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Exploring Shifts in Teaching Practice

through the use of Digital

Technology in the Mathematics

Classroom: A Qualitative Study

A thesis

submitted in fulfilment of the

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Abstract

Recent debates have highlighted the declining academic performance of New Zealand students in mathematics. This study explored the innovative use of digital technology in teaching practices to potentially enhance student performance. The aim of this study was to better understand year 7-10 mathematics teachers perceptions of the aspects that influence their use or not of digital technology.

Using a qualitative methodology, specifically Interpretative Phenomenological Analysis (IPA), the research allowed for open-ended exploration, providing narrative accounts that support teacher reflection and offer in-depth insights into their perspectives.

Discussions focused on the influences affecting digital technology use and its actual and desired roles in teaching. Professional learning and development were considered to illustrate the dynamic nature of digital approaches in mathematics classrooms and how teacher perceptions have evolved. The study identified a fluid nature in teaching practices, reflecting educators' commitment to meeting professional standards.

Literature debates the optimal use of digital technology for achieving educational outcomes, with some advocating for a one-size-fits-all student-centric approach. However, this study found that in secondary mathematics, out-of-field teaching is common, raising the profile of digital technology as a support tool, depending

on the software used. This highlighted issues such as mathematics anxiety among teachers and a lack of content knowledge. Collective efficacy emerged as a strength in schools that maximised dedicated mathematics software to enhance student outcomes. The use of a qualitative methodology like IPA has allowed for the research undertaken to be open ended, where outcomes cannot be predicted or controlled. This approach provided the narrative account to support teacher reflective capacity and equally allowed the researcher to interpret teacher perspectives and develop indepth insights.

Discussion was undertaken reflecting the influences at play, and the actual and desired role of digital technology at the time of the research. Consideration of professional learning and development helped to illustrate the dynamic nature of a digital approach within the mathematics classroom, and subsequently how teacher perception of what is desirable has changed. These factors suggested the fluid nature of teaching practice as changes were undertaken that reflect the commitment made by educators as they addressed the requisite standards of the teaching profession.

Debate exists within literature about the use of digital technology and the role played in achieving the optimal outcomes, perhaps considered, but yet to be achieved. The delivery of quality instruction is now thought of as inclusive of the use of digital technology. Theory suggests a one-size-fits-all adoption of student-centric practice will enable the transformative potential of digital technology use to be optimised. Debate exists within literature of this one-size-fits-all approach. In a secondary mathematics environment, it is not unusual for teachers to teach out-of-field, raising the profile of the use of digital technology in teaching practice, as a possible support, depending on the software. This highlighted the issue of mathematics anxiety faced by teachers and discussed within this study. Both considerations related to a lack of knowledge content by teachers within the mathematics classroom. Collective efficacy became a strength developed over time within two of the schools of this study as they maximised the potential of the dedicated mathematics software available to enhance student outcomes. The COVID-19 pandemic, occurring during the study, emphasised the impact of immersive online teaching models, adding depth to the dialogue on digital technology use.

The conclusions support the need for teacher participation in decisions regarding digital platform resourcing and usage. Collaborative decision-making between leadership and teachers can alleviate anxiety related to transforming teaching practices. Teacher resilience, identity and agency were significant in the transformative use of digital technology. The study identified multiple influences on teaching practices and teachers' choices regarding digital technology, suggesting that teachers are hybrid practitioners, employing both teacher and student-centric practices to achieve desire student outcomes.

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Table of Contents

List of Figures

List of Tables

CHAPTER ONE: INTRODUCTION

"Every teacher must . . . by regarding every imperfection in
the pupil's comprehension, not as a defect of the pupil, but as a
defect of his own instruction, endeavour to develop in himself the
ability of discovering new methods" (Tolstoy, 1967, pp. 65-66)

Exploring teacher practice

1.1 Introduction

This study explored teacher perception regarding the use of digital technology within teaching practice by teachers of years 7-10 junior secondary mathematics' students within provincial New Zealand classrooms. Within this broader exploration, the influences that impact upon teacher choice with regard to software/hardware selection and usage and the imaginative praxis undertaken by mathematics' teachers were of particular interest. Imaginative praxis is defined here as the "repackaging of non-digital cultural practices like exercises, to a digital form" (Monaghan & Trouche, 2019, p. viii). Imaginative praxis also refers to creativity and innovation, within teaching pedagogy, which are two (of many) interrelated dimensions of imaginative praxis. The use of digital technology by teachers is considered to be innovative. Actioning the innovation, taking the imaginative to the actual, within a digital environment is dependent upon mathematics teachers (Monaghan & Trouche, 2019).

It may be that explorative studies that analyse current teaching practice, could provide some insight on the movement from traditional practice, also known as teacher-centric practice, to student-centric practice given the pervasive nature of digital technology use within society and the education environment.

Additionally, the concept of the learning-centred classroom has to be introduced, given the rejection of the one-size-fits-all approach, which may not cater to individual needs. In addition, some insight is needed on the changing nature of professional learning and development needed to undertake imaginative praxis.

The background and literature review for this thesis was undertaken to critically scope the field of associated research, for comparison purposes, and to enable insight into current teaching practice. This allowed a discussion on global and local issues that have an impact upon the New Zealand education environment for example, targeted skills for future employment and identification of existing trends within mathematical achievement. The use of digital technology within teacher pedagogy, as identified by the literature, has changed the teaching and learning model to include an online teaching and learning component, reflective of an e-learning environment, with assisted teacher support for students. This has changed the pedagogy of teachers, some just for the duration of an enforced COVID lockdown, some permanently, as they adapt to a digitised teaching and learning environment, and subsequently a lessening of the traditional face-to-face interaction.

During the period of the COVID lockdown teachers had to quickly transform their teaching and learning programmes into an e-learning digital mode. This was problematic for some teachers and schools as new skills attached to software use were undertaken within an accelerative timeframe. An exploration of enablers and inhibitors given the changing nature of teacher practice with the increased use of digital technology indicative of the above circumstance and the passage of time could have relevance.

Previously, not considered by this researcher, was the school-wide e-Learning approaches used to support teachers in rural schools who experienced geographic isolation. Further to this, insight could be gained into the combined effect of geographic isolation and teaching-out-of-field (Sosa Díaz, 2021).

Teacher resilience and the interplay with teacher agency and teacher identity have been discussed given the impact of risk attached to changes in teaching practice. Significantly, as teacher practice has changed with the adoption of digital technology an exploration of the above could be considered to be timely.

The first chapter of this study is divided into five sections of: background and context, that situated NZ mathematics teaching within the international context and also provided some personal rationale for undertaking the study; research objectives and questions; significance of the research; overview of the thesis and a summary to this chapter, which have been numbered for easy identification from 1.2 to 1.6. The brief introduction undertaken above has been referred to as section 1.1. Undertaking a division of content in this way for this chapter will allow the reader to have in mind a clear overview of the nature and intent of this thesis content.

1.2 Background and context

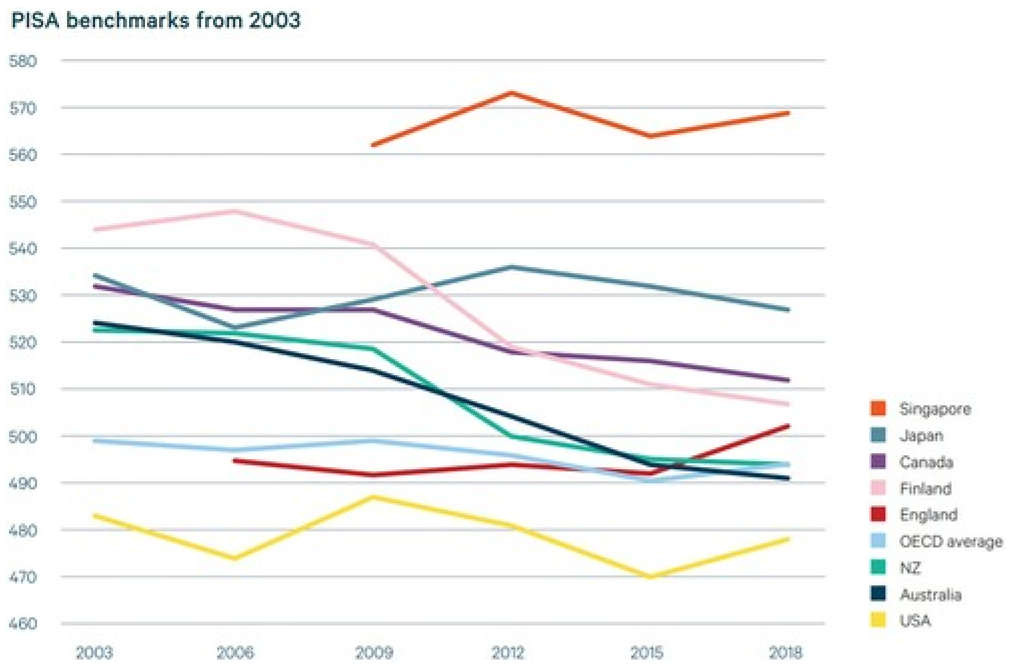
The decline in assessment results for New Zealand students by comparison to other OECD nations is a cause for concern given this decline occurs across consecutive years. It may be that a more effective adoption of the use of digital technology by teachers in mathematics might help alleviate the situation. Significant advances in technology have occurred over time which may allow the teaching and learning environment to be illustrative of these same changes. What are the influences that impact upon teachers within their mathematics classrooms that support the effective teaching profile? An overview of the NZ context is given in the background section of this thesis, followed by more detail and depth related to using digital technologies in mathematics teaching.

New Zealand is a member of the Organisation for Economic Co-operation and Development (OECD), whose membership represents 38 countries. The OECD is the parent organisation of the Programme for International Student Assessment (PISA) (Schleicher, 2019). The PISA assessment of reading, mathematics, and science ability occurs on a triennial basis, with the last assessment results available in entirety for this study reflective of 2022 (OECD, 2023a).

PISA assessments focus on the results obtained from 15-year-old students and their schools. The PISA assessment results are used to gauge existing trends on a short and long-term basis, with figure one showing the long-term trend from 2003 to 2018 (Morrow et al., 2022).

Figure 1

PISA BENCHMARKS FROM 2003-2018



Note. Mathematics achievement – Age 15-16 (Year 11). Source: Programme for International Student Assessment (PISA); (Mathematics and Statistics in Aotearoa New Zealand: (Expert Advisory Panel, 2021*)*. Online Access.

The PISA results for 2022 identified New Zealand as one of the member countries seen as operating above the OECD mean, based at 472 points for the discipline of mathematics. New Zealand results support a value of 479 points (PISA, 2022). However, since the first PISA tests undertaken in 2003, to the present time New Zealand has had a cumulative decline of 44 points, with the last assessment representative of a 16-point decline over a four-year period. Comparisons can be made against the relative stability of the OECD average, which has experienced a decline of 5 points (Morrow et al., 2022). This last assessment was the first time since 2012 that mathematics had been the focus area for PISA (PISA, 2022).

Further concern for New Zealand is the additional cumulative effect of the performance distribution of the top and bottom performers in 2018. These figures show 12% at the top two levels, representing level 5 and above, with 22% at the bottom levels. Effectively 1 in 5 students in New Zealand are low achieving (Morrow et al., 2022). The PISA results for 2022 echo the growth in low performing students at 29%, an approximate ratio of 1 in 4 students and the declining number of high performing students from 21% in 2003 to 12% in 2018 to 10% in 2022 (Gerritsen, 2023b; Schleicher, 2019). PISA assessments are structured to reflect real-life skills or applied mathematics (OECD, 2019d).

If we compare the performance of New Zealand's 15-year-olds to countries that are not echoing the trend of declining performance in mathematics, and have recorded assessment results as higher than the OECD average (Singapore, Japan, Korea, Chinese Taipei) a widening gap is confirmed (PISA, 2022). The difference in points between the highest performing country and New Zealand is now 96 points (575-479). With twenty points regarded as the equivalent of a year of learning for 15-year-olds (Gerritsen, 2023b).

Having discussed the assessment results represented by PISA attributable to 15 to 16-year-olds, we can further evaluate suspected trends with the 13-year-olds and the results obtained by the Trends in International Mathematics and Science Study (TIMSS) 2019 assessment. Out of the 64 countries that took part in the

TIMSS assessment, including the member countries of the OECD, New Zealand was ranked as one of the lowest performing OECD countries. This means that New Zealand was below the centrepoint across all participating countries. New Zealand is one of only four countries to experience a decline in achievement representing the timeframe of 2015-2019 (Mullis et al., 2020). Unlike PISA, TIMMS is a curriculum-oriented assessment, meaning that it is structured to reflect pure mathematics as opposed to applied mathematics.

This last published cycle of the TIMMS assessment confirmed a drop for New Zealand of 11 points, the largest margin since the study began in 1994. This represents a decline in average achievement to 482 points, on a scale where 500 is the midpoint. The year 9 scores represent the accumulation of teaching in years 4-8 (Gerritsen, 2020c; Mullis et al., 2020; TIMMS, 2019). The next round of TIMMS results supporting the 2023 exams is due to be released in December 2024.

Echoing this decline in achievement is the number of students leaving secondary education without a minimum qualification. Twelve percent of school leavers from 2019, representing 7,464 students, left school without a National Certificate in Educational Achievement (NCEA) qualification, out of 61,000 young people. This represents an increase of one percent from 2018 (Gerritsen, 2020d). In 2021, this figure changed to reflect 12.7%, again a slight increase (Ministry of Education, 2021a).

In 2023 the New Zealand Qualifications Authority advised pass rates for Level 1, 2, and 3 NCEA . These provisional pass rates were released in February and were as follows: Level 1 - 60%, a decrease of 4.9% from 2022; Level 2 - 72.2%, a decrease of 2.7% and Level 3 – 66.2%, a decrease of 6%. This reflects a drop in achievement for the third successive year (Nicol-Williams, 2024). The percentage of all school leavers with at least NCEA Level 1 for the period of 2017 to 2023 decreased by 6.2 percentage points (MOE, 2024b). Reflected within the NCEA requirement from 2024 is the compulsory literacy and numeracy standards which are now separated out from the Level 1-3 certificates.

With regard to the alignment of skills New Zealand is among the bottom 20-40%, confirming that the skills our youth have are not the skills valued for the labor market (OECD, 2019b). As the use of technology advances inclusive of the use of artificial intelligence, “young New Zealanders will need to continue their education to higher levels than in the past and acquire skills that are more highly valued in the labor market” (Carey, 2017, p. 3). Research has identified that rural students have an increased need for supports, with an associated impact upon lower academic aspirations (Echazarra & Radinger, 2019).

There is a strong association between educational achievement and GDP growth (Hanushek & Woessmann, 2012; May & Medina, 2023; Prinsley & Johnston, 2015; Wienk, 2017). The association between cognitive skills and economic growth suggests “that more skilled people contribute to a more rapid adoption of new technologies and production processes” (Hanushek & Woessmann, 2012,

p. 300). This suggests that schools and school policy can influence economic growth if quality education is achieved (Hanushek & Woessmann, 2012).

Suitably qualified teachers are those whose instructional capacity is often specialist in knowledge content at a secondary level, which is confirmed by the specialist qualifications gained. This is additional to undertaking the certification process necessary to teach in a New Zealand classroom (Teaching Council of Aotearoa New Zealand, 2021). Staff shortages have now become an issue within New Zealand schools and globally (McPherson et al., 2024), particularly in the field of Science, Technology, Engineering and Mathematics (STEM) (Fuentes & Bloom, 2023). The global reality is that there is a shortage of graduates within the fields of science, technology, engineering and mathematics to meet the growing demand (Fuentes & Bloom, 2023; Office of the Chief Scientist, 2014; Zhou, 2014). The long-term prognosis for graduates of STEM disciplines available for teacher training suggest the negative impact upon teacher availability within these disciplines (C D Howe Institute, 2022; Fuentes & Bloom, 2023; OECD, 2022).

Within a secondary school environment teachers who teach outside of their subject knowledge area, that is, they have no subject endorsement in the area they are teaching, are referred to as teaching out-of-field (Goos et al., 2020). Without formal qualifications, developing teacher instructional capacity to the desired and required knowledge content levels occurs over a three to five-year period (Du Plessis, 2020). An in-field teacher at a secondary school is one who has studied "a subject at a second-year tertiary level or in which the methodology of the subject has also been studied" (Weldon, 2015, p. 4). For the out-of-field teacher to teach effectively, an extended effort is then needed to develop subject knowledge to a higher level (Zhou, 2014). Instruction is hindered when schools cannot attract suitably qualified staff, an issue that affects New Zealand students (OECD, 2018a).

There is a link between teaching out-of-field and mathematics anxiety (Du Plessis et al., 2014). Mathematics anxiety also exists for those teachers who are not expected to be specialist, for example year 7 and 8 (Peker & Ertekin, 2011). The circumstance for both year 7 and 8, and year 9 and 10 relates to a lack of mathematical knowledge content (Du Plessis et al., 2014; Peker & Ertekin, 2011). It may be that teachers with insufficient knowledge content in mathematics could negatively influence their students (Peker & Ertekin, 2011). Equally as the COVID pandemic occurred anxiety across a range of circumstance resulted, affecting parents, the workplace, and as a response to digitilisation within society aggravated by the above (Chandel & Ratra, 2020; Petersen & Steiner, 2021; Pfaffinger et al., 2020).

School staff shortages reported by PISA separate schools into socio-economic groupings of advantaged and disadvantaged. Results have shown:

> In New Zealand, 50% of students enrolled in a disadvantaged school and 29% of students enrolled in an advantaged school attend a school whose principal reported that the capacity of the school to provide

> instruction is hindered at least to some extent by a lack of teaching staff (OECD, 2018a, p. 5).

PISA has also identified schools facing staffing shortages, inclusive of poorly qualified staff, these results show:

> In 2022, 44% of students in New Zealand were in schools whose principal reported that the school's capacity to provide instruction is hindered by a lack of teaching staff (and 24%, by inadequate or poorly qualified teaching staff). In 2018, the corresponding proportions were 37% and 16% (OECD, 2023a, p. 9).

Confirmation across most countries reflect a lower academic performance by students in mathematics for those principals reporting staff shortages (OECD, 2023a).

The importance placed upon having the right staff in the right place cannot be underestimated due to the links between appropriately qualified staff and increased student outcomes (Burroughs et al., 2019). Key teacher factors identified that may be associated with higher student achievement were: "teacher experience, teacher professional knowledge (measured by education and self-reported preparation to teach mathematics), and teacher provision of opportunity to learn (time on mathematics and content coverage)" (Burroughs et al., 2019, p. 14).

A school is identified as socio-economically disadvantaged in New Zealand with a low decile rating. “Socio-economic status was a strong predictor of performance in mathematics and science in all the PISA participating countries” (OECD, 2019a, p. 4). “In Aotearoa New Zealand, students from low socio-economic backgrounds had a larger drop in average mathematics achievement than more socio-economically advantaged students” (May & Medina, 2023, p. 1).

In New Zealand, participation in mathematics is further affected by the fragmentation of learning, with a high emphasis on assessment instead of curriculum content (Elley et al., 2004). The fragmentation of learning within mathematics became apparent to Universities from 2014, who have needed to repeat year 13 at entry-level, reflecting “difficult” subject areas within disciplines (Wood, 2020). The discipline areas of algebra and geometry reflect those “difficult” subject areas within mathematics (Glasse & Medina, 2022). The subject areas of algebra and geometry have been identified as areas of weakness while equally the subject areas of mathematics with statistics has been identified as an area of strength (Glasse & Medina, 2022). Current reforms seek to redress this fragmentation, with the introduction of new standards available for NCEA Level 1 from 2024 onwards, with a progressive roll out in 2026 and 2027 for Level 2 and 3 (Ministry of Education, 2019b).

Criticism of the high fail rate attached to the trialled numeracy and literacy digital assessments undertaken externally to date, have led to public outcry and criticism. Strong suggestions have been made that the new digitised assessment for numeracy and literacy be ‘decoupled’ from NCEA to allow student achievement to continue, without the shadow of a high failure rate (Gerritsen, 2023a). The requirement to pass NCEA Level 1, hinges upon the compulsory core of 20-credits, representing numeracy and literacy of 10-credits each, in addition to a 60-credit total from other disciplines to garnish the required 80-credit pass. NCEA Level 2 and 3 require 60-credits at each respective level, having obtained the compulsory core of 20-credits representative of numeracy and literacy at NCEA Level 1.

What the educative environment desires is the development of what have been described as the key competencies, among them critical thinking, logical reasoning, problem solving and decision making (Fadel, 2015; Hipkins, 2018), which are embedded within *the New Zealand Curriculum* document as the key competencies (Ministry of Education, 2007). Teaching and learning in the 21st century places student engagement as the key priority (Fadel, 2015; Hipkins, 2018). As the impact of digital technology use is reflected within student characteristics teaching pedagogy has to change to support student engagement. The characteristics of Generation Z, those born between 1995 and 2010, require the use of technology applied to their learning to facilitate student engagement as they are not passive learners (Fry & Parker, 2018; Hashim, 2018; Patall et al., 2013).

Unique to New Zealand is the *New Zealand Curriculum* document as an English medium and *Te Marautanga o Aotearoa Curriculum* document as a Māori medium (Ministry of Education, 2007, 2008). The English medium is underpinned by the key competencies, and the Māori medium is underpinned by the qualities of a graduate profile. The Māori medium is focused upon student learning shaped by family *(whānau)*, clan *(hapu*), tribe *(iwi)* and school *(kura)*. The graduate profile refers to the holistic development of the individual. "Where there is a requirement for an integration of Western and Indigenous knowledge systems, which requires respect for and an awareness of different cultures, suitably qualified, confident and knowledgeable teachers greatly affect the success of teaching STEM-related subjects" (Du Plessis, 2020, p. 1467; Le Grange, 2007). Mathematics is a STEM subject. Out-of-field teaching is acute in mathematics and is an international issue (Education Services, 2021; Zhou, 2014).

The education environment of New Zealand is now charged with delivering students skilled in critical disciplines, with the attributes identified by the key competencies listed in the *New Zealand Curriculum* document (Ministry of Education, 2007). The key competencies illustrate the skills identified as those necessary for the lifelong learner. No longer are there jobs-for-life with future forecasts predicting constant change occurring in job markets over time (OECD, 2019e). The global societal trend is indicative of lifelong learning, whereby the skills developed across a lifetime enable employment (Ansell, 2016).

Within New Zealand's desire to remain economically competitive, consideration of a skills-shortage within education has meant that immigration policies have been employed to fill this gap, not only in education but also across identified industry sectors (Immigration Department, 2019). Boosting New Zealand's low productivity rate in the field of ICT is seen as a reflection of structural reform, however the existing ICT skill shortage is attributed in part to students' poor performance in mathematics (OECD, 2022).

The building of transformative teaching practice has been given impetus with the decline in mathematical competency over time and has increased the focus on the change strategies undertaken within our mathematics classrooms (OECD, 2019a, 2023a). The innovative use of digital technology within teaching practice can be thought of as a change strategy, assisting as it does with the transition between teacher and student-centric teaching and learning. The appropriate use of digital technology may assist the development and maintenance of student motivation and engagement (Attard, 2018; Jones, 2020). However some studies report on student engagement as a by-product of technology use across all levels of education (Attard et al., 2020). It has been suggested, through research that has been undertaken, that engagement is largely dependent on the teacher's technology-related pedagogical practices (Attard, 2018). Digital technology is now thought of as an essential tool to achieve quality education (Abid et al., 2022).

With student engagement as a key priority, then the challenge to teaching practice is that it should preferably reflect strategies that enhance existing teacher pedagogy targeting the above, with the characteristics of Generation Z in mind. The desired outcome is to motivate students to learn resulting in engagement and hence achievement (Brewster & Fager, 2000; Harackiewicz et al., 2014). This becomes a reflection of the "motivate to engage" cycle, where sustained engagement necessitates motivation to learn, "because motivated students tend to engage in activities that help them to learn and achieve highly in academic settings" (Jones, 2009, p. 272). The digitised environment can be one that provides self-autonomy where students undertake material within an environment of choice and self-determination, where they feel as though they have some control over their own learning (Jones, 2009, 2020; Reeve et al., 2004). The MUSIC model of academic motivation, referred to in the findings of this study, support the five following factors that design in instruction should reflect to promote motivation: (1) empowerment, (2) usefulness, (3) success, (4) interest, and (5) caring (Jones, 2009).

Empowerment refers to students perceiving that they have some control over their learning. Useful refers to students understanding why their learning will be useful to their interests or career aspirations in the long-term, in the "real-world". With effort comes success, and students must feel that this is possible for them within their learning. The environment and how the learning is presented must promote interest from the student, they must feel that what they are learning is interesting. Students must feel that instructors care about their learning, and their success. The above factors promote academic motivation (Jones, 2009).

The opportunity to provide a greater degree of facilitation within teaching pedagogy is assisted by the use of digital technology, considered an innovative teaching practice (Drijvers, 2015; Gueudet et al., 2021). Curriculum reform taking place in France has been focused upon student autonomy and the use of digital technology, with autonomy originally seen as one of the seven competencies (reflective of the key competencies in New Zealand). The link between the use of digital technology and mathematical autonomy, or “aspects specific to mathematical content”, was considered central. The ability of digital technology to support the development of student autonomy, within this study was considered beneficial and useful (Gueudet et al., 2021, p. 1362).

Literature supports the slow nature of change undertaken within teaching practice with the adoption and innovative use of digital technology within teaching practice (Burner, 2018; Foulger et al., 2017; Harrell & Bynum, 2018). Innovative teaching practice with the use of digital technology as more than a tool (Puentedura, 2006), allows the use of technology within the teaching of mathematics to support and enhance student learning (Hamilton et al., 2016; Harrell & Bynum, 2018). Innovative use refers to the inclusion of artefacts in teaching practice or teaching with artefacts. With new approaches there is no restraint experienced by practices of the past, allowing for imaginative praxis. The movement targeted is from imaginative or innovative praxis, to applied praxis with the use of digital technology (Monaghan & Trouche, 2019).

The development of the individual encompasses skills such as thinking, collaboration, team building, and communication which is more than a focus upon knowledge transfer alone (OECD, 2009; Parsons, 2023). An analysis of 139 published studies reveals that the perceived potential of digital technology to transform the learning experience has not yet been achieved on a large scale (Bray & Tangney, 2017). The underutilisation of digital technology in a 21st century context is not isolated to individual countries like New Zealand but has been identified as a global issue (Azam et al., 2019; Graafland, 2018).

