(7) In what ways does <i>MathU</i> facilitate the delivery of differentiated instruction?	<i>I can see everything the kids do. It allows me to clearly see where my learners are at in terms of the content.</i>
TPK	(8) How does <i>MathU</i> contribute to creating an inclusive learning environment that promotes diversity?	<i>The kids always have fun when we do MathU, and they like the competition of it. It is cool that every learner is getting the support they need.</i>
TPK	(9) How do you ensure that <i>MathU</i> is accessible and inclusive for learners with disabilities or other challenges?	<i>Kids who are more visual can watch the videos explaining certain concepts. But I think there isn't much other accessibility features yet.</i>

At Question 4, Pam’s response highlights how MathU is able to support individualised instruction and feedback for her learners, particularly in cases where they struggle with tests.

These responses highlight the codes of *individualised instruction* and *immediate feedback*. Pam further notes that by presenting similar questions but broken down into more steps, MathU allows learners to engage with the material at a more granular level, which enhances their understanding and performance. This speaks to the code of *practice and mastery*. Pam emphasises the utility of the memo feature on MathU. According to Pam, this feature enables learners to “write down the answer and then flip it to check”, which supports active learning and self-assessment, further highlighting *personalised learning* and *learner autonomy*.

Interestingly, at Question 3, Pam expressed a preference for collaborative groupings to foster differentiation in her classroom. However, at Question 5, she noted that MathU does not support collaboration, which indicates that the tool does not align with her preferred method of differentiation.

While MathU offers other features that support differentiation, such as the ‘reroute options’ and the ‘generate chapter test’ tool, its lack of collaborative capabilities falls short of meeting Pam’s expectations for effective differentiation in her classroom.

The codes of *collaborative learning opportunities* and *mixed-ability groups* are highlighted here, as well as *technical support*.

Pam reveals how she integrates MathU into her teaching practice to accommodate her students’ varying abilities, interests, and learning styles at Question 6. She highlights the code of *gamified elements*, particularly the live leaderboard, which fosters healthy classroom competition and motivates learners.

This aligns with the codes of *interactive and adaptive learning*, *learner autonomy and ownership*, and *inclusivity and diversity*. Pam also encourages learners to watch content videos before completing activities, enabling better performance and leaderboard climbing, reflecting the codes of *individualised learning journeys* and *practice and mastery*.

Question 7 highlights the valuable data and statistics that MathU provides. According to Pam, the platform provides comprehensive visibility into learners' activities, allowing her to monitor whether learners have watched the content videos and answered the questions. This enables her to track learners progress and understand their grasp of the material: "What is nice is that as the teacher, I can see everything the kids do. Have they watched the content videos? Have they answered the questions?"

This allows Pam to tailor her instruction to meet the individual needs of her learners, providing targeted support, where necessary, and ensuring that each learner is progressing at an appropriate pace. For Pam, this is a crucial aspect of differentiated instruction, as it allows the teacher to adjust the learning experience based on the real-time performance and needs of each of her learners.

This aligns with the codes of *assessment and evaluation*, *data-driven decision making*, and *customised curriculum implementation*.

At Question 8, Pam mentioned that MathU contributes to creating an inclusive learning environment that promotes diversity by ensuring that each learner receives the support they need while also fostering a sense of enjoyment and engagement in learning. Pam noted that her learners "always have fun when we do MathU, and they like the competition of it", highlighting the platform's ability to make learning an enjoyable experience for all learners.

Additionally, the individualised support provided by MathU ensures that "every learner is getting the support they need", which is essential for catering to the diverse needs and abilities within the classroom.

This aligns with the codes of *inclusivity and diversity*, *learner engagement*, and *personalised feedback and support*.

Pam's response to Question 9 indicates that there is still room for improvement in terms of MathU and its features. While Pam highlights the availability of videos that explain certain concepts, which can be particularly helpful for visual learners, she also points out that MathU currently lacks a broader range of accessibility features, expressing a less positive view on this aspect of the platform.

Pam’s feedback indicates that MathU still needs to expand its accessibility options to better accommodate learners with various disabilities and learning challenges. Again, this aligns with the code of *technical support*.

Table 4.6: Pam’s Interview Responses to Questions 10 and 11

<b>TPACK Component</b>	<b>Question</b>	<b>Answer</b>
TCK	(10) In what ways does <i>MathU</i> adapt to the specific learning requirements of your learners?	<i>MathU</i> has ‘pathways’ for questions that learners struggle with. It provides extra guidance as they work through problem areas.
TCK	(11) How does <i>MathU</i> align with the curriculum and standards in an inclusive classroom setting?	<i>There were certain topics and concepts that we needed to cover, but MathU didn’t have any content for them yet.</i>

Pam’s answer to Question 10 reveals the technological advancements that MathU can offer.

Pam highlights that MathU adapts to the specific learning requirements of her learners by incorporating what MathU calls ‘pathways’ for questions that they struggle with, providing scaffolded support. If a learner gets something wrong, MathU presents them with more questions on that topic, broken down into smaller, more manageable steps. This extra guidance helps learners work through problem areas more effectively, ensuring that they receive the necessary support to master challenging concepts. This targeted and scaffolded approach allows MathU to cater to the unique learning needs of each of her learners. The last question asked if MathU meets all the needs of the curriculum and standards.

Her response revealed that whilst MathU constantly aims to align with the curriculum and standards in an inclusive classroom setting, there are areas where it currently falls short. Pam notes that while the platform covers many necessary topics and concepts, there are certain areas where content is lacking: “There were certain topics and concepts that we needed to cover, but MathU didn’t have any content for them yet.”

This indicates that while MathU can be a valuable tool for reinforcing and extending learning in many areas, its alignment with the full curriculum and standards is not yet complete. To fully support an inclusive classroom, MathU would need to expand its content to ensure comprehensive coverage of all required topics and concepts.

The codes *practice and mastery, individualised instruction, customised curriculum and content, inclusivity and diversity and technical support* are highlighted in these responses.

#### 4.2.3.2 Jim



Jim (a pseudonym for confidentiality) is an experienced teacher with 15 years in the teaching profession. For the past five years, he has been working at his current school, where he teaches Grade 7 Mathematics and Grade 7 Physical Sciences. Jim has been utilising the MathU tool for the last two years and has attended numerous training events organised by the MathU team. Jim's responses to Questions 1 and 2 are summarised in Table 4.7 below.

Table 4.7: Jim's Interview Responses to Questions 1 and 2

TPACK Component	Question	Answer
TK	(1) Can you describe the key features of <i>MathU</i> that you mostly use in the classroom?	<i>I like the real-time feedback it provides on learner- performance. I saw firsthand how this feedback helped improve my students' results.</i>
TK	(2) Can you discuss any challenges or opportunities you have faced while integrating <i>MathU</i> within your classroom?	<i>As a pilot school for MathU, I faced some challenges with bugs and incorrect answers from the app. But now these issues have been resolved.</i>

Question 1 asked about any specific features within MathU that teachers use most often in their classrooms. According to Jim, his favourite aspect is the real-time feedback MathU provides about each of his learners, the code *immediate feedback* is highlighted here.

Jim also mentioned that he “really appreciates that MathU shares immediate feedback on learner-performance, making the process of setting exams and assessments much easier.” The code of *data-driven decisions* comes to mind here. He also noted that the feedback provided by MathU could allow him to pinpoint exactly where each of his individual learners were struggling, thereby allowing him to tailor his instruction to address specific gaps. This highlights the code *individualised instruction*.

Jim mentioned that this feature is particularly useful when a new learner joins his class, and may have missed certain topics. The real-time feedback and data provided by MathU offer a quick baseline assessment, allowing Jim to immediately gauge where the learner is at in terms of mathematical needs. Jim highlights that “this saves me time and ensures I get new learners the support they need from day one.” The *data-driven decisions* code is highlighted.

Question 2 revealed Jim’s positive outlook towards MathU despite him facing initial challenges with MathU. Interestingly, Jim highlights that his school served as the pilot school for MathU two years ago. With this, there were some initial challenges that Jim experienced. Jim noted that at the early rollout and implementation stage, there were some technical issues that needed resolving.

Jim particularly noted that the first version of the app crashed quite frequently on learners’ iPads. However, Jim happily remarked that the MathU team were very responsive in addressing these problems, and the “initial growing pains were worth it for all the benefits MathU now gives us.”

The codes, *future improvements* and *technical support* are highlighted here.

Table 4.8: Jim's Interview Response to Question 3

TPACK Component	Question	Answer
PK	(3) How do you incorporate differentiation strategies to meet the diverse learning needs of learners in your classroom?	<i>I like to do formative assessments at the end of every unit I teach, so that I can see where my learners are at. I use quizzes on Microsoft Forms to do this.</i>

Question 3 highlighted the personal approach to differentiation that Jim employed in his classroom. Jim mentioned that formative assessments serve as a crucial tool in his classroom, as it allows him to gain an understanding of his students' grasp of content. Jim also made it clear that these formative assessments are not just "for checking who gets an 80% or 60%, but to see who understands what." Often Jim uses e-tools, such as quizzes on Microsoft Teams, Kahoot and even MathU to administer these 'exit tickets' as he calls them.

The codes *data-driven decisions, practice and mastery, as well as immediate feedback* are presented in Jim's response.

Table 4.9: Jim's Interview responses to Questions 4 to 9

TPACK Component	Question	Answer
TPK	(4) How does <i>MathU</i> support individualised instruction and personalised feedback for your learners?	<i>MathU provides me with instant, personalised feedback on each student's understanding. If a learner answers incorrectly, it pinpoints the specific area they are struggling with and automatically adapts with targeted practice just for them.</i>
TPK	(5) How does <i>MathU</i> support your pedagogical approaches in promoting differentiated learning?	<i>I use MathU's assessments as my formative assessments to check where my learners are after a unit is completed.</i>
TPK	(6) Can you share any examples of how you use <i>MathU</i> to address students' varying abilities, interests, and learning styles?	<i>I even use MathU for extension, if my learners keep getting the questions right, MathU automatically keeps on extending them.</i>
TPK	(7) In what ways does <i>MathU</i> facilitate the delivery of differentiated instruction?	<i>MathU allows the learners to keep working at their own pace, so some learners can be far ahead, while others are still behind, and no one is holding anyone back.</i>
TPK	(8) How does <i>MathU</i> contribute to creating an inclusive learning environment that promotes diversity?	<i>Because every learners can pace themselves and easily see where they are going wrong.</i>
TPK	(9) How do you ensure that <i>MathU</i> is accessible and inclusive for learners with disabilities or other challenges?	<i>I make sure I first teach the content and explain it properly, then I assign the learners chapter tests on MathU, if they forgot, they can always watch the videos in MathU to help them.</i>

When Jim answered Question 4, he highlighted that rather than just identifying a student's mistake, MathU will adapt, and present additional practice questions tailored to that specific student's needs and misconceptions.

This really helps him with individualised support and feedback to his learners. As Jim suggested, MathU pinpoints the precise area of struggle, such as a certain type of fraction operation, and automatically guides the learners through remedial work on those concepts. This personalised feedback allows MathU to identify and fill gaps in a student's understanding that may not be evident from coursework alone. While the general topic was taught, MathU can detect smaller areas of confusion buried within and adapt with custom practice to solidify that knowledge.

Learners receive custom-targeted feedback and resources to master the concepts they are struggling with rather than a one-size-fits-all approach.

The codes highlighted by Jim's answers include *Immediate Feedback, Individualised, Adaptive Learning Paths, Adaptive Learning, Practice and Mastery, and Data-Driven Decisions*.

Question 5 connected back to Question 3 when Jim discussed how MathU aligned with his pedagogical approach toward differentiation. In Question 3, Jim mentioned his use of formative assessments to gauge students' understanding of mathematical concepts. On this topic, Jim happily stated, "I even use MathU as an exit ticket before the kids leave my class", referring to MathU's capability to serve as a formative assessment tool. Jim recognised the value of frequent formative assessments in identifying areas where learners require additional support or enrichment. By leveraging MathU's real-time feedback and adaptive questioning, he could swiftly evaluate comprehension levels and pinpoint knowledge gaps. Implementing MathU as an "exit ticket" exercise allowed Jim to collect valuable data on learning before dismissing the class. This data could then inform his subsequent instructional planning, enabling a tailored and differentiated approach aligning with each student's needs.

The relevant codes highlighted here include *Formative Assessments and Data-Driven Decisions under Assessment and Evaluation, Immediate Feedback under Immediate Feedback and Support, and Adaptive Learning under Interactive and Adaptive Learning*.

Jim's answer to Question 6 shed light on an interesting aspect of MathU – its ability to differentiate for advanced learners. He pointed out that when learners consistently answer chapter test questions correctly, MathU recognises this pattern of mastery.

In such cases, the platform automatically increases the difficulty level, presenting learners with more advanced questions. Jim stated that, “this makes sure that my gifted learners are continuously challenged”. Jim appreciated this differentiated approach, as it prevents gifted learners from becoming disengaged.

The relevant codes highlighted here include *Future Improvements under Technology Integration, Practice and Mastery and Learner Autonomy under Personalised Learning, Adaptive Learning Paths under Personalised Learning, and Concept-Driven under Learning Approaches.*

Questions 7 and 8 are connected, as Jim mentioned that his learners can all progress through the content on MathU at their own pace. His advanced learners, as mentioned in Question 6, can move ahead with more complex concepts, whilst learners requiring more time and practice can work without being rushed or falling behind. Each learner can navigate the content according to their own level of understanding and readiness. This self-paced model prevents advanced learners from becoming bored or disengaged, while allowing struggling learners to solidify foundational skills before moving on. According to Jim, this is what highlights a truly inclusive learning environment, where according to him “no child can be left behind.”

The relevant codes highlighted here include *Flexible Learning, Learner Autonomy, and Adaptive Learning Paths under Personalised Learning.*

At Question 9, Jim highlighted MathU's accessibility features, specifically praising the video resources included at the start of each unit. Before assigning tests, Jim first teaches the content through his own lessons in class. He then directs his learners to carefully watch the MathU videos, which provide another explanation of the concepts. This allows Jim to clarify any questions learners may have after watching the videos and ensure their understanding is solid.

When learners later work on MathU assignments at home, they can re-watch those same videos if they get stuck or need a refresher. These videos provide an additional visual and auditory function to reinforce the material for diverse learners.

Learners can review the videos as often as needed for support, making the content more accessible, especially when practicing independently outside the classroom.

The relevant codes highlighted here include *Home Learning, Technical Support, and Reinforcement*.

Table 4.10: Jim's Interview Responses to Questions 10 and 11

TPACK Component	Question	Answer
TCK	(10) In what ways does <i>MathU</i> adapt to the specific learning requirements of your learners?	<i>MathU is always adapting with my learners, seeing what they need more support in. If a learner keeps getting something wrong, it alerts me, and recommends more activities and guided support.</i>
TCK	(11) How does <i>MathU</i> align with the curriculum and standards in an inclusive classroom setting?	<i>First, it is South African aligned, which is CAPS, but MathU has also now started to align it with the schools' standards. We can now choose which curriculum to do on the MathU app.</i>

At Question 10, Jim again highlighted the fact that MathU continuously monitors each student's performance and adjusts accordingly to provide personalised support where it is needed most. Interestingly, Jim noted that if a learner consistently struggles with a particular concept or type of problem, MathU will alert the teacher to this pattern. It then recommends additional activities and guided practice specifically tailored to reinforce that area of difficulty for that individual learners.

The codes *Individualised Learning, Adaptive Learning Paths, Practice and Mastery, Data-Driven Decisions, Immediate Feedback and Support* are highlighted here.

Question 11 revealed that MathU has been created first and foremost to be aligned with the South African CAPS for Mathematics, Physical Sciences and Mathematical Literacy from Grade 7 to 12.

However, Jim noted that recently, the MathU team have developed the app so that it can cater for his school's specific curriculum too, which is the IB curriculum. Jim highlighted that this meant some of the questions are more challenging now.

The codes *Concept-driven lessons*, *Taxonomised learning*, *Flexible Learning*, *MathU for Enrichment*, *Future Improvements*, *Individualised*, *Mixed-ability group*, *Data-Driven Decisions* and *Learner Autonomy* are highlighted.

#### 4.2.3.3 Toby



Toby (a pseudonym for confidentiality) is a relatively new teacher with five years of experience in the education sector. He recently joined the school, where he has been teaching for one year. Prior to his current role, Toby taught high school mathematics, but this year he transitioned to teaching Grade 7 Mathematics. This academic year marks his first experience with MathU, which he has begun to integrate into his classroom. Toby's responses are summarised in Table 4.11 below.

Table 4.11: Toby's Interview Responses to Questions 1 and 2

<b>TPACK Component</b>	<b>Question</b>	<b>Answer</b>
TK	(1) Can you describe the key features of <i>MathU</i> that you mostly use in the classroom?	<i>The pathways are pretty cool, it makes the learning really authentic for my children.</i>
TK	(2) Can you discuss any challenges or opportunities you have faced while integrating <i>MathU</i> within your classroom?	<i>A challenge has been ensuring access to technology for all learners. Additionally, addressing my initial learning curve for MathU has been another hurdle.</i>

At Question 1, Toby highlighted the 'pathways' feature of MathU as the one he most frequently employs in his classroom. He explained that these 'pathways' represent MathU's adaptive feedback technology, which activates when his learners answer questions incorrectly on their chapter tests. This feature offers personalised guidance and support for the specific questions learners struggle with, allowing them to engage in authentic learning experiences as they work through their mistakes.

The codes *Adaptive Learning Paths, Individualised Practice and Mastery, Immediate Feedback and Support, Flexible Learning, Learner Autonomy and Data-Driven Decisions* are highlighted.

At Question 2, Toby highlighted two interesting challenges he faced while implementing MathU in his classroom. The first challenge was related to device availability. Not all of Toby's learners consistently had access to iPads in class, either because they forgot them at home or didn't have them at all. This lack of devices prevented these learners from fully engaging with the MathU app. As a workaround, Toby provided 'offline' worksheets generated from the MathU app.

However, he noticed that his learners found these worksheets boring and were less motivated to work on them compared to using the interactive app. The second challenge Toby faced was his own lack of familiarity with MathU, due to the fact that he was a new teacher at the school. He felt insecure about using this tool in his classroom because he believed he had not received sufficient training on how to effectively implement it. Toby felt that this lack of confidence made it difficult for him to make use of MathU's full potential to support his students' learning.

The relevant codes highlighted here include *Device Availability, Learner Motivation, Teacher Training and Technical Support*.

Table 4.12: Toby's Interview Response to Question 3

TPACK Component	Question	Answer
PK	(3) How do you incorporate differentiation strategies to meet the diverse learning needs of learners in your classroom?	<i>I encourage collaborative problem-solving, which really helps learners learn from each other.</i>

At Question 3, Toby revealed that his preferred method of differentiation aligns closely with Pam's approach: using mixed-ability group collaboration. According to Toby, he “encourages his learners to work together on mathematical tasks.” He believes in the power of peer learning, where learners with different levels of understanding can support and learn from each other.

Toby sees this collaboration as an effective way to cater to the diverse learning needs in his mathematics classroom, fostering an inclusive classroom environment. The relevant codes highlighted here include *Mixed-Ability Groups, Peer Learning and Inclusive Classrooms*.

Table 4.13: Toby's Interview Responses to Questions 4 to 9

TPACK Component	Question	Answer
TPK	(4) How does <i>MathU</i> support individualised instruction and personalised feedback for your learners?	<i>It is almost like having a personal tutor for each of my learners.</i>
TPK	(5) How does <i>MathU</i> support your pedagogical approaches in promoting differentiated learning?	<i>MathU offers insights into individual learners' performance, which enables me to adjust my teaching accordingly.</i>
TPK	(6) Can you share any examples of how you use <i>MathU</i> to address	<i>There are videos, problem-solving scenarios, and pathways.</i>

	students' varying abilities, interests, and learning styles?	
TPK	(7) In what ways does <i>MathU</i> facilitate the delivery of differentiated instruction?	<i>It helps me as the teacher, because I can see all the data from my learners.</i>
TPK	(8) How does <i>MathU</i> contribute to creating an inclusive learning environment that promotes diversity?	<i>It promotes a supportive environment that values each student's strengths.</i>
TPK	(9) How do you ensure that <i>MathU</i> is accessible and inclusive for learners with disabilities or other challenges?	<i>I am not too sure about that. I don't know if <i>MathU</i> has accessibility features.</i>

Toby's answer to Question 4 likens MathU to that of a 'personal tutor for my students'. Emphasising that MathU is able to cater to all of his students' needs on a deeply personal level. Similarly to how a tutor would tailor their teaching to a student's specific needs, MathU adapts its content and approach based on students' performance and learning gaps. MathU provides instant feedback on students' work like a tutor.

The relevant codes highlighted here include *Personalised Learning, Instant Feedback and Tailored Instruction*.

At Question 5, Toby emphasised that the insights provided by MathU enable him to "adjust his teaching accordingly", tailoring his instruction to meet the unique needs of each learner. He valued the feedback and data that MathU generates for each learner, as this enables him to create what he describes as "individual learning plans" for each learner. This insight allowed him to adapt his teaching strategies, provide targeted support, and challenge his unique learners appropriately.

The relevant codes highlighted here include *Data-Driven Decisions, Tailored Instruction and Individual Learning Plans*.

Question 6 revealed the key features that Toby used with MathU so that his students' varying abilities, interests, and learning styles are met. He again mentioned the 'pathways' that adapt according to each of his students' needs and learning gaps

within the mathematics classroom. Toby also highlighted that he often used the videos to introduce certain concepts before instructing his learners to begin on their chapter tests.

The relevant codes highlighted here include *Adaptive Learning Paths and Learning Styles*.

Toby offered a concise statement to Question 7, when he said, “It [MathU] helps me as the teacher, because I can see all the data from my learners.” Toby recognised that MathU is powerful tool for teachers as it collects and presents comprehensive data on his students’ performance, progress, and learning patterns. For Toby, having access to this data allowed him to gain a deep understanding of each student’s learning journey, which enabled him to make informed decisions about his teaching strategies, lesson plans, and individualised support.

The relevant codes highlighted here include *Data-Driven Decisions, Learner Performance Tracking, and Informed Teaching Strategies*.

Interestingly, at Question 8, Toby shifted the focus from the academic benefits of MathU to its impact on the social-emotional climate of his classroom. He mentioned MathU’s ability to foster emotional inclusion among learners. Toby noted that when he uses MathU in his class, it creates an environment where his learners feel comfortable, positive, and supported. According to Toby, MathU allows each learner to work at their own pace as MathU creates a personalised learning journey for each learner.

Learners who need more time or support do not feel left behind, and advanced learners can move ahead without feeling held back.

The relevant codes highlighted here include *Emotional Inclusion, Personalised Learning and Learner Support*.

At Question 9, Toby admitted a gap in his knowledge regarding MathU’s capabilities. When asked about accessibility features that MathU might offer his learners, he confessed that he is not yet aware of any such features.

This response underscores Toby’s earlier point at Question 2 about feeling insufficiently trained on the MathU platform. Despite using it in his classroom and

recognising its benefits, there are still aspects of the tool that he has not fully explored or understood.

The relevant codes highlighted here include *Teacher Training, Knowledge Gaps and Accessibility Features*.

Table 4.14: Toby's Interview Responses to Questions 10 and 11

<b>TPACK Component</b>	<b>Question</b>	<b>Answer</b>
TCK	(10) In what ways does <i>MathU</i> adapt to the specific learning requirements of your learners?	<i>It adjusts difficulty levels and offers alternative approaches to solve problems.</i>
TCK	(11) How does <i>MathU</i> align with the curriculum and standards in an inclusive classroom setting?	<i>I think MathU is now following the IB curriculum.</i>

At Question 10, Toby mentioned that he appreciated how *MathU* creates personalised learning plans for each learner, adjusting the difficulty of questions based on their performance. He particularly valued *MathU*'s ability to cater to different learning styles. He noted that it does not just repeat the same type of problem; instead, it offers alternative approaches to explain concepts. According to Toby, this allows him to differentiate without overwhelming his workload.

The relevant codes highlighted here include *Personalised Learning Plans, Differentiation, and Learning Styles*.

At Question 11, when asked how *MathU* aligns with the curriculum and standards in an inclusive classroom setting, Toby tentatively responded, "I think *MathU* is now following the IB curriculum." His use of "I think" suggests that he is not entirely certain about this alignment.

The codes *Concept-driven learning, Taxonomised learning, Flexible Learning, future Improvements, Individualised, Mixed-ability groups, Data-Driven Decisions and Learner Autonomy* are highlighted.

#### 4.2.3.4 Michael



Michael (a pseudonym for confidentiality) is a well-experienced Mathematics teacher, currently serving as the Head of the Mathematics department at his school. With 30 years in the profession and 15 years at his current school, Michael has developed a deep expertise in teaching and leadership. Michael is also known as the ‘MathU champion’, where he ensures the smooth operation of MathU, facilitating training for both learners and staff. Michael’s responses for Questions 1 and 2 are summarised in Table 4.15 below.

Table 4.15: Michael’s Interview Responses to Questions 1 and 2

<b>TPACK Component</b>	<b>Question</b>	<b>Answer</b>
TK	(1) Can you describe the key features of <i>MathU</i> that you mostly use in the classroom?	<i>MathU’s dashboard page is similar to that of a social media website, making it engaging for the learners.</i>
TK	(2) Can you discuss any challenges or opportunities you have faced while integrating <i>MathU</i> within your classroom?	<i>I really can’t think of one challenge.</i>

At Question 1, Michael highlighted the learners dashboard as his favourite feature of MathU, likening it to a typical social media interface, which, according to him, significantly enhances his students’ engagement with the application.

This dashboard allows learners to track their progress, view assignments, and receive instant, personal feedback based on their chapter tests.

Additionally, gamified elements, such as leaderboards keep learners motivated as they work through the Mathematics curriculum. This creates a supportive and dynamic learning environment.

The relevant codes highlighted here are: *Individualised learning, Learner Autonomy, Data-Driven Decisions, Immediate Feedback and Support, Practice and Mastery, Adaptive Learning Paths, Gamification, Technical Support and Flexible Learning.*

At Question 2, it is interesting to note that Michael, as the MathU Champion, reported that he faced no challenges in integrating MathU within his classroom. His expertise likely plays a crucial role in ensuring a smooth implementation, while the platform's user-friendly design and comprehensive support features facilitate a seamless adoption process.

The codes reflected here are *Technical Support, Practice and Mastery as well as Future Improvements.*

Table 4.16: Michael's Interview Response to Question 3

TPACK Component	Question	Answer
PK	(3) How do you incorporate differentiation strategies to meet the diverse learning needs of learners in your classroom?	<i>I make sure to offer extra support classes for everyone, and I have enrichment or extra-support work for my learners.</i>

At Question 3, Michael highlighted that he incorporates differentiation strategies to meet the diverse learning needs of his learners by offering extra support classes for all learners and providing enrichment or additional support work tailored to individual needs. This ensures that learners who require more help receive the necessary assistance, while those who are ready for more challenging material are adequately stimulated.

The codes *Mixed-ability groups, Individualised learning, Flexible Learning, MathU for Enrichment, Practice and Mastery, Adaptive Learning Paths, Learner Autonomy and Diversity* are illustrated here.

Table 4.17: Michael's Interview Responses to Questions 4 to 9

TPACK Component	Question	Answer
TPK	(4) How does <i>MathU</i> support individualised instruction and personalised feedback for your learners?	<i>MathU helps my learners take control of their own learning.</i>
TPK	(5) How does <i>MathU</i> support your pedagogical approaches in promoting differentiated learning?	<i>On the teacher side on the dashboard, I can see all the data.</i>
TPK	(6) Can you share any examples of how you use <i>MathU</i> to address students' varying abilities, interests, and learning styles?	<i>MathU's immediate and specific feedback for each individual helps all learners.</i>
TPK	(7) In what ways does <i>MathU</i> facilitate the delivery of differentiated instruction?	<i>The exercises in MathU are very interactive and adaptable to each learner.</i>
TPK	(8) How does <i>MathU</i> contribute to creating an inclusive learning environment that promotes diversity?	<i>My learners engage in good competition when they play on MathU. They try to top the leaderboards.</i>
TPK	(9) How do you ensure that <i>MathU</i> is accessible and inclusive for learners with disabilities or other challenges?	<i>MathU has little icons next to words, like a little film strip next to the word video.</i>

At Question 4, Michael illustrated that *MathU* can empower his learners with critical self-reflection skills. As Michael observed, the platform allows learners to revisit instructional videos and explanations whenever they encounter difficulties, whether in class or at home.

This fosters a sense of autonomy in their learning journeys. Michael stated, “And then what is so nice about this is if I’m in the class teaching this concept, and the learners cannot remember, then he can go and watch this video over and over and over.”

This ability to access instructional resources empowers learners to take control of their learning process, promoting deeper comprehension and retention of concepts. By providing immediate access to instructional materials and feedback, MathU equips learners with the tools they need to engage in critical self-reflection and take ownership of their academic success.

The codes highlighted include *Learner Autonomy, Individualised Learning, Flexible Learning, Practice and Mastery, Adaptive Learning Paths, Home learning, Immediate Feedback and Support, Technical Support and Data-Driven Decisions.*

At Question 5, Michael confirmed that the implementation of MathU within his teaching practices demonstrates a strong alignment with his principles of differentiation in his classroom. Through features, such as video pausing and question prompts, MathU engages learners actively in their learning process, ensuring comprehension and fostering accountability for their progress.

This approach accommodates diverse learning needs by allowing learners to interact with the material at their own pace and depth of understanding. Furthermore, MathU's ability to track individual progress enables Michael to identify areas where additional support or enrichment is needed, enabling him to tailor his instruction accordingly.

The codes found here include: *Individualised Learning, Flexible Learning, Practice and Mastery, Learner Autonomy, Immediate Feedback and Data-Driven Decisions.*

Michael's response to Question 6 revealed that MathU addresses learners' varying interests, abilities, and learning styles by providing immediate, tailored feedback and targeted instructional support. As Michael noted, "once you do an assessment or exercise, it gives you the memo immediately", allowing learners to quickly see how a problem should be solved. Further, Michael highlights that if a learner struggles to understand the solution, they can access a video explanation that focuses specifically on the question at hand, rather than a broad topic overview.

This is a targeted approach which helps learners grasp particular concepts they find challenging. Additionally, as the teacher, Michael has access to all the data from his learners, enabling him to more intimately support their learning journey by identifying areas of strength and weakness and providing personalised guidance and assistance.

This contrasts with the traditional approach of addressing a general concern of the class, which may only answer a small percentage of learner queries, thereby ensuring that each learner receives the individualised support they require to succeed academically.

Here are the relevant codes identified in Michael's response to Question 6: *Individualised, Flexible Learning, Practice and Mastery, Learner Autonomy and Immediate Feedback.*

Michael's response to Question 7 again underscored the adaptive nature of MathU, which enables a differentiated approach in the mathematics classroom. The platform's ability to provide immediate feedback and targeted instructional support based on individual learner-performance ensures that each learner receives exact, personalised assistance tailored to their specific needs.

Based on Michael's response to Question 7, the following codes are relevant: *Adaptive Learning Paths, Individualised Learning, Flexible Learning, Practice and Mastery and Immediate Feedback.*

At Question 8, Michael mentioned that MathU contributes to creating an inclusive learning environment that promotes diversity by fostering healthy competition among learners. This aspect encourages active participation from all learners, regardless of their ability level. In this case, MathU promotes a sense of belonging and empowerment amongst all learners. A striking feature is the fact that these leaderboards are based on individual progress, rather than a collective measure, highlighting MathU's commitment to recognising the unique contributions of each learner.

Based on Michael's response to Question 8, the following codes are relevant: *Diversity, Gamification and Learner Autonomy.*

In response to Question 9 about ensuring accessibility and inclusivity for learners with disabilities or other challenges, Michael highlighted a feature within MathU where little icons are used alongside words, such as a film strip icon next to the word "video". These visual cues serve as alternative means of navigation and comprehension,

particularly beneficial for learners who may struggle with processing written text. The codes highlighted here are that of *Accessibility and Inclusivity*.

Table 4.18: Michael's Interview Responses to Questions 10 and 11

<b>TPACK Component</b>	<b>Question</b>	<b>Answer</b>
TCK	(10) In what ways does <i>MathU</i> adapt to the specific learning requirements of your learners?	<i>MathU gives that one question he had wrong, they give him five or six of them, so that he can learn how to do that specific question.</i>
TCK	(11) How does <i>MathU</i> align with the curriculum and standards in an inclusive classroom setting?	<i>MathU is really customisable, you can change the school logo, and the content you want it to show.</i>

Michael's response to Question 10 illuminated how MathU can adapt to different learning requirements of his learners. Through the "pathways" feature on MathU, the platform ensures personalised instruction tailored to individual needs. According to Michael, when a learner answers a question incorrectly on a chapter test, MathU transforms the assessment into a "pathway", providing targeted practice opportunities on the specific concept they struggled with. As Michael explained, "MathU gives that one question he had wrong, they give him five or six of them, so that he can learn how to do that specific question." This explicit repetition allows learners to grasp challenging concepts effectively. Furthermore, after completing the pathway, learners have the choice to either redo the assessment to better their leaderboard score or continue with the next lesson.

Based on Michael's response to Question 10, the following codes are relevant: *Adaptive Learning Paths, Individualised Learning and Practice and Mastery*.

At Question 11, Michael affirmed that MathU indeed demonstrates alignment with the curriculum. As Michael highlighted, MathU offers customisation options, allowing teachers to tailor the content to meet specific curriculum requirements and standards. Additionally, MathU's customisable features extend to the interface itself, including the

ability to change the school logo. This level of customisation enables schools to create a personalised learning environment that reflects their unique identity and priorities.

Based on Michael's response to Question 11, the following codes are relevant: *Customisation and Curriculum Alignment*.