As well, there exists a relationship between a principal’s technology leadership and teacher’s technology integration within a school, one was undoubtedly driven by the other. Technology leadership is considered to represent all technology-related activities at school (Thannimalai & Raman, 2018). Management by principals in the undertaking of digitilisation within their school is considered to be complex and demanding (Håkansson Lindqvist & Pettersson, 2018). The role of school leadership is considered to be integral to the change initiative reflective of digitilisation (Barton & Dexter, 2020; Navaridas-Nalda et al., 2020; Rashid et al., 2011).

Distributed leadership is a practice that supports school and teacher resilience, as an individual the teacher has a greater sense of involvement, as a school the effectiveness of the outcome of the decision is affected (Supovitz & Tognatta, 2013). When participative decision making does not take place teacher choice and voice is impacted (Ainsworth & Oldfield, 2019; Johnson et al., 2014; Supovitz & Tognatta, 2013; Wilcox & Lawson, 2017). This then impacts upon teacher identity, resilience and agency.

The ability of a teacher to structure change to achieve success is considered an aspect of teacher resilience (Drew & Sosnowski, 2019). Some debate exists on where the responsibility lies for the development of teacher resilience. What is known is that there is a selection of risk and protective factors that impact upon teacher resilience. The understanding with teacher resilience is that there is an interdependent relationship that exists with the person and the environment.

These could be described as internal and external factors (Beltman, 2021). The table below lists these factors through the lens of personal context, which is relevant to this study where ‘rich’ text qualitative data has been gathered from the perspective of teacher perception.

Table 1

RISK AND PROTECTIVE FACTORS FOR TEACHER RESILIENCE

VARIABLE	*INDIVIDUAL*	*CONTEXTUAL*
Risk Factors		
	Negative self-beliefs and confidence	*Behaviour management*
	Reluctance to seek help	*Meeting needs of disadvantaged students*
	Conflict between personal beliefs and practices	*Heavy workloads and time required for non- teaching duties*
		Lack of resources
		Relations with students' parents
		Difficult schools or classes
Protective Factors		
	Altruistic motives	*School administrative support*
	Sense of competence and pride	*Mentor relationships*
	Strong intrinsic motivation	*Support from peers and colleagues*
	Tenacity and perseverance	*Working with the students*
	Internal locus of control	
	Proactive, problem-solviing skills	
	Self-insight and reflections	
	Professional aspirations	

Note. Reprinted from Understanding and Examining Teacher Resilience from Multiple Perspectives, by S. Beltman, 2021, Understanding Teacher Resilience, chapter 2, p. 13. Copyright 2021 by the Creative Commons Attribution International License 4.0. Open Access.

The table above illustrates risk and protective factors from a person-focused approach, given the concerns raised with personal teacher capacity and skills. It is thought that context plays a part in the development of resilience. Resilience in teachers is thought to be influenced by individual qualities in interaction with contextual influences (Beltman, 2021; Drew & Sosnowski, 2019). Resilient teachers have "resources to act upon, rather than reacting to their environment" (Biesta & Tedder, 2007; Drew & Sosnowski, 2019, p. 493). Adaptation within teaching practice is not the construct of the teacher alone, but also the nature of the conditions which teachers are expected to work within (Ainsworth & Oldfield, 2019). The lack of adequate resourcing when considering teacher stress, lowers teacher resilience and adds to teacher attrition (Sutcher et al., 2016).

In a literature review published in 2023, encompassing the timeframe between 2010 to 2021, studies reviewed have findings related to prospective and inservice teachers among others. Mathematical resilience is found to be influenced by both psychological and social/environmental factors (Xenofontos & Mouroutsou, 2023).

Further to teacher resilience is a consideration of a need for further investigation into the relationship between mathematics pedagogy and the use of digital technology (Bretscher, 2021). In addition in a review of Australasian research (2016-2019), related to the use of digital technologies in mathematics education from early childhood through to tertiary education, within the primary and secondary sector it was noted that there was a distinct lack of research attentive to the specific needs of the secondary mathematics classroom (Attard et al., 2020).

Pedagogical change with the use of digital technology has been depicted as above. The desire to gain individual teacher perception has meant that the use of IPA as a qualitative methodology would enable the 'richness' of individual perception to be revealed. A characteristic of an IPA methodology is the ability to reveal the unique nature of individual perception (Schussler, 2006).

It could be that a New Zealand context could give a greater depth of influential factors as befits an IPA approach simply because we are looking to reverse the decline of trends over time as evidenced above. This could incentivise a risk-taking approach. Additionally the role of professional learning and development for New Zealand teachers of mathematics, reflecting the New Zealand education environment may have changed with the uptake of digital technology (Dobbertin-King, 2017; Haawera et al., 2017; Ministry of Education, 2007). It may be that practicing teachers' of mathematics and their schools could have developed their own strategies given the unique vantage point practicing teachers' of mathematics have (Bansilal et al., 2018).

1.3 Research objectives and questions

The aim of this study was to better understand year 7-10 mathematics teachers perceptions of the aspects that influence whether they use digital technology when teaching mathematics. The three research questions undertaken that allowed an examination of this aim were:

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

1.4 Significance of the research

The education environment is experiencing teacher shortages specifically in the discipline of mathematics, and STEM disciplines overall. Schools are expected to comply with the education requirements of teaching core subjects, inclusive of mathematics, regardless of whether they can attract teachers with the appropriate specialist qualifications. Leadership practices are challenged with overcoming shortfalls in teacher skills, by employing strategies that can overcome inhibitors to the desired student outcomes. This is particularly relevant in mathematics, with the impact of a declining student performance combined with the shortage of appropriately qualified teachers. This study helped to reveal the strategies that schools have employed to overcome these inhibitors to student outcomes.

The total immersion in digitalisation attached to the pandemic COVID-19 and lockdown scenarios had a significant impact upon teaching practice. This was due to the adoption of a new online teaching and learning model, previously unknown. How the immersion in digitilisation, without human interface, has impacted upon teachers has research value, as subsequent teaching practice could be influenced, either positively or negatively. This study helped to clarify what has occurred and therefore how this could influence future teaching practice.

Debate exists within education on the reasons why a total adoption of student-centric practices has not occurred and significantly how the transformative potential of digital technology has not been utilised to reflect the above. The shifts in teaching practice that reflect the movement from the traditional teacher-centric to the requisite adoption of student-centric teaching practice imply that quality instruction may only reflect one approach. Learning-centred classrooms employ both teacher and student-centric practices.

Within research identification of student characteristics attached to Generation Z and subsequent generations have been identified as requiring digital interactivity as a reflection of individual identity. This study helped to identify how these characteristics influence teaching practice, if at all, from the perspective of teachers.

The *New Zealand Curriculum* document has an equal weighting attached to the teaching of knowledge content and the key competencies (Ministry of Education, 2007). This is significant to teacher practice as the document guides teacher practice, both by lesson and task design (Hanif et al., 2023). An analysis of teacher perception revealed those influences that impact upon those design choices with the uptake of digital technology within teaching practice. Teachers undertake professional dialogue and interact with their colleagues either individually or collectively, to support the development of their teaching practice inclusive of their use of digital technology. Teacher perception reflecting their understanding of what it is to be competent both as an individual and as a school may now be altered. Equally how teachers perceive the effective teaching profile, may also have changed.

Teachers undertake professional learning and development as a requirement of their professional growth cycle utilised to support their ongoing teacher registration. The use of digital technology has impacted upon professional learning and development undertaken, for teachers as current practitioners and as an indicator of changes needed for preservice teacher training. The profile of professional learning and development may have changed, which is illustrated within this study.

Within the host of influences, some of which are mentioned above, there exists the issues of resilience, both for the school and for individual teachers. As change occurs within teaching practice, risks attached to the success or failure of the prospective change have impact, both upon the school and the individual teacher. This study identified resilience practices employed by both individuals and schools when undertaking innovative responses to change.

As the use of digital technology within teaching practice becomes more pervasive the findings from this study could privilege the significance of this study as mentioned above.

1.5 Overview of thesis

The overview of this thesis is encapsulated with chapters in the following order: Introduction; Literature Review; Methodology; Findings; Discussion; Conclusions with Recommendations and Contributions to Existing Research.

The literature review chapter, including synthesizing and critically reflecting on the research literature in a review, provided an informed base of knowledge for this researcher. The scope of the literature review is divided into the sections, Mathematics Education; Models for Teaching Mathematics; Professional Learning and Development and Coping with Change. Each of these sections was deemed to be influential to the study, while also giving opportunity to compare and contrast with other contexts and situations.

Likewise, the methodology undertaken which was Interpretative Phenomenological Analysis (IPA) is reliant on individual perception, in this case the teachers taking part in this study. The scope of the methodology is divided into sections of the key theoretical perspectives that underpin the methodology undertaken, that is Interpretative Phenomenological Analysis (IPA); a discussion of the best methods used to generate data to address the research questions;

the participants and their context; the process of analysis and the ethical practices undertaken.

Thereafter are the findings chapters, where the research questions are discussed in order as mentioned in section 1.3. The discussion chapter mirrors the findings chapter in order of the first to third questions. Teacher perception provided the findings chapter content, which was dialogic in nature. Questions posed were undertaken through semi-structured interviews. This approach allowed consistent questions to be asked across all participants but allowed conversation that occurred to develop naturally, without being curtailed by the questions asked. Open conversations became very revealing. Findings were then analysed and reported upon with an adherence to identifiable main themes within the data. The discussion chapter synthesized and discussed the findings chapters and linked them to the existing literature identified in the literature review. After this comes my conclusion chapter, the final chapter, which follows the order established in our findings and discussion chapters, targeting question one, two and three. It also outlines the research's contributions to the field; it's implications for practice, institutions and policy; limitations and suggestions for future research.

This researcher intends to show that the presentation of chapters in this format will allow ease of reflective thought around what is revealed or considered interesting for any reader of this study.

1.6 Summary

The use of digital technology by mathematics teachers may assist in influencing the delivery of quality instruction and subsequently promoting student outcomes. The role of PLD related to the use of digital technology in effective teacher practice assumes importance as a support to changing existing teacher practice (Goos et al., 2020; Rajaram, 2021). The student characteristics of Generation Z reveal the impact of digital technology as a way of life as, in general, they have been immersed with it from birth (Hashim, 2018). This equally applies to previous and subsequent generations as the pervasive nature of the adoption of technology within society continues. The impact of student characteristics upon the delivery of quality instruction, combined with, what quality instruction now looks like with the adoption of digital technology, for the teachers of this study, could provide insight within a New Zealand context.

Teacher perceptions that allow changes to existing practice are dependent upon the reflective capacity of the individual teacher concerned and their desire to improve upon existing student outcomes (Education Review Office, 2012). Teacher identity can be damaged when change to existing practice is undertaken if it is not successful, which is a consideration of the perception of risk (Day, 2018b; Le Fevre, 2014). Teacher resilience is thought to influence the potential of the individual teacher and their capacity to undertake change with the use of digital technology (Handayani & Sulastri, 2022).

As this study is situated within classrooms located in the provinces and embraced practicing mathematics teacher participants, a unique perspective could be gained from the rich text data gathered, which could add to existing literature held to further inform the New Zealand educative environment. This could occur particularly in consideration of the following four areas of interest: Digital technologies may change the potential ways to engage with mathematics; changes in pedagogy may be associated with this; issues with recruitment in provincial cities are compounded by the lack of specialised mathematics teachers resulting in teachers teaching out-of-field highlighting the changing nature of professional learning and development; and, the potential that digital technology may have to support and assist teachers to improve their delivery of the learning process. These factors support the literature review undertaken below.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Teaching practice has an effect on student academic achievement and student outcomes, hence the desire by the education environment to better align teaching practice to the trends identified by society (Burner, 2018). The New Zealand Governments transition from a focus on agriculture to the creative industries sector for the promotion of long-term growth strategies supports innovative technologies. The growth of this sector is dependent upon the STEM disciplines (Frommherz & Narayantoroa 2022; Hanushek & Woessmann, 2012). Mathematics serves as a foundational discipline within STEM fields, and is considered as being closely tied to technological innovation. Teachers are required to adopt progressive pedagogical approaches to equip students for the skills needed for the future. This literature review explores various strategies for adapting teaching methods to support this change, with a focus on the use of digital technology. Teacher resilience is impacted by change. Understanding teacher resilience is necessary to support successful outcomes for both teachers and students, as schools embrace change initiatives guided by government directives.

The research undertaken within this literature review supports the applicability of digital technology use within the mathematics classroom (Calder et al., 2021; Calder & Murphy, 2018; Sailor et al., 2021). However, it could be that there is some debate on what quality instruction looks like, with a one-size-fits-all approach considered to be unable to cater for individual need. This could be due to the constraints placed upon teachers by the realities of their classrooms, inclusive of assessment regimes, and their belief about what effective pedagogy looks like (Bremner, 2019; O'Sullivan, 2004).

Within teaching pedagogy teachers are expected to exploit design features attached to the digital technology available to them. This includes the use of small apps through to the use of subscription-based packages. Some consideration must be given then on the way this impacts upon the professional learning and development undertaken. Some consideration must also be given to teacher choice and voice as the targeted outcomes sought, require delivery by teaching staff.

The aim of this study was to better understand year 7-10 mathematics teachers' perceptions of the aspects that influence whether they use digital technology when teaching mathematics. The three research questions undertaken that allowed an examination of this aim were:

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

This literature review will provide an overview of the various influences that teachers may encounter and how these influences can affect their teaching methods. It may also identify gaps in the research literature related to the aim of this thesis. Chapter one identified the significance of the research undertaken and listed the following factors which were: digital technologies may change the potential ways to engage with mathematics; changes in pedagogy may be associated with this; issues with recruitment in provincial cities are compounded by a lack of specialised mathematics teachers, with may mathematics teachers teaching outside of their primary field; and the potential that digital technology may have to support and assist teachers to improve their delivery of the learning process.

This literature review is divided into four sections of Mathematics Education; Models for Teaching Mathematics; Professional Learning and Development and, Coping with Change. The first section, Mathematics Education, has been split into four subsections numbered from 2.2 to 2.5. These four subsections consider creative pedagogy, different pedagogical models, and change strategies within mathematics education.

Mathematics Education - Section One

2.2 Teaching and learning of mathematics with digital technologies

One of the suggested initiatives identified by education research for the improvement of student achievement and engagement is the effective use of digital technology within the teaching and learning environment (Bolstad et al., 2012). This section of this literature review will address the innovative use of digital technologies within teaching pedagogy and the need for further studies to take place. The accelerative pace of technological developments in mathematics education raises many questions, among these questions and of interest to this research project is, what are the main purposes of using digital technologies in mathematics education? How does the use of digital technology impact upon the role of the teacher and the educational context? How does teaching pedagogy exploit the design of the digital tool in use?

In a study undertaken (Drijvers, 2015), the three critical factors identified across six case studies were, the design, the role of the teacher and the educational context. Design included the design of the activities, the design of the digital technology tool itself, and the design of the lessons. The role included the role of the teacher when orchestrating the learning within a technology-rich environment, the integration of the technology to other mathematical activities, and identifying tool techniques. The educational context includes teacher pedagogy, assessment, student motivation and engagement, and the out-of-school settings. The focus for this study was on what the six cases from leading studies described as decisive success factors with the incorporation of digital technology to existing teacher practice. The limitations of this study were the size of the study, being small in nature. As part of this study the guides to digital technology integration within existing teaching practice include the use of the instrumental orchestration model, and the TPACK model. Both of these models are discussed within section two of this literature review. In consideration of digital technology use it could be that assuming a new digital tool may force change on existing teacher pedagogy, given the design of the tool, for example *Facebook*, with suggested approaches discussed in section two, under the instrumental orchestration model.

It is how digital technology is used that supports changes in teaching pedagogy and the desired student outcomes. In a summary of a meta-analytical study undertaken (Hillmayr et al., 2020), conducted with a secondary school focus from 2000 to 2018, across three databases, *WebofScience*, *Scopus and ERIC*, from ninety two studies, ninety one articles were analysed across the disciplines of science and mathematics. The positive impact of digital technology use on the student learning undertaken was confirmed. Additionally the impact of teacher training with the use of digital technology was found to be positive. Further analysis of these studies suggest that a variety of other instructional methods in addition to the use of digital technology as opposed to substitution by digital technology enhanced student outcomes. Limitations to these studies presented in the form of bias as consideration could not be given to unpublished studies, gray literature, thesis, and those studies that report on statistically nonsignificant outcomes. It was felt that further studies were needed to obtain different forms of feedback from study participants. What is supported by this study is that the use of digital technology is enhanced by other instructional methods, which suggests a combining of teacher and student-centric approaches, as indicated by the instrumental orchestration method, mentioned in section two. It may be that the blended learning environment where face-to-face instruction can occur, with an online component could be the targeted ideal outcome.

In a meta-analysis and second-order meta-analysis study undertaken (Sailor et al., 2024) within a higher education setting (k-12), findings confirmed that when non-digital technology instruction was substituted with digital technology instruction, there was no change in student cognitive outcomes. The substitution, augmentation, modification, redefinition, (SAMR) model was utilised as the gauge for technology use in conjunction with the student observation tool, known as the interactive, constructive, active and passive (ICAP) tool. The significance of this study supports that it is how digital technology is used that promotes student cognitive understanding. In addition, features of the digital technology tool that provide sequencing, feedback and scaffolding can foster student learning. This meta-analysis was undertaken across the timeframe of 2004 to 2023, inclusive of 28 studies. The second-order meta-analysis was undertaken from 2011 to 2023, with 60 meta-analyses included. Limitations to this study suggest that there could be a bias from the incorporation of poor quality studies, a skewing due to the effect size (ES) of large to small studies and the varying level of detail provided given the student observation feedback reported, among others. This could suggest that pedagogy is enhanced with the features of the digital tool, as long as the teacher has expertise with the tool in question.

In a second-order meta-analysis undertaken by (Young, 2017), spanning a thirty-year interval from 1985 to 2015, conclusions drawn support that; the didactical functionality of the digital technology in use or the way it is designed and how it is used within the mathematics classroom is important; there is a moderate cumulative effect of technology-enhanced instruction on mathematics achievement, and lastly that meta-analytic research methods matter due to their quantitative focus. Twenty three meta-analyses were identified from ERIC, PsycINFO, ProQuest Dissertations and Theses Full-text, and Academic Search Complete. The limitations to this study were that metacognitive, affective and motivational outcomes were not measured in this study. This suggests that the participant feedback tool may need to be uniform to allow greater understanding gained from studies undertaken, for example the ICAP tool. Additionally teachers are modelling personal skills in addition to teaching knowledge content, with both needing to be developed. This also suggests that pedagogical expertise and expertise with the digital technology in question are both needed for teaching practice to advantage student outcomes.

In a meta-study undertaken incorporating the six-years from 2017-2023, (Drijvers & Sinclair, 2024) and searching the SCOPUS database, 299 studies were analysed. Findings from this study support that there is an increasing overlap between the use of digital technology and the teaching and learning undertaken in mathematics. A limitation of this study is that only papers written in English were analysed. This meta-analysis suggested that not only are the digital technologies in use being studied but also how the digital technologies in use are studied as they relate to teaching practices, to assessment, to the affective domain and to equity within a teaching and learning environment. This suggests that for teachers to remain current in their teaching practice, this will necessitate keeping abreast of developments in research and digital technology, for example; new tools and design features.

Further revelations confirmed by literature have found that teachers will only change their pedagogical approach if advantages to student outcomes can be achieved (Attard, 2012; Hegedus et al., 2016). The dialogue above positions this study and provides focus within this study for the inclusion of the use of digital technology in mathematics. This can be referred to as imaginative praxis. The definition of imaginative praxis means the “repackaging of non-digital cultural practices like exercises, to a digital form” (Monaghan & Trouche, 2019, p. viii). The pedagogical approach undertaken with the inclusion of imaginative praxis can be grouped in the order of teacher-centric, student-centric and models of teacher practice (Drijvers & Sinclair, 2024). One of the models of teacher practice discussed in section 2.3 of this literature review is the learning-centred approach (Bremner, 2019), where both teacher and student-centric approaches are utilised subject to classroom influences.

Imaginative praxis allows for new approaches and activities to be developed to augment existing mathematical activities. As advances in technology continue so can the inspiration of lesson design as new technological tools inspire new approaches to teaching and learning. An example here could be the use of chrome devices and iPads. These may be thought of as catering for personalised learning, whether by mobility (anywhere, anytime) or by changing contexts (shaping experiences to meet specific needs) or by peer interaction (Willacy et al., 2017). The reflection here is on tools that exploit high band-width connectivity and enable learner interaction.

Social interaction can also be enhanced by the use of digital pedagogical media. A study undertaken within America (Hegedus & Otálora, 2023), investigated the development of geometric reasoning in six year-9/10's who undertook nine activities. The use of a *multi-touch Dynamic Geometry Environment* with the iPad as the device enabled social interaction, by design, resulting in "collaborative behaviors and socially mediated metacognitive processes" (Hegedus & Otálora, 2023, p. 289). The limitations of this study suggest the small size of this participant group indicative of qualitative approaches. If we consider the *New Zealand Curriculum* document teachers need to know and demonstrate among other skills "relating to others" and "participating and contributing" (Ministry of Education, 2007, p. 12).

Equally the employment of a WiiGraph, in a study undertaken in England, with four 11-year-old children, allowed the attainment of understanding of the concept of abstraction, within an early understanding of algebra (Nemirovsky et al., 2020). Again given the qualitative approach limitations reflective of participant size apply.

Further studies, based in America, with nine undergraduate participants from within the university, across differing fields of study, undertook virtual reality activities. These studies enabled the movement from 2D to 3D, targeting geometric understanding, with positive outcomes perceived as being greater than traditional approaches (Dimmel et al., 2021). The limitations of this study, reflect the small participant size given the qualitative approach. The findings for the above two studies support the role that digital technology can play in advancing the teaching and learning undertaken.

Within an Ocean Education project, the use of creative pedagogy and digital technologies using augmented and virtual realities was undertaken (Chappell & Hetherington, 2023). This was applied to a science, technology, engineering, art, and mathematics (STEAM) context, meaning transdisciplinary. This STEAM or STEM approach is discussed in greater depth in subsection 2.10.

The aim of this qualitative study was to develop students' ocean literacy through the combined educative principles of creative pedagogies and digital technologies (virtual and augmented). The groups targeted represented the upper primary and lower secondary schools, with six groups of 4-5 students each. Digital technology was by design used to support pupil learning with: model-based inquiry and data-driven learning; visual and/or augmented realities, and communication technologies. One of the outcomes of this study, designed to be playful and immersive, was an understanding that the natural, cultural and technological worlds experienced by the children in this project provided grounds for creativity and learning.

Creative pedagogies bring student agency to the fore and empower students to work individually and collaboratively (Chappell & Hetherington, 2023). The features of creative pedagogy are identified as: “generating and exploring ideas; encouraging autonomy and agency; playfulness; problem-solving; risk-taking; co-constructing and collaborating; and teacher creativity” (Cremin & Chappell, 2021, p. 299). These features were identified within a literature review detailing creative pedagogy, ranging from 1990 to 2018, inclusive of 35 papers. The four databases that were sourced were the British Educational Index (BEI), Educational Resources Information Centre (ERIC), Education Research Complete and ProQuest. However, the understanding gained was that the link between student creativity and creative pedagogy was inconclusive (Cremin & Chappell, 2021).

Several key factors have been identified that influence teachers’ creative pedagogy. In a systematic literature review, utilising the two databases *Scopus* and *Web of Science*, research was undertaken on the factors that influence teachers’ creative pedagogy. The following three factors were identified; demographic, individual and organisational (Pazin et al., 2021). Two key features identified were self-efficacy and environmental support, meaning self-belief and the resourcing that is provided by the organisation (Angeli & Valanides, 2018; Holden & Rada, 2011; Li et al., 2015; Moreira-Fontán et al., 2019; Tondeur et al., 2017). This suggests the creative potential of teacher pedagogy can be enhanced by resourcing, but also that teachers may have to believe in the benefits of using digital technology to want to change existing teaching practice.

Creative pedagogy is the teaching and learning beyond chalk and talk (Ministry of Education, 2007; Pazin et al., 2021). Creative pedagogy includes the use of digital technology, regarded as fundamental to teaching creatively (Bereczkia & Kárpátib, 2018; Tang et al., 2022). Within education new products including artificial intelligence, cloud, and big data technologies support the diverse nature of the software, platforms, and devices available to promote teaching creatively. What is considered worthy of further investigation is the appropriate implementation of scaffolding strategies undertaken by teachers for different kinds of digital technologies to achieve the desired student outcomes, which in this study, was student creativity (Tang et al., 2022). The results of this study were based upon 61 articles indexed by the Social Sciences Citation Index (SSCI). The incorporation of scaffolding within teaching practice is part of standard teaching practice, with or without digital technology tools.

Social media platforms have been found to support the teaching and learning environment. Teaching and learning interventions driven by *Facebook*, undertaken with grade 9 mathematics students, confirmed that these interventions assisted academic performance positively (Anggoro & Rueangrong, 2021). This study was based in the Philippines and included 120 participants. These participants were distance learners. The limitation here is that all participants were from the same school and the study occurred over a two-month timeframe.

The role of social media, then supports the blended learning approach, with face-to-face and online instruction allowing for differing instructional methods of lecture, discussion group, and self-paced activity (Brown, 2017; Goos et al., 2020; Joubert et al., 2020; Pham et al., 2020). Within the COVID lockdown situation, the online teaching and learning model with the digitilisation of communication through social media proved an effective educational platform for some (Insorio & Olivarez, 2021; Pham et al., 2020).

These studies relate to student outcomes, and the need to enhance existing teacher pedagogy with the use of digital technology seen as a means to employ innovation. Improved student outcomes imply enhanced student cognitive processing. Debate must then take place on why the use of digital technology can advantage cognitive processing. This is explored below with a discussion on the cognitive theory of multimedia learning.

With the use of digital technology within a mathematics classroom, cognitive processing analysis confirms that cognition is advantaged by using multimedia learning materials (Mayer, 2005a; Mayer & Moreno, 2002). The cognitive theory of multimedia learning (CTML) has been split into: "limited capacity, dual-channel, and active processing" (Atkinson, 2005, p. 404). These three factors help to maximise the use of working memory. Limited capacity identifies that disparate or non-integrated information is detrimental to working memory and hence learning. Integrated formats as evidenced by digital technology, facilitate learning by assisting with the management of cognitive load. The dual channel refers to the presentation of information simultaneously in visual and aural form. The assertion being that "people learn more deeply from words and pictures, then from words alone" (Mayer, 2005a, p. 31). "Working memory capacity is optimised under dual-mode" (Atkinson, 2005, p. 404). Active processing allows for the incorporation of signals like flashing or highlighting, guiding learners to make sense of the material in front of them (Atkinson, 2005). The theory of CTML supports the use of digital technology within the mathematics classroom as it enables an ease of learning, targeting working memory capacity, and confirms the advantages to student engagement if used in an innovative way, indicative of effective pedagogy.

Generation Z and beyond learn differently, given their immersion in digital technology from birth (Hashim, 2018). The changing nature of learning for Generation Z and beyond supports the need to further investigate changes to existing teaching pedagogy. Increased student engagement with the use of digital technology reflecting the above assists the changes that could take place within teaching pedagogy, promoting innovative practice. The hope is that increased student engagement will result in improved student achievement. This theory supports the advantages attached to digital technology use and increases the emphasis placed upon the effective teacher profile with the use of digital technology (PPTA, 2019).

The availability of technology increases the complexity of teaching practice which challenges the stability of traditional teaching practice (Drijvers et al., 2010; Lagrange & Monaghan, 2009; Robert & Rogalski, 2005). Given the immersive nature of digital technology reflecting societal trends, this could suggest that younger teachers are more accomplished with their use of digital technology simply as a reflection of the above. When evaluating teachers, a bias can exist where those teachers without a childhood spent immersed in technology are considered not as expert with the use of digital technology as early career teachers who have experienced this immersion (Orlando & Attard, 2016; Prensky, 2001). The illustration of this is in the individual teacher's teaching practice.

The teachers who have been using digital technology in childhood are referred to as "digital natives" as opposed to their counterparts who are referred to as "digital immigrants" (Buentello-Montoya et al., 2021; Prensky, 2001, p. 1). It is a myth to suggest that early career teachers (digital natives) are "expert" in a teaching sense with their familiarity with technology use. Within teaching, pedagogy comes first, and technology comes second (Orlando & Attard, 2016). "Teaching with technology is different from using technology" (Orlando & Attard, 2016, p. 119). It is the experienced teacher of mathematics who, having developed digital competency, can then use pedagogy to advantage student achievement (Attard, 2018). "Without a deep knowledge of pedagogy, the possibilities are limited" (Orlando & Attard, 2016, p. 119). "It is the pedagogical relationships that inform the use of technology, the pedagogical repertoires that embed technology and the way that technology is embedded in teaching and learning" that reflect the 'how' of teaching (Attard, 2018, p. 54).

If pedagogical change is to take place with the use of digital technology as more than a tool, then discussing the different pedagogical theories to clarify understanding and illustrate approaches adopted in the mathematics classroom assists in placing the dialogue above. This is undertaken in the following section, pedagogical practice.

2.3 Pedagogical practice

An opportunity exists in teacher pedagogy for innovative practices that would support an effective teaching and learning environment. One of these innovative practices is the use of digital technology as more than a tool (Abid et al., 2022; Puentedura, 2006), meaning the use of technology in the context of teaching mathematics, supporting and enhancing student learning (Hamilton et al., 2016). Previously, in section one, I have referred to imaginative praxis as a component part of innovative practices.

Generation Z and beyond have been immersed in digital technology from birth (Hashim, 2018) resulting in students who are “digital natives” with the consequent impact upon changes in student knowledge construction, where “they think and process information, fundamentally differently” (Gu et al., 2013; Prensky, 2001, p. 1). This was previously referred to in section 2.2. Supporting and enhancing student learning is part of the practice of building innovative, constructive classrooms, where pedagogy comes first, and the use of technology in the digital age enhances this process (Hamilton et al., 2016).

Pedagogy can be thought of as the science of teaching. Further elaboration could also define pedagogy as “the performance of teaching, the theories, beliefs, policies and controversies that underlay, influence and explain teaching” (Shah, 2021a, p. 10). However a more modern definition could be as an “applied science,” that is, as a discipline geared towards the practical application of acquired knowledge” (Shah, 2021a, p. 15) .

We can then refer to the two models of pedagogy, the pedagogy of teacher-centred teaching and the pedagogy of learner-centred teaching, or teacher-centric and student-centric teaching approaches. Teacher-centric models are based upon the behaviourist theory, where instruction is formal, and the teacher controls the lesson content and how the lesson is taught (Kaymakamoğlu & Küçük, 2018). The advantage to this approach is that it can work well for large classes, with few resources, where facilities can be limited. An example here would be a developing country. Of interest here is China, who perform well in international assessments, and are taught in large, formal classes (Shah, 2021a). The use of digital technology can be appropriate to either a teacher or student-centric model, meaning formal or informal approaches (Adam, 2014).

Student-centric models include the constructivist, collaborative, inquiry-based, reflective, problem-solving or integrative teaching practices. These models are examples of activity-based learning, where there is significant student involvement in the learning process to varying degrees, giving students more control over their learning (Kaymakamoğlu & Küçük, 2018). These approaches are based upon the social constructivist learning theory or constructivist theory. These approaches allow for the use of concrete props, visual aids, and relevant examples. The use of digital technology can easily be assumed within these approaches (Barber, 2021). It is the skill of the teacher that supports the use of digital technology to the advantage of student engagement. It would be poor pedagogical practice that would assume that the use of a device alone, without teacher input, would assist in student engagement (Attard, 2018).

A third theory can be entertained and is referred to as learning-centred, as opposed to a learner-centred approach. This model encourages teachers to use the methods which best support students' learning within the realities of their classrooms (Bremner, 2019; O'Sullivan, 2004). This allows for teacher experience, resourcing, facilities, culture, and learner background.

The learning-centred approach has allowed a wider evaluation of teaching practice. It may be that teachers understand the complexities of their classroom and school and seek to be "hybrid practitioners," meaning a "teacher who was able to decide, in a principled way, which activities to use in a given situation" (Bremner, 2019, p. 62).

In addition to the above, consideration can be given to the belief systems of individual teachers as teachers' belief systems can influence their teaching pedagogy. Teacher beliefs are described as being "developed on the basis of personal experiences; experiences with schooling and instruction; and experience with formal knowledge" (Shah, 2021b, p. 3890).

Individual teacher belief systems described above, do not assume priority over other influences, for example, resourcing or professional learning and development. The discussion below allows for consideration of the impact belief systems may have on pedagogy. This is illustrated by the ten points of evaluation showing a comparison between teacher-centred and student-centred approaches adopted depicted below in Table 2 (Kaymakamoğlu & Küçük, 2018). The adoption of a learning-centred practice within teacher pedagogy moves beyond the one-size-fits-all approach (Bremner, 2019), incorporating both aspects of Table 2.

Table 2

TRADITIONAL AND EXPERIMENTAL MODELS OF EDUCATION; A COMPARISON

DIMENSION	TRADITIONAL MODEL: BEHAVIOURISM	EXPERIENTIAL MODEL: CONSTRUCTIVISM
View of Learning	Transmission of knowledge	Transformation of knowledge
Power Relation	Emphasis on teacher's authority	Teacher as "learner among learners"
Teacher's Role	Providing mainly frontal instruction; professionalism as individual autonomy	Facilitating learning (largely in small groups); collaborative professionalism
Learner's Role	Relatively passive recipient of information; mainly individual work	Active participation, largely in collaborative small groups
View of Knowledge	Presented as "certain" application problem-solving	Construction of personal knowledge; identification of problems
View of Curriculum	Static; hierarchical grading of subject matter, predefined content and product	Dynamic; looser organisation of subject matter, including open parts of integration
Learning Experiences	Knowledge of facts, concepts, and skills; focus on content and product	Emphasis on process; learning skills, self-inquiry, social and communication skills
Control of Process	Mainly teacher-structured learning	Emphasis on learner, self-directed learning
Motivation	Mainly extrinsic	Mainly intrinsic
Evaluation	Product-oriented; achievement testing; criterion-referencing (and norm-referencing)	Process-oriented; reflection on process, self-assessment, criterion-referencing.

Note. Reprinted from Teachers' Beliefs, Perceived Practice and Actual Classroom Practice in Relation to Traditional (teacher-centred) and Constructivist (learner-centred) Teaching (Note 1) by S. E. Kaymakamoğlu, and F. Küçük, 2018, *Journal of*

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The comparison of pedagogical approach could be described as polarising, with traditional teacher-centric practice at one end, (Adam, 2014; Buchan et al., 2020) and student-centric practice at the other, with student-centric the desired pedagogical style (Barber, 2021; Rajaram, 2021; Saad, 2020; Yang & Tan, 2019). The motivation behind pedagogical change being the concept of the provision of quality education. The use of technology within teaching practice becomes a reflection of teacher beliefs about effective ways of teaching (Chappell & Hetherington, 2023; Horn, 2015; Kim et al., 2013)

The view of learning in a traditional model looks at the transmission of knowledge, or information that is communicated, with the teacher having the knowledge and the student the recipient of knowledge. In the experiential model knowledge transformation takes place, or learning by doing, assisted by teacher facilitation. Experiential models are collaborative, with traditional models targeting the individual. The experiential model has component parts of experiencing, reflecting, thinking and acting (Lehane, 2021). This occurs in a cycle of concrete experience, reflective observation, abstract conceptualisation and active experimentation. The learner's role is active in the experiential model and passive in the traditional model, as evidenced by table 2 above.

However, the situation is complex in practice. A teacher may espouse belief in student-centric practices but adopt teacher-centric instruction given the contextual factors of time and pressure. It is sometimes quicker to deliver rather than construct knowledge content. “Lecture-based activities become an expedient means of covering textbook content” (Liu, 2011).

A study was undertaken in Taiwan in 2011 involving 1,139 Taiwanese teachers. The Taiwanese government had targeted, prior to 2011, across the last two decades technological environments in educational settings. Findings from this study found that, “when teachers believe that constructivist teaching with technology will not enhance student achievement, they implemented lecture-based teaching based on their primary concern for test scores” (Liu, 2011, p. 1020). Whatever the teaching approach, “academic achievement remains the principal focus of teachers” (Liu, 2011, p. 1020). This suggests that for the pedagogical emphasis to change, it may be that assessment criteria must also change.

A critical synthesis of research on technology-related classroom practice was undertaken which focused on Australasian research. The timeframe for the critical synthesis was from 2016 through to 2019. The study encompassed research from primary through to tertiary education. This synthesis identified and provided evidence confirming that the teacher remained in control of how technology was used. This synthesis targeted the areas of subject, classroom, and task (Attard et al., 2020).

In 2018, a small qualitative study was undertaken in a Turkish state secondary school. This study involved ten experienced, practicing secondary teachers, of

English as a foreign language (EFL). The instruments for data gathering were semi-structured interviews and observation undertaken within their classrooms. The observational data undertaken, showed that traditional practice was more frequent than constructivist practice (Kaymakamoğlu & Küçük, 2018).

Teacher effectiveness is the focus of most teaching environments, given the positive impact on student engagement and student achievement. The effective teaching profile which includes the combined characteristics of personal qualities, mathematics knowledge, cultural awareness, and teaching approaches (single, integrated), is enhanced, with a commitment within a teacher's professional capacity to innovation with the use of digital technology (PPTA, 2019-2022; Teaching Council of Aotearoa New Zealand, 2021).

The increased utilisation of digital platforms utilised in assessment is evidenced within the New Zealand education environment, by the Common Assessment Activities (CAA) of numeracy and literacy within the NCEA exams. Assessment conditions and the way assessments are undertaken, assume significance as they may support student outcomes. Digital technology is now utilised to enhance existing assessment environments. Assessment when undertaken, "should be in line with the students' activities with technology; not doing so would suggest that in the end, the use of digital technology is not important" (Drijvers, 2015, p. 148).

Descriptors attached to achieving a positive relationship between teacher quality and student success are "enthusiasm, creativity, flexibility and adaptability"

(Duta et al., 2015; Mackey et al., 2015). Many examples exist of the required personal qualities that support an effective teacher. Examples are being: expert, kind, calm, understanding, flexible, adaptive, empathic, sensitive, balanced, self-controlled, prestigious, objective, sociable, accessible, active, organised, informed, able to listen, speak, and explain (Koutrouba, 2012). There is no single factor alone that indicates to us what an effective teacher looks like (Evertson et al., 1980), but the thinking in some educative circles is that school reform is dependent on highly-skilled teachers (Darling-Hammond, 2009).

The effective teacher profile publicly supported and endorsed within the New Zealand education system is inclusive of our obligation to the Treaty of Waitangi. Reflected here is the combined inclusion of socio-cultural knowledge and academic content (Rata, 2020). As an illustration of the effective teaching profile and cultural identity, New Zealand undertook a research programme in 2004 which involved 12 mainstream schools across 422 teachers called the Te Kotahitanga Professional Development Programme (Ministry of Education, 2020b). This programme targeted the relationship between teacher and student, emphasising a non-deficit view of Māori students, where teachers could make a difference for these students (Bishop & Berryman, 2009). The role cultural identity plays in student achievement is acknowledged and, accordingly, the skills developed within teaching practice supportive of cultural identity. Cultural awareness sits within a framework of effective practices applied by the teacher, indicative of the nature of pedagogical awareness, which addresses more than a siloed delivery of knowledge content alone.

In consideration of the effective teaching profile and the mathematics classroom the following ten points have been listed in Table 3 as component parts for effective teaching within the mathematics classroom:

Table 3

A SUMMARY OF EFFECTIVE MATHEMATICS TEACHING

FACTOR	EXPLANATION
“An ethic of care	Caring classroom communities that are focused on mathematical goals help develop students’ mathematical identities and proficiencies” (Anthony & Walshaw, 2009, p. 7).
“Arranging for learning	Effective teachers provide students with opportunities to work both independently and collaboratively to make sense of ideas” (Anthony & Walshaw, 2009, p. 9).
“Building on students’ thinking	Effective teachers plan mathematics learning experiences that enable students to build on their existing proficiencies, interests, and experiences” (Anthony & Walshaw, 2009, p. 11).
“Worthwhile mathematical tasks	Effective teachers understand that the tasks and examples they select influence how students come to view, develop, use, and make sense of mathematics” (Anthony & Walshaw, 2009, p. 13).
“Making connections	Effective teachers support students in creating connections between different ways of solving problems, between mathematical representations and topics, and between mathematics and everyday experiences” (Anthony & Walshaw, 2009, p. 15).
“Assessment for learning	Effective teachers use a range of assessment practices to make students’ thinking visible and to support students’ learning” (Anthony & Walshaw, 2009, p. 17).

"Mathematical communication	Effective teachers are able to facilitate classroom dialogue that is focused on mathematical argumentation" (Anthony & Walshaw, 2009, p. 19).
"Mathematical language	Effective teachers shape mathematical language by modelling appropriate terms and communicating their meaning in ways that students understand" (Anthony & Walshaw, 2009, p. 21).
"Tools and representations	Effective teachers carefully select tools and representations to provide support for students' thinking" (Anthony & Walshaw, 2009, p. 23).
"Teaching knowledge	Effective teachers develop and use sound knowledge as a basis for initiating learning and responding to the mathematical needs of all their students" (Anthony & Walshaw, 2009, p. 25).

Note. Adapted from "Effective Mathematics Teaching" by G. Anthony, and M. Walshaw, 2009, *International Bureau of Education (IBE)*. UNESCO. Copyright 2009 by Gonnet Imprimeur. Reprinted with permission.

The depiction within Table 3 places a spotlight upon professional capacity within teaching practice, as mathematics teachers seek to provide quality instruction. For the mathematics classroom teacher, the profile is then one of a professional practitioner who is multi-skilled and multi-literate.

Table 4, listed below identifies some points raised in consideration of the effective teaching profile undertaken in the discussion above. This table is not an exhaustive list but hopes to summarise for evaluation a summary profile of the effective mathematics teacher profile.

Table 4

A SUMMARY OF THE EFFECTIVE TEACHER PROFILE

QUALITIES	DESCRIPTION OF QUALITIES
Personal Qualities	Enthusiasm, creativity, adaptability, flexibility (to name a few of the personal qualities)
Commitment to the Treaty of Waitangi	Socio-cultural knowledge
Mathematical Content Knowledge	Knowledge content on each discrete section of mathematics, for example, algebra, geometry, numeracy, statistics, calculus, measurement, probability
Pedagogy	Having qualified, having trained as a teacher (knowing your craft) Teacher-centric to student-centric shifts
Digital Technology Skills	ICT literacy, knowledgeable with software packages and hardware devices applicable to the teaching of mathematics and teaching
Curriculum and Task Design	Integrated or single task discipline delivery

Note. Data summarised by the author on the qualities and description of the effective mathematics teacher profile October 2024.

Mathematical knowledge content is a requirement of an effective mathematics teacher. The unfortunate reality is that there is a global shortage of suitably qualified mathematics teachers (Sutcher et al., 2016), and for some there is an identification of an aging workforce with a supply of teachers in the specialist field of mathematics that is not likely to increase over the next 10 years (Weldon, 2015). The position in New Zealand is also concerning. A report undertaken by the Institute of Economic Research canvassed teachers new to the primary workforce between the years 2017-2022. A quarter of these new teachers who attempted the compulsory mathematics requirement targeting 15-year-olds in New Zealand, could not pass (Gerritsen, 2024). As we move beyond the primary sector and look at the secondary sector the awareness exists of long term concerns with the staffing levels of mathematics teachers, with positions being identified as hard to place (PPTA, 2024).

As the teaching of mathematics is broad in scope and isolated by discrete sectioning evidenced by *the New Zealand Curriculum* document, (Ministry of Education, 2007), the teaching of mathematics with the use of digital technology is effected by a growing software expanse and therefore a required expertise of software use. The teaching of mathematics then includes teaching students the software package in use, to enable learning outcomes to be enhanced.

Supporting the ICT skills students have allows participation in society in a more inclusive way (OECD, 2022). There exists an interconnection across subjects, particularly relevant in mathematics and within real-world contexts, which suggests to us that mathematics can be taught both individually and as an integrated subject (Beswick & Fraser, 2019; OECD, 2018b; A. Smith, 2004). The requirement here would be for teachers to have content knowledge of more than one subject area, reflective of an integrated approach regarding teaching and learning. “Discipline-specific content, in this type of method, is addressed and treated as a single, fluid study, rather than divided” (Abu Khurma et al., 2023, p. 1).

Within the New Zealand context, the integration of curriculum subjects was surveyed across primary and secondary schools and the following was found: "The least frequently integrated subject was maths, followed by science" (McDowell & Hipkins, 2019, p. 4). The two reasons given for this were the hierarchical nature of knowledge development and the need to teach concepts in a certain order (McDowell & Hipkins, 2019).

Given the single, fluid study, rather than a divided approach of discipline presentation reflecting teaching and learning, modules of work depicting the above would necessitate task redesign to enable successful integration of STEM disciplines to occur. The ability to undertake effective task design, reflecting single and integrated teaching of mathematics becomes another skill required to be an effective teacher of mathematics. "Design thinking seeks to change and improve current situations and create what is desired" (Tsai & Chai, 2012, p. 1058). Design capacity becomes a reflection of design thinking skills and disposition for the integration of digital technology within education (Hoyles, 2016; Tsai & Chai, 2012). Teachers must then design lessons to achieve changes in pedagogical delivery. This is further discussed in Section 6.1.

Within the summaries listed in the tables 3 and 4 above, the expectation is that teachers will have the pedagogical skills to incorporate the development of the key competencies. This means they need to achieve shifts along the continuum of teacher to student-centric practice within their teaching pedagogy. Member countries of the OECD will each have their version of the key competencies, however from analysis of fifteen 21st-century skills frameworks, the common elements that have been identified fall into three common categories of “to know, to act and to value” or foundational knowledge, meta-knowledge and humanistic knowledge (Kereluik et al., 2014, p. 130).

The impact upon foundational knowledge (to know) by digital media and the internet and subsequently familiarity with the internet is considered immense. It is the readily available access to large amounts of information and the desired ability to produce meaningful knowledge from this that has caused the greatest change, with the commensurate need to develop new skills that reflect these changes (Ansell, 2016; Beswick & Fraser, 2019). Meta-knowledge (to act) takes foundational knowledge and makes it meaningful. This involves problem-solving and critical thinking, communication and collaboration, and creativity and innovation. Humanistic knowledge (to value) is needed for life and job skills, ethical and emotional awareness, and cultural competence. These three categories will overlap and are not thought of as discrete (Kereluik et al., 2014). It is here that teachers need to know and demonstrate these skills so as to best teach these skills to their students (United Nations Educational Scientific and Cultural Organisation, 2016).

The key competencies that underpin the *New Zealand Curriculum* document are:

- “Thinking
- Using language, symbols, and texts
- Managing self
- Relating to others
- Participating and contributing” (Ministry of Education, 2007, p. 12).

The proficiency level indicators that underpin Te Matauranga o Aotearoa Curriculum document as a Māori medium are:

- “Selecting and using language, symbols, and texts to communicate
- Managing self and relating to others
- Participating and contributing in communities
- Language knowledge
- Cultural knowledge” (Ministry of Education, 2008, p. 81)

These key competencies and proficiency level indicators are cognitive, social, and affective outcomes. These outcomes are considered essential for the development of higher-order thinking and lifelong-learning attributes.
The use of digital technology is not what teachers are instructed to do; it is rather the use of digital technology that exemplifies the key competencies that exist within the *New Zealand Curriculum* document (English) that present the challenge to teachers (Ministry of Education, 2007). Not only do teachers have to possess these skills, themselves to teach them, but they must also know how to impart, within an educative context, this knowledge to their students to be effective.

The art of teaching may have become a reflection of cognitive, operative and affective facets, (Attard, 2018), that could enable a greater control by students in what they learn; an increased personal relevance within their learning; the development of critical voice, and the ability by students to manage peer negotiation within discussion (Taylor, 2014). The teacher’s ability to develop within their student body the elusive concepts of: to value: to enjoy, and to see mathematics as connected to real life may have become a part of the picture of effective pedagogy (Attard, 2018).

As digital technology is now integral to and a reflection of modern society the use of digital technology has become another teaching and learning avenue, available to mathematics teachers given their dynamic, graphical and interactive application within mathematics (Hoyles, 2016; Hoyles, 2018). Additionally, some digital platforms utilise entertainment for engaging mathematics students, for example, “shoot ‘em up” times tables (Sinclair et al., 2020; Soldano et al., 2019). Digital software programs may now enhance existing mathematical skills, depending upon the choice of software and the desired outcomes.

If teachers are shifting their practice across the continuum of teacher to student-centric pedagogy, aided by their use of digital technology, and as befits the development of the key competencies, the teaching space could then become an illustration of the learning-centred environment (Ting, 2015). This suggests that there will be facets of both teacher and student-centric approaches within teaching pedagogy.

Managing self, or self-regulation is listed as a key competency within the *New Zealand Curriculum* document (Ministry of Education, 2007). Blended learning environments are thought to support student self-regulation. In a literature review undertaken (Van Lear & Elen, 2017), the attributes of blended learning environments that support learners’ self regulatory abilities were identified. This study looked at the timeframes from 1985 to 2015 and encompassed 95 pieces of literature. It was found that seven characteristics were present. These were authenticity, personalisation, learner control, scaffolding, interaction, reflection cues and scaffolding cues (Van Lear & Elen, 2017). The self-regulated learner is one who understands how to use a range of flexible problem-solving strategies. When referring to table two, point eight, the self-directed or self-regulated learner is a desired outcome aligned with the student-centred approach.

In consideration of the external influences that exist design research has become an industry that typifies innovation (Frommherz & Narayantoroa 2022). This is in line with the New Zealand Governments transition from agriculture to the creative industries sector for the promotion of long-term growth strategies. Science, technology, engineering and mathematics disciplines (STEM) are reliant on the cognitive or thinking skills typified by the key competencies and have become integral to design research. Design research is reliant on those "difficult" subject areas within mathematics, like algebra and geometry. Sustaining longevity in mathematics attainment in those "difficult" subject areas enables a competitive parity with other OECD countries indicative of individual social, cognitive and affective ability, reflective of the use of digital technology within society (Glasse & Medina, 2022; Hoyles, 2016; Hoyles, 2018; OECD, 2019c).

For the majority of students there has been little application of these "difficult" subject areas outside of school – hence their invisibility. It is this lack of visibility that is thought to have a compounding effect on the decline of student interest and performance in mathematics. What is meant by this is that there is little connection to life outside of school, illustrating a lack of relevance for the learner

(Hoyles, 2016). By teaching the relevance of mathematics in a real-world context, increased student engagement could result (Fitzmaurice et al., 2021). Design research supports real-world applications, like smartphone technology, computer animation and artificial intelligence (AI) (Hoyles, 2016). This supports real-world relevance, meaning the application of mathematics in a visible way. The inclusion of the use of digital technology within mathematics, can enable the visibility of these “difficult” subjects (Dimmel et al., 2021; Hegedus & Otálora, 2023; Soldano et al., 2019).

In addition to the discussion above the use of digital technology could assist with the development of the key competencies, knowledge content, and with effective teaching pedagogy. What must also be considered are the external drivers or change strategies that influence teaching practice. Accordingly these are discussed below.

2.4 Strategies to orchestrate change

With both pedagogical imperatives and external drivers evident in the research literature related to using digital technologies in mathematics education, what is then important as a consideration are strategies to change existing teacher beliefs about integrating technology within teaching practice. Strategies can include observation, practice, reflection, and social-cultural support (Kim et al., 2013; Pinskaya et al., 2019). The strategies of observation and practice have been in place within the New Zealand appraisal system and are tied into the New Zealand system of teacher certification. The two strategies of reflection and social-cultural support reflect changes undertaken within a current context. Reflection within professional practice has been targeted in the teaching-as-inquiry cycle , the spiral-of-inquiry and social-cultural support in the form of communities of learning as government-led strategies to promote changes in teaching practice (Ministry of Education, 2019a, 2019c, 2020a).

Further to systemic changes advocated by government was the support given to more flexible learning spaces, which illustrate large open working spaces of 60 or more students, with breakout rooms. These are referred to as innovative learning environments (ILE). The changing physical environment, a movement away from a one-cell classroom environment, poses challenges to the established teacher/student pedagogy which must be reimagined to accommodate the changes to the physical environment. Once the physical space is altered to accommodate the increased classroom size of 60 or more students' teachers work toward more effective pedagogy, hoping to achieve enhanced student engagement leading to positive student achievement. Innovative learning environments (ILE) can influence pedagogical change (Starkey & Wood, 2021; Taylor, 2016; Watson et al., 2013).

Crucial to integrating technology is strong principal advocacy and management support (Kim et al., 2013). The use of mobile technologies, often referred to as chromes/tablets, enhances the ability of students to cater to the changes in the physical environment as mentioned above (Willacy et al., 2017), more so than a fixed personal computer. This mobile affordance enables students and devices to move together.