#### 4.3 Conclusion

Chapter 4 focused on presenting the study's results, drawn from the ITS exploration, policy document analysis, and semi-structured interviews with the four participants. The chapter outlined the key data without delving into extensive interpretation, providing a foundation for understanding the study's outcomes. Chapter 5 will now build on these results by examining the findings in greater depth, connecting them to the sub-research questions and the TPACK framework, and exploring their broader implications for inclusive education and differentiated teaching practices.

## Chapter 5: Findings

### 5.1 Introduction

Chapter 5 begins by examining the findings, interpreting them in relation to the literature review and research methodologies from Chapter 3. The chapter starts with a summary of the research, followed by a discussion of the study’s findings, organised around eight themes mapped onto the TPACK model: inclusive education context, technology integration, personalised instruction, curriculum alignment, inclusive teaching strategies, mathematical curriculum design, effective instructional methods, and inclusive technology use in mathematics education. These eight themes are represented in Figure 5.1 below.

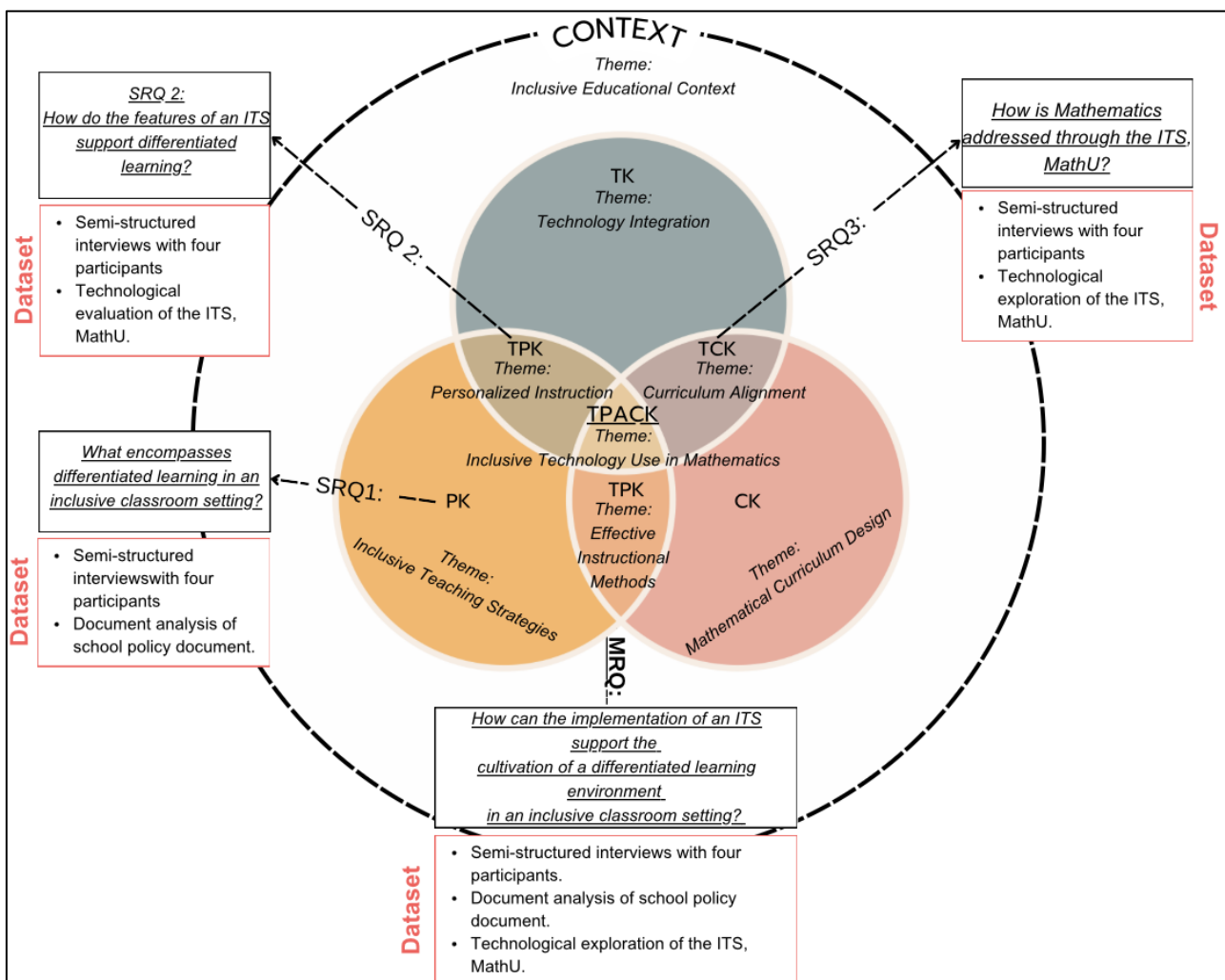


Figure 5.1: Themes Identified from the Data Mapped onto the TPACK Model  
Adapted from Mishra and Koehler (2006)

These themes were derived from the codes which the researcher discussed in Chapter 4, developed through the thematic analysis process outlined in Chapter 3. During Step 3 of the analysis, themes emerged inductively from the data, shaped by the initial coding of interview transcripts, policy documents, and ITS exploration. Steps 4 and 5 involved refining these themes and aligning them with the TPACK framework, ensuring they accurately addressed the research questions.

## 5.2 Summary of the Literature Findings

ITSs are computer-based instructional tools that assist learners by adapting learning experiences to their needs and abilities, recording performance data, and providing personalised instruction and feedback (Holmes et al., 2019; Katsaris, 2021; Kulik & Fletcher, 2016; Papanastasiou, 2021). These systems facilitate adaptive assessments and adjust difficulty levels to support learners, ultimately enhancing knowledge and skills in various areas (Akkila et al., 2019). This research investigates the integration of ITSs within inclusive education in South Africa, focusing on how ITSs can support differentiated teaching approaches to enhance inclusive educational environments.

Differentiated learning, as described by Tomlinson (2001), involves offering diverse pathways for learners to access content, comprehend concepts, and produce outcomes tailored to their needs, abilities, and learning styles. Inclusive classrooms employ differentiation to embrace diversity and provide equitable educational access (Ambrose et al., 2010; Louden et al., 2005). ITSs can support teachers in creating inclusive classrooms through differentiation (Wang et al., 2023). This study explored MathU, an ITS designed to support mathematics education for secondary school learners within the IB curriculum.

Globally, there has been a policy shift towards inclusive education, as highlighted by the Salamanca Statement and Framework for Action on Special Needs Education (UNESCO, 1994). However, challenges remain in implementing differentiation in inclusive classrooms due to factors, such as insufficient preparation time, large class sizes, and lack of resources and support for teachers (Onyishi & Sefotho, 2020; Scott et al., 1998; Yuen et al., 2005). Despite their potential, ITSs remain underutilised for creating inclusive educational environments (Al-Aqbi, 2017; Ali & Abdel-Haq, 2021). There is a significant research gap concerning the application of ITSs in the South African inclusive education context.

The MRQ guiding this study is: *How can the implementation of an ITS support the cultivation of a differentiated learning environment in an inclusive classroom setting?*

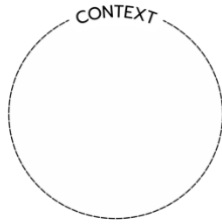
To address this, the study utilised the TPACK framework to explore SRQs related to defining differentiated learning, the features of ITSs that support differentiation, and how ITSs can be tailored to address specific subject matter.

This study aimed to investigate the potential of ITSs to facilitate differentiation in inclusive classrooms, examining best practices and challenges. It seeks to provide insights for teachers, learners, and policymakers on the application of ITSs to support differentiated learning and align with inclusive education policies in South Africa. The research fills a gap by exploring how ITSs can support differentiation practices and contribute to inclusive education.

### 5.3 Interpretation and Discussion of Results

In this section, the researcher interprets and discusses the results of the study. Following Braun and Clarke's thematic analysis approach (2022), the researcher identified key themes through a systematic process. Step six, as outlined by Braun and Clarke (2022), marks the stage where all writing activities across the research journey converge, integrating insights from the literature review. In this step, the researcher unveils the themes identified in Chapter 4 and proceeds to Chapter 5, where deeper discussions and analyses unfold.

The findings are presented and analysed based on the eight themes derived from the thematic analysis: inclusive education context, technology integration, personalised instruction, curriculum alignment, inclusive teaching strategies, mathematical curriculum design, effective instructional methods, and inclusive technology use in mathematics education. Additionally, the components of the TPACK framework are highlighted and integrated within the discussion of each theme.



### 5.3.1 Theme 1: Inclusive Education Context

The analysis of the school's inclusion policy, the exploration of the MathU ITS, and the interviews conducted with four teachers revealed a comprehensive commitment to fostering an inclusive learning environment. This commitment is closely aligned with the contextual aspect of the TPACK model, which underscores the importance of adapting to specific educational settings (Chai et al., 2013). It was clear that the school's inclusion policy manifested a true commitment to creating an inclusive learning environment, ensuring equitable access to educational opportunities for all learners irrespective of their abilities, race, or gender.

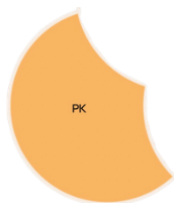
The policy outlines several core principles of inclusive education, including engaging with diverse ways of knowing and being, prioritising relational dynamics, and assuming shared responsibility for learning outcomes. These principles resonate with Sanger's (2020) views on inclusive pedagogy, which seek to integrate equitable access and opportunities for learner achievement within the classroom and curriculum. Florian and Black-Hawkins (2011) articulate that inclusive pedagogy is based on a paradigm shift where, instead of an approach that works for most learners while providing something 'alternative' for those who experience difficulties, inclusive pedagogy rather involves creating rich learning opportunities that are universally accessible, allowing all learners to engage fully in the classroom environment.

This institutional framework provides a solid foundation for the adoption and implementation of inclusive pedagogical practices, which are further enhanced by the integration of technological tools, such as MathU. This approach to include educational technology is substantiated by scholarly literature, including findings from the Organisation for Economic Co-operation and Development (OECD). The OECD posits that digital technologies can play a pivotal role in supporting the inclusion of diverse learner populations in educational settings. Specifically, these technologies enhance accessibility to educational content, facilitate greater personalisation of learning experiences, and offer opportunities for distance learning, as evidenced by their significant role during the COVID-19 pandemic (Gottschalk & Weise, 2023).

The integration of the MathU ITS stands out as a pivotal element in promoting inclusive education. The ‘pathways’ feature of MathU personalises learning trajectories based on individual learners performance, thereby addressing a wide spectrum of learning needs. All interviewed teachers highlighted MathU’s capacity to deliver immediate, personalised feedback, facilitating timely interventions and support. Additionally, the platform’s dashboard functionality enables teachers to meticulously track learners’ progress, aligning with the school’s policy of continuous monitoring and data-informed instructional decisions.

Yet, while MathU incorporates several features conducive to inclusivity, such as the integration of visual cues alongside text, there is room for enhancement in terms of accessibility features specifically tailored for learners with disabilities. This observation aligns with the school policy’s commitment to identifying and dismantling barriers to learning and participation.

Despite MathU’s positive reception and its potential to enhance inclusive education, certain implementation challenges were identified. Toby highlighted inconsistencies in iPad accessibility for all learners, posing a barrier to equitable technology integration. Furthermore, both Toby and Pam underscored the necessity for more comprehensive training on the effective use of MathU to support inclusive educational practices.



### 5.3.2 Theme 2: Inclusive Teaching Strategies

Inclusive teaching strategies, which fall under the Pedagogical Knowledge component of the TPACK model, are fundamental to creating equitable and effective learning environments for all learners. The data collected from teacher interviews and school policy documents revealed a range of approaches and considerations in implementing inclusive practices.

A prominent theme that emerged from the data is the use of collaborative learning strategies. Both Pam and Toby expressed a preference for utilising mixed-ability group work as a means of fostering inclusion. This approach aligns with research suggesting that heterogeneous grouping can promote peer learning, enhance social skills, and improve academic outcomes for learners across ability levels (Kim et al., 2020).

Importantly, differentiation emerged as another key strategy for inclusive teaching. Michael's approach of offering extra support classes and providing both enrichment and additional support work demonstrates an understanding of the need to cater to diverse learning needs. This aligns with Tomlinson's (2014) principles of differentiated instruction, which emphasise the importance of adapting content, process, and product to meet individual learner needs.

Furthermore, the use of formative assessment as a tool for inclusive teaching was highlighted by Jim, who emphasised its role in gauging learner understanding and tailoring instruction accordingly. This aligns with the well-known anecdote that "practice makes perfect" suggesting that learners develop their skills and knowledge when given opportunities to practise (Ontong, 2021). Empirical evidence supports the effectiveness of formative assessments in fostering better educational outcomes, making them a vital component of inclusive education practices (Ontong, 2021).

The school's inclusion policy document further underscores the importance of these strategies, emphasising the need for "differentiated instruction, formative and summative assessments, and collaboration among teachers to identify and address students' learning difficulties". This institutional support for inclusive practices provides a crucial foundation for teachers' pedagogical approaches. Additionally, the school's policy on tiered intervention approaches demonstrates a systematic attempt to address diverse learning needs.



TK

### 5.3.3 Theme 3: Technology Integration

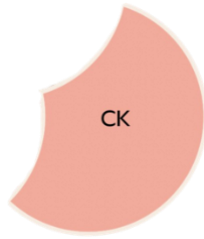
The integration of MathU as an ITS within the mathematics classroom is a significant component of Technological Knowledge in the TPACK framework. Analysis of data from MathU explorations and teacher interviews revealed several key aspects of this integration. One prominent feature is MathU's adaptive learning capabilities, which include personalised learning pathways based on learner performance. As noted by Jim, the system alerts teachers when a learner is struggling and recommends additional activities and guided support. Pam appreciated the platform's real-time feedback feature that also facilitates the process of setting exams and assessments.

Another crucial technological aspect is MathU's data analytics and visualisation capabilities. The dashboard, likened to a social media interface by Michael, enhances learner engagement and provides comprehensive performance data. This data consolidation is highly valued by teachers, as highlighted by Toby. Additionally, the integration of multimedia learning resources, such as instructional videos and interactive exercises, has been noted as beneficial. Jim and Michael emphasised the usefulness of these resources, which learners can access and review as needed, while Toby pointed out the adaptability of the interactive exercises to individual learning needs.

The incorporation of gamification elements, such as leaderboards, has been identified as a motivational factor, with Michael observing that learners are driven to engage in competition to achieve top rankings. Although some accessibility features, such as icons accompanying text, were mentioned by Michael, they are not extensively developed. The alignment of MathU with curriculum standards is another noteworthy aspect. Jim indicated that the system is aligned with the South African CAPS curriculum and has recently included support for the IB curriculum.

Michael also noted the platform's customisability, allowing for modifications to the school logo and content presentation.

Despite the overall positive reception, challenges in technology integration have been identified. Issues, such as inconsistent access to iPads, technical glitches, and a steep learning curve were reported by teachers like Toby, Jim, and Pam. Yet, Jim noted that initial technical issues have been addressed, and recent additions of curriculum options demonstrate the platform's responsiveness to user feedback. These findings underscore the need for continued support, training, and development to fully realise the potential of this technology integration.

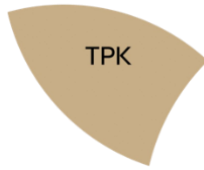


#### 5.3.4 Theme 4: Mathematical Curriculum Design

The exploration of Mathematical Curriculum Design, situated within the Content Knowledge domain of the TPACK framework, reveals significant insights into the structure and delivery of mathematics education.

A notable aspect of the mathematical curriculum design at the school under study is its alignment with the IB programme. The IB curriculum is renowned for its emphasis on conceptual understanding and enquiry-based learning, which represents a shift from traditional content-based approaches to mathematics education. The concept-based teaching approach, as opposed to a purely content-based model, emerges as a central theme in the curriculum design. This approach focuses on big ideas and enduring understandings in mathematics, rather than isolated facts or procedures. As noted by Erickson (2007), concept-based curricula aim to develop students' ability to transfer knowledge across different contexts and to engage in higher-order thinking. In the context of mathematics, this might involve exploring overarching concepts, such as patterns, relationships, or change, which can be applied across various mathematical domains.

The curriculum also appears to incorporate real-world applications of mathematical concepts, a feature often emphasised in modern mathematics education. This approach helps to contextualise abstract mathematical ideas and demonstrate their relevance to students' lives and future careers. Such contextualisation is a key principle of effective mathematics curriculum design, as it enhances learner engagement and promotes deeper understanding (Gravemeijer et al., 2017)



### 5.3.5 Theme 5: Personalised Instruction

The integration of MathU as an ITS has enhanced teachers' capacity to deliver differentiated instruction, a crucial aspect of Technological Pedagogical Knowledge within the TPACK framework. The data from teacher interviews and MathU exploration reveals a multifaceted approach to personalised instruction and differentiation, leveraging various technological features to meet diverse learner needs.

Central to MathU's personalisation capabilities is its adaptive learning paths feature. This aligns with the aims of AI researchers, who seek domain applications for tracking students' progress in a course (Hibbi et al., 2020). Teachers consistently highlighted the platform's ability to create individualised learning paths based on learner performance. For instance, Pam emphasised the 'generate chapter test' feature, which tailors assessments to students' previous performance, while Jim noted how MathU provides targeted guidance as learners navigate challenging concepts. Michael elaborated on this aspect, explaining that when a learner answers incorrectly, MathU generates multiple similar questions to reinforce understanding of that specific concept.

Real-time feedback and assessment have emerged as another crucial component of personalised instruction facilitated by the MathU technology. Teachers have expressed appreciation for the platform's ability to deliver immediate, individualised feedback, comparing it to having a personal tutor for each learner. This prompt feedback loop enables timely interventions and assists learners in quickly identifying and correcting misconceptions. As highlighted by Gheorghiu and VanLehn (2008), the provision of feedback and hints at each step of a multi-step procedure is an essential feature of an effective ITS.

Furthermore, the integration of MathU's data analytics capabilities has emerged as a pivotal element in facilitating data-driven instruction. Within the interviews, the teachers often emphasised the value of MathU's comprehensive data on individual learner performance as a means to inform their pedagogical decisions, refine instructional strategies, and create appropriate learning activities tailored to each student's specific needs.

This data-centric approach enables a more nuanced and responsive form of personalised instruction, aligning with contemporary educational theories that emphasise the importance of adaptive learning environments (Taylor et al., 2021). This rich data empowers teachers to make informed decisions about when and how to intervene, adjust their teaching methodologies, or offer targeted support to individual learners. As noted by Luckin and Cukurova (2019), such AI-driven systems can significantly enhance teachers' ability to provide timely and relevant interventions, thereby optimising the learning experience for each learner.

Notably, MathU has been praised to promote learner autonomy and self-paced learning, which are key elements of differentiated learning and pedagogy for inclusive classrooms. Teachers observed that MathU empowers learners to take control of their own learning journeys, allowing them to progress at their own pace without being hindered or rushed by their peers. This aligns with a self-directed learning approach, which fosters independence and motivation among learners (Francom, 2010). Self-directed learning involves setting goals, implementing learning plans, self-evaluating, and using metacognition, motivation, and domain knowledge (Loyens et al., 2008). By integrating these principles, MathU enhances self-directed learning by providing a platform where learners can set personal goals, track their progress, and receive immediate feedback, thereby supporting learners' metacognitive skills and motivation.

While the overall response to MathU's personalisation features was positive, several areas for potential improvement were identified. One notable limitation is the platform's design, which restricts opportunities for collaborative learning, as learners primarily work independently on their devices. This posed a challenge for many teachers, who expressed a preference for using mixed-ability grouping and collaborative teaching as methods of differentiation. Advocates of inclusive education argue that mixed-ability grouping is an effective strategy for inclusive education (Hove, 2022). However, unfortunately, these approaches could not be implemented effectively with MathU. Additionally, there was some uncertainty regarding the availability and effectiveness of accessibility features for learners with disabilities, indicating a need for further development in this area.



TCK

### 5.3.6 Theme 6: Curriculum Alignment

The theme of curriculum alignment is a key aspect of Technological Content Knowledge within the TPACK framework. The data collected from teacher interviews and the MathU exploration reveals both strengths and challenges in this area.

A significant strength of MathU, as reported by the teachers, is its alignment with established curricula. Jim noted that the platform is primarily aligned with the South African CAPS for Mathematics, indicating a strong foundation in local educational standards. This alignment is crucial as it ensures that the technological tool supports rather than detracts from the mandated educational content. Furthermore, Jim's observation that MathU has recently incorporated support for the IB curriculum demonstrates the platform's adaptability to diverse educational contexts, a valuable feature in an increasingly globalised educational landscape.

As highlighted by Michael, the customisability of MathU's content represents another significant aspect of curriculum alignment. The platform's ability to tailor content and visual elements, such as school logos, indicates a high degree of flexibility in adapting to specific institutional needs. This customisation potential is supported by research indicating that the effectiveness of educational technology is enhanced when it can be adapted to local contexts and specific curricular requirements (Major et al., 2021).

However, the data also revealed challenges in achieving comprehensive curriculum alignment. Pam's observation that "there were certain topics and concepts that we needed to cover, but MathU didn't have any content for them yet" points to gaps in content coverage. This highlights a common challenge in educational technology: the difficulty of keeping pace with evolving curriculum standards and the diverse needs of different educational systems (Koh et al., 2018). Furthermore, the teachers' varying levels of familiarity with MathU's curriculum alignment capabilities, as evidenced by Toby's uncertainty about its alignment with the IB curriculum, underscore the need for ongoing professional development.



### 5.3.7 Theme 7: Effective Instructional Methods

The theme of Effective Instructional Methods, situated within the Technological Pedagogical Knowledge component of the TPACK model, emerged as a critical area of focus when examining the intersection of MathU's technological features and the Grade 7 IB mathematics curriculum.

MathU's adaptive learning paths feature stands out as a particularly effective instructional method for teaching Grade 7 mathematics concepts. As Michael explained, when a learner answers a question incorrectly, "MathU gives that one question he had wrong, five or six more of them, so that he can learn how to do that specific question." This targeted approach aligns well with the IB curriculum's emphasis on conceptual understanding and problem-solving skills. By providing multiple opportunities to engage with similar problems, MathU reinforces key mathematical concepts, a strategy that research has shown to be effective in developing procedural fluency and conceptual understanding (Rittle-Johnson et al., 2016).

The platform's use of multimedia resources, including instructional videos and interactive exercises, offers diverse representations of mathematical concepts. This multi-modal approach aligns with the IB curriculum's focus on multiple representations in mathematics and caters to different learning styles. As Toby noted, "There are videos, problem-solving scenarios, and pathways." This variety of instructional methods supports the development of mathematical thinking and communication skills, key components of the IB mathematics curriculum (International Baccalaureate Organization, 2019).

MathU's real-time feedback mechanism emerged as another effective instructional method. Jim likened this feature to "having a personal tutor for each of my learners". This immediate, personalised feedback allows for rapid correction of misconceptions and reinforcement of correct understanding, a practice that has been shown to significantly enhance mathematics learning (Hattie & Timperley, 2007). The alignment of this feature with the IB curriculum's emphasis on formative assessment and continuous learning is particularly noteworthy.

However, the data also revealed areas where the intersection of MathU’s technology and the IB mathematics content could be enhanced. Pam’s observation that, “there were certain topics and concepts that we needed to cover, but MathU didn’t have any content for them yet” suggests that there may be gaps in content coverage. This highlights the need for ongoing development to ensure comprehensive alignment with all aspects of the Grade 7 IB mathematics curriculum.

Thus, MathU demonstrates several effective instructional methods that align well with the Grade 7 IB mathematics curriculum, particularly in areas of adaptive learning, multimedia representation of concepts, and immediate feedback. These technological features enhance the delivery and understanding of mathematical content, supporting key curriculum objectives. However, there are also opportunities for further development, particularly in areas of content coverage.



#### 5.3.8 Theme 8: Inclusive Technology Use in Mathematics Education

The theme of Inclusive Technology Use in Mathematics Education is situated at the intersection of Technological, Pedagogical, and Content Knowledge. This theme emerged as a critical aspect of fostering differentiated teaching for Grade 7 mathematics in an inclusive classroom.

The data from teacher interviews and MathU exploration revealed a multi-faceted approach to inclusive technology use in mathematics education. MathU’s adaptive learning paths, as highlighted by all four teachers, demonstrate how technology can be used to tailor mathematical content to individual learner needs. For instance, Jim’s observation that MathU provides “extra guidance as they work through problem areas” illustrates how the platform adapts content presentation based on individual learner performance.

The real-time feedback mechanism of MathU, consistently praised by the teachers, showcases the potential of technology to provide immediate, personalised support in mathematics learning. This feature is particularly crucial in an inclusive classroom, where timely intervention can prevent the widening of achievement gaps.

As Toby noted, MathU “adjusts difficulty levels and offers alternative approaches to solve problems”, demonstrating how technology can provide multiple representations of mathematical concepts, a key aspect of inclusive mathematics education (Boaler, 2016).

The platform’s data analytics capabilities, emphasised by all teachers, highlight how technology can inform evidence-based, differentiated instruction in mathematics. By providing detailed insights into individual learners performance, MathU enables teachers to make informed decisions about instructional strategies and interventions. This data-driven approach aligns with research suggesting that effective use of learning analytics can significantly enhance inclusive practices in mathematics education (Herodotou et al., 2019).

MathU’s multimedia resources, including instructional videos and interactive exercises, demonstrate how technology can cater to diverse learning styles in mathematics education. This multi-modal approach to content delivery supports the principles of differentiated instruction, allowing learners to engage with mathematical concepts in ways that best suit their individual learning preferences (Tomlinson, 2017). Further, the gamification elements of MathU, such as leaderboards, represent an innovative approach to fostering engagement in mathematics learning. However, as Michael noted, these features need to be carefully balanced to ensure they promote inclusive participation rather than exacerbating existing disparities.

The challenges identified by teachers, such as Toby’s uncertainty about accessibility features for learners with disabilities, underscore the importance of continuous development in educational technology to fully support inclusive mathematics education.

In conclusion, the integration of MathU in Grade 7 mathematics classrooms demonstrates the potential of technology to foster differentiated teaching in an inclusive environment. By providing adaptive learning paths, real-time feedback, data-driven insights, and diverse representation of mathematical concepts, MathU exemplifies how the intersection of technological, pedagogical, and content knowledge can enhance inclusive practices in mathematics education. However, the findings also highlighted the need for ongoing development and thoughtful implementation to ensure that technology truly serves the goals of inclusive education.

Future research could explore how to further optimise such technologies to support the full spectrum of learners in inclusive mathematics classrooms, and investigate best practices for teacher professional development to maximise the inclusive potential of educational technologies in mathematics education.

#### 5.4 Conclusion

This study's findings chapter provided a comprehensive exploration of the implementation of the MathU ITS in Grade 7 mathematics classrooms, viewed through the lens of the TPACK framework. This investigation, drawing on data from the MathU exploration, school policy document analysis, and semi-structured interviews with four experienced teachers, revealed a complex interplay between technology, pedagogy, and content in fostering inclusive and personalised mathematics education. Throughout the analysis, the TPACK framework proved to be a valuable lens for understanding the complex interactions between technology, pedagogy, and content in the context of MathU implementation. The findings revealed both the transformative potential of this ITS in supporting inclusive, personalised mathematics education and the challenges that arise in its practical application. In conclusion, this chapter presented a nuanced picture of MathU's implementation, highlighting its strengths in promoting inclusive and personalised learning while also identifying areas for improvement. These findings contribute to our understanding of how ITSs can be effectively integrated into mathematics education, informing future research and practice in this rapidly evolving field. The insights gained underscore the importance of continued exploration and refinement of educational technologies to fully realise their potential in supporting diverse learners and enhancing mathematics instruction.

## Chapter 6: Conclusions

### 6.1 Introduction

This chapter provides a final analysis of the study's findings, focusing on addressing the research questions that guided this investigation. It offers a critical evaluation of the extent to which these questions have been answered and discusses the study's conclusions. Emphasis is placed on the implications of these findings for inclusive education and differentiated teaching practices, as well as the contributions the study makes to the field of educational technology. The chapter minimizes repetition by synthesizing key insights and highlighting their significance, while also acknowledging and examining the limitations and potential shortcomings of the research methodology.

Additionally, it provides targeted recommendations for teachers and other members of the education community affected by the study's outcomes and it articulates the contributions of this research to the field. Specifically, this study focused on exploring how the integration of an ITS known as MathU can support differentiated learning in inclusive South African classrooms.

The aim was to assess MathU's effectiveness in facilitating a personalised learning experience that accommodates diverse learner needs and promotes educational equity. This investigation was guided by the TPACK framework, which provided a comprehensive lens to examine the intersection of technology, pedagogy, and content knowledge in the implementation of MathU.

The chapter concludes by exploring the potential for future research, identifying suggestions for further investigation, and discussing the broader implications of the findings within the context of educational technology and inclusive pedagogy.

### 6.2 Responding to the Research Questions

This chapter begins by demonstrating how the main research question of the study is addressed through detailed discussions of the three SRQs. Each discussion presents the core findings relevant to that SRQ, integrates these findings where appropriate, and incorporates relevant literature. The MRQ was formulated at the beginning of this study (see *Section 1.3.2*).

The findings related to the MRQ serve as the cornerstone for the final conclusions drawn. The MRQ, along with the SRQs, steered the research process, informing the selection of literature, the conceptual framework, and appropriate methodological approaches. Ultimately, these questions guided the researcher's efforts to address the study's core enquiries (Maree, 2007).

This study examined the ITS, MathU, with the primary goal of identifying success factors that facilitate differentiation within an inclusive educational environment. This objective was pursued through three SRQs:

1. What encompasses differentiated learning in an inclusive classroom setting?
2. How do the features of an ITS support differentiated learning in an inclusive learning environment?
3. How is specific subject matter addressed through an ITS?

#### 6.2.1 Sub-Research Question 1

What encompasses differentiated learning in an inclusive classroom setting?

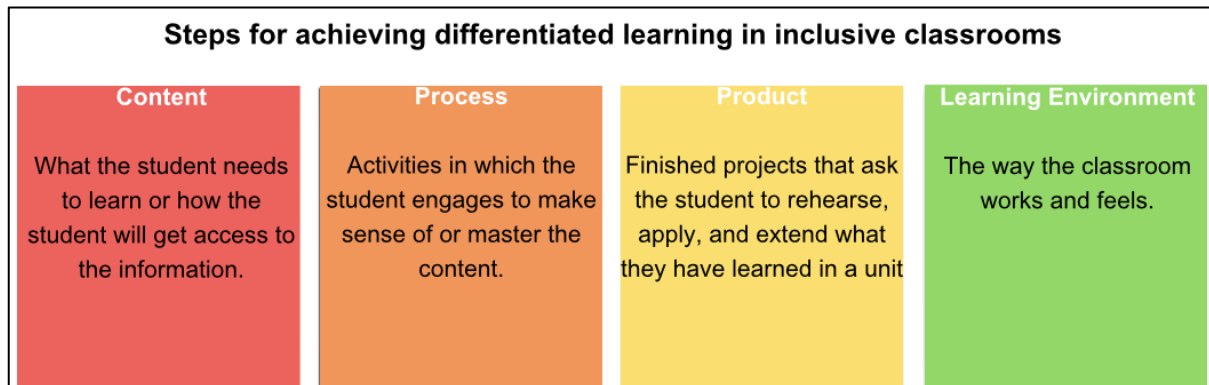
SRQ 1 falls under the aspect of PK within the TPACK framework. It emphasises the importance of teachers' understanding of how to adapt their teaching strategies to accommodate diverse learners in an inclusive educational setting.

In the study, the analysis of semi-structured interviews, along with document analysis, highlighted key findings across several themes.

As discussed in *Section 2.3.1*, differentiated learning, defined by De Jager (2017), is an educational method employed to educate learners with varying skill levels within a single, inclusive classroom setting. This pedagogical approach emphasises recognising and responding to learner diversity within inclusive educational environments.

Tomlinson (2017) provides a comprehensive framework for defining differentiated learning in inclusive classrooms. This framework proposes four elements including, content, which pertains to what the learners need to learn or how they will access the information; process, which involves the activities the learners participate in to comprehend or master the content; products, which are final projects that require the learner to practise, apply, and expand upon their learning from a unit;

and learning environment, which refers to the dynamics and atmosphere of the classroom. These elements are illustrated in Figure 6.1.



*Figure 6.1: Four Aspects of Differentiated Learning  
(Adapted from Tomlinson, 2017)*

This framework that Tomlinson (2017) presents is robust, and theoretically, if all teachers adhere to this, they can achieve differentiated learning. Yet, the practical and lived experiences of differentiation in inclusive classrooms were revealed through interviews conducted in this study. Even though ideally, the answer to what differentiated learning in inclusive classrooms should look like ought to appear straightforward, the data from the case studies suggests otherwise.

Data collected from interviews with four participants revealed that teachers predominantly utilise their PK for differentiated learning by adapting their teaching materials, instruction, and assessment types (formative assessments) to meet the individual needs of their learners.

The analysis also highlighted differences between more and less experienced teachers. More experienced teachers exhibited greater comfort and autonomy in the classroom, while less experienced teachers reported feelings of insecurity and apprehension about unexpected situations. Additionally, more experienced teachers demonstrated advanced PK by effectively integrating new information with their existing knowledge of learners and employing personalised assessments.

Interestingly, despite none of the participants explicitly mentioning Tomlinson (2017) or her comprehensive framework outlining four aspects of differentiated learning when asked what differentiation means to them, they did demonstrate aspects aligned with her principles.

Pam highlighted process differentiation through collaborative efforts, Jim emphasised assessment differentiation using formative assessments, and Michael focused on creating differentiated learning environments. In contrast, Toby appeared uncertain about differentiation. It is noteworthy that the participants displayed an innate understanding of differentiation principles, suggesting an implicit familiarity despite lacking the explicit knowledge of Tomlinson's (2017) framework.