In a New Zealand study undertaken with reluctant learners of age 16-18 years old, the use of iPads and apps focused upon numeracy, became instrumental in a positive attitudinal response, and hence an assessment related gain for these students (Calder & Campbell, 2016). Student engagement was stimulated as discussed with the CTML theory above (Mayer, 2005b). Every effort was made to engage these reluctant learners with innovative and transformative pedagogy with the use of digital technology, inclusive of the use of a digital assessment (Calder & Campbell, 2016). This was a case study approach across three different Youth Guarantee classes. Interviews were undertaken with 41 students *(tauira)* and 8 teacher participants *(kaiako)*.

Although a move toward greater digital technology inclusion within teaching practice has occurred over time, varying stages of success have been achieved with the adoption of change slower for some schools and teachers than others (Bray & Tangney, 2017; Lai & Widmar, 2021; Sosa Díaz, 2021). The COVID-induced lockdown scenario generated change within education which accelerated the adoption of an online teaching and learning model (eLearning). In many cases this went beyond usage within parts of a lesson to a total packaged online teaching and learning model encompassing differing software packages (Hassan et al., 2020).

One New Zealand study undertaken focused upon an e-learning environment as a result of lockdown. This teacher education programme identified that after an initial adjustment phase related to stress and anxiety, some advantages evolved over time. These were considered to be, the use of mathematics apps to assist with problem-solving, collaborative problem solving approaches, and enhanced communication by asynchronous (e.g., Moodle) and synchronous (e.g., Zoom) means (Calder et al., 2021). This was a small comparative case study involving three New Zealand students' perceptions involving questionnaires and semi-structured interviews.

The advent of the pandemic COVID-19 meant that for schools that the adoption of an online teaching and learning model became a necessity (Edelhauser & Lupu-Dima, 2021). This study became an opportunity to obtain teacher perception after this intensive use of digital technology and the associated professional learning and development that went with it. Total immersion of this nature had never taken place on this scale before, with such a significant use of digital technology.

In New Zealand schools, the second term of 2020 meant that teaching and learning were undertaken in an environment of lockdown, where the physical attendance of students in classrooms was prohibited due to the COVID-19 pandemic response of restrictions undertaken to reduce viral transmission (Edelhauser & Lupu-Dima, 2021). Teachers and students worked from home, with families in lockdown together (Darragh & Franke, 2022). This became a scenario of `'education in emergency' (Pokhrel & Chhetri, 2021).
For teachers the preparation timeframes, indicative of the adoption of a new teaching and learning model and the planning needed for this adoption were reduced due to the sudden nature of the COVID-19 lockdown. In addition eighty

thousand households in New Zealand reported a lack of connectivity. This effected approximately 145,000 students (Gerritsen, 2020b). To offset this teachers and schools utilised a combined approach of hard-pack educational materials and digital technology. Computers were sent to students as a distance learning response in a lockdown scenario.

Supports for learning ranged from the use of TV channels (TV 2+1, TVNZ on Demand, Sky Channel 502, and Māori Television) to personal responses from teachers (Gerritsen, 2020b). The teacher response involved the use of telephones, zoom, Google hangouts, Google classroom, video-conferencing programmes, associated software already in use, and can be summed up as largely the school-wide and departmental undertaking that supported the response of individual teachers within a crisis scenario. It was an attempt to maintain educative reality within an unprecedented lockdown scenario. The use of digital technology to enhance the learning experience was unprecedented, with 94% of children worldwide or 1.6 billion children affected as a result of COVID (Pokhrel & Chhetri, 2021; United Nations Sustainable Development Group, 2020).

Teaching and learning took place, where both the teacher and student had limited exposure, prior to the event of COVID, with an online teaching and learning model. This also meant that the home environment during lockdown had to support the learning process (Darragh & Franke, 2022; Pokhrel & Chhetri, 2021). The degree of psychological distress and anxiety was immense (Collie et al., 2020; McCarthy et al., 2022). As the world reacted to the COVID pandemic and the subsequent lockdown event, teachers continued to try and teach and likewise students to learn. Identified by research was that the best practices for different age groups for emergency online homeschooling were not clear, with conducive home environments lacking uniformity (Petrie et al., 2020; Pokhrel & Chhetri, 2021).

Teachers have had to become increasingly adaptive to the use of digital technology, in creative and innovative ways in a short timeframe due to the COVID circumstance. This had an impact on quality instruction (Blömeke et al., 2016; Kreydun et al., 2022) and presented challenges to existing pedaogy (Dias, 1999; Hanif et al., 2023; McLean, 2003). COVID was unexpected and has supported emphasis to be placed on the need for teachers and students to maintain their digital orientation with different online educational tools (Pokhrel & Chhetri, 2021; United Nations Sustainable Development Group, 2020) as further pandemics may occur. With the maintenance of existing digital skills the stress undertaken with the accelerative nature of digital upskilling by teachers within this first lockdown could be avoided should further pandemics occur, with corresponding benefits to teaching and learning overall.

As education responded to COVID as discussed above, an acknowledgement of historic first to fourth order inhibitors and enablers can be made. Historic inhibitors and enablers to the use of digital technology within teaching practice, are reflected by first-order (Harrell & Bynum, 2018; Singhavi & Basargekar, 2019), second-order (Snoeyink & Ertmer, 2001), and third-order criteria (Tsai & Chai, 2012), with an enhanced digital divide illustrated by the COVID-19 pandemic (Lai & Widmar, 2021; Ramsetty & Adams, 2020). These inhibitors and enablers can be further categorised as external and internal inhibitors and enablers. These represent Wi-Fi availability, device shortages and software resourcing to name a few. Internal inhibitors and enablers relate to beliefs and skills relative to the school community. These points have been touched on in the discussion below. With the adoption of technology within education over time we may assume that predominantly internal inhibitors and enablers may have more relevance.

In a review of inhibitors by country, this does not appear to be the case, with an editorial review for an EdTech magazine confirming beliefs (Ertmer, 2005), and a later study confirming external factors (Vongkulluksna et al., 2018). This study had 624 sixth-to twelfth-grade teacher participants and 20 administrators from 16 schools across a Midwestern state in the United States. Online surveys were used.

Country-specific patterns have been identified in a study undertaken (Schmitz et al., 2022). In general it appears that there is a higher negative impact of technological barriers in less technologically developed countries and teacher-belief related barriers prevalent in developed countries. Secondary teachers were targeted through an online survey that was completed by mathematics, science, or language teachers from 30 European countries. It appears that educational contexts and countries can have an influence.

Research has revealed that the equivalent yardstick of measure for inhibitors has now changed due to the passage of time, whereby external inhibitors that referred to device shortage, for example, now look to the diversity of devices and the quality of computer use. Equally internal inhibitors which looked at basic ICT skills now refer to more advanced digital competencies. As technology use advances different indicators reflecting inhibitors are employed (Starks & Reich, 2023).

There are also enablers to digital technology use. In a study undertaken in a Turkish primary school, these were divided into school and teacher factors. Enablers for schools were the provision of laptops for teachers, ICT support, training availability for staff, and a school policy supportive of ICT. Teacher enabling factors were beliefs (positive), levels of pedagogical and ICT skills, and an awareness of the value of using ICT in the teaching and learning undertaken (Cubukcuoglu, 2013). This study had seven secondary participant teachers based at one school. These teachers taught mathematics, foreign languages, social sciences and science. Semi-structured interviews were undertaken of 30 minutes each, at the beginning of two consecutive terms. This approach is indicative of a qualitative methodology, as it promotes the gathering of rich-text data. In addition the capacity of the participant and interviewer to dialogue off script is enabled given the semi-structured interview sheet is a guide only (Smith et al., 2009). Similarly this approach has been undertaken and discussed in the next chapter of this thesis.

In a more recent study undertaken targeting special education, the following enablers were identified; teacher training, involvement in decision making, advisory and leadership roles, quick approval for software requests, on-site tech support, supportive leadership, supportive colleagues, shared planning time, and home-school communication (Starks & Reich, 2023). This study although using differing identifiers and specifically researching special education, generally had a similar pool of enablers. This study involved 20 individual video chat interviews, with teacher surveys distributed by email after the interview. This study was based in the United States. The shift in enablers and inhibitors based upon teacher perception allowed consideration of the changes and expectations attached to the adoption of technology within teaching practice given the passage of time for prospective research projects.

This concludes the first section of our literature review with findings summarised and critiqued below.

2.5 Summary of Section One

Innovative practices with the use of digital technology within mathematics are seen as an avenue to promote student achievement. They are also indicative of the key competencies that allow for social, affective, and cognitive development. Pedagogy can be thought of as the science of teaching, with three models reviewed within this last section. The adoption of student-centric as opposed to teacher-centric practices are thought to advantage the changing nature of student characteristics that depict Generation Z and beyond, who have been immersed in digital technology since birth and therefore process information differently. The development of the key competencies and knowledge content are equally endorsed by the *New Zealand Curriculum* document (Ministry of Education, 2007). It is this document that is supporting the desired pedagogical changes illustrating a shift from teacher-centric to student-centric practice.

However, a third model exists which suggests that a learning-centred approach enables a better fit to the influences that occur within the classroom. The criticisms of the adoption of one model only (either teacher or student-centric) refers to a uniformity of student characteristics and assumes that all students will achieve academically with the one model. This becomes a one-size-fits-all approach (Bremner, 2019), which may not cater to individual need.

Learning-centred approaches allow for a teacher who is flexible to the changing scenarios that present in the classroom and are therefore responsive to student needs in any given situation. They are hybrid practitioners of blended teaching and learning scenarios, meaning they move comfortably between the respective teacher pedagogy of teacher and student-centric approaches. Research presented has shown the reliance on traditional teacher-centric practice, governed by time and pressure. It is equally suggests that an awareness exists within the teaching fraternity of the need to adopt student-centric practice within teaching pedagogy (Patra & Shastry, 2022).

Student academic achievement is central to teacher practice. The effective teacher profile has become a plethora of skills and competencies, both professional and personal. Every aspect of school reform is reliant on highly skilled teachers, within an environment of a global mathematics teacher shortage. The New Zealand education system is again under reform as a response to indicators of poor academic achievement, with mathematics highlighted as an area of concern.

As we reflect on the literature discussed above one limitation to the existing studies undertaken was small sample sizes which is indicative of a qualitative methodology (Dimmel et al., 2021; Hegedus & Otálora, 2023; Nemirovsky et al., 2020). The strength of a qualitative approach, indicative of small studies is the collection of rich-text data. However, the studies in general concluded, that further studies were needed to provide different forms of feedback from study participants, with others noting the absence of a level of detail (Hillmayr et al., 2020; Sailor et al., 2024). Some studies did not measure the metacognitive, affective and motivational outcomes (Young, 2017). Other studies support existing initiatives within research that have combined the use of digital technology as they relate to teaching practices, assessment, to affect and to equity (Drijvers & Sinclair, 2024). These studies relate to student outcomes, and the need to enhance existing teacher pedagogy with the use of digital technology seen as a means to employ innovation.

A further study that focused upon creative pedagogy, as a means to advantage student outcomes revealed that the natural, cultural and technological worlds experienced by the children in this project provided grounds for creativity and learning. Literature reviews undertaken identifying creative pedagogy found that the the link between student creativity and creative pedagogy was inconclusive

(Cremin & Chappell, 2021). However in a literature review focused upon teacher pedagogy the two key features identified that supported creative pedagogy were teacher self-efficacy and environmental support, with the use of digital technology considered necessary to achieve creative pedagogy (Bereczkia & Kárpátib, 2018; Tang et al., 2022). In a further review of literature undertaken the need for teachers to provide scaffolding strategies when employing digital technology within their practice was thought to be supportive to student creativity.

Due to the combination of factors listed above, the incentive to utilise digital platforms to increase visibility and enhance the learning undertaken within the mathematics classroom is assuming an increased impetus, echoing a real-world relevance. The use of digital technology is further endorsed by the CTML theory if pedagogy is effective. Pedagogical expertise comes before expertise with digital technology. The characteristics of Generation Z are also advantaged with the use of digital technology within teaching practice.

Further literature reviews and qualitative studies were discussed to enable an understanding of what teachers are actually doing within their classrooms, confirming that teachers remain in control of device use, and often resort to teacher-centric practices with the use of digital technology. This suggests that there is a role for professional learning and development to play as digital technology is employed within teaching practice and an increased adherence to the effective teacher profile may be needed. It may be that a new digital tool may force change on existing teacher pedagogy, given the design of the tool. It may be that the blended learning environment where face-to-face instruction can occur, with an online component could be the targeted ideal outcome. This also suggests that pedagogical expertise and expertise with the digital technology in question are both needed for teaching practice to advantage student outcomes. It could be that for teachers to remain current in their teaching practice, will necessitate keeping abreast of developments in research and digital technology, for example; new tools and design features. These are a few of the assumptions that can be made, although not all.

Education in emergency necessitated a complete online teaching and learning model, given the COVID occurrence. This meant that teachers and students were immersed in the experience of teaching and learning without face-to-face interaction and a total reliance on the use of digital technology, previously unprecedented. This highlighted the need to be innovative and creative with lesson delivery. It also highlighted the inhibitors and enablers faced by schools, teachers and students with an online delivery.

Models for Teaching Mathematics – Section Two

2.6 Introduction

When undertaking the teaching and learning of mathematics, several desired models are identified within literature that reflect the use of digital technology in an appropriate manner to support student-centric practice. Targeting the desired framework or models with the use of digital technology allows the development of expertise by teachers in technology rich environments. One such framework is the Instrumental Orchestration Framework indicative of a combined teacher and student-centric practice, subsection 2.7.

To provide an overview for the use of digital technology within mathematics we also discuss the Technology, Pedagogy, Content, Knowledge (TPACK) Model subsection 2.8, and the Substitution, Augmentation, Modification, Redefinition, (SAMR) Model subsection 2.9. These models are indicative of the use of digital technology within teaching practice, with TPACK evaluating the balance of skills needed inclusive of technology use and SAMR looking at technology competency in a linear fashion.

The discussion on models would not be complete without an understanding of the difference when teaching mathematics as a single discipline or a STEM approach embracing integration of disciplines, subsection 2.10. We then discuss inquiry-based learning, the intention of which is a teaching pedagogy that is focused upon knowledge construction, subsection 2.11. A summary is then undertaken with subsection 2.12.

Within the pedagogy of a teacher, a movement along a continuum of practice may illustrate the use of the above models, as the teacher looks to achieve the priorities attached to the desired and targeted student outcomes.

2.7 Instrumental orchestration

Instrumental orchestration illustrates a combined teacher and student-centric approach to utilising digital technology. A sequence of steps, referred to in this instance as the instrumental orchestration framework, are undertaken. The first three steps are teacher-centric by design, with the last three steps considered to be student-centric. The sequence of steps for the instrumental orchestration framework are: "Technical-demonstration; Explain-the-screen; Link-screen-board; Discuss-the-screen; Spot-and-show, and Sherpa-at-work" (Drijvers et al., 2010, p. 219). This study was undertaken by observing three female mathematics teachers, across 38 lessons, reflective of five classes. This study sought to identify stages of instrumental orchestration as teachers with varying degrees of expertise with technology incorporated the use of digital technology. In this example an applet called *Digital Mathematics Environment (DME)*, was used within their teaching practice.

Technical-demonstration, Explain-the-screen and Link-screen-board are reasonably self explanatory given that they are whole-of-class approaches where the teacher controls the process. Technical-demonstration allows the teacher to explain the tool techniques. Explain-the-screen is a whole-of-class explanation which is guided by what happens on the computer screen. Link-screen-board allows the teacher to demonstrate what happens in the technological environment and then to marry this to what occurs with mathematics on paper or the white board.

Discuss-the-screen, Spot-and-show, and Sherpa-at-work still involve input from the teacher, but also input from the students. Discuss-the-screen allows a whole-of-class discussion about what is happening on the screen. Followed by discussion using a whiteboard, with perhaps a problem set on *DME* or paper. The point of difference being that if technology is used feedback and problem-solving are instantaneous. The goal at this stage is collective instrumental genesis, meaning the development of expertise with the tool at hand, which was *DME*. Spot-and-show enables the teacher to undertake evaluation of digital work completed by the student and utilise this within a whole-of-class discussion, whilst getting the student to explain what it is they have undertaken with *DME* as an example. So lesson preparation by the teacher needs to be undertaken. Sherpa-at-work allows the student control of the technology to display their work. The student may carry out the work needed using the digital technology with teacher direction if needed. Both teacher, student and whole of class undetakings are enabled.

This framework identified that teachers set up instrumental orchestrations fostering the student understanding and ability to use the tool or artefact combined with mathematical knowledge (Drijvers et al., 2010). Recently this approach has been elaborated upon to study the objectification of mathematical procedures with the use of digital technology. In consideration of the use of

Computer Algebra Systems (CAS) the following negative aspects were identified: “loss of distinctive features of concept formation, a consequential reclassification of mathematical objects, instability of CAS solutions as objects, and prevailing a posteriori reasoning on students’ behalf when relying solely on CAS in their mathematical work” (Jankvist et al., 2019, p. 67).

To investigate this further in another study it was found that if approached appropriately the use of drawing, in a 3D dynamic geometry environment, promoted the movement from drawing to the desire to undertake mathematical calculation to confirm understanding gained. This is described as an intellectual need for mathematical proof instigated by the use of 3D software in a dynamic geometry environment (Mithalal & Balacheff, 2019).

In addition, it is suggested that the use of digital technology with instrumental approaches creates instrumental distance, referring to a qualitative gap here, between the environments of digital, and pen and paper (Haspekian et al., 2023). This study identified differences in approaches in teaching algebra with digital technology for example, where pen and paper gave a symbolic approach to equation solving and exact values, the use of GeoGebra gave a functional approach to equation solving and approximate values. The distance referred to within this study is with regular algebraic contents (Haspekian et al., 2023).

In summary we can say that the nature of instrumental orchestration and the use of digital technology is not without advantages and disadvantages and would require some planning by teachers around the use of software programmes to advantage student outcomes.

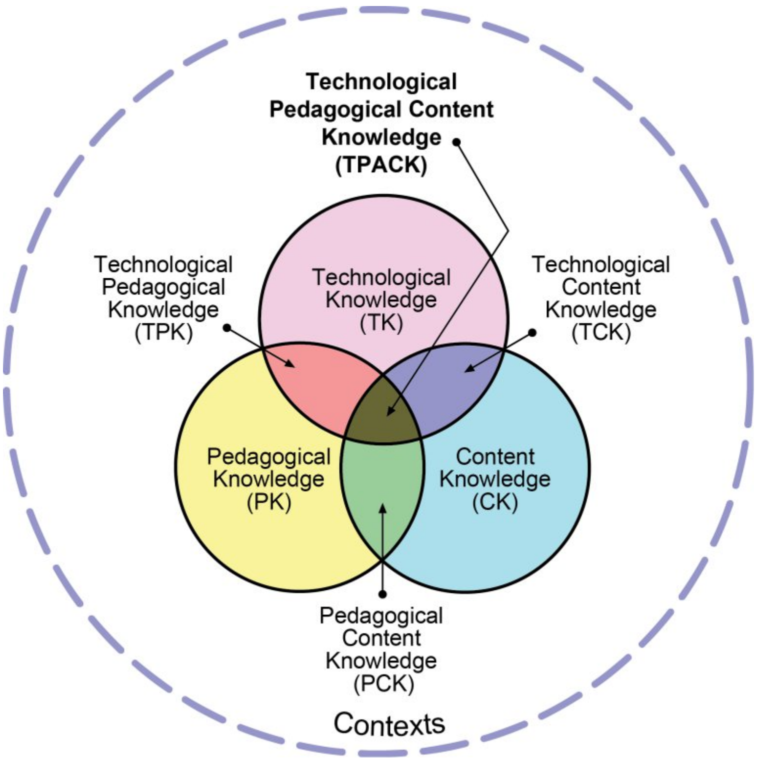
The discussion below looks at alternative models for teaching and learning with the use of digital technology, to better illustrate the differing pedagogical approaches. Further to the above discussion, alternative teaching models that are thought to reflect the effective, appropriate use of digital technology, known as the TPACK and SAMR models are discussed below. This better aligns teaching practice with a movement along the continuum of the adoption of student-centric pedagogy.

2.8 Technology, pedagogy, content, knowledge (TPACK) model

For the development and support of the key competencies, we then look at the effective integration of technology within teaching practice. The Technology, Pedagogy and Content Knowledge (TPACK) model (Mishra & Koehler, 2006) is a model of the teacher knowledge required to allow for effective technology integration. The integration of technology within teaching practice requires a balance between TPACK skills and can occur in stages (Mishra & Koehler, 2006). The TPACK model is one model that can be used to evaluate the effectiveness of the approach undertaken (Mishra & Koehler, 2006). This model divides knowledge areas into technological, pedagogical, and content (mathematics) knowledge. Pedagogy is the way teaching and learning are approached. Technology encompasses the chalkboards and the digital age. Content knowledge is the discipline knowledge that is required to teach. Overall, we have three primary knowledge bases, content, pedagogical, and technological. Figure 2 shows the intersection of the three knowledge bases and pairs: pedagogical content knowledge – specialised professional knowledge for teachers, which makes teachers experts in pedagogical content, rather than content teachers (Park & Oliver, 2008); technological content knowledge – knowledge of mutual relationships between technology and content (Koehler et al., 2014); and technological pedagogical knowledge – knowledge of the affordances and constraints of technologies to specific pedagogical practices (Koehler et al., 2014). Refer figure 2 below.

Figure 2

THE TPACK MODEL

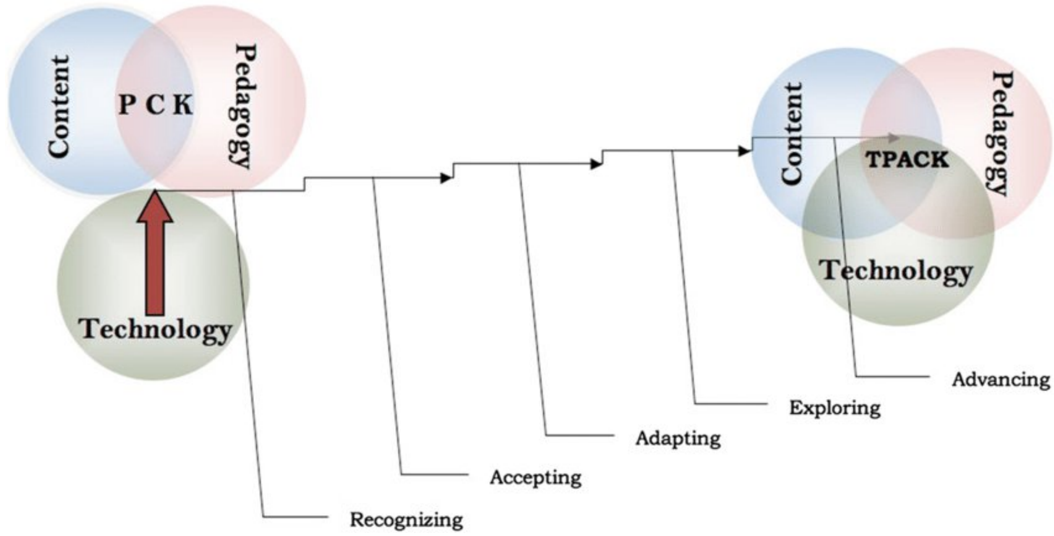


Note. P. Mishra and M. J. Koehler (2006). Adapted from *The TPACK Model.* (http://tpack.org) Copyright 2012 by tpack.org

Within the intersecting area of the Venn diagram in Figure 2 is where the three knowledge pair areas intersect, referred to as TPACK (Thompson & Mishra, 2007). The TPACK framework challenges teachers to execute teaching with a firm understanding of the interactions between the “core” components and their summative outcomes. As we look to adopt a blending of technology within teaching practice, figure 3 depicts the progression along the continuum of the five levels of teacher growth. These are recognising, accepting, adapting, exploring, and advancing. The application of these progressive stages will allow for skill development within each area of; curriculum and assessment, learning, teaching, and access (access to technology). The TPACK model of pedagogical content knowledge and technology depicts the result of the intersection of the three knowledge pairs, referred to in the overlap of the Venn diagram in Figure 2 (the intersection of all skills) and the achievement within the progressive skill levels to an advanced stage in figure two, to achieve TPACK (Niess et al., 2009)

Figure 3

THE DEVELOPMENTAL MODEL OF TPACK



Note. This figure was produced by Niess, Ronau, Shafer, Driscoll, Harper, Johnston, and Kersaint in 2009 summarising a visual description of teacher levels as their thinking and understanding merge toward the interconnected and integrated manner identified by TPACK. From "Mathematics Teachers TPACK standards and development model," *Contemporary Issues in Technology and Teacher Education Journal*, 9 (1) p.10. Copyright 2016 CITE Journal licensed under the CC Attribution-Non-commercial License Design.

Of importance is the need to view the professional development of a teacher as responsive to the different skills, views, and commitment to the learning of the individual teacher (Levin & Wadmany, 2008). The metaphor of one-size-fits-all becomes inappropriate in consideration of an individual teacher's approach to incorporating digital technology use within their teaching practice (Levin & Wadmany, 2008).

If we consider the continuum of teacher-centric to student-centric teaching practice and the use of digital technology, an understanding exists that teachers must learn to use the technology in question, and then change how they teach reflecting the appropriate use of digital technology. The Developmental Model of TPACK (Niess et al., 2009) shows a progression of interactive stages as expertise develops over time in relation to specific technologies.

The assumption of a linear progressive stage-like incorporation of digital technology within teacher practice has been challenged and amended to suggest that incorporation of digital technology may have stage-like properties but does not evolve in a one-stage-at-a-time fashion (Levin & Wadmany, 2008). This is due to the nature of the simultaneous influences that occur in a classroom, which could be described as dynamic.

In undertaking the teaching of STEM subjects, with mathematics, and the use of digital technology, Harrington et al. (2016) recommended a systems approach, which incorporates multiple technology use to enhance learning. The systems approach under discussion was the use of TPACK.

In recent times TPACK then becomes DPACK which refers to the extension of technical knowledge through digitality. The word digitality is defined as "the area of action and perception in people which is therefore extended by digitally transmitted spaces” (Huwer et al., 2019, p. 230). This is described as; digitality-related knowledge or (DK) and encompasses the digitality knowledge about the handling of technologies and completely includes all aspects of the technological knowledge category previously represented. Hence the advent of DPACK (Huwer et al., 2019; Thyssen et al., 2023). It is thought the DPACK model is widening the perspective of digitally enhanced STEM-teaching originally depicted by the TPACK model, reflecting the sociocultural knowledge domain.