Thus, it would be beneficial for school policies to adopt a structured approach akin to Tomlinson's (2017) framework, thereby providing clarity and a standardised understanding of differentiated learning.

The school's inclusion policy in *Section 3* on Support and Intervention, states that "all learners in class receive general differentiated instruction". Whilst this statement explicitly indicates that differentiated learning is an essential agreement in the classroom, it does not specify how to provide differentiated instruction. Indeed, while participants in this study recognised the necessity of implementing differentiated instruction, many lacked a clear understanding of its principles and practical application within their teaching practices. Furthermore, despite these clear guidelines on differentiation within the school's policy, there seemed to be a lack of adequate training and professional development opportunities for teachers, which constituted a barrier to successful implementation (Lavania & Nor, 2020).

In fact, the newest teacher, Toby, expressed insecurity and uncertainty about implementing differentiation in his classroom. Pam also noted significant challenges in implementing differentiation, particularly due to time constraints in her lessons.

These challenges corroborate the findings of Barua et al. (2022), who observed that teachers struggle with dedicating time to provide differentiated instruction, ensuring learner understanding, and tracking individual progress. It is also worth noting that the school's inclusion policy dedicates an entire section to extension, noting that differentiated learning also includes extending learners. This was reflected in Jim's comments, who mentioned that he ensures to extend his learners when implementing differentiation in his classes, aligning with the school's policy guidelines.

Again, this aligns with the notion above that teachers are influenced by the requirements and standards set by school policies.

### 6.2.2 Sub-Research Question 2

#### **How do the features of an ITS support differentiated learning in an inclusive learning environment?**

This question falls under the TPK component of the TPACK framework. It explores how the integration of technology, specifically ITS, can enhance pedagogical strategies to cater to students' diverse needs of learners, facilitating personalised and adaptive learning experiences in inclusive classroom settings.

To address how the features of an ITS like MathU support differentiated learning in an inclusive learning environment, the researcher leveraged multiple sources, namely the school policy document on inclusion, the MathU ITS exploration, and interview results.

The researcher consulted the school policy document on inclusion to understand the institutional framework guiding inclusive education practices. This document provided insights into the goals and principles of inclusivity, highlighting the need for adaptable teaching methods and resources that accommodate diverse learners. By aligning the features of the ITS with these policy guidelines, the researcher could assess how effectively MathU ITS supports the objectives of inclusive education, ensuring that the technology integrates seamlessly with established pedagogical practices.

The exploration of MathU ITS focused on its features and capabilities to determine how well it supports differentiated learning. Key features of MathU ITS, such as personalised learning pathways, adaptive feedback, and individualised assessments, were evaluated to understand their impact on addressing varied learner needs. For example, the system's ability to adjust difficulty levels based on learner performance and provide targeted interventions supports personalised instruction, a critical aspect of differentiated learning. The exploration revealed that MathU ITS facilitates adaptive learning experiences that align with the principles of inclusivity by catering to individual learning styles and paces.

The semi-structured interviews with teachers provided practical insights into how MathU ITS is utilised in real classroom settings. Interviews revealed how teachers implement the system's features to support differentiated learning, such as using data from the ITS to adjust instructional strategies and provide targeted support.

Teachers' experiences highlighted the effectiveness of ITSs in enhancing pedagogical approaches, such as differentiating content, varying instructional methods, and offering personalised feedback.

According to Kulik and Fletcher (2016), the effectiveness of the ITS technology in differentiation pedagogy is underscored by the ability of this technology to offer personalised pathways and interactive responses that adapt to students' actions in real time. This adaptivity is crucial in addressing the varying pace and depth of learning, ensuring that each learner receives appropriate challenges and support aligned with their proficiency levels and learning trajectories (Nye, 2015).

Moreover, ITSs facilitate differentiated instruction by providing comprehensive guidance throughout problem-solving processes, focusing not only on final answers but also on the steps leading to solutions (VanLehn, 2011). This feature is pivotal in scaffolding learning experiences and promoting deeper engagement and understanding among learners of diverse abilities (Waalkens et al., 2013).

The effectiveness of ITS in supporting differentiated learning hinges on several key models identified in the literature. Firstly, the domain model within an ITS serves as the foundation by encapsulating subject-specific knowledge and facilitating adaptive interactions with learners (Barbhuiya et al., 2011).

This model influences the generation of feedback, problem selection, and instructional guidance, which is crucial for addressing varied learning needs (Ricucci, 2008). Secondly, the learner model in ITS stores and utilises individual learners data to personalise instruction, aligning with diverse learning profiles and abilities (Barbhuiya et al., 2011; Ma et al., 2014). Furthermore, integrating affective models into ITS, such as emotional support mechanisms and adaptive feedback, enhances learners engagement and motivation (Graesser et al., 2018).

These models are pivotal in creating inclusive learning environments where learners with diverse emotional and cognitive profiles can thrive (Steenbergen-Hu & Cooper, 2014).

While exploring the ITS, MathU, the researcher observed that several key features closely align with these findings from the literature. Corresponding with Kulik and Fletcher's (2016) concept of personalised pathways, MathU utilises adaptive learning strategies that guide learners through personalised learning journeys based on their performance and identify areas needing improvement.

For instance, its 'generate chapter test' feature tailors assessments to meet individual learning needs, thereby offering targeted practice opportunities that reinforce learning. Moreover, the researcher identified accessibility features within MathU, such as icon-based prompts and visual aids, which enhance differentiation by providing multiple entry points for learners with diverse learning styles and abilities. This observation resonates with VanLehn's (2011) assertion that ITS systems facilitate differentiated learning by offering comprehensive guidance throughout problem-solving processes, emphasising not just final answers but also the steps leading to solutions.

Moreover, findings from the interviews with four teachers highlight MathU's practical benefits in inclusive classrooms. Participants emphasised the platform's ability to facilitate personalised learning experiences through features like adaptive questioning, immediate feedback, and differentiated pathways.

They noted that MathU supports inclusive teaching strategies by allowing for individualised instruction catering to diverse learning needs, promoting engagement and academic success. Despite these benefits of MathU, the teachers did, in fact, mention some shortcomings and suggestions for improvement in MathU's ability to enhance differentiation, such as the need for enhanced accessibility features and clearer instructional summaries.

These insights from interviews also reveal how MathU effectively implement the differentiated learning strategies related to Tomlinson's (2017) four key principles of differentiation. Firstly, participants highlighted MathU's capability to cater to diverse learning preferences through content differentiation. The platform presents subject matter in various formats, offering personalised pathways and adaptive learning features based on individual learner performance.

This approach ensures that learners engage with content in ways that best suit their learning styles and abilities. In terms of process differentiation, MathU supports teachers by offering a range of instructional tasks and resources that can be tailored to meet diverse learning needs.

Teachers can customise learning experiences by assigning different activities within MathU, adapting to the unique requirements of their learners and varying instructional contexts. Product differentiation is facilitated through MathU’s flexibility in assessment methods. Learners can demonstrate their understanding through personalised assessments like the ‘generate chapter test’ feature, allowing them to choose how they present their learning outcomes.

This empowers learners with autonomy and encourages active engagement in their learning process. MathU contributes to creating a supportive learning environment by fostering inclusivity and engagement. Its interactive features and collaborative tools promote a safe atmosphere where all learners feel valued and supported. This aligns with creating a classroom environment that sets high expectations and promotes academic success for every learners.

Figure 6.2 illustrates an adapted version of Tomlinson’s (2017) differentiation framework, showcasing how the researcher’s findings from the data demonstrate the practical implementation of the differentiated learning principles within an inclusive classroom setting using the ITS MathU.

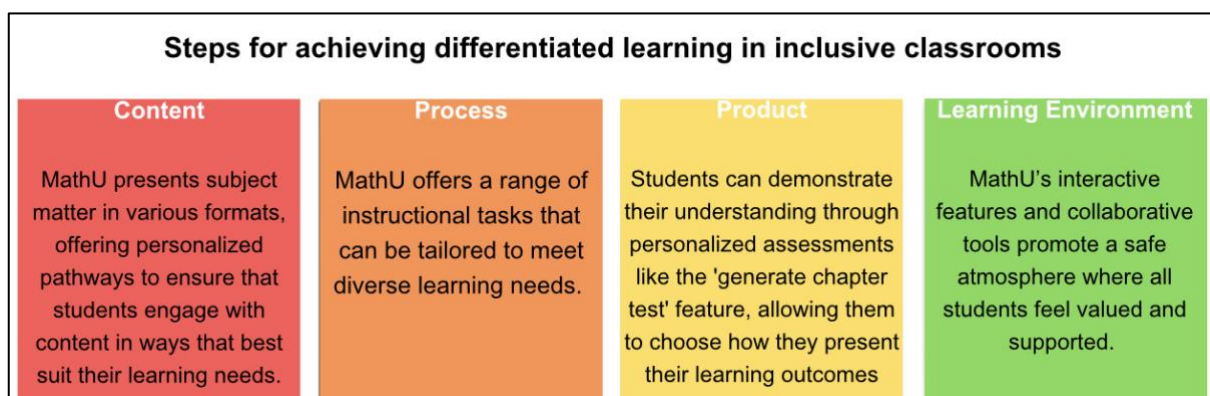


Figure 6.2: MathU's Interactions With the Four Aspects of Differentiated Learning  
(Adapted from Tomlinson, 2017 and Researcher's findings)

Indeed, ITSs like MathU exemplify the potential of AIEd, particularly in facilitating differentiated learning approaches. By offering adaptive pathways, personalised feedback, and inclusive features, ITSs are able to support diverse learner needs and empower teachers to deliver differentiated learning.

### 6.2.3 Sub-Research Question 3

#### **How is mathematics addressed through the ITS, MathU?**

This SRQ aligns with TCK component of the TPACK framework, which emphasises the effective use of ITS technology in teaching specific subjects, such as mathematics, in the case of this research study. To understand how mathematics is addressed through the ITS MathU, the researcher utilised semi-structured interviews and the exploration of MathU as key data instruments. These tools provided comprehensive insights into how MathU supports the teaching and learning of mathematics, particularly within an inclusive educational context.

The semi-structured interviews with teachers were instrumental in revealing how MathU is applied in real classroom settings. Through these interviews, the researcher gathered qualitative data on the practical implementation of MathU's features in teaching mathematics. Teachers shared their experiences with the system, highlighting how MathU's personalised learning pathways, adaptive feedback, and real-time assessments were used to address various mathematical concepts. The interviews also offered insights into how MathU helps in identifying and addressing individual learner needs, thereby supporting differentiated instruction and reinforcing key mathematical skills.

The exploration of MathU focused on analysing the system's design and functionality in relation to mathematics education. This involved examining MathU's capabilities in delivering instruction on mathematical topics, providing interactive exercises, and offering immediate feedback. The exploration revealed how the system's algorithms and features support the teaching of mathematics by adapting to students' learning progress, offering tailored practice problems, and tracking performance over time. The researcher assessed how these features align with effective instructional methods and curriculum alignment, ensuring that MathU addresses the diverse needs of learners in mathematics.

The literature highlights that ITSs have emerged as innovative educational tools that support learners across various subjects, particularly within the STEM fields. According to Almasri et al. (2019), ITSs offer functionalities, such as guided enquiry learning, collaborative problem-solving, natural language processing, and adaptive educational games. The primary objective of these tools is to deliver advanced instructional guidance on a personalised level, mirroring a human tutor (del Olmo-Muñoz et al., 2023).

Santhi et al. (2013) highlight three key functions of successful ITSs in addressing specific subject matter: diagnosing a student's knowledge level, deciding on appropriate instructional strategies, and providing timely feedback. VanLehn (2011) compared the efficacy of human tutoring to ITS tutoring, concluding that ITSs can be as effective as one-on-one human tutoring, especially in STEM subjects. However, it is crucial to note that ITSs should complement rather than replace traditional classroom settings (del Olmo-Muñoz et al., 2023). VanLehn's (2011) findings also suggest that ITSs are more impactful when used for short-term interventions rather than extended periods.

The MathU ITS exemplifies how these principles are applied in practice. The researcher's technological exploration of MathU revealed its strengths in customisation and personalisation, which align closely with the literature above. For example, MathU allows teachers to select pre-designed tests and lesson plans or assign individualised activities based on specific learning needs. After completing an initial test or activity, MathU generates personalised learning pathways for learners, providing targeted exercises to address identified gaps.

This adaptive approach ensures that each learner receives the support they need, aligning with the core functions of ITSs as outlined by Santhi et al. (2013).

Interview participants emphasised MathU's role in supporting differentiated learning strategies. For instance, the platform's ability to present subject matter in various formats caters to diverse learning preferences, exemplifying content differentiation. MathU's adaptive questioning system, which adjusts the difficulty and type of questions based on learner performance, supports process differentiation by meeting the unique needs of each learner.

MathU also facilitates product differentiation by offering multiple ways for learners to demonstrate their understanding, such as through customisable tests and exercises. The platform fosters a supportive learning environment by providing immediate feedback and additional resources, similar to having a personal tutor. This environment encourages active engagement and supports learners in overcoming learning challenges. Regarding assessment differentiation, MathU provides real-time feedback and generates adaptive learning paths based on students' performance.

This data-driven approach allows for formative assessments that guide effective instruction and continuous improvement. The platform's ability to align with various curriculum standards, including CAPS and IB, ensures that the content is relevant and meets educational requirements.

ITSs, such as MathU addresses specific subject matter by utilising adaptive learning features, personalised pathways, and comprehensive support mechanisms. By adhering to established ITS design principles and incorporating feedback from teachers, MathU showcases the potential of ITSs to enhance differentiated learning in inclusive educational settings. The alignment of MathU's functionalities with curricular goals, coupled with its emphasis on a user-friendly and accessible design, underscores its value as a significant tool in inclusive education.

#### 6.2.4 Main Research Question

**How can the implementation of an ITS support the cultivation of a differentiated learning environment in an inclusive classroom setting?**

In this study, each SRQ was aligned with the TPACK framework. Figure 6.3 illustrates the key aspects investigated in the three separate research sub-questions to provide a visual representation of how the TPACK framework guided this study.

This diagram highlights the intersections between technological, pedagogical, and content knowledge, showcasing how these elements were examined in relation to the integration of the MathU ITS in inclusive South African classrooms. The figure highlights how these interconnected aspects collectively addressed the main research question by mapping out the specific components of the TPACK framework explored in each sub-question.

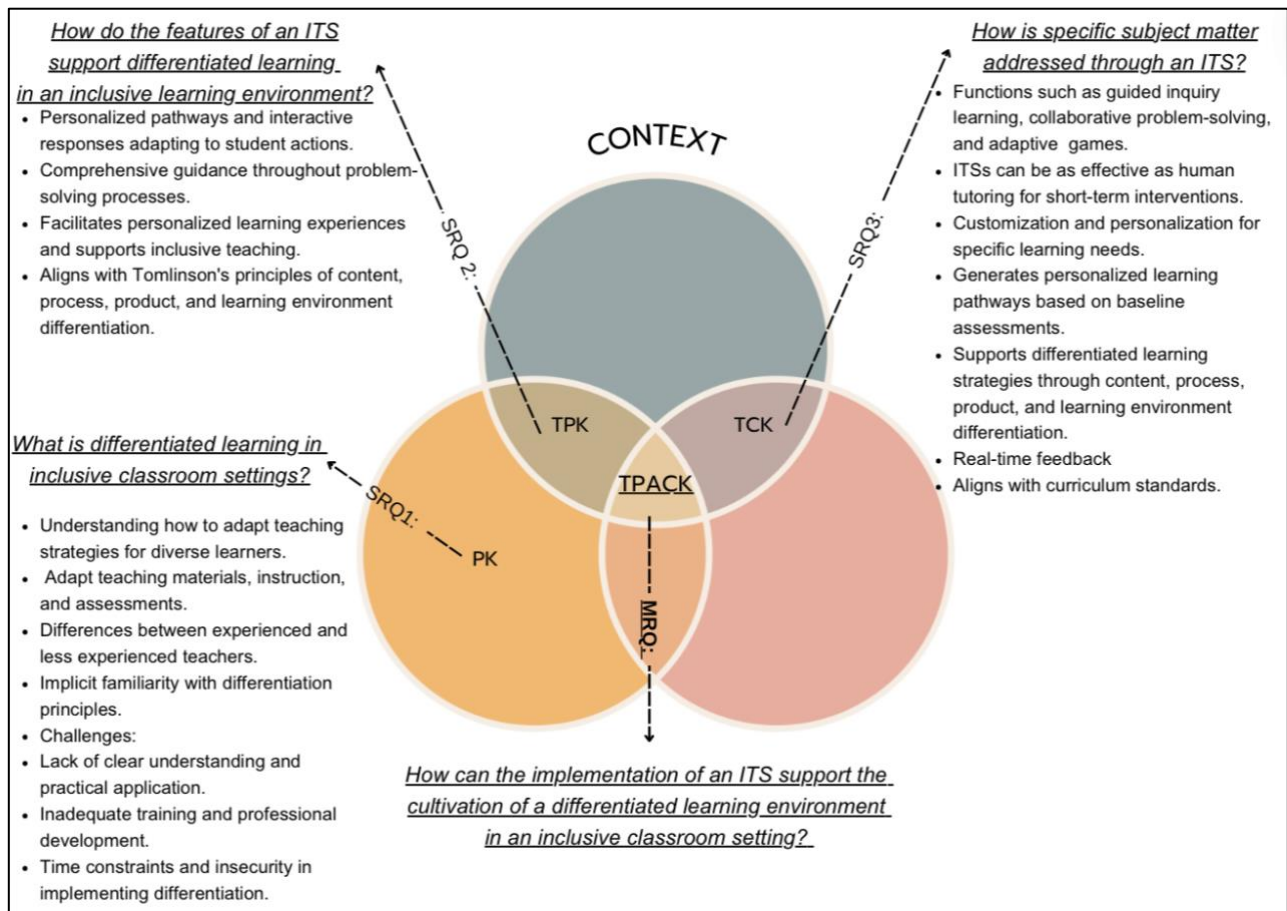


Figure 6.3: The TPACK Framework Illustrating the Key Findings of the Study

#### 6.2.4.1 Understanding Differentiated Learning in Inclusive Classroom Settings

The findings reveal that differentiated learning is a crucial pedagogical approach in inclusive classroom settings, requiring teachers to adapt their teaching strategies to accommodate diverse learners. Teachers need to tailor teaching materials, instruction, and assessments to meet the unique needs of each learner.

However, this approach poses significant challenges, including:

a. Lack of Clear Understanding and Practical Application:

Teachers often struggle with grasping the theoretical and practical aspects of differentiation.

b. Inadequate Training and Professional Development:

There is a need for more comprehensive training programmes to equip teachers with the necessary skills for effective differentiation.

c. Time Constraints and Insecurity:

Teachers face time limitations in planning and executing differentiated activities, leading to feelings of insecurity about their implementation.

*6.2.4.2 Features of Intelligent Tutoring System Supporting Differentiated Learning*

ITSs like MathU can significantly support differentiated learning by automating various aspects of the process:

a. Personalised Pathways and Interactive Responses:

ITS can create individualised learning pathways and provide interactive feedback based on learner actions.

b. Comprehensive Guidance:

These systems offer continuous support through problem-solving processes, aligning with Tomlinson's (2017) principles of content, process, product, and learning environment differentiation.

c. Support for Inclusive Teaching:

By facilitating personalised learning experiences, ITS enhances inclusive teaching practices.

*6.2.4.3 Addressing Specific Subject Matter Through Intelligent Tutoring System*

ITS can also address specific subject matter effectively by:

a. Customisation and Personalisation:

ITS allows for the customisation of learning experiences to meet individual learner needs.

b. Generation of Personalised Learning Pathways:

These systems develop learning pathways based on baseline assessments, ensuring that each learner receives targeted instruction.

c. Real-time Feedback and Curriculum Alignment:

ITS provides instant feedback and aligns with curriculum standards, supporting differentiated learning strategies across content, process, product, and learning environment.

#### 6.2.4.4 *The Essential Role of Teachers*

While ITS offers substantial benefits, the active involvement and expertise of teachers remain indispensable. Teachers are the critical factor in:

a. Implementing and Integrating Technological Tools:

Successfully integrating tools like MathU relies on teachers' ability to leverage technology to enhance educational outcomes.

b. Learner Success:

As Johnson (2013) articulated, "Although technologies can be powerful means to improve learning, the teacher remains the critical factor to learner success."

#### 6.2.4.5 *Conclusion of Findings*

Ultimately, the findings indicate that despite the numerous benefits of differentiated learning, teachers still face several obstacles in its implementation. This observation aligns with existing research on the successes and challenges of differentiated instruction. Joseph et al. (2013) found that while graduates from teacher education institutions in Trinidad and Tobago generally understood the concept of differentiated instruction, they often experienced difficulty integrating Tomlinson's (2017) framework for differentiation, including the aspects of content, process, and product differentiation in their classrooms (Tomlinson, 2001). This suggests a gap between theoretical knowledge and practical application, underscoring the need for additional support and training to effectively implement differentiated learning strategies. A significant challenge is time constraints. Diversifying educational activities and identifying students' characteristics and traits demand substantial time, which is often scarce due to the pressures of teaching (Corley, 2005; Schumm & Vaughn, 1991). Additionally, some teachers struggle to implement differentiated strategies due to a lack of knowledge or experience.

However, ITSs like MathU are invaluable tools in overcoming these differentiation challenges. By automating many aspects of differentiation, such as the diversification of tasks and learning experiences in the form of pathways, providing real-time feedback, and offering customisation, ITSs assist teachers in creating and maintaining a differentiated learning environment.

Yet, it is important to emphasise that the active involvement and expertise of teachers are crucial for the successful implementation and integration of technological tools, such as MathU in their classrooms. Johnson et al. (2016) echoed this sentiment, stating, although technologies can be powerful means to improve learning, the teacher remains the critical factor to learners success.

### 6.3 Contributions

This study significantly contributes to the understanding and application of ITSs in inclusive learning environments. The first contribution relates to that of enhanced differentiation strategies. The research demonstrates how the MathU ITS supports effective differentiation in inclusive classrooms. By making use of its technological features, such as personalised pathways, interactive responses, and real-time feedback, this study shows how ITS can adapt teaching strategies to accommodate diverse learning needs. This contribution is valuable for teachers who are seeking to implement differentiated instruction effectively, especially those who may be less familiar with differentiation principles, such as Tomlinson's principles for differentiated learning (2001). Secondly, this study also contributes to the informing of policy development. The research offers insights that can inform the development of policy documents related to inclusive education. By demonstrating how the MathU ITS supports differentiated learning and inclusive teaching, the findings can guide the creation or revision of school policies to address the needs of diverse learners. This contribution emphasises the importance of integrating technological tools into policy frameworks to promote equitable educational practices and enhance learning opportunities for all learners.

### 6.4 Reflections

In this section, the researcher reflects on the journey undertaken during the course of this study, detailing the various phases encountered from inception to completion. Reflection is a crucial aspect of the educational field, as highlighted by scholars like Helyer (2015) and Helyer and Kay (2015), who emphasise its importance in personal and professional development through various forms, such as journals, portfolios, and reports.

The study began with a keen interest in AIEd, a field that is gaining significant attention in educational technology. The introduction to MathU, a new program piloted at the researcher's school with AI features, such as adaptive assessments, sparked a deep curiosity to explore how such an ITS could enhance differentiation in inclusive classrooms. This focus stemmed from the researcher's own struggles with differentiation in her teaching practice.

A pivotal moment in the research journey was the guidance provided by her supervisors. The initial question they posed—"Is MathU really AI or not?"—prompted a critical discussion that significantly shaped the study's direction. This challenge led to a thorough examination of MathU's technological claims, refining the study's focus and methodology. The discussions with supervisors were instrumental in aligning the study with its objectives and ensuring a coherent narrative.

Throughout the study, the researcher discovered numerous technological tools that not only informed but also transformed her practice as an IT teacher. Engaging with these tools and exploring their applications deepened her understanding of their potential in educational settings. This experience has profoundly shaped her career and teaching approaches, leading to a more informed and innovative practice.

Interviews with four passionate teachers provided valuable insights into the practical applications of MathU ITS for differentiated learning. The enthusiasm and perspectives shared by these teachers enriched the study and confirmed the researcher's own experiences with differentiation. Reflecting on the journey, the researcher acknowledges the significant impact of the study on her career and teaching methods. The process of exploring technological tools and integrating them into practice has been transformative. It is hoped that the findings and insights from this study will similarly benefit other teachers, guiding them in their own journeys to enhance teaching and learning through technology.

## 6.5 Limitations

This study presented potential limitations that could impact the final results. Firstly, there was a notable lack of research on integrating ITSs for differentiated learning in an inclusive South African context. This paucity of literature posed challenges in formulating the study's research objectives. Although there is substantial research on the individual components analysed in this study, differentiation, inclusive education, and ITSs, the combined examination of these three elements remains unexplored. Additionally, at the time of this study, MathU was the most prominent ITS within the South African context. However, since the conclusion of this research, other South African ITSs, such as *MindJoy*, have emerged.

Another significant limitation of this study was the sample size. The study included only four participants, all of whom were teachers at a specific independent IB school in Pretoria, Gauteng. This small sample size restricts the results' generalisability and poses challenges for replication. Expanding the sample size in future research could potentially yield more accurate and representative results.

Moreover, the study was conducted in an affluent school, which does not reflect the broader educational landscape of South Africa, where many schools struggle with affordability issues when planning and implementing educational technology like ITSs. Future studies should strive to incorporate a more diverse South African context when designing activities, emphasising cost-effective solutions to mitigate financial barriers.

## 6.6 Recommendations

This section presents recommendations for future research. Researchers should explore the use of AI-driven educational tools and their implications for policy documents in schools. Specifically, integrating tools, such as ITSs should be examined across various subjects and grade levels to assess their impact on learner performance and teacher satisfaction. Incorporating these tools into educational policy documents can guide their effective implementation and support a broader understanding of their benefits and challenges.

## 6.7 Benefits to the Field of Study

This study offers several significant benefits for teachers and educational technology implementers. Firstly, it aids teachers in addressing differentiation needs by providing insights into how ITSs can support tailored instruction for diverse learners. This is particularly valuable for teachers operating in inclusive teaching contexts, where meeting the varied needs of all learners is essential. The study demonstrates how ITSs can facilitate personalised learning pathways, thereby enhancing the educational experience for learners with different learning abilities and needs. Secondly, the study provides specific assistance to teachers teaching mathematics. By examining the use of MathU, a prominent ITS in the South African context, the research highlights practical strategies and approaches that can improve learner engagement and achievement in mathematics. This can lead to higher levels of teacher satisfaction and effectiveness in teaching this subject.

Furthermore, the study offers valuable guidance for educational technology implementers at schools. It suggests effective e-tools like ITSs and provides practical insights into how teachers can integrate these tools into their classrooms. This can help schools in planning and executing technology-enhanced learning strategies, ensuring that such implementations are both effective and sustainable.

## 6.8 Final Conclusion

ITSs can be highly effective tools for differentiation, particularly in short-term interventions. This research study demonstrated that ITSs are not merely technological novelties but valuable assets that can significantly enhance teaching and learning. By offering personalised learning pathways and real-time feedback, ITSs support diverse learning needs and improve educational outcomes. Their integration into classroom practices aids in managing differentiated instruction and boosts teacher satisfaction. In the hands of skilled teachers, ITSs can truly transform the educational landscape, making the adoption of these systems a strategic and worthwhile investment for fostering inclusive and learning environments in South African classrooms.

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## Appendices

### 8.1 Appendix A

#### 8.1.1 ITS Exploration

Feature Category	Key Features	Description	TPACK Component
Adaptive Learning Capabilities	User Environment Adaptation	Adjusts learning environment based on student needs.	TK
	Content Adaptation	Modifies learning content according to the student's current skills, knowledge, and progress.	TCK
	Pace Adaptation	Adjusts the speed of instruction to match the student's learning pace.	TPK
	Search Functionality Adaptation	Customizes search functions to align with students' preferences and needs.	TK
	Facilitation of Communication and Cooperation	Supports group activities by enabling communication and collaboration among students.	TPK, TCK
Step-Level Guidance	Problem-Solving Support	Provides detailed assistance throughout problem-solving processes.	PCK
Personalized Instructional Guidance	Tailored Learning Experiences	Delivers advanced, personalized instructional guidance tailored to individual student needs, mirroring the support a human tutor would provide.	PCK, TCK, TPK
Diagnostic Capabilities	Knowledge Level Assessment	Accurately diagnoses a student's current knowledge level through diagnostic assessments.	CK
	Instructional Strategy Selection	Decides on appropriate instructional strategies based on individual student data.	TPK, TCK
	Strategy Adaptation	Continuously adapts instructional strategies as the student progresses.	TPK, TCK
Feedback Mechanisms	Timely and Constructive Feedback	Provides immediate feedback to help students identify and correct errors during the learning process.	TCK
Content-Specific Knowledge	Discipline-Specific Instructional Content	Grounded in discipline-specific knowledge (e.g., mathematics, physics, language studies, programming) to offer relevant and accurate instructional content.	CK
Data Analytics	Student Interaction and Performance Data	Collects and analyzes data on individual student interactions, performance, and academic progress to refine instructional approaches.	PK
Natural Language Processing	Interactive Conversations	Incorporates NLP techniques to understand and generate human-like language, enabling engaging and interactive conversations with learners.	TPK
Integration and Interoperability	System Integration	Ensures seamless integration with other educational technologies and platforms.	TK
	User-Friendliness	Provides an intuitive and accessible user interface for both students and educators.	TK
	System Stability	Maintains high levels of system reliability and stability during use.	TK
	Data Security Measures	Implements robust data security protocols to protect student information.	TK
Additional Considerations	Cultural and Contextual Sensitivity	Tailors learning content and interactions to be culturally relevant and contextually appropriate.	Context
	Scalability	The system should be scalable to accommodate varying numbers of users and diverse educational settings.	Context

## 8.2 Appendix B

### 8.2.1 Policy Document on Inclusion

#### Academic Inclusion Policy

##### 1. Introduction and Philosophy

- 1.1 The learning community recognises that education is a social endeavour benefiting all its members individually and collectively.
- 1.2 An inclusive learning community engages with different ways of knowing and being, prioritizes people and their relationships, and assumes shared responsibility for learning, health and well-being of all students.
- 1.3 Everyone in the learning community has agency, seeing themselves as contributors to its strength and success, and taking action to affect change.
- 1.4 Inclusion requires that all students be permitted access to a single school system and not to be segregated, as far as possible, according to abilities, race, gender or any other form of segregation. However, individual subject choice may cause certain students to be grouped together for no other reason than the time-tabling requirements of the subjects chosen.
- 1.5 \_\_\_\_\_ encourage students to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.
- 1.6 Our schools and their curriculum are organized in such a way that student diversity of all kinds can be included as a resource, seeing individual differences as opportunities for enriched learning.
- 1.7 \_\_\_\_\_ continuously strive to improve practices to achieve better outcomes for their students and remain relevant to the needs of the students across their various school communities. This encompasses
  - 1.7.1 conducting ongoing evaluation of the impact of the Learner Support Programme on student achievement and the success of its implementation,
  - 1.7.2 using evaluation of data to identify successful implementation and student improvement,
  - 1.7.3 evaluating their progress, adjust practices based on the evaluation and monitor changes to ensure sustainability of the Learner Support Programme,
  - 1.7.4 introducing innovative practices to enhance the match between the Learner Support Programme and the evolving needs of the school, and
  - 1.7.5 providing regular professional development for teachers to empower and guide them in meeting the needs of all students in their care.

## 2. Principles of inclusive education

The curriculum at \_\_\_\_\_ supports the following principles which are addressed in a collaborative, non-threatening and non-discriminatory context:

- 2.1 developing the schools' cultures, policies and practices to include all students
- 2.2 incorporating the views of all key role players
- 2.3 safe-guarding the interests of all children
- 2.4 actively seeking and removing barriers to learning and participation
- 2.5 all students being afforded the opportunity to achieve to their personal potential
- 2.6 providing and offering the right skills training, strategies and support

## 3. Support and Intervention

- 3.1 \_\_\_\_\_ strive to live by the core principles of inclusive practices, and to identify and work with students requiring additional educational support and/or to identify difficulties or barriers to learning, through the provision of tiers of intervention and monitoring continuous progress. This approach includes providing tiers of increasingly intensive, high-quality instruction and intervention matched to students' needs, measuring and continually monitoring students' progress over time, and using resulting data to drive educational decision-making.

### 3.1.1 Tier 1 intervention

**3.1.1.1 All students in class receive general differentiated instruction.**

- 3.1.1.2 Teachers are empowered with appropriate strategies and information to help work with and identify students requiring assistance.
- 3.1.1.3 Continuous teacher/formative and summative assessments are used to identify and monitor students requiring assistance.
- 3.1.1.4 If, after a brief period of time, progress monitoring shows that there has been very little progress, the teacher will consult with other staff members at the school.
- 3.1.1.5 Together, teachers may decide that the best way to help a child who has not improved with the general education curriculum (Tier 1), even with extra help, would be to give the child Tier 2 instruction.

### 3.1.2 Tier 2 intervention

- 3.1.2.1 Students not making adequate progress in Tier 1 are provided with more intensive systematic instruction.
- 3.1.2.2 These services are provided in addition to instruction still in the general curriculum.
- 3.1.2.3 Teachers can implement intervention with help from another staff member/support teacher.
- 3.1.2.4 These interventions are provided in small group settings. Students may be withdrawn from classrooms temporarily for this support to take place.

3.1.2.5 Students who continue to show little progress at this level of intervention are then considered for more intensive interventions as part of Tier 3.

**3.1.3 Tier 3 intervention**

3.1.3.1 Interventions at this level are specialized and may consist of individual, small group, and/or multi-disciplinary interventions.