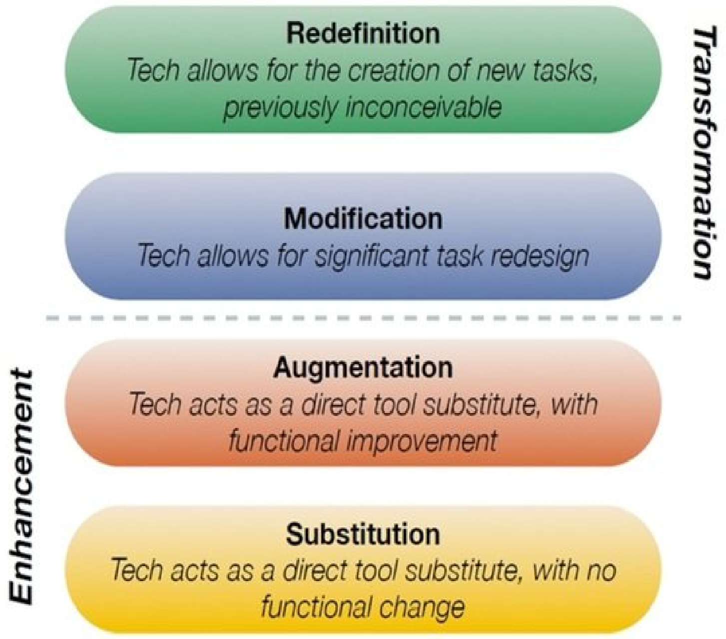
Although popular in literature TPACK is not the only approach to be considered with the substitution, augmentation, modification, redefinition (SAMR) model discussed below (Hamilton et al., 2016; Te Kete Ipurangi, 2023).

2.9 The substitution, augmentation, modification, redefinition model (SAMR)

The second model, advocated by the Ministry of Education, is technology-based (Ministry of Education, 2021b). SAMR is a four-level, taxonomy-based approach for the use of digital technology in teaching. The concepts of the SAMR model are represented as a ladder and requires the teacher to move from one level to the next in a progressive approach to increasing expertise with the use of technology in teaching. Refer Figure 4 below:

Figure 4

SAAMR MODEL



Note. Hamilton, Rosenberg and Akcaoglu (2016). Adapted from the SAMR Model. (https://digifoe.files.wordpress.com/2016/04/samr.jpg) Copyright of this photo is by an unknown Author and is licensed under CC BY-SA-NC

In consideration of the SAMR model, a linear division between categories is made. Substitution and augmentation refer to the use of technology as a tool and therefore are the bottom rungs of the ladder, categorised as enhancement. Modification and redefinition are the top rungs of the ladder and are intended to show increased levels of teaching expertise with technology use, categorised as transformation. The author intended this model to be used as a tool to describe and characterise K-12 teachers' uses of classroom technology (Hamilton et al., 2016).

Critical reviews of this model refer to challenges attached to this model's use as; lacking context, rigid structure, and product over process (Hamilton et al., 2016). In addition, this model depicts that any use of technology is an enhancement. In consideration of context, this model further places emphasis on the use of technology instead of the integration of contextual factors that make up an education environment, specifically an individual classroom, and how technology is integrated with consideration of these factors.

As every teaching context is unique and teaching practice places pedagogy first, the use of technology cannot be privileged above pedagogy. Predefining levels of expertise by category of technology use is at odds with the pedagogical approach utilised by teachers. Pedagogy reflects the unknown aspects of task design, lesson design, and teacher and student nature. Taxonomies of this nature are linear processes, referred to as rigid, whereas the nature of teaching and learning is a dynamic process. It can be said that one process is at odds with the other process. With product over process, we have emphasis placed on instructional activity (product), whereas in teaching and learning, the emphasis is placed upon learning outcomes and objectives (Hamilton et al., 2016).

As we move along the pedagogical continuum of teacher-centric to student-centric teaching and learning the use of digital technology as more than a tool reflects innovation within teaching practice, where teachers must learn how to use the technology and then change how they teach. Teachers are not usually expert in technical skills; these are usually gained through experience and exposure to problem solving with technological issues. However teachers do usually possess strong critical thinking skills through their experience and this can support active knowledge construction (Levin & Wadmany, 2008). Learning is a process where technology integration is utilised to achieve learning outcomes instead of emphasising a change to instructional activity (product) (Hamilton et al., 2012). The SAMR model by contrast to the TPACK model is focused upon technology alone, not the interaction between pedagogy, knowledge content, and technology.

A model of teaching and learning that looks at disciplines and the combining of disciplines in various combinations is the science, engineering, technology and mathematics (STEM) model discussed below. This is a pedagogical approach to the integration of disciplines, of which mathematics is one (Hobbs et al., 2018; White, 2014). As we look to improve our instructional delivery of mathematics, combining disciplines reflecting a science, technology, engineering, mathematics (STEM) application is a real-life illustration of an education-based approach.

2.10 STEM models

The STEM disciplines are often viewed as being synonymous with innovation, in real-life contexts, which is where competitive economic advantage lies (Even et al., 2023). As a member country of the OECD, New Zealand seeks to remain economically competitive. One way of doing this is to support and enhance STEM within education (McKibbon, 2021). What is also known is that digital learning has a positive impact on student outcomes within a STEM approach (Hobbs et al., 2018).

The depiction of the separated mnemonic (STEM) helps to illustrate the different STEM approaches taken. If a STEM approach is adopted with model one, each discipline is taught separately, within a unit of work. The processes and skills applicable to mathematics could be in complex problem solving. With model two a teacher could integrate mathematics and science within a challenge-based unit of work. Model three suggests a dominant subject, for example mathematics, with some engineering and science units, but with limited links across the science and engineering subjects. Model four suggests a mathematics teacher integrating all other STEM disciplines into a challenge-based unit of work. Model five requires a combined STEM unit of work, where each teacher teaches their discipline within this unit of work in their separate subject, to solve a common problem (Hobbs et al., 2018, p. 144).

The approach to the teaching and learning of STEM can be indicative of the models identified below:

1. “Teach each discipline separately within a unit of work (S-T-E-M). Mathematics is taught separately, applicable to problem solving.

2. Teach all four with an emphasis on one or two (S-t-e-M). The emphasis is on mathematics and science. A challenge-based unit of work.

3. Integrate one discipline into the other three being taught separately. The emphasis depicted by model three is on mathematics.

   M

   (S E).

   T

4. Total integration of all (STEM). Mathematics will have equal emphasis as other disciplines integrated by the teacher.

5. Division of a STEM curriculum into the separate subjects. Four teachers teaching their own discipline having designed a combined unit of work and using their approaches to solve a common problem. This model shows an emphasis on mathematics”.

   T

   (M)

   S E

   (Hobbs et al., 2018, pp. 144, Figure 8.3).

The differing disciplines would require the use of, and differing approaches to, software selection and use. Integrated approaches imply design or challenge-based approaches. Innovation with the use of digital technology can support the teaching of mathematics identified with the following points: “Develop students’ critical thinking to evaluate digital resources, tools and algorithms; Develop and explain computational processes; Solve problems; Think logically, algorithmically and recursively, and, develop creative thinking through designing digital interfaces to communicate" (Hobbs et al., 2018, p. 143).

Some schools elect to use a STEM approach with an integration of the disciplines of science and mathematics. Innovative undertakings do carry with them an element of risk, as changes to existing practice are undertaken. It can be said that innovation brings uncertainty, which can be thought of as encouraging growth and renewal (Levin & Wadmany, 2008).

2.11 Inquiry-based learning – a teaching model

Inquiry-based learning within mathematics is a pedagogical approach that supports active learning with a scaffolded sequence of tasks (Ernst et al., 2017). The outcome of which is knowledge construction. This illustrates a student-centric teaching and learning approach. Key to an inquiry-based approach are "two principles of; deep engagement in rich mathematics and opportunities to collaborate" (Ernst et al., 2017, p. 571). "Inquiry-based learning is grounded in constructivist theory and is an approach to active learning that is driven by authentic problem-based learning" (Blessinger & Carfora, 2015, p. 7).

The application of inquiry-based learning within mathematics allows for thinking, experimenting, asking questions, participating, where students themselves build their own mathematical capabilities (Ernst et al., 2017). The use of an inquiry-based teaching and learning approach supports the development of the key competencies, previously mentioned in section one.

Using an inquiry approach allows students to learn how to learn, which means they can often transfer or apply the essential inquiry learning skills, dispositions, and attitudes to new situations. Students may apply an inquiry-based learning approach to any topic, context, or learning area of the curriculum. The use of digital technology, when used appropriately, could support the inquiry-based learning approach, identified as naturally suited for STEM subjects (Hobbs et al., 2018).

Inquiry-based learning is oriented around the three main components of exploration and investigation, authentic inquiries, and research-based approaches. This student-centric approach is considered to be a learning strategy for developing higher-order thinking and lifelong learning (Blessinger & Carfora, 2015). Within the overview of learning-centred classrooms, the criticism here would be a one-size-fits-all, if this were to be the only approach to learning undertaken, or the adoption of a student-centric model only. A summary of this section is presented below.

2.12 Summary of Section Two

The instrumental orchestration framework provides a process of teaching in a technology rich environment. The framework has six distinct stages incorporating both teacher and student-centric practice. The framework could apply across differing software applications, subject to teacher and student expertise. There are some criticisms with the incorporation of differing software applications and the impact of this upon student understanding or student outcomes. Some criticisms refer to the promotion of instrumental distance and loss of distinctive features of concept formation in consideration of the teaching of algebra with the software in use. Equally the positives have been the intellectual need for mathematical proof prompted by digital technology use aligned to the software in use when undertaking geometry.

The requirement for transformative teaching practice, as a reflection of digital technology use within the class, supports a systemic approach, allowing a balance between the knowledge bases, as evidenced by the TPACK model (Niess et al., 2009). This is a student-centric approach. The Technological Pedagogical Content Knowledge overlap in the TPACK diagram is interpreted as educational knowledge integrating technological tools in subject and content teaching. The criticism of this model is that it is outdated, with technological knowledge being replaced by the digitality related sociocultural knowledge domain, which now becomes the DPACK model (Thyssen et al., 2023).

The second criticism of this model when referring to the stage-like properties of the developmental model of TPACK is that the incorporation of digital technology within teaching practice may have stage-like properties but does not evolve in a one-stage-at-a-time fashion, given the fluid and dynamic nature of the classroom. Emphasis is given to the fact that one-size-fits-all does not apply to individual teacher's approach to incorporating digital technology.

The SAMR model is technology-based and looks at a linear progression of gain in expertise with the use of digital technology. The critique of the SAMR model, is that it places emphasis on a linear progression of technology competency and as such is a taxonomy-based technology model (Harrington et al., 2016). Pedagogy incorporates the use of digital technology as more than a tool, but within a multiplicity of competing foci, as befits the effective teaching profile, hence the criticism of a single focus based upon technology.

The increased emphasis on ways to advantage the teaching of STEM subjects, of which mathematics is one, allows for cross-discipline approaches, with the requirement from teaching faculty to work either in isolation or collaboratively. The requirement for knowledge content of more than one discipline is convenient if STEM is taught as more than a single discipline. Factors that contribute here are the design of a task and techniques needed that advantage the teaching of respective disciplines inclusive of technology use (Murphy et al., 2018).

The inquiry-based learning teaching model supports active learning with a scaffolded sequence of tasks, resulting in knowledge construction. This model lends itself to student-centric approaches. The teaching approach adopted assumes increased importance in consideration of the decline in mathematics achievement and a decline in STEM graduates overall (OECD, 2023b).

The adherence to a framework or the adoption of successive models for teaching to allow the integration of digital technology within teaching practice, does not guarantee increases in student outcomes, as pedagogical skill prevails above technology use. What is significant with the inclusion of digital technology in teaching practice is the identification of the fact that information processing has changed for Generation Z and beyond. So now we look to increased pedagogical skill with the use of digital technology to better engage. Digital technology is a means of achieving this if pedagogy is effective.

Teachers may use digital technology within their classroom practice, the frequency and diversity of which implies pedagogical shifts which are discussed further in the findings chapter. The necessity to undertake Professional Learning and Development (PLD), either formally or informally, is discussed below in our next section.

Professional Learning and Development – Section Three

2.13 Introduction

For change to be undertaken successfully within the pedagogy of a teacher supports are required. This allows for the design of a successful change initiative, which is what is desired. PLD is one of the supports that can be provided to underpin the process of change. The change initiative undertaken discussed below is the integration of digital technology within teaching practice.

Section three is divided into four subsections, 2.14, 2.15, 2.16, and 2.17. Integrating digital technology within teaching practice necessitates a discussion on existing practice and what the integration of digital technology may achieve. This first subsection 2.14 discusses professional learning and development in practice. In line with this we evaluate the professional obligation that teachers hold to undertake a reflective process. What is understood is that reflection is both individual and collective. Hence the second subsection 2.15 discusses the reflective process, with subsection 2.16 discussing the Spiral of Inquiry as a reflective model. Subsection 2.17 provides a summary of section three.

Professional learning and development in practice discusses the growth of teacher practice and the prompts that exist within the educational system which promote teacher growth and the place of digital technology within this. The discussion on the reflective process refers to the capacity of the teacher to continue to develop their teaching practice and sustain shifts in pedagogy, with a continual cycle of improvement, both individually and collectively as a school.

The models presented to illustrate this process are the Teaching as Inquiry and Spiral of Inquiry models.

The concept of individual teacher wellbeing attached to the effective teaching profile, and the role of digital competency in maintaining individual wellbeing impacts upon teacher resilience, agency and identity (Ainsworth & Oldfield, 2019; Beltman, 2021). How teachers manage their time is aligned to the individual teacher's perception of the relevance of the PLD undertaken. For example, PLD imposed by external sources, or PLD imposed by school leadership would be perceived differently and hence would be influential in terms of the relevance of and time engaged with the PLD. What often lies beyond teacher capabilities is: the overall resourcing of PLD, the limitations of the PLD undertaken and the perceived gaps in PLD reflective of individual teacher desire (Bagdžiūnienė et al., 2022).

Group and individual teacher practice places emphasis upon; a risk-taking mindset and a reflective capacity. Change cannot occur without a risk-taking mindset. Reflective capacity, undertaken both formally and informally, is employed to ascertain whether changes have produced the desired improvements (Education Review Office, 2012; Henriksen et al., 2021). Within existing teaching practice the emphasis is toward student-centric practices, echoing the necessity to move away from teacher-centric practices (Yang & Tan, 2019). As this movement in teaching practice is undertaken, both risk-taking and reflective capacity could be employed.

2.14 Professional learning and development (PLD) – in practice

To teach in New Zealand, there is a requirement for entry-level qualifications as befits the teaching profession, and the primary, secondary, and tertiary levels that make up the nature of the education environment. This becomes a reflection of the professional standards undertaken to maintain current certification as a practicing teacher (PPTA, 2019). The organisation that monitors current certification status for teachers to enter any classroom is the Teachers Council. In line with a system-wide impetus for change and supported by the Teachers Council of New Zealand, is an overhaul of the existing evidence-based appraisal system, replaced by a cycle of professional growth which has taken effect as at February 2021 (Teaching Council of Aotearoa New Zealand, 2019, 2020). The maintenance of a professional growth cycle for teachers is a way of enabling the growth of each teacher’s individual teaching practice and supports current certification (Teaching Council of Aotearoa New Zealand, 2020). Growing teacher practice is a dynamic process undertaken over time, reflecting the changing student classroom composition.

With an adherence to the professional standards which support teacher registration is an emphasis upon the incorporation of highly effective teaching techniques. The use of digital technology within classroom practice can be thought of as effective and innovative, for example the advent of Mind Lab, which launched in 2013. “The vision of Mind Lab is to transform New Zealand education by aligning digital skills and capabilities with the demands of the contemporary world" (The Mind Lab, 2019, p. 2). Research New Zealand has identified that pedagogical change for teachers is a problem when using digital technologies for learning (Research New Zealand, 2017).

A teacher-centric approach to teaching allows the teacher to direct the process and control the learning outcomes. A student-centric approach promotes student agency and an active participation in the learning process, refer table 2. Inhibitors to change described by Grant & Hill (2006) as the five factors that might affect the teachers' decisions to use student-centred, inquiry-based pedagogy are:

> "(1) recognition and acceptance of new roles and responsibilities on the part of teachers and learners
> (2) comfort level of teachers and learners
> (3) tolerance for ambiguity and flexibility
> (4) confidence in integrating technology; and
> (5) integration of the new pedagogy within the larger realities beyond the classroom" (as cited in Murphy et al., 2019, p. 10).

The use of digital technology reflects an open, emergent, chaotic nature of online interaction in comparison to the rigidly organised social structure of formal education (Zhang et al., 2009). This illustrates the impact of change for teachers and their existing practice. Teachers then have to develop a tolerance for ambiguity and flexibility (Dole et al., 2016). This then becomes an avenue for PLD to be undertaken to increase the comfort levels of teachers when undertaking change (Dole et al., 2016; Murphy et al., 2019).

The intended purpose in studies undertaken in Qatar (Murphy et al., 2018, 2019) was the need to bring about shifts in pedagogy along the inquiry-based learning continuum. The strategy employed to illustrate the shift in pedagogy was the use of digital resources known as WebQuests. A WebQuest is an inquiry-oriented activity in which students get all information from the web. The skill targeted is critical thinking through analysis, evaluation, and creativity. The process reflected the following:

“1) the PLD should be developed with personnel in Qatar

2) teachers should be provided with practical, classroom-based, manageable strategies; and

3) the PLD should include sustained regular in-class support” (Murphy et al., 2019, p. 9).

In this study professional development specialists provided regular in-class support and feedback for the teachers across two terms. Transformation in teaching practice illustrated facilitation and not direction. Teachers felt that this was evidenced by critical decision-making undertaken by their students (Murphy et al., 2019). In an attitudinal analysis undertaken using an inquiry-based learning model the inhibitors previously identified by Grant and Hill (2006) were also confirmed in a further study undertaken by Murphy et al., (2019). Provocations reflective of the points raised by Grant and Hill (2006) were expressed by teacher participants at the start and for some at the end of the study. However, overall, teachers experienced a positive attitude toward inquiry-based change areas of growths in teaching pedagogy due to the workshops undertaken, emphasising the beneficial role PLD can have (Murphy et al., 2019).

The importance of the teacher is widely recognised, and models such as TPACK (Mishra & Koehler, 2006), and instrumental orchestration (Ruthven, 2009), help promote understanding of what is different in teaching with technology, and how this impacts upon pedagogy. Additional to pedagogy is the software expertise needed to allow imaginative praxis and innovation to occur, with different software packages requiring mastery to be achieved prior to delivery within the classroom. Mastery experiences may be the strongest source of teacher self-efficacy (Anderson et al., 1995; Mueller et al., 2008; Rutherford et al., 2017). Research supports that teachers who value professional development undertaken, in this case, with mathematics learning games, may have higher self-efficacy for teaching with the use of mathematics learning games (Rutherford et al., 2017; Soldano et al., 2019).

The Manaiakalani Outreach Programme is now in operation across eleven schools in the area that the research was undertaken and nine regions nationwide (Parkinson, 2018). This programme targets teachers as learners with a cybersmart curriculum and is focused upon a learn, create, share pedagogy. This programme of digital immersion enables facilitators employed by the programme to enter classrooms for an hour per week across the year to assist with the digital literacy of both teachers and students. This programme has been independently funded by the HB Williams Family Charitable Trusts, is overseen by the Tairawhiti Connext Charitable Trust, with research undertaken by the Woolf Fisher Research Centre. The funding was undertaken for a 3-year term, as of 2018, to a total investment of $1.2 million (Parkinson, 2018).

Instructional coaching is another option for professional learning and development. Independent instructors work one-on-one with teachers, a movement away from the traditional one-size-fits-all. This is based upon classroom observation and involves a cycle of goal setting, learning, observation and data collection, and reflection. Coaching is purposefully differentiated (Blazar & McNamara, 2019).

In 2014, National government policy implemented the Kāhui Ako/Communities of Learning (COL's) initiative. As a country, we are at the leading edge with an approach that is countrywide as opposed to regional or district-based (Education Review Office, 2017). Kāhui Ako were designed to work in the spaces between organisations, targeting the teaching and learning of students (Kamp, 2019). One such Kāhui Ako is Manaiakalani, which targets connectedness in decile 1 and 2 schools. Communities of learning (COL's) can collaborate around a particular achievement challenge, like literacy and numeracy, as evidenced by the Primary Strategy Learning Networks (PSLN) initiated in England (Kamp, 2019). The benefits of a community of practice would be the sharing of resources and professional support, leading to new ideas, possibilities, and innovative practices.

There are 220 Communities of Learning/Kāhui Ako that exist in New Zealand, as at January 2021 (MOE, 2021). At present due to the existing government moratorium put in place as at 2019, no new Communities of Learning /Kāhui Ako are able to be formed (Gerritsen, 2020a). This was last reviewed in 2021, as evidenced on the Ministry website (MOE, 2024a). There is a strong call from principals to dissolve the scheme, with others requesting a review and analysis of the evidence for improved student achievement and a reduction in competition (Gerritsen, 2020a). The opportunity for a community of practice to be developed supports the intention for professional growth by strengthening and sustaining collaborative activity, as opposed to individual activity (Kamp, 2019). Increasing student achievement in mathematics, with the use of digital technology, as evidenced by effective teaching practice, could be applied utilising a COL framework as a professional learning and development strategy, given that the initiative would be greater than the efforts of a single teacher.

Teacher training programmes presently in place in New Zealand work to reflect the requirements of teacher placement. The Community of Learning framework has been thought of as a place within which teacher training programmes are identified as “a natural place to start this integration” (Kay, 2006, p. 384), reflecting as it does a collective of professionals targeting the effective teaching profile.

2.15 The reflective process

Teaching pedagogy assumes a reflective capacity, whereby a process of continual improvement is targeted. Reflection occurs due to wanting to do something better than what you have done before, to improve upon results gained within the classroom (Orlando & Attard, 2016). Sometimes you reflect to confirm if the right approach or action gave the required feedback or results. Questions asked by Schulman (1986), which were considered to be key questions regarding the development of teachers were; “Where do teacher explanations come from?”

and “How do teachers decide what to teach; how to represent it; how to question students about it, and how to deal with problems of misunderstanding?” (Schulman, 1986). These questions are an illustration of the reflective capacity integral to teaching practice.

The following process illustrates the reflective cycle: you have an experience (concrete experience), reflect on the experience (reflective observation), learn from the experience (abstract conceptualisation), and then try out what you have learned (active experimentation) (Svinicki & Dixon, 1987). Reflection can be divided into reflection-on-action and reflection-in-action (Schön, 1983). Schön (1983) refers to reflection-on-action as not occurring in the “action-present,” but after the fact, whereas reflection-in-action occurs in the present. Reflection-for-action occurs in consideration of the future and anticipates what changes can be made based upon past experiences subject to an event that may occur.

Reflection-in-action is a response to student learning in the present (behaviour as it happens), with reflection-on-action a way of preparing and practicing for these opportunities when they occur (after the event, to review, analyse and evaluate the situation). To become a practitioner of reflection-in-action and reflection-on-action within teaching practice is reflective of an inquiry-based practice of a greater depth of inquiry than teaching lectures or direct instruction. The focus here is on reflection undertaken on teaching practice, from direct involvement with the situation.

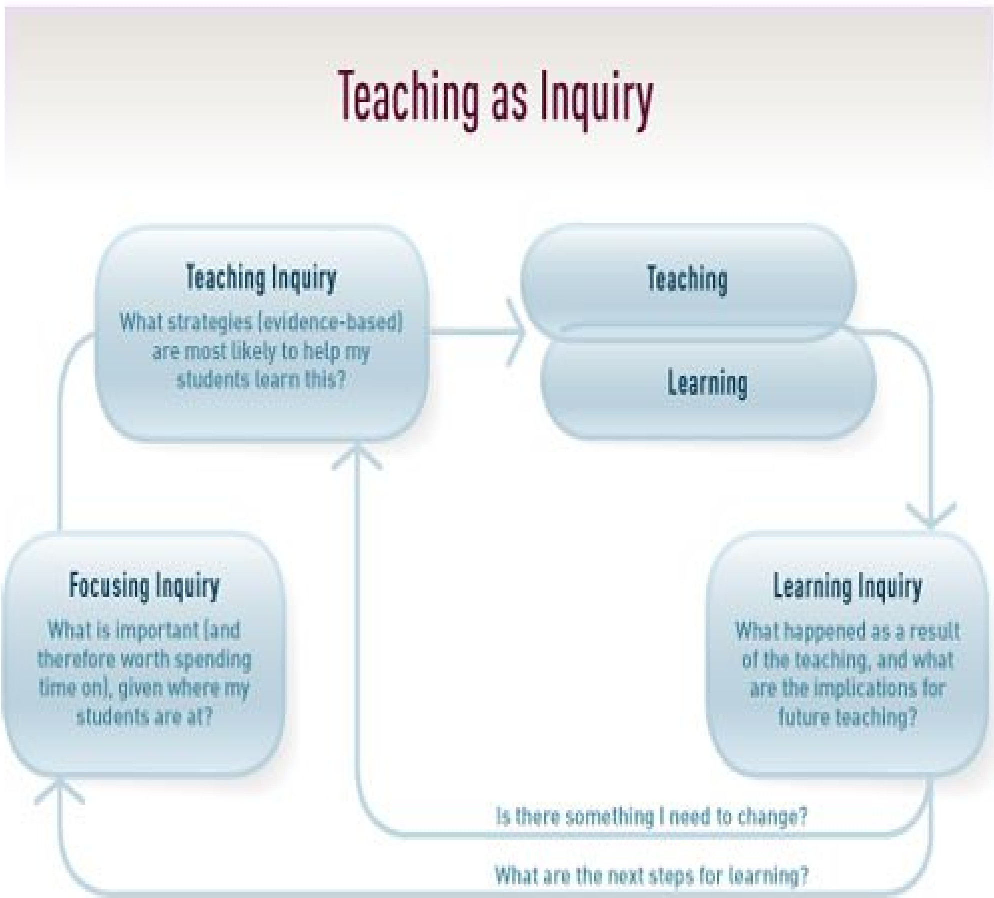
Reflection-in-action is the process of drawing on knowledge with the concept of self-talk. Self-talk is the teacher's ability to impart knowledge/skills clarity that enables increased learning and identification of teaching strategies that work with individual students. The teacher is dialoguing with themselves about teaching approaches, to communicate to the student to clarify or enhance teaching points (Education Review Office, 2012).