3.1.3.2 All individuals working with students are specialists in this level of intervention.

3.1.3.3 There is ongoing use of appropriate assessments to analyse the academic challenges being addressed, as well as further assessments that match the student to effective interventions for their personal areas of concern.

3.1.3.4 A detailed intervention plan is developed to help staff with continuing support in class.

3.1.3.5 When required, additional support services could be offered at the parent's own expense, e.g. occupational therapists, speech therapists, etc.

**4. Extension**

4.1 Extension forms an integral and necessary part of education.

4.2 Teachers should strive to identify and work with students who would benefit from extension and enrichment over and above the general curriculum.

4.3 Teachers are empowered with appropriate strategies and information to work with and identify these students.

4.4 Extension programmes could occur in small group settings, where students may be removed temporarily from the classroom.

## 8.2.2 Policy Document Analysis Criteria

TPACK	Checklist Criteria	Comments
TK	Does the policy recognize the role of technology in supporting inclusive education?	<i>Emphasis on the importance of using technology to support inclusive education, particularly in data-driven decision-making and differentiated instruction (section 1.7.3 and 3.1.1.2.)</i>
	Is there mention of the allocation of technological resources to support students with diverse needs?	<i>Acknowledges continuous improvement and innovation (section 1.7.4), but could more explicitly discuss the allocation of technological resources for inclusive practices.</i>
	Does the policy emphasize the use of technology for continuous assessment and progress monitoring?	<i>Highlights the importance of using data to evaluate the success of interventions (section 1.7.3) and drive educational decisions</i>
	Are various technological tools mentioned or implied to support differentiated instruction?	<i>Supports the use of technological tools in differentiated instruction through its emphasis on innovative practices and continuous monitoring of student progress ( sections 1.7.3, 3.1.1.3).</i>
CK	Does the policy ensure that curriculum content is designed to be inclusive and accessible to all students?	<i>Underlines the need for a curriculum that includes student diversity as a resource (section 1.6)</i>
	Is there an emphasis on providing equal learning opportunities for all students regardless of their background or abilities?	<i>Promotes equal learning opportunities by rejecting segregation and encouraging an inclusive environment (section 1.4), ensuring that all students can achieve their personal potential (section 2.5).</i>
PK	Does the policy outline specific strategies for differentiating instruction according to students' needs?	<i>Differentiation is central to the policy, with clear guidelines on tiered interventions to meet diverse student needs (sections 3.1.1 - 3.1.3).</i>
	Does the policy highlight the importance of collaboration among teachers, staff, and other stakeholders in supporting student learning?	<i>Advocates for collaborative approaches among teachers and other stakeholders in identifying and supporting students requiring additional assistance (sections 3.1.1.5, 1.7.5).</i>
	Is there a provision for regular professional development for teachers to help them meet the needs of all students?	<i>The policy ensures continuous professional development for teachers to empower them in meeting diverse student needs (sections 1.7.5)</i>
TCK	Does the policy discuss how technology is integrated to facilitate access to educational content for all learners?	<i>Implies the use of technology to enhance access to educational content, particularly through its focus on innovation and data-driven interventions (sections 1.7.3, 1.7.4).</i>
	Are innovative technological practices encouraged to enhance the Learner Support Programme?	<i>Innovative technological practices are encouraged to enhance the Learner Support Programme, ensuring that it meets the evolving needs of students (1.7.4).</i>
TPK	Does the policy ensure that technology use aligns with pedagogical goals for inclusion?	<i>Aligns the use of technology with pedagogical goals by focusing on differentiated instruction and continuous assessment (section 3.1.1.3), ensuring that technology supports effective teaching practices.</i>
	Is there mention of how technology can be used to support differentiated instruction and interventions?	<i>The policy supports the use of technology for differentiated instruction, particularly through its structured approach to tiered interventions (section 3.1.1 - 3.1.3).</i>
PCK	Does the policy include strategies for adapting curriculum content to meet the diverse learning needs of students?	<i>Emphasis on the adaptation of content to meet diverse learning needs (section 1.6), ensuring that all students can access and benefit from the curriculum.</i>
	Is there a focus on seeing student diversity as a resource for enriched learning and not a barrier?	<i>The policy views student diversity as a resource, not a barrier, fostering an environment where individual differences are seen as opportunities for enriched learning (section 1.6).</i>
TPACK	Does the policy reflect a comprehensive integration of technological, pedagogical, and content knowledge to support inclusive education?	<i>Comprehensive integration of technological, pedagogical, and content knowledge, particularly in its structured approach to differentiated instruction and tiered interventions (section 3.1.1 - 3.1.3).</i>
Context	Does the policy recognize and address the importance of context in shaping instructional practices?	<i>Acknowledges the situated nature of instruction by emphasizing the need to adapt practices to the specific needs and contexts of the school community (sections 1.7.4, 2.6).</i>
	Is there consideration of the cultural, social, and community contexts in which learning takes place?	<i>The policy is sensitive to the cultural and social contexts in which learning occurs, ensuring that all students are included and supported (sections 1.2, 2.5).</i>

## 8.3 Appendix C

### 8.3.1 Interview with Pam

**Researcher:**

Thank you so much for allowing me to have this conversation with you! In essence, I just want to find out more about how you experienced MathU, and your experiences with the tool in your practice thus far. I'm specifically focusing on differentiation, because I know you must do that in this school, I am also focusing on inclusion because this is an inclusive school. So, in that light, can you tell me more about your favourite features on MathU, specifically what makes MathU good for differentiation in this inclusive school.

**Pam:**

Cool! Well, recently, a new added feature in MathU is quite nice, where they have levelled the different kinds of questions. So, it sort of gets kids used to different levelling of exam questions. So, they can expect a level 1, 2, 3 or 4 question. MathU now started, like labelling the difficulty of the question as well. So, it exposes kids to the various kinds of questions they can expect and the range of questioning also. So, it's not just straightforward recall, it's also application, it's critical thinking it is different levels. Another cool feature is the generate chapter test feature. Okay, so after they've done a chapter, MathU summarises content that they've been doing, and then they can write like a class test on for you to evaluate where the kids are, it saves you a lot of time because of the test that's been set up. I think I just have to get used to the kind of formatting and questioning; I have a specific layout that I wanted. So, I'm trying to sort of integrate it a little bit more than I did this year. So that the kids have that different testing perspective, so that when they get somewhere like high school and its different person altogether, we're sitting their papers and the exams, they don't get like a culture shock, because they've already been exposed to the various kinds of testing and questioning.

**Researcher:**

That's true. And I know, like MathU has a feature where it adapts to the students' performance. Can you tell me more about this?

**Pam:**

Ya! It's like a reroute kind of thing in MathU, where if the kids don't do so well in the quizzes or activities, there's like a reroute in questioning, like very similar, questions,

but with more steps so that they are able to actually do better. Oh, it's got the memo feature on the iPad, so kids can write down the answer and then flip it to check.

**Researcher:**

That really helps. Do you think you can use MathU to incorporate differentiation in a diverse classroom?

**Pam:**

It is really useful, you can target the weaker learners who are struggling with certain concepts as reinforcement, and you can go back and redo like sets and topics again, but you can also use it for enrichment for those who like extension activities kind of thing, right?

**Researcher:**

Okay. So how do you typically use MathU to support your teaching practice in your classroom?

**Pam:**

Well with MathU, anything could be done, but for me it really depends on how the kids want to work on the tool as well. So they can decide if they want to work alone. Some kids work better alone and some work better in groups – you can also differentiate that way. You pick up a with a learners with a stronger level and then they work through together, or you have collaborative learning where they all mixed levels in a group and then you can differentiate like that, unless there's different levels of kids so that, you know, they can answer the questions and explain to each other.

**Researcher:**

Yes, that is a very nice way to differentiate! Can you tell me more about how MathU aligns with the curriculum and standards in your classroom?

**Pam:**

There were some gaps actually – like there were certain things in this school that we did cover, but MathU did not feature. So we had to obviously email the MathU teams our extra notes and things and be like, you know, you need to add this on there because there's missing content. So now they are looking at revamping and adding more content hopefully.

**Researcher:**

Okay, yes, I see what you say – that is interesting. What about, like the delivery of differentiated instruction? How does MathU facilitate that?

**Pam:**

So in terms of like, the mathematical concepts, MathU really helps with concept-driven lessons. Not so much theory-related lessons. And the chapter tests really help for us teachers to see how our kids are performing, and provide us with more opportunities to support each individual kid. There's lots of opportunity for them to practice.

**Researcher:**

In terms of an inclusive classroom, because we've spoken about the technology, we've spoken about your teaching strategies, but in inclusive classrooms, does MathU actually promote inclusive inclusion and diversity?

**Pam:**

Look, MathU allows kids to learn at their own pace, because they do give a memo and also self-guided activities. They are able to check their answers and do activities suited for their own mathematics needs. The only issues is that MathU doesn't really show the breakdown of calculations so the kids can see exactly where they went wrong and what they did wrong.

**Researcher:**

Ah yes. Okay, so would you say that is a challenge in MathU?

**Pam:**

I would say so, yeah! Obviously, there are always challenges. But I think using it as a platform on its own is very different to using it as a platform for enrichment.

**Researcher:**

What do you mean by that?

**Pam:**

Well, if I was using MathU day to day, as part of my teaching life, and the MathU work was the only work that I posted, and that was the work that, you know, the work that the kids must do? Yeah, it would be better. But now, we have to integrate MathU and still do regular day-to-day teaching – it is pure madness. And on top of things that you got to teach, like additional things that you have to teach. So, it becomes a bit challenging. But I think you need to find a routine where it's like, one day, there's a MathU day where they just asked questions, and they work on MathU, and then you project on the board. You know, work through it with them.

**Researcher:**

I see what you're saying. Yeah. Okay. And then, um, do you think MathU is an accessible tool? Is it accessible for your learners?

**Pam:**

Um, well I don't actually know if it's got an audio function to read out questions, but that would be quite nice. Yeah. But I don't think it is streamlined for kids with any impediments yet. Because it's still a new tool, like a relatively new app.

**Researcher:**

Yeah? Okay, well those are my questions. I don't know if you have any other comments you have to add?

**Pam:**

Ya! I think for me, coming from a school that never used MathU, it was a bit difficult for me to integrate. But like I said, you need to get into some sort of routine that works for you. Whether it is like exam revision, or test revision, or you want to incorporate it as part of your lesson. Yes, it's up to you. But it's quite useful, especially when you're checking data analysis. It's easy to track everybody's progress. So it like, it even gives you like an analysis of each chapter. Have they watched the content videos? Have they answered the questions have they done with them? That has ended as soon as two-point analysis so it's quite useful to also drive some sort of competition in your class as well to see who is actually invested and they love it, like they always mentioned like the challenges and the rewards.

It's like the gamification elements. Yeah, love it. So next year, we're going to extend MathU in Grade 6 too. And the MathU team are also making a lot of changes also. There is now like little mini celebrations or confetti things after they've completed a set of questions. They've adapted quite a bit. There's a lot of minor changes, but those minor changes are making the biggest difference.

**Researcher:**

Wow! Thank you for this – this has been an awesome conversation.

**Pam:**

Thank you, it was really interesting and I had a lot of fun.

### 8.3.2 Interview with Jim

**Researcher:**

Okay, so thank you so much for joining me today. Um, my study is all about MathU, and Grade 7 maths. Therefore, I've chosen you as one of my participants. And yes, thank you so much for agreeing to be here. So first of all, I'd like to know just how you experienced MathU, have you used MathU before?

**Jim:**

Okay, I use it in the maths class, which is actually excellent because it gives you real data about the learners. And I like the way do you use inclusive? Why? Because based on the question that the learners answered, Yes, if you get something wrong, it gives them instant feedback. And it makes you read to some other questions based on your personal needs. So it works with an individual, and ensures that it caters for their specific needs.

**Researcher:**

So if I get fractions wrong...

**Jim:**

Yes! And then, and then it knows exactly what type of fractions. So it refers you back and give you more other questions to do. See.

**Researcher:**

So you would say that MathU then fills the gaps in learning?

**Jim:**

Definitely, because some of the things that I might not have picked up, that doesn't strike me, okay, when I find your homework, and then go and do it, when it gives us them the feedback and say, Okay, you did not get this one right. Rather, you didn't get this one? And then it fills those gaps. Yes, you know, and it shows that they better not understand, whereas I've given it to them in a bigger context. Okay. But within that bigger topic, yes, there was something specifically that had been understood. So it does fill the gaps.

**Researcher:**

So, if you can see every child's individual data, and you can actually also see where there are gaps and openings...

**Jim:**

Yes! And how many times they've attempted, and how much time they're spending. So, you get a real feedback from it as a teacher.

**Researcher:**

Okay, cool. So do you actually, would you say that it helps you in your professional practice?

**Jim:**

It is helping is because when I also have to set my formal assessment, I now know, looking at the feedback, which I've been getting, based on where my learners were, how they were performing, and which ones were problematic. So, I know how to assess and what to assess them on.

**Researcher:**

And are you able to extend them?

**Jim:**

Definitely. You can even give them more extension. That's differentiation, too, because it's like, the gifted learners also need to be extended.

**Researcher:**

Can you maybe give me an example or just like your scenario of how you would use MathU in, in a classroom?

**Jim:**

So how it works is that I will teach a topic as a teacher. And then when I'm done with teaching the topic as a teacher, I give them MathU homework. And this homework when they do it, I get an instant feedback. It also gives them their, their, their feedback, they get a score. And based on that score, when they get back their score, if they got something wrong, it says, please go back and do question 12340. It can even take them back and say, listen to this explanation.

**Researcher:**

Okay, and I believe it has videos.

**Jim:**

It does. Yes. So typically, homework could be good. But now, they've also updated the work, and I can print out the full exam preparation. And I can set up a paper from it. So I can even set the tests from it, you just select question and it makes that nice test for me.

**Researcher:**

Would you say that the MathU is aligned to the curriculum you teach?

**Jim:**

Okay. So it is CAPS-based number one, which is okay. But they also adapted it with school standards. I don't know if that is the answer you were looking for?

**Researcher:**

Yes, definitely, definitely. So is it possible if you notice, like, maybe there's something missing, could MathU fill that in? Is it possible?

**Jim:**

There was a quick, you know, feedback when we log a call. And so we do log calls quite often, okay, when you get an instant book instant, but there's people that are available to act and respond. You know, you can even make [a] suggestion and say, what about we do this? And like, that allows us, actually, every week, we're now starting to get feedback on a new topic that they're aiming at stuff. That's new questions.

**Researcher:**

Okay. Yeah. That's very cool. Um, do you think MathU allows for an inclusive environment?

**Jim:**

Okay, because you know what, every child, they can pace themselves. And they can actually easily identify their gaps. For example, if I get a child that was new in my class, and they've missed certain topics, if I assigned them home learning with MathU helped them.

**Researcher:**

That's cool. Like, I actually didn't think about that if it's a new child.

**Jim:**

Yes. And then you can actually almost do a baseline assessment and see where they are.

**Researcher:**

And with MathU you mentioned that you can print out a paper version, or you can have it online on an iPad.

**Jim:**

Yes! And that's, that's good. Because I know like learners, we have some learners who can't. They prefer working on devices that appeals to them. And then we have learners who want paper.

**Researcher:**

Yeah. So that actually is one of my next questions – about the accessibility of MathU, are there like maybe features that can help with disabilities?

**Jim:**

There are videos, but I think they can actually make it much more clearer. You know, they can maybe even have summaries, video that summarises because someone might not have the time, learners might not have the time, and maybe the ability to concentrate and listen for that long. So I think different ways can be explored on how they present some of the topics. Yeah.

**Researcher:**

So then, are there any other challenges, maybe any possible challenges or technical issues, or maybe like frustrations you've experienced with MathU?

**Jim:**

The only thing is before, most of MathU had errors. And I really felt some questions were too challenging. It wasn't well balanced.

**Researcher:**

Okay, my final question – Do you think MathU is a good tool for IB learning? Would you say it allows for learners voice and choice and allow for inquiry-based learning?

**Jim:**

Yes! Because the learners already know their login details, and they can go ahead before the topic is discussed in class. It gives them some agency. They can even do their own questions.

**Researcher:**

Okay. Do you have any other questions, any comments?

**Jim:**

But then so, so can I ask for your research? What's your question?

**Researcher:**

My main research question is how does MathU support differentiation in inclusive classrooms? So, I'm focusing on differentiation because that's something I really struggle with. And I know we are in an inclusive setting. So, I was wondering how like a technology can be a tool. And MathU was nice because it's new and we use it and it's relevant.

**Jim:**

That's amazing. Because we were one of the pilot schools who started MathU. So, it's really good because it's about that.

**Researcher:**

Absolutely. Okay, thank you. Once I'm finished, I will give you a copy so you can read it! I appreciate your time, thanks again!

**Jim:**

Thank you, and good luck!

### 8.3.3 Interview with Toby

**Researcher:**

Hi Toby, thank you for taking the time to chat with me. I'm really interested in learning more about how you use MathU in your Grade 7 maths class. Could you tell me about some of the key features of MathU that you find most useful in your classroom?