The Education Review Office supports reflection-in-action as a part of teaching practice, so much so that it is referred to as “the most advanced phase in the development of inquiry” (Education Review Office, 2012, p. 20). Reflection as a component of professional teaching practice is personal to the individual teacher and their practice (Robinson & Rousseau, 2018). It is the reflective capacity of the teacher that enables the continuous cycle of improved student outcomes with the adoption of new teaching and learning models. One of these models is referred to as the teaching as inquiry cycle and is discussed below.

Teaching as inquiry is a cycle of the teacher self-reflecting to some extent based on student outcomes and the need to continually evaluate changes to teaching strategies, to maximise student learning and subsequently improve student outcomes (Benade, 2015a). Teaching as inquiry is a practice expected of all teachers and necessitates teacher evaluation of the effectiveness of their teaching, in addition to building a collaborative community of professionals. The interpretation and use of evidence, collected from students, to inform teachers about student learning, and therefore strategies to improve student learning, require a mindset of teaching as inquiry (Timperley, 2010). Refer to figure 5.

Figure 5

TEACHING AS INQUIRY MODEL



Note. Ministry of Education (2019c). Teaching as Inquiry template retrieved from https://assessment.tki.org.nz/Teaching-as-Inquiry/Teaching-as-Inquiry-practical-tools-for-teachers/Teaching-as-inquiry-templates. Crown Copyright

The teaching-as-inquiry cycle provides an organising framework that teachers can use to help them learn from their practice and build greater knowledge (Otago University, 2019). The Ministry of Education 2007, the Education Review Office 2011, and the Education Council 2019 advocate for the teaching as inquiry process. In 2012 the Education Review Office reported that “teaching as inquiry needed to be better supported” (Education Review Office, 2012, p. 16). The Education Review Office identified four forms of inquiry for teachers as “collaborative inquiry; self-review; documented personal reflections, and reflection-in-action” (Education Review Office, 2011; 2012, p. 16).

The identification by the Ministry of Education of the need for a reflective approach undertaken by teachers about teaching practice, as evidenced by the teaching-as-inquiry cycle, focuses upon the need for different strategies for different students within different contexts in the teaching and learning environment. Being able to do this depicts the skill of the teacher with reflection-on-action (Ministry of Education, 2007b, p. 35).

Teaching as inquiry is where teacher actions promote student learning by the teacher critically reflecting on what they have done and what impact this has had on student achievement. The cycle shown in figure 5 identifies three types of inquiry: teaching inquiry, learning inquiry, and focusing inquiry. Briefly summarised, the explanation of what these inquiries mean is illustrated in the following way; teaching inquiry – how and what approach is needed to help my students learn; learning inquiry – what happened, or what is implied as a result of the teaching, and focusing inquiry – what is important or what can be changed given where my students are at (Benade, 2015a).

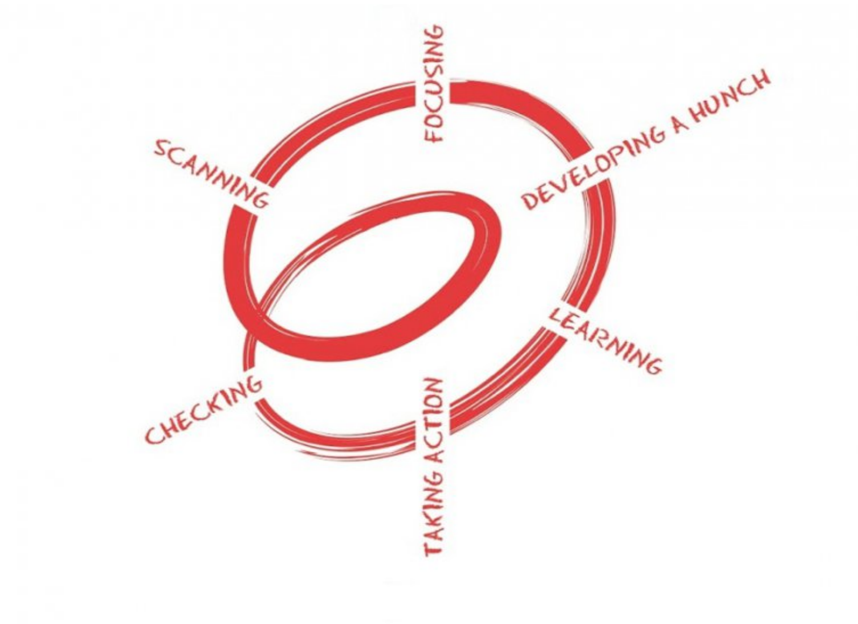
Collaborative, critical teacher and individual teacher reflective practice are reliant upon the desire by a teacher to develop their teaching practice in an “open-minded, fallible and persistent” manner (Benade, 2015a, p. 116). This is a model that requires critical self-examination. This model also supports collaborative interaction between professionals and is not limited to individual practice. If collaborative interaction and dialogue with colleagues and others do not occur, then the reflective capacity evidenced by this model is minimised. Evidence of student achievement or gains made in classroom endeavours need to reflect research; therefore, the evidence is more than assessment information. The intention here is to develop a community of professionals who target critical inquiry and are not limited to scholastic or classroom only data (Benade, 2015a).

2.16 Reflective models – Spiral of Inquiry

The Spiral of Inquiry is another reflective process whose emphasis has changed to be inclusive to the learner, their families, and their communities. This is one of the most significant differences in this framework by comparison to teaching as inquiry (Timperley, 2010). The movement is one from student voice to student agency. Inquiry then becomes a collective professional agency as opposed to an individual teacher agency. Where we have the teaching as inquiry process, which enables reflection on an individual and collective basis about student achievement, the Spiral of Inquiry has a collective, across the schools focus. The focus is on involving the learners, their families, and their communities in identifying issues with their learning and coming up with solutions supporting student agency. The two overriding questions here are: What is going on for our learners?; and how do we know? (Timperley, 2010). Refer Figure 6.

Figure 6

SPIRAL OF INQUIRY



Note. From "A framework for transforming learning in schools: Innovation and the Spiral of Inquiry," by H. Timperley, L. Kaser and J. Halbert, (2014), *Seminar Series Paper Number 234*, April 2014, p.5. Copyright 2014, Centre for Strategic Education.

If we dissect the parts of the Spiral of Inquiry, scanning tells us that we look at the student experiences, across the school, from the perspective of a collective of involved teachers, in addition to individual classrooms. This will enable a building of knowledge about this student. Focusing is the next step in the spiral, allowing us to concentrate team effort on what scanning has revealed to orchestrate a change that is beneficial and significant to what was revealed within the scanning process. Informal hunches inform scanning and guide focusing. Hunches will often tell us what we believe is leading to what; consideration for what it is that we alone can change is integral to this process. Learning refers to teachers developing new skills and abilities given the scanning, focusing, and hunches that have been investigated and validated. Professional learning must be associated with student need for the Spiral of Inquiry to have relevance to the collaborative intent. Actions refer to informed actions that will make a difference in the student learning environments, enough for their experiences to change. In a complex scenario, collective thinking before action is undertaken is necessary. Checking allows us to investigate our actions to see if we have done enough or if there is still more to do. Did the anticipated or desired change occur? Evidence gathered in the focusing stage is revisited to allow an analysis of changes that may have occurred. This is a team approach and a collective endeavour.

The Spiral of Inquiry, and the steps identified are not seen as discrete and may mean that there can be overlaps that are experienced. But the intention is that this process becomes a way of professional practice and is embedded as an approach to constant change scenarios in a transformative endeavour that supports learners' education. This is a collaborative inquiry process that is targeting transformation within existing education systems.

2.17 Summary of Section Three

The emphasis placed on changes to traditional teaching practice, to accommodate the thinking processes of students immersed in digital technology from birth, are system wide, embracing both teachers in practice and preservice teachers. Changes to existing teacher training programmes by established providers reflect the certification requirements the teachers of New Zealand undertake, where an expectation is placed upon the teacher to utilise best practice, inclusive of digital technology use.

Within teaching practice evidence-based appraisal has been shelved in favour of the professional growth cycle, which supports reflective capacity on an individual and school-wide basis. Support with changes to pedagogy are provided by respective schools to varying degrees and in differing ways in the form of PLD. One of the initiatives that was thought to be supportive to changes in practice was the advent of the COL's. The COL collectives were initiated to establish communities of learning, where expertise could be shared, however the COL collectives have been subject to review within existing political reform.

Systemic support in the form of Teaching as Inquiry and the Spiral of Inquiry allows for reflection on teaching approaches and student outcomes both individually and collectively. This is intended to be critical inquiry. Both reflective models support change to existing practice, and individual and collective endeavours. The Spiral of Inquiry is a movement across schools involving the learner, their families, and their communities. Concentrated team efforts moving beyond what occurs for the individual within the class to better support their learning endeavours become a desirable outcome. Equally, what occurs in class is also desirable due to the teaching practice undertaken and results obtained. The push for collaborative undertakings within education signals the desire for transformative practice, as a movement beyond existing traditional teaching practice. The achievement of transformative school-wide teaching practice is considered to be unachievable by any single individual and looks to a community of those within education (Te Kete Ipurangi, 2020; Wright, 2010).

What research has revealed in consideration of professional learning and development is that there is no one-size-fits-all approach. Within New Zealand, the Ministry of Education has provided free of charge to all schools, Pathways Awarua, a software package designed to support the numeracy and literacy requirements represented by the digitally assessed CAA's. These assessments are available to students of year 9-13. The increased adherence to assessment impacts upon teaching pedagogy with time and pressure and although PLD is considered an enabler for the adoption of digital technology supportive to student-centric practice, the movement toward teacher-centric practice inclusive of the use of digital technology may become a response.

Teaching practice is supported by reflective capacity, with individual teachers and schools targeting professional growth cycles where improvements to existing practice and student outcomes are recorded. The availability of appropriate professional learning and development to infuse the use of ICT into established teaching practice may not be available, equally schools may provide creative solutions to the development of expertise and experts within the immediate school environment.

The next section of this study considers the impact of changes to pedagogy and the coping strategies available to teachers when undertaking change. Can teachers be supported in ways that empower their sense of identity and thereby allow risk-taking and innovation to occur. Are schools able to assist with a classroom change initiative that benefits all targeted outcomes?

Coping with Change – Section Four

2.18 Introduction

The undertaking of a successful classroom lesson, unit, or programme of work rests on the capacity of the teacher to navigate the scenario of success and failure based upon the achievement of the targeted student outcomes. The factors that support change are discussed in subsection 2.19 and are summarised in subsection 2.20.

Teacher identity, agency and resilience are interdependent and reliant on the supports that may exist within the school and educative communities, without which change can be perceived as challenging. The supports of school leadership and PLD are thought of as enablers to change. The target for teachers and schools is to develop a professional community that embodies effective teaching practice, and therefore positive student outcomes.

2.19 Supporting change

A resilient teacher has the ability to manage the ongoing challenges that present within the classroom and wider educational environment. This reflects positive adaptation in the face of negative circumstance. Resilient teachers act upon available resources, as opposed to reacting to the demands of teaching (Biesta & Tedder, 2007). Teacher resilience can be described as “the capacity to manage the unavoidable uncertainties inherent in the realities of teaching” (Day, 2018b; Gu & Day, 2013, p. 39), or as the ability to “maintain equilibrium and a sense of commitment and agency” (Day, 2018a; Gu & Day, 2013, p. 26). Post COVID teacher resilience has been described as “the capacity of teachers to survive and thrive in extremely adverse circumstances and sustain their educational purposes” (Forbes & Poultney, 2020; Kowitarttawatee & Limphaibool, 2022, p. 1). Teacher identity can be described as a teachers’ sense of “teacher self” , and tends to be unstable (Cobb, 2020). Teacher agency is something that emerges or is achieved through teachers’ engagement with the environment, rather than possessed by individuals (Sang, 2020).

The interplay between teacher identity, agency and resilience is impacted upon by the influences within the immediate environment of respective teachers. Teacher resilience can be thought of as a reflection of personal and contextual factors (Mansfield et al., 2016). “Most resilience research has been conducted with children, not adults” (Drew & Sosnowski, 2019, p. 493). It could be said that resilient teachers will undertake change, but what if teachers are not resilient? The opposite can then occur, which becomes teachers who are resistant to change.

Resistance can be interpreted as a refusal, rejection or withdrawal (Giles, 2006). Resistance presents as resistance to change and within schools is seen as “a desire and intention to maintain existing practices in the face of changes” (Giles, 2006, p. 180). This can take the form of vocal opposition, hostility, cynical staff cliques, procrastination, discrediting the agents of change, being absent for PLD, and going through the motions of change (Giles, 2006). This is not an exhaustive list but serves to indicate the characteristics of resistance and are often thought of as belonging to the individual. As resilience is a desired individual and school community characteristic, the concept of resistance necessitated a mention given its polar nature to what is desired. The practices that promote teacher and school resilience are discussed below.

To try something new within teaching pedagogy, in order to try to improve student outcomes is risk-taking. The risk is attached to whether the new initiative is going to have the desired results. “Risk-taking occurs when the school’s learning culture supports it” (Education Review Office, 2012, p. 26). Innovative practice with the use of digital technology can be thought of as risk-taking. Development of a reflective capacity by teachers would assist with trying something new. Given the many and varied changes undertaken in the New Zealand education environment since 2012, teachers can become risk-averse to change (Mutch, 2012). The resultant effects on teacher self-efficacy can be detrimental to teacher effectiveness (Mutch, 2012). Reflective practices both teacher and school-wide can be employed to allow evaluation of the success and failure that comes with change.

Although teacher resilience can be thought of as an individual quality, the sense a teacher has of being a part of the school community is significant to the development and maintenance of teacher resilience. This occurs when teachers feel that they are “heard, seen, supported, valued and belong” (Drew & Sosnowski, 2019, p. 503). The relational interaction that exists within school communities can nurture and support individual teacher resilience and in doing so build communities of resilience (Poultney & Forbs, 2020). School communities can be influenced by school leadership. School leadership can be seen as a support to the development of individual teacher resilience.

Within the school community the teaching role has been subject to two processes over a series of decades – these are intensification and professionalisation. Intensification is defined as “an expectation that teachers must respond to greater pressures under conditions that are not improving” (Bagdžiūnienė et al., 2022, p. 2). Professionalisation is defined as “an expansion of the teacher’s role and expected skills” (Bagdžiūnienė et al., 2022, p. 2). These two processes increase the focus upon the role of school leadership.

Teacher resilience and wellbeing are enabled with supportive school leadership and administration. School leadership has the ability to buffer the effects of external changes (Giles, 2006). School leadership has been recognised as a significant contextual factor in the creation of teacher resilience, with leadership recognition and support identified as key (Gu & Day, 2013). School principals that support shared leadership and flattened traditional structures enabled resilient responses with autonomous behaviours from teaching staff, identified within the actions of shared teamwork, adaptability, and flexibility (Giles, 2006). Recent research has summarised the impact of supportive school leadership and teacher resilience as positive, with an amplification of resourcing reflective of opportunities for professional learning and development, the fostering of teachers’ autonomy, feedback and sense of relatedness with colleagues (Bagdžiūnienė et al., 2022).

Shared teamwork or whole school approaches move beyond the idea of teacher self-efficacy (individual) and involve collective efficacy (group). A significant relationship exists between collective efficacy and student achievement within a school (Donohoo et al., 2018; Goddard et al., 2004; Goddard et al., 2015; Zakeri et al., 2016). Collective efficacy therefore aims for positive increases in student achievement, with a collective approach which requires leadership support (Dimopoulou, 2012; Donohoo et al., 2018; Zakeri et al., 2016). When teachers as a group in a school believe in the success of an adopted collective endeavor, it is more likely that as individuals they will persist until they are successful, reflective of targeted group outcomes (Brown, 2017; Donohoo et al., 2018; Goddard et al., 2004; Zakeri et al., 2016).

Professional learning and development (PLD) opportunities are thought to be avenues that provide individual teachers with skills and awareness. The use of digital technology becomes a part of the PLD environment and is ongoing as befits society's technological advances and the update scenario reflective of software and hardware use. In the Post Primary Teachers Association, (PPTA) the dimensions of the Professional Standards applicable to a currently certified teacher support both Professional Development and Teaching Techniques, specifically the use of currently available technologies (PPTA, 2019). This is an endorsement of the use of digital technology within the secondary mathematics classroom. It is thought that professional learning experiences facilitate resilience (Drew & Sosnowski, 2019).

Can teacher resilience be thought of in isolation from agency and identity? Recent studies support teacher identity, resilience and agency as concepts that are interdependent, and are referred to as working in tandem (Cobb, 2022; Day, 2018a). "The key components of professional identity are individual and collective efficacy, agency, emotional management professional empathy, and a capacity for resilience" (Day, 2018a, p. 68). All of these key components impact upon the professional identity of a teacher within the context of educational change referred to as continual reform. These key components are in a dynamic relationship (Day, 2018a). It has been suggested that "identity-resilience-agency is a triadic relationship that works in concert to orchestrate positive adaptation to pressure and challenge" (Cobb, 2022, p. 9).

Previous studies have looked at separate concepts of identity, efficacy, and agency; identity and emotions; and identity and resilience. Whichever way studies have been approached, the spotlight upon the three concepts of identity, resilience, and agency has maintained relevance as a reflection of the educational environment and concerns expressed over teacher attrition and retention (Drew & Sosnowski, 2019; Mansfield et al., 2016).

Taking each component part in isolation, professional teacher identity can be described as the way teachers "view and understand themselves either individually or collectively" (Mockler, 2011, p. 2). Identity can be thought of as dynamic, fluid, multi-dimensional, and emergent to name a few descriptors. Key components of professional identity are individual and collective efficacy, agency, emotional management, professional empathy, and a capacity for resilience. These key components of teacher identity are in a dynamic relationship. Teacher identity is mediated by workplace contexts and cultures (Day, 2018a).

Research confirms that teacher identity is impacted by self-efficacy and teacher agency. "They are part of an on-going, complex interactional dynamic between individual strength of (moral) purpose and the emotional dynamic of workplace and external social and policy environments" (Day, 2018a, p. 64). Teacher agency can occur either on an individual basis or as a collective. School culture can influence teacher agency and therefore identity. What is meant by school culture is "who we are and the way we do things around here" (Bower 1966, as cited in Day, 2018a, p. 64).

Resilience is now thought of as a capacity, not a fixed trait. To understand this we have to reject the notion that resilience is about "bouncing back"(Downes, 2017 as cited in Day, 2018a, p. 64). Teacher resilience can be further defined as an "individual response resulting from the interaction of risk factors and protective factors both from within and outside the individual facing a crisis" (Handayani & Sulastri, 2022, p. 175).

2.20 Summary of Section Four

Teacher identity, resilience and agency are concepts that have maintained relevance over time. The focus of resilience studies has in recent times shifted to include the interrelationship of identity, resilience and agency, and therefore resilience as not influential enough to be analysed in isolation (Cobb, 2022). No matter the approach by researchers in education, the relevance of the concepts has not been diminished.

To be resistant to change is to work against school outcomes. To overcome resistance to change, school leadership can build resilience for both individuals and school communities with alternative strategies; for example, flattened structures and participative decision-making across schools or with the provision of individual PLD.

PLD supports teacher resilience as teachers cope with a changing educative environment. Change in this instance reflects shifts along the continuum of teacher to student-centric pedagogy, inclusive of the integration of digital technology within teaching practice, combined with an adherence to the *New Zealand Curriculum* document (Ministry of Education, 2007).

2.21 Overview

Teachers who are learning-centred employ both teacher and student-centric practices within their classrooms to generate the desired and targeted student outcomes. The use of digital technology in teaching practice has been seen to be a way of enhancing existing student achievement, as it caters to Generation Z and beyond, who now process information differently, necessitating changes in pedagogical approach (Hashim, 2018).

Education in emergency necessitated the adoption of an online teaching and learning model, where the use of digital technology was immersive for most, allowing for innovation and creativity to occur. The COVID scenario meant an easy identification of enablers and inhibitors for schools and teachers undertaking digital immersion. The enhanced visibility of digital platforms became a reality.

Teaching models with digital technology include the instructional orchestration model (teacher-centric), the TPACK model (student-centric), and the SAMR model (technology-based model). Teaching models that support student-centric practice are the STEM and inquiry-based teaching and learning models. Learning-centred instruction that responds to the simultaneous nature of the influences that occur within the classroom may be the default position for teachers. What is known is that a one-size-fits-all approach does not cater to every student.

Reflective practices are encouraged with the professional growth cycle. Both the Teaching as Inquiry and Spiral of Inquiry allow for this, with the Spiral of Inquiry a collective or whole of school endeavour. This supports transformative teaching practice which is a movement beyond what can be achieved by an individual teacher alone.

When undertaking PLD for preservice and existing teacher training, there is no one-size-fits-all approach. The concept of PLD may indeed change as schools develop their own whole of school approaches, which if successful support collective efficacy. The face of PLD has broadened with the inclusion of digital technology as software expertise is developed and maintained, with new apps and updates regularly occurring.

The concept of teacher identity, resilience and agency is triadic, as each has an impact on the other. When faced with the challenges associated with change it is the resilience of the individual teacher and the triadic nature of identity, resilience and agency that determine whether change is undertaken or resisted.

Teaching 'out-of-field' impacts upon teacher identity, as teachers see themselves as having expert knowledge within a subject area at a secondary school level and when teaching out-of-field, need the time to develop the expertise required (Biebricher, 2023). In New Zealand, evidence suggests that a relationship exists between higher student qualifications and increased teacher qualifications and higher student qualifications with an increased length of teaching service (Alexander et al., 2010).

The effective teaching profile endorses innovation with digital technologies when embedded effectively within teaching practice. The theory of CTML supports the use of multimedia learning materials. Support for change is undertaken with PLD where the evolving nature of software becomes immersive for teachers given the ongoing need to keep pace with change.

As teachers cope with change, the reality of teacher resilience, agency, and identity surface, when undertaking targeted success or facing possible failure with desired student outcomes. Schools and subsequently teachers target successful outcomes for their students as a reflection of being part of an effective educational environment. The ability to positively adapt in the face of negative circumstance could be thought of as the essence of teacher resilience. This literature review has painted a picture of the educative environment and the cognitive and affective factors in play for individual teachers as they negotiate change with the introduction of digital technology to their existing teaching practice.

CHAPTER THREE: METHODOLOGY

Interpretative phenomenological analysis (IPA)

3.1 Introduction

This chapter begins with an overview of IPA and the component parts that illustrate IPA, before going into specific dialogue on the objectives and questions undertaken within the research design (section 3.2 and 3.3). Specific features of IPA are then introduced with a greater dialogue undertaken on the theories underpinning IPA. These are phenomenology, hermeneutics and idiography (section 3.4). A summary is then presented on the methodological approach with a presentation on the limitations of the methodology (sections 3.5 and 3.6). A description and discussion are undertaken detailing research design (sections 3.7 and 3.8), followed by analysis of the research methods (sections 3.9, 3.10, 3.11, 3.12, 3.13, and 3.14). The approach to the analysis of the data undertaken is then discussed (section 3.15) The final sections describe trustworthiness and ethics as, reflected within this methodology (sections 3.16 and 3.17), with a final summary of the methodology (section 3.18).

3.2 Overview of IPA

The perceptions that teachers hold are reflections of human lived experience. In this sense, our thinking process is forever changing as our perceptions change, and our thinking evolves. This can be thought of as a cycle of rebirth or regeneration of perspectives and worldview. When this process of renewal is applied to the teaching and learning environment, teaching practice becomes coloured by the perceptions held by teachers which hence shape the individual teaching practice adopted. The adopted research methodology undertaken must then be able to illustrate the varying individual and shared perceptions held. Interpretative Phenomenological Analysis (IPA) can assist in the exploration of teacher perception. IPA is a qualitative research methodology, which targets the human lived experience. Data collection as befits a qualitative research methodology is about generating in-depth, rich text data.

In combining the interpretative and reflexive aspects of IPA, an exploration of the varying perceptions held will allow a greater depth of analysis and, hopefully, the understanding which is gained (Smith et al., 2009). A discussion of where this methodology sits within qualitative research necessitates identification of the appropriate paradigm, ontology, and epistemology illustrative of this methodology. Within naturalistic research, applicable to the nature of this inquiry, the interpretive paradigm is applied. The interpretive paradigm is reflected in an IPA methodology. We endeavour to understand the subjective world of human experience, which reflects naturalistic research but applies an interpretive paradigm (Cohen et al., 2018). Ontology is then about the nature of reality or ways of being. Naturalist research targets increased understanding, not prediction and control (Lincoln & Guba, 1985). The acceptance of multiple realities allows for studies at a holistic level with targeted outcomes of increased understanding. Epistemology is the relationship between the knower and the known. The focus of epistemology is upon the way we research the nature of reality (Cohen et al., 2018).

A component of IPA methodology is its phenomenological approach, one that focuses on the lived experiences of individuals (Cohen et al., 2018). With the phenomena of lived experience is an understanding that all phenomena are interpreted. Hermeneutics is the theory of interpretation (Smith et al., 2009). The emphasis here, given the humanistic aspect, is idiographic, a focus on the particular and unique experiences undertaken (Cohen et al., 2018). Together these three theories reflect IPA.

The formulation of the question asked allows identification of the methodology used within the interpretive paradigm. This research question considers the influences at play when a teacher decides or not to use digital technology within the mathematics classroom. There are peripheral issues that surround the use of digital technology, such as the how and why of its use. Additional to this, would be the identification of the support teachers have or have not experienced when undertaking the commitment to alter their teaching practice to include digital technology. "What is taught is modified by how it is taught and how something is taught is determined by the teacher's understanding of it" (Gallagher, 1992, p. 264).

As there will be varying perspectives of the teachers taking part in this study, the ontology of IPA will allow for this, as ontology is a way of being and the nature of reality and within an IPA framework, including the varying and shared realities (Cohen et al., 2018; Lincoln & Guba, 1985; Smith et al., 2009). Epistemology is the basis of knowledge. In IPA research, this is the relationship between the knower and the known, that is, ways of knowing. In order to gain understanding, epistemological reflexivity is required (Pietkiewicz & Smith, 2014). Consideration is given to how the questions asked, define, or limit what can be found, given the desire to obtain a depth of understanding (Smith et al., 2009). As the focus within IPA is idiographic, this supports an understanding of the particular event, phenomena, or individual. This allows the varied perspectives given to have equal authenticity (Cohen et al., 2018; Pietkiewicz & Smith, 2014; Smith et al., 2009).

Teachers are experienced practitioners within the classroom, as a reflection of repetitive experience undertaken over time, which speaks to familiarity within praxis. This study is an exploration of whether the potential of digital technology use, is or can be met, within the mathematics classroom. If this has not occurred, research undertaken by this study may reveal the identification of what would enable the potential optimisation of digital technology use to occur within the mathematics classroom. This research study allowed the personal experiences of practicing teachers of mathematics to be obtained within a format of semi-structured interviews/dialogue. A choice was given to practicing teachers of mathematics to include any field notes and documents, inclusive of a reflective diary. Within the interpretive paradigm, phenomenology is a type of naturalistic research, which means it occurs in the natural world (Cohen et al., 2018; Golafshani, 2003). In this case, it was within the natural world of the practicing mathematics teacher within their classroom because the context in this environment will provide meaning (Lincoln & Guba, 1985). It also influenced their lived experiences and perspectives.

The interpretive paradigm, or worldview, applied to IPA, is emphasised by inductive logic. Research questions were constructed to enable expansive responses and were therefore broad-based (J. Smith, 2004). Research questions have been expanded upon with conversation between researcher and participant as befits the intention of the semi-structured interview scenario. This flexibility allowed for the revelation of the unknown or unexpected responses or themes. These revelations reflected a tacit knowledge, illustrated by more in-depth meaning, as befits the interpretive tradition. As there was no existing hypothesis or pre-existing theory applied to either the response or analysis, inductive logic applied. The ontological perspective of the interpretive paradigm accepts that all reality, in this case, teacher perceptions, were correct, hence the acceptance of the shared and varying realities held. The epistemological perspective of the interpretive paradigm contends that the relationship between the knower and the known is integral and inseparable (Lincoln & Guba, 1985). As the relationship between the knower and the known is inseparable, we looked for meaning rather than causality (Lincoln & Guba, 1985; Smith et al., 2009). Naturalistic research suggests that meaning can be value-laden (Lincoln & Guba, 1985).

The optimisation of the use of digital technology is where digital technology use supports teaching practice, as more than a tool (Puentedura, 2006). There is a widening gap between what theory states can happen and what does happen within teaching practice, with the use of digital technology (Bray & Tangney, 2017). The questions for this study investigated and explored the reasons for this. The points discussed are targeted within the overarching aim, and sub-questions asked.

3.3 Research objectives and questions

The aim of this study was to better understand year 7-10 mathematics teachers perceptions of the aspects that influence whether they use digital technology when teaching mathematics. The three research questions undertaken that allowed an examination of this aim were:

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

These questions assisted in understanding the reasons if and why there was a gap between theory and practice with the optimising of digital technology use within the classroom. The broad-based nature of the questions asked enabled expansive responses. Because the desire is to provide a depth of insight within teacher responses a quantitative approach was not considered. The design and intention of a quantitative approach being at odds with the research focus held. Equally this rationale applied to a mixed methods approach, reflective of a combined qualitative and quantitative approach. It is the construction of the research question that leads the researcher to the identifiable methodology (Smith et al., 2009). The discussion below will support the methodology of IPA. The reflection here is on phenomenology, hermeneutics, and idiography.

Methodological approach of interpretative phenomenological analysis (IPA)

3.4 Introduction

A qualitative approach to research provides a depth of response not available with other methodologies. This made IPA the selected methodology, reflecting as it does a small target group, within a semi-structured interview process, allowing for in-depth responses from participants within this study. Participant responses were expansive, detailed and allowed for expression of individual perception and reflective capacity.

Three theoretical points of view underpin the methodology of IPA. These are phenomenology, hermeneutics, and idiography (Smith et al., 2009). To gain an understanding of IPA necessitates a detailed discussion on these three theories and the philosophers who have been integral to each approach. Following that will be a discussion of how they interact and are mutually influential in IPA.

3.4.1 Phenomenology

Phenomenology focuses upon the human lived experience. It is concerned with the subjective view of the participant taking part in the research.

Phenomenologists look to move beyond descriptive analysis to interpretative analysis, which is both inductive and emergent by design. “Phenomenology rejects the notion of one single reality” (Denscombe, 2014, p. 97). In rejecting the one single reality indicative of quantitative research, phenomenologists accept the existence of a shared reality between groups, cultures, and societies, and it is at this level the concept of multiple realities is held (Denscombe, 2014). The sharing of interpretation of events within groups allows for a social life, dependent upon the human experiences and the thinking processes that allow the creation of perception (Denscombe, 2014). To understand phenomenology necessitates a discussion on the phenomenologists who have shaped and contributed to this theory. The four discussed below are Husserl, Heidegger, Merleau-Ponty, and Sartre.

Edmund Husserl's focus was on the process of reflection or reflexivity (Smith et al., 2009). Husserl wanted us to “look beyond the details of everyday life to the essences underlying them” (Cohen et al., 2018, p. 21). To do this requires a “bracketing” or a series of reductions. This bracketing aims to see the experience with the eyes of the participants. Bracketing means that the researcher has to set aside their thoughts, feelings, opinions, and preconceptions. Effectively the researcher has to operate as a naïve stranger (Denscombe, 2014). Husserl placed great emphasis on finding the essence of the experience. The essence of experience can be thought of as “individual psychological processes, such as perception, awareness and consciousness” (Smith et al., 2009, p. 16). Husserl believed in the lived experience within the life-world (Denscombe, 2014).

Martin Heidegger carried the work of Husserl on. Heidegger believed that phenomenology was not just transcendental but also hermeneutic, which is interpretive. To accurately reflect Heidegger, this is the interpretation about a state of being discovered by an investigation. The intention of the investigation is to reveal a shared or hidden underlying meaning of being. To enlarge upon this, Heidegger also believed in *dasein*, the “mode of being, realised by human beings” (Wheeler, 2018, p. 5). Heidegger's philosophy suggests that being is an evolving state, given that interpretation evolves and continues to develop within a spiral structure as our understanding increases and therefore evolves. This process requires both reflexive awareness and self-reflection on our state of being. Heidegger did not believe in the disentanglement of self, or bracketing, as possible, given the emphasis he placed upon *dasein*, the mode of being. There is an acceptance here, of objectivity as being unobtainable (Lincoln & Guba, 1985). Heidegger believed in “fundamental ontology - what it is that unites and makes possible our varied and diverse senses of what it is to be” (Wheeler, 2018, p. 3). Maurice Merleau-Ponty's interpretation of phenomenology is based upon perceptual experience. Merleau-Ponty saw phenomenology as describing human experience through perception. Describing human experience through perception is defined as the “embodied nature of our relationship to that world” (Smith et al., 2009, p. 18). The role of the body relates to perception, “the body is a permanent part of one's perceptual field” (Toadvine, 2019, p. 8). The body is not an object as part of the world or separate from the world. The body is a means of communicating with the world and allows us to know about the world. Jean-Paul Sartre believed that our ideas are products of experiences of real-life situations, with the human consciousness having no effect on the surrounding inanimate objects and situations. Sartre believed that we are always becoming ourselves. Sartre's interpretation of phenomenology focuses on “the developmental, processual aspect of being human” (Smith et al., 2009, p. 19). Sartre was also aware of what was present, but also what was absent. It was the influence of this presence and absence upon human consciousness that concerned Sartre. The presence of others influences our perception and builds upon Heidegger's worldliness, reflecting personal and social relationships.

Phenomenology is thus a reflection of the philosophies indicated above. Husserl's descriptive and transcendental focus has become interpretative, with an emphasis upon the perspective of the individual and their lived experience. The individual is situated within the world and is not in isolation, as they are interacting with others. Phenomenological research targets, among other human traits, people’s perceptions or meanings (Denscombe, 2014). IPA is a methodology that will allow for, through the philosophy of phenomenology, an understanding of people's relationships to the world, the meaning they give to the activities they undertake, and the events that occur (Smith et al., 2009). Meanings allow for interpretation, and interpretation is the focus of hermeneutics, the second theoretical point of view underpinning IPA, discussed below.

3.4.2 Hermeneutics

The theories of hermeneutics and phenomenology are separate bodies of thought but can merge into hermeneutic phenomenology. One of the proponents for hermeneutic phenomenology is Heidegger, as discussed above. Hermeneutics, as an independent theory, is the theory of interpretation (Smith et al., 2009). Hermeneutics was initially the interpretation of texts. Over time these texts included biblical, historical, and literary works. It was Heidegger who proposed that hermeneutics embrace all forms of interpretation, not just text, reflecting the human experience (Gallagher, 1992). The three hermeneutic theorists under discussion are Schleiermacher, Heidegger, and Gadamer. The review of the three hermeneutic theorists may then enable an understanding of the interpretation needed relative to IPA methodology.

Friedrich Schleiermacher believed among other aspects of his theory, that interpretation had two elements attached to it, one was linguistic or grammatical, and the other was psychological. Linguistic interpretation targets a shared or common understanding (Forster, 2017). Linguistic interpretation was based upon the written word in the form of text (Smith et al., 2009). Psychological interpretation targets an understanding that is distinctive to the author (Forster, 2017). If we apply this to the written word, it becomes coloured by the intention of the writer or speaker (Smith et al., 2009). We then have a text or spoken word targeting a shared or common understanding influenced by the intentions of the writer/author, or speaker.

The notion of the writer/author is mentioned here as the original focus of hermeneutic theory, was based upon interpretation of a text. Considering the author and their intentions then enables the interpretation of qualitative research data to include intuition, gained from detailed analysis or analysis of bigger data sets, as examples. In the wider context, hermeneutics and the meanings gained from interpretation move beyond text and language to include social processes, human existence, and “being”.

Martin Heidegger, as discussed above, believed in phenomenological philosophy as illuminating something which may be hidden and was therefore, interested in the perceptual and the analytical. It is the interpretation of the text and the illumination of something which may be hidden, which allows for hermeneutic phenomenology. Heidegger incorporates fore-conception with the interplay of the new knowledge resultant from the interpretation taking priority with consideration of the fore-conception (Smith et al., 2009). Heidegger believed that hermeneutics is reflected in all types of interpretation, not just linguistic or textual, as an illustration of the human experience (Gallagher, 1992). It was the textual interpretation that was the original focus of hermeneutics, applicable to texts like the bible.

Hans-Georg Gadamer rejected the methodological importance and method as a priority and prioritised understanding within the hermeneutic theory (Malpas, 2018). Gadamer reiterates the importance of Heidegger's hermeneutic theory and Husserl’s bracketing. He further identifies the interplay between the foreground and the new knowledge, the interpreter, and that which has been interpreted as occurring as they occur in the spirit of openness (Smith et al., 2009). Gadamer gave priority to the meaning of the text, above understanding the person. He believed interpretation of the text by the original author was subject to the passage of time. This meant that interpretation of the text is made in the light of the present, as opposed to reliving the past (Smith et al., 2009).

The hermeneutic circle is integral to hermeneutic theory and looks at the movement back and forth within the data. The hermeneutic theory is a circular, iterative process as opposed to a linear one. The hermeneutic circle allows for the process of interpretation and analysis to be developed within qualitative research and IPA, in particular. “To understand any given part, you look to the whole; to understand the whole you look to the parts” (Smith et al., 2009, p. 28). Proponents of hermeneutic philosophy accept the applicability of the hermeneutic circle, relevant as it is to the interpretation of the text.

Schleiermacher believed that moving between the parts and the whole would lead to a complete understanding; or that any piece of text needs to be interpreted in light of the broader language, whole text, historical context, genre, authors whole corpus, and psychology (Forster, 2017). Gadamer thought that closure or completeness was not achievable, given the iterative process of interpretation, which expands our knowledge, changing our interpretation. Gadamer believed that this process continues without end (Gallagher, 1992). This process of expanding knowledge and changing interpretation can be described as a cycle of rebirth. Ricoeur extended the scope of hermeneutics beyond text to dialogue with his theory of interpretation adding rigor to the interpretative process (Tan et al., 2009).

The double hermeneutic applies to IPA in two different ways. The first opportunity to apply the double hermeneutic is where the researcher experiences life as the participant does. However, the researcher can only experience this as the participant reports on it. What this means is that the researcher can only experience the participant's experience in a second-order sense. “The researcher is making sense of the participant making sense of *x*” (Smith et al., 2009, p. 35). The second way the double hermeneutic can apply is the interpretative methodology of IPA. The researcher can be empathic and questioning to gain understanding. We are “trying to see what it is like for someone” (Smith et al., 2009, p. 36). To take this a step further, we are also “analysing, illuminating, and making sense of something” (Smith et al., 2009, p. 36). These steps together are the second double hermeneutic applicable to IPA methodology.

The last theory for consideration in the structure of IPA is idiography. Idiography looks at detailed information and analysis and moves beyond generalisations applied to populations, with a concern for the particular person, event, or phenomena. Hermeneutics enables a process of moving back and forth when thinking about the data, an iterative process. The hermeneutic circle engages with the part-whole relationship of the text. These aspects of the theory of hermeneutics allows meaning to be gained at a number of different levels. Idiography gives insight with detail and therefore depth of analysis. The commitment for idiography is about gaining an understanding focused upon a particular person, within a particular context.

3.4.3 Idiography

Within research, often a nomothetic approach is adopted. The nomothetic approach is where generalisations made apply to all people to better understand large scale social patterns. “Idiography is the study of the particular” (Smith et al., 2009, p. 29). This detailed information is about particular people in a specific context. If we think of *dasein*, it can be thought of as the “mode of being, realised by human beings” (Wheeler, 2018, p. 5). *Dasein* places experience as “immersed and embedded in a world of things and relationships” (Smith et al., 2009, p. 29). Here we accept that people can give unique, personal perspectives concerning phenomena. Individual, personal perspectives are ideal for the intention of the research to be undertaken and integral to the IPA methodology.

Key to idiography is the detailed analysis made of the individual experience, before a thematic analysis across the group. Analysing the personal experience before undertaking a thematic analysis allows for the identification of the shared experience, which can be interpreted radically differently by the individuals concerned (Miller et al., 2018). Idiography enables the identification of individual perception, those that are the same and those that are different, based on the shared lived experience (Pietkiewicz & Smith, 2014). Analysis undertaken within IPA from data collected is focused upon interpretations made from individual perceptions, beyond a descriptive focus, then moves toward the shared common themes, moving back and forth, within this data. The focus is upon what is revealed by data collection, without seeking to make findings fit with any pre-existing theory. Generalisations cannot be made, as this naturalistic inquiry is time and context-bound (Lincoln & Guba, 1985). Inquiry-based research targets an increased understanding of phenomena, that is, the why or why not when undertaking the use of digital technology within the year 7-10 mathematics classroom when considering the optimisation of digital technology use.

3.5 Summary of the methodological approach

With the discussions above, we can see that IPA is comprised of the theories of phenomenology, hermeneutics, and idiography. IPA is "concerned with the detailed examination of the human lived experience" (Smith et al., 2009, p. 32). IPA is phenomenological as it tries to get as close as possible to the lived experience. However, without interpretation, which is hermeneutic theory, the understanding of the meaning gained of the personal experience would not be visible. IPA is idiographic as it is particular to this event, person, and phenomena.

As a researcher, I have obtained the perceptions held by the teacher participants as they lived them through their mathematics classroom practice and their use or not of digital technology. As this research process looks at the particular, I asked my participants to be reflective. Most of this reflection has occurred in real-time, which allowed me to pursue points of interest as they presented during the semi-structured interview scenario. To support this, given to each participant in advance was the questions that I could/might put forth to them in the semi-structured interview scenario, dependent upon where the conversation led. My analysis focused on the individual's data and, data at the group level. As a researcher, I was interpretative, reflective, and, aware of the preconceptions that I held, hence the bracketing that took place, for the participant to be my focus. The use of digital technology within the teaching practice of others is not a subjective issue for this researcher, which supports the use of bracketing, to maintain objectivity. Curiosity about the perceptions held by other practicing mathematics teachers was a motivator. I accept that objectivity, in a pure sense, is unobtainable, which is why trustworthiness is one of my criteria utilised to ensure as much as possible that I maintained a system of checks and balances that allowed for balance and fairness, as much as possible (Lincoln & Guba, 1985).

What I achieved is a look at the human lived experience from within, as opposed to looking at the human lived experience from the outside (Cohen et al., 2018; Gallagher, 1992). I am hopeful that the reader can see that phenomenology allowed us to become involved in these lived experiences of the participants; hermeneutics has enabled us to interpret the experiences of each participant and researcher and, idiography enabled analyses of particular experiences to be undertaken, occurring in real-time, as the researcher questioned for clarity and a deeper analysis of responses obtained.

3.6 Potential limitations of IPA

With any research method utilised there exists aspects of the methodology that are considered to detract from data gathered. An awareness of the limitations to IPA methodology allows for an objective viewpoint and, in some instances, correction or minimalising of these limitations. Listed below are the limitations known within IPA methodology. These are:

- The relative “newness” of IPA methodology
- Limitations applied to hermeneutic theory
- Sample size
- The tension between the researcher and participant perspectives
- Ethical boundaries
- The generation of common themes
- The pitfalls of thematic analysis (being descriptive with data as opposed to analytical, using your data collection questions as your actual themes, weak analysis, and unfounded claims) (Braun & Clarke, 2006; Joy et al., 2023).

IPA first emerged in 1996 and is considered twenty plus years later to be emerging still (Smith, 1996). What this means for the novice researcher is the lack of availability of communities of knowledge, versed, and experienced in the use of IPA (Wagstaff et al., 2014). The emerging nature of IPA can lead to difficulties in clarifying any uncertainties experienced by the researcher, given the lack of available, knowledgeable parties to undertake a dialogue with.

There are three criticisms of the theory of hermeneutics. The first criticism of the theory of hermeneutics considers the role of bias, and the impact of this upon interpretation undertaken. These biases or prejudices exist beyond the control of the researcher and reflect reproduction. To mitigate this, according to Gadamer, involves basing interpretation on productive bias and elimination of the non-productive bias (Gallagher, 1992). Productive biases can preserve interpretations that enable truth. Taken a step further, a claim can be made, that the objectivity of the methodological process undertaken negates the subjective factors of interpretation (Gallagher, 1992). Within education, as an example, this bias may present in the form of acceptance of teacher-centric practices already in existence.

The second criticism of the theory of hermeneutics is the debate on the impact of authority, power structures, and tradition upon understanding gained. Are these reproduced, due to their embedded nature, within interpretation, or does the role of critical reflection transcend and break up these existing structures (Gallagher, 1992)? Within education, this may present as the domination of existing educational practices and ideologies. Given the existing dominant thinking, it may be that rational personal autonomy on the part of the teacher may be deferred due to existing authority structures.

The third criticism of the theory of hermeneutics can be the debate between trust and suspicion. Ricoeur (1981) refers to the hermeneutics of trust as involving the restoration of meaning (Gallagher, 1992). By contrast, Ricoeur (1981) refers to the hermeneutics of suspicion as involving a distrust of what purports to be the truth (Gallagher, 1992; Langdridge, 2004). Within education, the simplified version of this debate is, can the existing education system, reflecting as it does the dominant western thinking, be trusted to illustrate transformative educational practices. These are theoretical debates illustrative of hermeneutic theory and are outside of the realms of the ability of the researcher to change, but can be identified, prior to data collection and can be illustrated within individual and collective themes, adding depth to findings discussed and conclusions reached.

Idiography reflects small sample groups, a significant aspect of IPA methodology, and the gathering of rich text data. The small sample size limits the broad-based application of findings across populations, as representative of population parameters. What it does allow for among other aspects, is an intimacy of rich text data gathering, exploration, and flexibility not present in quantitative data gathering (Smith et al., 2009). The target of naturalistic research is a movement away from population generalisations in order to gain an increased understanding of human lived experience (Lincoln & Guba, 1985).

Previous studies undertaken reveal that tension between the researcher and participant perspectives can arise. The application of the double hermeneutic allows both perspectives' relevance. Here we have both parties looking at the same phenomena but from different angles. Tensions can arise with the introduction of sense-making and the involvement of theoretical perspectives. The researcher can disagree with the surface meaning obtained from the participant but agree with the deeper meaning (Smith et al., 2009).

IPA, as discussed above, has an idiographic focus. Idiography is a concern for the particular. The individual account of a particular phenomenon in a particular context. Researchers can experience resistance within themselves to a movement from individual accounts toward common themes collected from a sample group. This resistance reflects the focus on the particular. However, in the details held by similarities and differences across individual accounts and where patterns emerge, the distinctive voices of individual accounts can still be described (Smith et al., 2009).

Within the process of rich text, data collection is an intimacy of shared stories. Ethical sensitivity has to be applied to the sharing of stories, as the opportunity for exploitation exists, professional conduct, applicable to IPA methodology has to be maintained (Wagstaff et al., 2014). The following two examples illustrate this point. If a researcher were to hold a senior role in an organisation and is interviewing a party junior to themselves, within the same organisation this is representative of a power imbalance, which could be misconstrued as intimidating. A further example could be the sensitivity of the nature of information shared. Sensitivity to this shared space forms part of the ethical boundaries that exist as an IPA researcher. Rapport building is a crucial aspect of the participant/researcher relationship. Connectivity, humanness, and empathy (CHE) principles strengthen rapport, which in turn strengthens the participant/researcher relationship (Brown & Danaher, 2019).

In addition to the points listed above, I can include theoretical and philosophical positioning and the involvement of software use within qualitative research. However, the conflict illustrating this first point describes the meaning of cognition relative to the discipline of psychology and, as such, is not relevant to my study. Within this, IPA looks at individual perspectives on lived experience, and both concepts could be accommodated within this process of sense and meaning-making (Smith et al., 2009). The second point of software use debates the role of active analysis in contrast with automatic coding when using software

(Wagstaff et al., 2014). The use of software was vetoed as the ‘rich’ text data obtained required a greater depth of familiarity by the researcher. This familiarity assisted in the active analysis gained. This allowed myself, as the researcher, to obtain as many different perspectives as possible.

The pitfalls of thematic analysis relate to experience on the part of the researcher. The first pitfall is where the researcher describes the data, as opposed to analysing the data. An experienced researcher will take the extracts of thematic data used and use them to illustrate analytic points made (Braun & Clarke, 2006; Joy et al., 2023). The second pitfall is the use of the data collection questions from the interview schedule as your actual themes, which means that no analysis has occurred at all (Braun & Clarke, 2006; Joy et al., 2023). The third pitfall is a weak or unconvincing analysis due to errors in theme identification and coherence. Themes should centralise around an idea or concept (Braun & Clarke, 2006; Joy et al., 2023). The fourth pitfall is due to unfounded analytical claims. Data must support claims made. Interpretation must be consistent with the data extracts undertaken (Braun & Clarke, 2006; Joy et al., 2023).

To overcome these apparent pitfalls, I referred to a qualitative check on good thematic analysis. This is a 15 point checklist, confirming and identifying a process of systematic and rigorous application illustrative of good thematic analysis (Braun & Clarke, 2006; Joy et al., 2023). The strengths of thematic analysis include flexibility, an ability to highlight similarities and differences in data collection, an ability to summarise key features of the data and, an ability to generate unanticipated results, to name a few (Braun & Clarke, 2006; Joy et al., 2023). This is not an exhaustive list of advantages but is illustrative of the IPA process and focus.

In summary, every research methodology has a scenario of strengths and weaknesses, and IPA as a method is no different. The last five bullet points of the discussion on IPA limitations were within my control as a novice researcher. These limitations were minimised and are discussed further under thematic analysis, pilot study, and semi-structured interview techniques. With awareness comes an understanding of the obligations to the research process by the researcher.

Research design - interpretative phenomenological analysis (IPA)

3.7 Recruitment process

The overarching aim of this study is to understand year 7-10 mathematics teachers perceptions of the aspects that influence their use of digital technology within their classroom teaching practice. Sampling took place in a single geographic region of New Zealand. A core group of six mathematics teachers took part in this study obtained from two high schools and two intermediate schools. Purposive sampling has enabled a group of participants who met the criteria and volunteered to take part in this study.

Purposive sampling has been utilised, meaning the intentional selection of practicing mathematics teachers operating within a classroom environment. This has provided me with a selection of practicing mathematics teachers, that are using digital technology to some degree within their teaching practise, allowing an illustration of real classroom experiences. "IPA studies benefit from a concentrated focus on a small number of cases" (Smith et al., 2009, p. 49). An intensive focus on a small number of cases enables the researcher to focus upon individual analysis with greater accuracy, given the smaller number of participants. The individual analysis occurred before the group and thematic analysis.

The context for this study was junior mathematics reflecting year 7-10 teacher practitioners. It may be that there are differing mathematics classroom practices that support classroom achievement for year 7-8 as opposed to year 9-10. Teaching practice is aligned to targeting individual student learning needs where lessons are pitched to cater to group and individual student attainment. Student attainment within mathematics across this bracket of year levels can be immersive, where students are functioning at the same curriculum levels regardless of year level.

The *New Zealand Curriculum* document caters to curriculum levels as opposed to year levels (Ministry of Education, 2007). This means, for example, that curriculum level four is reflected from year 6 through to year 11 (Ministry of Education, 2007). This is where differentiation in student learning needs was considered, with teachers teaching to individual student curriculum levels as opposed to teaching to a perception of student year level achievement. This aspect of the context of this study allowed the evaluation of both intermediate and high school teacher perception of teaching practice within mathematics.

Two of the schools of this study were year 7 through to year 13 and so the teachers often taught in all four levels.

Additionally, some secondary teacher training programmes reflect junior mathematics to be inclusive of year 7-10 within New Zealand, for example the University of Waikato. Some composite schools also include year 7-13 within their junior high school programmes, and some junior high schools reflect year 7-10. The inclusion of year 7-10 teacher participants is then reflective of the junior mathematics design brief.

Participants who volunteered to take part in this study were from schools within this same geographic area, although additional rural area and secondary schools were invited to take part, only those that were willing responded. This was in addition to more than one approach by this researcher. I was able to obtain six volunteer participants from four schools on this basis. The influence of COVID and teacher workload and stress were apparent, with those refusing to take part stating the circumstances listed above as contributing factors.

My approach to each school, inclusive of intermediate and secondary schools in this area as befits the year 7-10 mathematics brief, initially was made by sending a letter by email to each respective principal (see appendix B), in addition to a power point presentation. Once this was undertaken, the principal concerned organised volunteer contact given the COVID scenario. As the scenario of COVID-19 prevailed over a substantial length of the research timeframe, the actions undertaken by all participants adhered to the restrictions imposed by this pandemic. Accordingly, group meetings were mitigated where possible by the power point presentation giving a project brief and schools calling for volunteer teachers to take part. The process of volunteer participation was undertaken in good faith by the respective schools. My role in this process became one of administration initially, as the volunteers were made known to me. At organised timeframes negotiated with each participant via email, meetings were set up. Once I contacted each teacher individually and confirmed their voluntary participation, I was able to initiate formal approval in writing, from each participant (see appendix C).