**Toby:**

Sure, absolutely! MathU has quite a few key features that really enhance the learning experience for my learners. So, you know, it includes adaptive learning paths, real-time assessment, and interactive problem-solving exercises. These features make the learning experience really dynamic and engaging for the learners.

**Researcher:**

That sounds fascinating! How does MathU support individualised instruction and personalised feedback for your learners?

**Toby:**

Ah, yes, great question. MathU really supports individualised instruction by tailoring exercises based on each student's progress. It offers immediate feedback and provides additional resources to address specific learning gaps. It's like having a personal tutor for each learners, you know?

**Researcher:**

That's incredible! How does MathU adapt to the specific learning requirements of your learners?

**Toby:**

Well, MathU adapts to the students' learning requirements through personalised learning plans. It adjusts difficulty levels and offers alternative approaches to cater to diverse learning styles. This flexibility really helps me meet the needs of all my learners.

**Researcher:**

I'm curious, how do you incorporate differentiation strategies to meet the diverse learning needs of learners in your classroom?

**Toby:**

Ah, yes, differentiation is key. I try to leverage MathU's adaptive quizzes and assign varied exercises based on students' proficiency levels. I also encourage collaborative problem-solving, which really helps learners learn from each other.

**Researcher:**

That sounds like a great approach. How does MathU support your pedagogical approaches in promoting differentiated learning?

**Toby:**

Well, MathU offers insights into individual learners performance, which enables me to tailor instruction accordingly. It fosters a learners-centred learning environment, which aligns perfectly with my pedagogical approach.

**Researcher:**

I see. How does MathU align with the curriculum and standards in an inclusive classroom setting?

**Toby:**

MathU aligns with the curriculum through customisable content, ensuring it meets standards while allowing flexibility to address diverse learning needs. This makes it really adaptable to an inclusive classroom setting.

**Researcher:**

Can you provide examples of how MathU supports the development of mathematical concepts, problem-solving skills, and critical thinking for learners in the inclusive classroom?

**Toby:**

MathU supports the development of mathematical concepts through interactive simulations, problem-solving scenarios, and adaptive challenges. It really fosters critical thinking skills by providing learners with opportunities to think creatively and analytically.

**Researcher:**

That's wonderful to hear. How does MathU contribute to creating an inclusive learning environment that promotes diversity?

**Toby:**

MathU accommodates diverse learning styles, fosters collaborative learning, and promotes a positive, supportive environment that values each student's unique

strengths. This really helps create an inclusive learning environment where all learners feel valued and supported.

**Researcher:**

How do you ensure that MathU is accessible and inclusive for learners with disabilities or other challenges?

**Toby:**

Well, I ensure MathU's accessibility by incorporating assistive technologies, providing alternative formats, and collaborating with support services to address specific needs. It's important to me that all learners have equal access to learning resources.

**Researcher:**

Absolutely. Can you discuss any challenges or opportunities you have faced while integrating MathU within your classroom?

**Toby:**

Sure, one challenge has been ensuring equitable access to technology for all learners. Additionally, addressing initial learning curve concerns has been another hurdle. However, the opportunities lie in fostering a more inclusive and engaging learning environment for all learners.

**Researcher:**

Thank you so much for sharing your insights, Toby. This has been incredibly valuable for my research.

**Toby:**

You're welcome! If you have any more questions or need further clarification, feel free to reach out. Goodbye and best of luck with your research!

#### 8.3.4 Interview with Michael

**Researcher:**

All right. Good morning, Mr. E. How are you doing today? Okay, so we are talking about MathU today, and I want to look at the technological knowledge involved with MathU itself. So firstly, I want to know, I know you have used MathU before, could you possibly tell me about any features that you like the most about MathU, or what you use the most often in MathU with your Grade 7s?

**Michael:**

Certainly! Would you like to hear from a teacher's point of view, or the student's point of view?

**Researcher:**

You can refer to any point of view you feel comfortable with!

**Michael:**

Okay, I will touch on the student's point of view first, because it will make sense where this is going. Okay... So, have just like any program, or like a social media platform, MathU has a dashboard. So, when you, or when I, as a teacher log on to it, you know, I have a dashboard that I can work from, but what I always do is, I have what the learners view is, also open on that topic. Make sense? See my screen? So, I can see what's happening on both sides. So, what happens is on the students' view, they give you like, the options of the different grades. For instance, we'll choose Grade 7. May I show you while I speak? It will just make sense. So, if you go on to Grade 7, it gives you all the math chapters. At this point, because they are still developing the program, we archive all the old chapters. So, if I want to refer back to some old stuff I can, but then they have the new chapters as well.

**Researcher:**

Okay, so what do you mean when you refer to chapters?

**Michael:**

So, what they talk about in chapters, is that they've got the different chapters in the grade that we cover in the curriculum. And what's so wonderful about the MathU team of people, it's not just the computer software thing. But I personally, as a teacher, I have contact directly to the MathU team. And I can contact Jenny and say, Jenny, I need for the chapter of exponents, I need you to focus on something more and give

me questions on the following. I can suggest questions, and they turn it into those kinds of questions for me, and then when I go onto it, then my questions are there!

**Researcher:**

Okay cool. So, they can actually customise it for every different school as well.

**Michael:**

Yes, for every different school, for every different country. Very cool. Nice thing about us, as you can see, on the one that I'm on, even our school logo is on. If you have access, but are not part of a school that has joined MathU, and you just go on as a public person, it will just not have the school logo, and they give you like a standardised platform on which you can work.

**Researcher:**

And MathU can be used across all devices, is that correct?

**Michael:**

Yeah, it can be done on a cell phone, an iPad, computer, but the computer and the iPad is very much the same.

**Researcher:**

Wow, it really is a diverse platform!

**Michael:**

Absolutely Andrea! And if you have now chosen your chapter, they have three amazing things for the learners. So, I'm going to start, I think, from the students' point of view before I explain the teachers', because then this makes sense. So, you have, for instance, 1.1. If you go and look, you will see there is a little thing, which indicates that this is a video to watch. The other thing can you see looks like a film strip. Yeah. So, that is a video that they can watch on those two topics. Now because we are in the chapter that says exponents, obviously when they say order of operations, it's not just general order operations, it is exponents order of operations. So, it will include that in the order of operations because you can have order of operations in just whole numbers, you can have it as common fractions, you can have it in different elements as well. And then obviously, you'll have with a combination of all of those. And then what is so nice about this is if I'm in the class teaching this concept, and the learners cannot remember when he goes home, he wants to do his homework, and he can't remember what to do, then he can go and watch this video over and over and over. He doesn't need to wait until tomorrow or the following week, or whenever he can go for an academic lesson.

Because most of the times, without MathU, by the time my kids come to my academic lessons, they can't remember what it was that they couldn't understand.

**Researcher:**

That's literally exactly where the study is going. Because it's focusing on that individualised instruction.

**Michael:**

Yes, so there is a big emphasis on the child's individual learning journey at this school.

**Researcher:**

So, how would you say MathU is able to support your pedagogical teaching strategies in promoting differentiated learning?

**Michael:**

Well from a teacher's perspective, I find, you know, especially with high school kids, what they do is they will go onto the video clip and play it through just for the sake of playing. But on the teacher side on the dashboard, I can see oh, he's watched the video, but they have done it in such a way that after a few seconds, the video stops and says, Oh, you still want to learn? But what they do as well is they ask questions, alright, of this part that you've been watching? What about this and this and this and then they need to explain before they can continue to watch and show interest, which is so cool. So, it keeps the kids active all the time, and that they can't just think oh, I'm going to play the video clip and go to the shower or whatever. Every child takes charge of his own learning, at his own pace!

**Researcher:**

Yeah, that is cool! Can you then share any examples of how you use MathU to address your students' varying abilities, interests, and learning styles?

**Michael:**

Yes, well the exercises in MathU are very interactive and adaptable to each learners. And you can think that the kids will cheat. But I have done my research on this in class to see if they are cheating and they honestly are not cheating. Because I think once they start doing this, they realise wait, I benefit from this. So, once you do an assessment or exercise, it gives you the memo immediately. So, if they struggle with it, and they don't understand, they can go to the memo and see oh, wait, this is how it was meant to be done. If they still don't understand it, the video explains only this question, not in general, the topic, but this question specifically on how you would go about answering that question.

**Researcher:**

That's very cool. So, it helps them in their individual learning process.

**Michael:**

Precisely, it's like instant feedback that they get. And it's cool because it's like immediate. They don't have to wait till tomorrow to ask the teacher how do I do this? They can immediately see, they can like, for instance, exponential formats... three times three times three times three. Okay, the question says right exponential format. And that's one thing that I've learned, with any learners, doesn't matter what age, if you don't understand the terminology, you're not going to understand what to do. So now if they don't understand what the exponential means it's going to be useless. So, they can go onto the memory they didn't understand that, the video clip will explain, exponential means this

**Researcher:**

And then once you finish, can you actually mark this assessment?

**Michael:**

Yeah, see that's why the memo is there. So what I told the kids in the class, when you do the exercise, you do the question, once you're done with it, you immediately mark the question to check whether you are right or wrong. Because if you had it wrong, then you need to learn immediately.

**Researcher:**

Could you maybe share more with me how you integrate MathU in your daily teaching practice?

**Michael:**

Yeah! So, there are different exercises I assign my kids. Sometimes it's one exercise, sometimes I give two, three or four exercises for each chapter. Once they have done the exercise, they then can do this assessment. But for me personally, as a teacher, I prefer it if they do all assessments at the end of the unit. Because then they have a chance to first learn and see how it works. Now they do the whole thing. Wait, let me just rephrase this with assessments. They don't do it on paper, they write the answer immediately in the blocks. Once they're done writing, MathU gives them the score immediately. So, it's almost like writing a test at the end of all, you're working and studying and what not, you're at a test to see how well you understand the work.

Now, let's say for instance, the learners did not do so well, even if he has only one answer wrong, what it does, is the word assessment on the dashboard now turns to the word pathway.

**Researcher:**

That is very interesting and a very clever word choice! Can you tell me more about these pathways?

**Michael:**

Okay. When the kids go on the pathway, MathU gives that one question he had wrong, they give him five or six of them, so that he can learn how to do that specific question. By the fifth or sixth time he's done, and he understands how to do it, then he has the option – Do I want to do redo the assessment, or do I want to just continue?

**Researcher:**

Wow, okay. So, if they are like, let's say they had everything wrong, then they will give more than one pathway to ensure that he can learn through the process and that's really like, individualised. Would you say this is differentiation?

**Michael:**

Yes, that's differentiation! like with the tool? You can't find it better, because every single learners will not have the same wrong answers or the same results. So, it focuses on each individual and how he can improve his results.

**Researcher:**

Have you experienced any issues with MathU?

**Michael:**

Now the amazing thing about this is even if we have technical issues, like sometimes I struggle to sign in, the people from MathU together with the technical support people we have at school, they can sort out the problem so easily. So, as a teacher I can focus only on the learners and not have to worry about tech issues. But that's cool that they come and help.

**Researcher:**

Very cool! What about curriculum alignment? Would you say MathU is well aligned to teach Grade 7 mathematics in this school following the IB curriculum?

**Michael:**

Yes! What is so amazing about MathU is that the developers are really hands-on, and they have a great response time to assist with this. They have helped us map the IB maths curriculum for the Grade 7s this year.

They use the IB way of questioning. But they have different resources from all over. So, they try and cater for every single school like the IB schools and all of those other government schools as well. So, they make sure that it doesn't matter which school you are from, because with MathU everything that is in your school will be covered. Kids from overseas can join it because it aligns with those levels.

**Researcher:**

Can you provide examples of how MathU supports the development of mathematical concepts, problem-solving skills, and critical thinking for learners in the inclusive classroom?

**Michael:**

Yes! This is so important, because a lot of times learners don't realise why they're actually struggling with maths. They just say I can't do math. Yeah. Now you can tell him no, you can't do fractions. You can do maths. Yeah, you are struggling. And I know exactly how to help you. And then you can tell it to parents, if parents come in, they say, Why is my child struggling? Then you say this is the problem. MathU is really data driven, it's like very based on data and supports differentiation.

**Researcher:**

Yes, I really like the fact that this program is based on solid data from the learners. How does MathU contribute to creating an inclusive learning environment that promotes diversity?

**Michael:**

Absolutely. Okay. Well, if you look, for instance at the leaderboards, you can see which position your class and every learners is at, which is actually healthy competition as well. And that's gamification. And what I love doing is to display this in the classes to the kids so they can see because then they challenge each other in the other classes as well. You can physically see the leaderboards change, because it's a live system, you could physically see oh, he's here on number 10. You refresh. And he's on number five, and you refresh. And he is at number one. My kids would run to the front of the class and hit refresh. Because they want to see, I've worked on this now, where am I now you know, so it's amazing. It is actually very empowering, because MathU captures each individual child's achievements, even if they make mistakes here and there, the pathways that I spoke about earlier still count as achievements.

**Researcher:**

Wow, well this really looks like a good tool for inclusion! Does MathU feature any accessibility features?

**Michael:**

No definitely, you know that Ben 10 child who came from France? He cannot speak a word of English, but you know what? He really liked MathU, because he felt success for the first time in the school when he was doing well with MathU, he was able to learn at his own pace, rewatch the videos and complete all the suggested pathways, and now he is at the top of the MathU leaderboard! So MathU definitely helps with the international children who cannot understand our teaching language.

**Researcher:**

Yes, that is a wonderful story! Well, thank you so much! This marks the end of our interview, you have been amazing Mr. E! Thank you so much.

**Michael:**

Oh, it is a big pleasure! Please come back if you want to ask me any other questions! Thanks.

## 8.4 Appendix D



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### LETTER OF CONSENT

August 2023

#### **Integrating intelligent tutoring systems for differentiated learning in inclusive classrooms**

##### **Dear Teacher**

I am Andrea Kruger, a Master of Education student in the Faculty of Education at the University of Pretoria. I am working under the supervision of Mr. Joubert and Prof. Callaghan from the Department of Department of Science, Mathematics and Technology Education at the University of Pretoria. I am writing to invite you to participate in my research entitled ***"Integrating intelligent tutoring systems for differentiated learning in inclusive classrooms"***. The aim of this research is to explore the integration of intelligent tutoring systems (ITSs) for differentiated learning in inclusive classrooms.

Should you decide to participate in this research, your involvement would take two forms:

Firstly, will be conducting a semi-structured interview with you. This interview will be scheduled as per your availability and will take place at any venue convenient to you for a period of no longer than 45 minutes. I would like your permission to make audio recordings of the interview. This is to ensure that the transcriptions of the interview data is valid and authentic.

Secondly, I will be collecting documents in the form of lesson plans and policy documents. In this regard, I would like to ask you to share at least one lesson plan where you have integrated an ITS in a lesson. Further, I would ask you to share any policy documents, which you find relevant, with me.

The data collected will include the interview recording and transcription as well as the documents that you will be providing. These documents will be kept confidential and anonymously and will be safely stored at the University of Pretoria. As a participant, you will have the opportunity to access and verify the recordings and the transcriptions of interviews and the documents that you provided.

You are free to choose to participate in this study. Should you choose to be a participant in this study, you are free to withdraw your participation at any time without consequence or prejudice. You will be referred to by a pseudonym or code name in the study and any publications arising from the research. You are encouraged to ask questions before or during the time of participation. If you have any concerns, kindly notify me or my supervisor.

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

Should you agree to participate, please read the following:

- I consent that data from this study can be used for research purposes in the Master of education in Computer integrated education study as well as for dissemination in research output as indicated in this letter.
- I acknowledge that:
  - I have been informed that participation is voluntary and I am free to withdraw from the project at any time without explanation or prejudice and to withdraw any unprocessed data previously supplied.
  - I have been informed that the confidentiality of the information collected will be safeguarded.
  - My educational environment, as well as I, will be referred to by pseudonym or code name in the study and any publications arising from the research.

Thank you for considering this request. If you have any further questions, please do not hesitate to contact me.

Sincerely,

Principal Investigator: Ms. Andrea Kruger

[u17015783@tuks.co.za](mailto:u17015783@tuks.co.za)

Supervisor: Mr. Jody Joubert

[jody.joubert@up.ac.za](mailto:jody.joubert@up.ac.za)

Co-supervisor: Prof. Ronel Callaghan

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## LETTER of CONSENT

### INDIVIDUAL CONSENT

#### VOLUNTARY PARTICIPATION IN THE RESEARCH PROJECT ENTITLED

##### Integrating intelligent tutoring systems for differentiated learning in inclusive classrooms

I, (Full name) \_\_\_\_\_,

(Please tick the appropriate block)

give consent

do not give consent

to participate as an individual / school in the above-mentioned study introduced and explained to me.

I also understand, as explained to me by the researcher, the aim, scope, the purpose of collecting and processing data by the researcher, and how the research will ensure confidentiality and integrity of my information.

\_\_\_\_\_  
Ms. Andrea Kruger  
Researcher

\_\_\_\_\_  
Participant

Date: \_\_\_\_\_

\_\_\_\_\_  
Mr. Jody Joubert  
Supervisor

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