Upon receipt of their informed consent in writing, I was able to forward to each participant a full set of interview schedules (3), for them to be fully aware of the intended semi-structured interview questions (see appendix D). Interview timeframes were 60 to 90 minutes in length. Initially each participant received a full set of diary questions, with the emphasis placed on the voluntary nature of these entries and the intention for these diary entries to be completed weekly across 12 weeks.

The diary commitment was an open and flexible process for both participation and time spent, however it soon became apparent that the teachers concerned preferred to respond to the intended diary questions, within the consecutive interview scenarios. I left this open, for any additional thoughts and comments to be expressed at a later date which did not occur. Within the interview circumstance the opportunity to reflect on responses before the interview took place, also negated the diary keeping, as expressed to me by the participants.

The original intention of the 4-week time frame and the keeping of a reflective journal was to allow a reflection to take place on the use of digital technology either for a whole or part of a lesson, at least once a week. The thinking within this design was that a block of four weeks would target each research question as each interview took place with each participant.

The participant could then record and reflect as the lessons occurred. The time allocation was made to accommodate those that had ready access to devices to use within their lessons and those participants that did not. The thinking being if a booking system was in play, and device use was influenced by availability that a strategy to accommodate reflective capacity for all participants became a component part of the design of this study.

It became clear that the use of digital technology was within each lesson for those with access and a desire for those without ready access. This circumstance became a reflection of the influences at play. As a researcher I felt that both circumstances gave depth to this study with or without the inclusion of a reflective journal.

I left the 12-week timeframe in place even without the reflective diary component as it meant that time was given for reflective capacity, across each of the interviews one, two and three, which targeted questions one, two and three respectively, thereby increasing my qualitative data collection. My intention in doing this was justified I felt, particularly within the post COVID environment of high teacher anxiety/stress and increased workload as befits a recovery process. I worked within the existing time bound commitments that each teacher had. Timeframes were at teacher convenience, which meant that interviews took place after a full teaching day for most and interviews occurred when teachers had available free time.

I had to take care of my participants within this hither to unknown circumstance, of a pandemic scenario, the resultant lockdown, and the “catch-up” nature of the educational environment thereafter, by giving adequate timeframes that were generous, between interviews, which numbered three in total. I felt that a 4-week timeframe between each interview, from audio taping, to transcription, to confirming the transcription, to emailing the diary questions on a weekly basis, to submitting the interview questions in advance, to booking/appearing for the next interview, was a generous timeframe. This timeframe allowed me to care for the wellbeing of the participants of my study, which I felt assisted with the free-flowing nature of our dialogue.

3.8 Participants

To gain qualitative data and within the boundaries of the methodology that I have used, I have looked at a core group of six practicing mathematics teachers of year 7-10. This became a reflection of two high schools and two intermediate schools. The schools and participants who indicated interest and were willing to participate are as follows:

School One is a high school which has a role of approximately five hundred with 29% who identify as Māori. Results show, based on NCEA and national standards that students perform well above schools of similar type with Māori learners experiencing similar success. This school is a co-ed school with gender composition of male 51% and female 49%. Mathematics at year level 7-10 is both a discrete subject and a cross-curricular subject (with one other subject area e.g., Science), with a thematic delivery. An example of this would be teaching by a unit reflecting knowledge content of both disciplines.

The timetable allows for cross curricular modules to be taught for four x 85-minute blocks each week. The timetable also allows for the teachers concerned to teach two lessons of 45 minutes of mathematics within a school week (90 minutes in total). The discrete lessons and the cross curricular thematic lessons are in open classrooms. In addition, annexed off the open classroom area, are optional break out rooms and science labs available for use at teacher discretion illustrative of the innovative learning environment (ILE). Team teaching can occur. This school has a readily available resourced digital programme.

The two participants of this secondary college were both experienced teachers. One of these teachers was a male from overseas, whose discipline and specialist qualification supported mathematics. The New Zealand teacher was female, whose discipline and specialist qualification supported science. Both teachers I would describe as experienced, qualified teachers of their disciplines. I have given the pseudonyms of Laurell to the New Zealand based high school teacher and Matiu to the overseas based high school teacher within the findings chapter.

Both teachers were experienced in their use of technology and were well supported with both resourcing and professional learning and development. Laurell, the New Zealand based teacher had duties within management of the school. The paid for resource available to them was *Education Perfect*, and should they desire, any other resourced software. Devices were utilised on a one student to one device basis, meaning not a booking system, where usage was as it occurred. Both teachers took advantage of the school offer attached to professional learning and development provided by Manaiakalani.

School Two is a co-ed intermediate school which had a role of approximately six hundred students. Approximately 50% of these students identify as Māori. Gender composition is equally divided. Most students achieve at or above national standards. This school has a Head of Department Mathematics teacher, who facilitates professional development for staff in this discipline, in addition to co-ordinating and providing supplementary tutoring for students on an identified basis. Mathematics is taught within class, outside of this. The timetable for mathematics, occurs within teacher discretion, of approximately four hours per week. This school is committed to a resourced digitised mathematics programme.

The teachers at this school had pseudonyms of Courtney and Arihia and are both female. Courtney is an experienced teacher of many years with a specialist area targeting mathematics and is also a member of the management team, meaning the Head of Department of Mathematics within this intermediate school. Arihia is a beginner teacher within this environment but has teaching experience in early childhood education prior to this time. Arihia has had two years teaching at this level.

This school has used *Mathletics* over several years and are happy with the targeted student outcomes achieved. Both teachers are positive about their use of digital technology within their classrooms. Both teachers are from New Zealand. Both teachers have received generous professional learning and development support and have also individually sought additional training targeting mathematics apps and digital technology. This school has a BYOD policy in place and endeavours to provide one device to one student.

School Three has a role of approximately four hundred students and is a co-ed intermediate school. Gender breakdown is equally divided between male and female students. Approximately 72% of these students identify as Māori. There is some disparity between achievement in mathematics for Māori and Pasifika in comparison to achievement in mathematics for Pākehā. The latest ERO report (2019) shows significant acceleration of progress for at risk learners in mathematics. This Intermediate school has a Head of Department Mathematics teacher, who facilitates professional development for staff in this discipline, in addition to a SENCO role. Additional support is provided to students for mathematics, outside of existing classroom activities. The timetable for mathematics is reflective of four hours per week, within teacher discretion. This school is committed to a resourced digitised mathematics programme.

Taylor, (pseudonym), is an experienced male teacher who has come from overseas, and is both management based, SENCO and a provider of training opportunities for other teachers of mathematics. Taylor is an experienced teacher with a focus upon mathematics and drives achievement in this discipline for this intermediate school. The software in use here is *Mathsbuddy*. Taylor is supported with professional learning and development. Devices are readily available across the school. Taylor is multi-lingual.

School Four has a role of approximately 800 students and is a single gender high school. Approximately 60% of these students identify as Māori, with 30% of students who identify as Pākehā. Entry level data shows that students at year 9 are performing significantly below curriculum expectations within both literacy and numeracy. The timetable for maths reflects a commitment to approximately four hours each week, reflected in each teachers block timetable. The school does not have a readily available resourced digitised mathematics programme.

The pseudonym for this teacher is Joelle. Joelle is an experienced female teacher, who has a specialist qualification in her discipline of mathematics. Joelle is a member of management within this high school and across other areas targeting mathematics within the wider education environment. At the time of this study Joelle was Assistant Head of Department of Mathematics. Joelle has had extensive professional learning and development opportunities with specialist software programs, specifically targeting senior mathematics. Devices are not available on a one student to one device basis, with a booking system in place.

Joelle is enthusiastic about the use of digital technology within her teaching practice.

Two of the schools had dedicated mathematics software in the form of *Mathletics* and *MathsBuddy*, and two of the schools had mathematics software in the form of *Education Perfect*. One of these schools had *Education Perfect* made available during COVID only, reflecting free trial periods. Three schools had unrestricted device usage. One of the schools had adopted the innovative learning environment (ILE), (School One), which employed two teachers who participated in this study, (Laurell and Matiu). This was a decile six school, considered by participants to be well resourced.

Table 5 below lists all the participants and their schools, together with the software resourced by their respective schools.

Table 5

PARTICIPATING AND CONTRIBUTING SCHOOLS

SCHOOL TYPE	SCHOOL NUMBER	TEACHER PARTICIPANT	COUNTRY	DESCRIPTION	RESOURCED SOFTWARE IN USE
Secondary	School One Decile 6	Laurell (science specialist)	NZ	Cross curricular Teacher (ILE)	*Education Perfect*
		Matiu (mathematics specialist)	Overseas	Specialist mathematics Teacher (ILE)	*Education Perfect*
Intermediate	School Two Decile 4	Arihia	NZ	Beginner teacher	*Mathletics*
		Courtney	NZ	Head of department mathematics	*Mathletics*
Intermediate	School Three Decile 2	Taylor	Overseas	Head of department mathematics	*MathsBuddy*
Secondary	School Four Decile 3	Joelle (mathematics specialist)	NZ	Head of department junior mathematics	Free trial *Education Perfect*

Note. Participant and school data collected by the author during August 2020.

Interpretative phenomenological analysis (IPA) - research methods

3.9 Data gathering

The data I have been interested in gathering, as mentioned above, is by direct, verbal discussion within a semi-structured interview scenario, over a series of three interviews. (Mackey & Gass, 2005; Smith et al., 2009). I have utilised semi-structured interviews as they provide the desired rich text data. I was open to the collection of any other data to provide context. I was thinking here of perhaps a lesson plan or use of the reflective diary but found that this did not occur. I did not force the gathering of data of any sort but allowed the opportunity of freely given information to occur. I felt that the degree of dialogue, which was extensive and informative within the interview process, with all participants negated the necessity or need to include or try and gather any additional information.

As a researcher, I have used a reflective journal to record any bias that I think that I may have had or any thoughts about what had occurred during the interviews. My research design necessitated a pilot phase, given the need to gain experience about my interview technique, timing, clarity of questions asked, among other points of relevance. These factors are discussed below.

3.10 Pilot study

As a researcher, in this study, the pilot phase allowed me to pre-test my semi-structured interview schedule and my interview technique on my volunteer participant. This gave me the opportunity to employ and develop my reflective capacity before undertaking a series of semi-structured interviews. I felt that this contributed to an improved interviewing technique.

The pilot phase having taken place, consisted of a volunteer practicing teacher, who sat down and read the questions relating to the reflective diary entries, representative of one week, of approximately 20 minutes. We also completed the first interview and undertook reflective dialogue upon completion. Comment was made by my volunteer to link the reflective diary entries into the interview scenario, but I left this open for each teacher to action as they desired. This volunteer participant indicated that the pressure of time would negate the keeping of a reflective journal.

I confirmed within this pilot study that the first interview timeframe allocated of 60-90 minutes was appropriate. It became apparent thereafter, over consecutive interviews, with three interviews with each participant that the timeframes would fluctuate, dependent on the reflections undertaken by the volunteer teachers. Each participant undertook dialogue of more than two hours each in total across three interviews.

A pilot allowed me, as the researcher, an opportunity to make any necessary adjustments or revisions needed before undertaking my research. This pilot study gave me the opportunity to check on the trustworthiness of my research design, gain feedback on a variety of data, as mentioned a check on timeliness, a check on the questions and instructions, prompt clarity, allow any misunderstandings to be identified, or to generate thoughts on contextualisation (Cohen et al., 2018).

This pilot study allowed me to add to the rigour of my research design overall, given my novice researcher status. Undertaking the pilot study allowed me to assess my readiness, capability, and commitment as a qualitative researcher (Beebe, 2007; Brown & Danaher, 2019). I was initially hesitant about my ability to undertake conversational dialogue of interview quality but found that as the material was of interest to the participant teacher, reflecting teaching practice undertaken and myself in the role of researcher, that dialogue was not a barrier. Teacher participants had the opportunity to share their thoughts, give opinions and dialogue about their work environment.

As the interviews took place in a real-time context, as befits the IPA methodology, in a school environment, I found myself sitting in private pockets within school settings, where privacy was encouraged, with minimal distractions and interruptions, trying to identify the best timeframe for the interviews to occur. Generally, I planned for the successful collection of data.

One thing the pilot allowed me to identify as a researcher was the degree of bracketing needed to be undertaken by myself. This identified for me that I should be as free of common sense assumptions as possible, which enabled me to be open and receptive as a listener (Chenail, 2011). I found that throughout the study making the participant the focus of the conversation, listening to their experiences, and obtaining their viewpoint on the phenomena, actually meant that my own viewpoint was put to one side as the interview dialogue took precedence due to the interest the participant and myself had about the subject material (Mackey & Gass, 2005). I was more interested in their response than any thoughts of my own. The pilot allowed me to identify; ambiguities and difficult questions, time allocation, interpretation of responses given, shorten or reword questions, potential prompts, and my own researcher bias (Chenail, 2011).

3.11 Semi-structured interviews

Semi-structured interviews follow an interview schedule. The topic and questions are presented to the participant in advance and revisited within the interview. Questions may be open or closed. However, open-ended questions are advocated. Whether open or closed questions are used, opportunities exist to prompt for further insights, follow up questions to seek clarification, follow an unexpected area of response and deviate from the intended questions at times. The nature of semi-structured interviews allows for flexibility and adaptability, whilst maintaining a focus on the intended direction of the semi-structured interview.

A greater prevalence of open-ended questions allows for a wider range of responses from participants. My interviews targeted the recipient entering into a dialogue which was pitched to go in whatever direction the participant chose, or the depth the dialogue took us. This reflected the open and flexible nature of the interview process. Participant responses were explored with prompts and probes, which assisted with clarification and exploration. This allowed for a depth of response, comprehensiveness, honesty, and richness (Cohen et al., 2018; Naz et al., 2022; Ruslin et al., 2022).

As an interviewer I then had discretion over the order the questions were asked, and the wording used. What I as an interviewer had hoped to achieve, was the tailoring of the interview to the individual interviewee. What can be achieved with open responses by participants in the development of the dialogue, in real-time, is the depth of response in ways unforeseen when the interview schedule was initially constructed (Brown & Danaher, 2019). It can be said that some of the questions I have asked within either the diary entries or the semi-structured interviews were not as open as they could have been, and therefore a criticism of my data gathering process. My response to this is that I was inundated with dialogue throughout each interview and my skeleton of questions delivered in advance did serve to stimulate discussion. Open and closed questions are considered appropriate in a semi-structured interview. The provision of the skeleton questions given in advance is a feature of the semi-structured interview process. I was not restricted to the questions on the interview sheet, they served as the initial prompts and were preparatory in nature to the actual dialogue of the interview.

Semi-structured interviews sit between structured interviews, where the interviewer does not deviate from the interview schedule and unstructured interviews that reflect emergent conversations on general topics rather than questions asked (Brown & Danaher, 2019). For my study, the semi-structured interviews were held face-to-face onsite at each respective school, due to participant convenience of location and time. Across the three interviews undertaken a total of two hours or more was spent within an interview scenario. This meant that some participants spent more time than this with two hours a minimum. Each semi-structured interview had an approximate timeframe of one hour.

Some of the advantages attached to the use of semi-structured interviews are: the ability to obtain in-depth information; that these interviews are flexible and adaptable; these interviews hold their direction; it is an easy data collection method, and these interviews use a guide which goes over the main topics of the interview (Naz et al., 2022; Ruslin et al., 2022).

Some of the disadvantages of the semi-structured interviews are: The findings are dependent on the skill of the interviewer (leading questions, inappropriate probing); the necessity of undertaking a pilot interview, and the necessity of having some knowledge of the subject domain (Naz et al., 2022; Ruslin et al., 2022).

As I am following an IPA methodology, my research participant group was small, with six participants in total (Smith et al., 2009). I attempted as a new researcher to follow the connectivity, humanness, and empathy (CHE) principles within my interview technique. CHE principles support the relationship between the participant and the researcher (Brown & Danaher, 2019). The relativist ontology of IPA will enable the expression of multiple interpretations of the human lived experience. The epistemology of my study is about knowing something well based on personal experience (Cohen et al., 2018). CHE principles also consider axiological values. Axiological values reflect an ethical stance that places value on otherness and difference (Thiele, 2014).

The application of the CHE principles within the semi-structured interview enabled a rapport to develop between myself as the researcher and the participant teacher(s) in an environment of trust. Rapport building is considered to be a critical factor in consideration of the relationship dimension undertaken within successful semi-structured interviews (Brown & Danaher, 2019; Pitts & Miller-Day, 2007). Given the pandemic scenario, often the interview acted as a sharing space, allowing the participant to express the emotions they felt attached to anxiety, but also the need to reestablish the continuity of face-to-face dialogue, about the difficulties of picking up a new teaching and learning model indicative of the online nature of lockdown, and a where-to-from-here thought process.

I understood that, as the researcher, I was in a privileged position where I was sharing the participants' world. From a shared frame of reference to the participants' world comes understanding. This understanding is developed from within, meaning from within the text produced by the participant (Cohen et al., 2018; Smith et al., 2009).

Connectivity between myself, as researcher and each participant individually became about establishing rapport, reflective of openness. Connectivity was achieved using first names, maintaining eye contact, the appropriate positive body language (smiling), and a friendly approach (tone of voice) (Pitts & Miller-Day, 2007). The focus here was on interpersonal connection with recurring communicative behaviours (Pitts & Miller-Day, 2007). Humanness allowed for informality and removing distance between myself as a researcher and each participant teacher (Brown & Danaher, 2019). I applied empathy to each interview scenario. Empathy encourages active listening, appropriate verbal responses, and a position of humility. The researcher is not an expert and is not seen as an expert as lived experience prompted the narration. The questions asked reflected the desire to elicit an individualised response based on individual perception.

As a researcher, I am aware of the privilege of being able to access the thoughts, feelings, and opinions of another. I worked toward the development of an interview-style, that let each individual participant know that I was interested in what they had to say, in as much detail as they could give and that there were no right or wrong answers (Smith et al., 2009). "The goal will be to facilitate rapport-building and respectful and reciprocal relationships … " (Brown & Danaher, 2019, p. 85).

I held three interviews for each participant. Each participant had three semi-structured interview schedules given to them prior to the interviews taking place. This occurred due to each of the three research questions being the focus of each separate interview. Therefore, each interview targeted a separate question, with a focus different to the other two questions. Each interview was specific in the focus applied to the interview.

To transcribe each interview, I undertook an audio taping. Once the interview was transcribed, I asked the participant to check the typed transcription for accuracy and gave the participant the opportunity to amend any detail as desired. Interview questions were revisited in my semi-structured interview over the three interviews. Possible prompts provided in the interview schedules resemble a neutral tone elicited for a response. Audio taping provided in total approximately two hours of narration for each participant.

3.12 Clarification of interconnecting data

When undertaking the interviews and looking at my thematic data and emergent themes, I was aware of the interconnection or overlapping nature of data collection. By this, I mean that when undertaking interview one, data for interview three may appear, and vice versa. As well, in say interview one, at times, the interviews may move in the direction of topics/issues related to research question three, so I might pursue that line of inquiry at that point. The interconnectedness of data will occur with all of the data gathered, reflecting the nature of the opportunity given to keep a reflective journal and the interview process which took place. I was aware of this and looked for these connections and overlaps as they occurred and collated and analysed as applicable. The interconnectedness of data is the nature of rich text data collection.

As my data was collated into major themes the interconnectedness of data was analysed by theme and this did not mean that I had to differentiate data by interview number. Although, for example, findings in interview three may have been mentioned in interview one, with interviews occurring separately, the theme nature of my analysis allowed for this.

3.13 The researcher and her reflective journal

To maintain myself as a naïve stranger, I kept a reflective journal (Denscombe, 2014). My reflective journal was undertaken from the pilot study and throughout all of the data collection process (Chenail, 2011). I found that I did not make a lot of journal entries, but when obvious thoughts presented, I did write about them after the event, and did not allow my own opinion to colour the interview, the interview process, or the analysis thereafter. This enabled me to see how others made sense of the events (Denscombe, 2014).

I did this to get a clear view of the way that participant teachers saw their world, which is what I was targeting (Denscombe, 2014). Also, I attempted to separate my experiential and theoretical knowledge, also referred to as bracketing. I recorded my ideas, thoughts, impressions, reflections, and feelings during the pilot and primary studies. Undertaking this reflective process enabled me to develop an understanding of my personal bias and feelings and the possible impact that these influences could have had on my research (Chenail, 2011). A reflective journal also helps to establish credibility, dependability, and confirmability (Lincoln & Guba, 1985). I have worked toward contributing toward the integrity of my research.

The reflective diary was important to me, as although there were not a lot of entries, I did not want my own experience as a mathematics teacher, interviewing other mathematics teachers, to colour my thoughts, or the dialogue that was undertaken. I was immensely grateful within the initial three-year timeframe of this study, to not be working at a school, in a classroom, in any capacity. I felt that this assisted with the open nature of my thought process.

Interpretative phenomenological analysis (IPA) - data analysis

3.14 Phases of thematic analysis

There is no right or wrong way of undertaking an analysis of this sort, and I utilised manual analysis, which gave me familiarity with the findings (Smith et al., 2009). As I transcribed this data, familiarity with the data gave the opportunity for reflective thought which I felt assisted with an increased understanding. One of the limitations referred to with rich text data, is that two different researchers could both take the same data and determine different outcomes. For this reason, I have looked at different ways of treating my new data. Manual transcribing and analysis will allow comparative approaches to data analysis of qualitative research (Braun & Clarke, 2006; Joy et al., 2023; Smith et al., 2009). The steps undertaken below depicted in Table 6, will allow thematic analysis to occur.

Table 6

PHASES OF THEMATIC ANALYSIS

PHASE	NAME	DESCRIPTION
1	"Familiarise myself with the data."	"Transcribe, re-read the data, note down the initial idea."
2	"Generating initial code."	"Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code."
3	"Search for themes."	"Collate code into potential themes, gather all data relevant to each potential theme."
4	"Review themes."	"Check if the themes work, in relation to the coded extract, and the entire data set, generate a thematic "map" of the analysis."
5	"Define and name theme."	"Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generate clear definitions and names for each theme."
6	"Produce the report."	"Selection of vivid, compelling extract examples, analysis of selected extracts, relating back to the research question and literature, producing a report of the analysis."

Note. Reprinted from Using Thematic Analysis in Psychology by V. Braun and V. Clarke, 2006, *Journal of Qualitative Research in Psychology*, *3*(2) p. 87. Copyright 2006 by Edward Arnold (Publishers) Ltd.

3.14.1 Phase one - reading and re-reading data

Initially, I audiotaped my data, with transcription carried out after the interview had been audiotaped. Transcribing allowed me to listen to each interview several times. After that, I typed my transcripts and revisited my interviewee with the transcript for their final approval. Any requested amendments were carried out, and discussions within my report have not mentioned any discarded excerpts from the amended data.

It was important to me to look at each interview, on an individual basis, as befits IPA methodology, before moving on to the next interview. It is at this point that I noted down any initial ideas or highlighted the essential points mentioned within the text. Repeated reading and immersing myself in the text was an active way of engaging with the text and allowed myself to identify meanings and see patterns (Braun & Clarke, 2006; Joy et al., 2023; Smith et al., 2009). This is a crucial aspect of analysis and grows familiarity with the data. This initial noting also included recollections and thoughts about the interview, and I recorded these to assist me in utilising a bracketing approach to immerse myself within the participant's world. It was essential here to transcribe all verbal and non-verbal cues and to retain the accuracy of punctuation to illustrate intended meaning (Braun & Clarke, 2006; Joy et al., 2023).

3.14.2 Phase two - initial noting/generating initial code

Once familiar with the data, an initial list of ideas was compiled. This is an organisational process of grouping. This process allowed me to undertake comprehensive notetaking about the data. It is here that I was able to start identification of what mattered to the participant (value, principles, events), to name a few, and the meanings of these things to the participant (what they are like). I started my interpretation from these notes on the participant's world, and how and why they thought the way they did. More significant interpretation can be gained from looking at the descriptive, linguistic, and conceptual comments made. From this point, I divided my transcript, for analytical purposes, for theme development (Braun & Clarke, 2006).

3.14.3 Phase three - developing emergent themes

It is here that the hermeneutic circle is utilised, and we look at the parts that make up the whole. In saying this, future analysis will enable us to look at the whole again, but emergent themes are more straightforward to analyse in part. By this, my example of an emergent theme could be, identification of professional development with the use of the software is needed. The narrative would identify this theme. To carry this further, it could be a problem of a lack of resourcing or an issue of self-confidence. A lack of resourcing is a grounded issue, and self-confidence would be an abstract issue. Theme identification then becomes a process of description and interpretation (Smith et al., 2009). Thematic mapping and using data extracts are utilised here (Braun & Clarke, 2006; Byrne, 2021; Joy et al., 2023). Refer diagram below figure 7, which shows an example of an initial thematic map. Thematic mapping should reveal data patterns and the relationships between them, complete with contradictions.

3.14.4 Phase four - searching for connections across the data and identifying the emergent themes

With emergent themes, I would be looking at abstraction, subsumption, polarisation, contextualisation, numeration, and function to bring the themes together. In this way, the analysis will work for this study and the material collected (Smith et al., 2009). This approach to the analysis is not exhaustive nor mutually exclusive.

Abstraction allows for the identification of the significant emergent themes and the development of an overview relative to the significant theme. Subsumption is where a major theme has been identified through the process of abstraction, which brings together related themes. Polarisation is the opposite association between emergent themes. Contextualisation is structured to consider the connections between emergent themes and the issues that surround these themes and the events and times when they have occurred. Numeration is the number of times a theme appears within the data. Function gives a representation of the connotations, whether negative or positive, that surround the emergent themes and, subsequently, their organisation according to these connotations. Bringing-it-together is the term used to describe the organisation of themes in more than one way, or the creative process, which allows higher levels of analysis to be undertaken (Smith et al., 2009).

As we progress throughout this process, which occurs to satisfy the overarching theme of the research questions, as opposed to the direct questions asked in the interview scenario, final thematic analysis can occur. My own thematic map from this analysis is depicted in figure 7. This is my initial thematic map, with my final thematic maps depicted in the findings chapter 4 and 5, figures 11, 12 and 13 and repeated below as figures 8, 9 and 10.

As the progress of analysis occurs amongst participant data, we can undertake thematic mapping a number of times, across a number of key ideas, in order to best satisfy the aim of the research undertaken. This does not mean that key issues are ignored or not reported on. Conflict within findings adds to the quality of the research undertaken and, it may be that what is unexpectedly revealed is a finding additional to that targeted.

Figure 7

INITIAL THEMATIC MAP FOR THIS STUDY

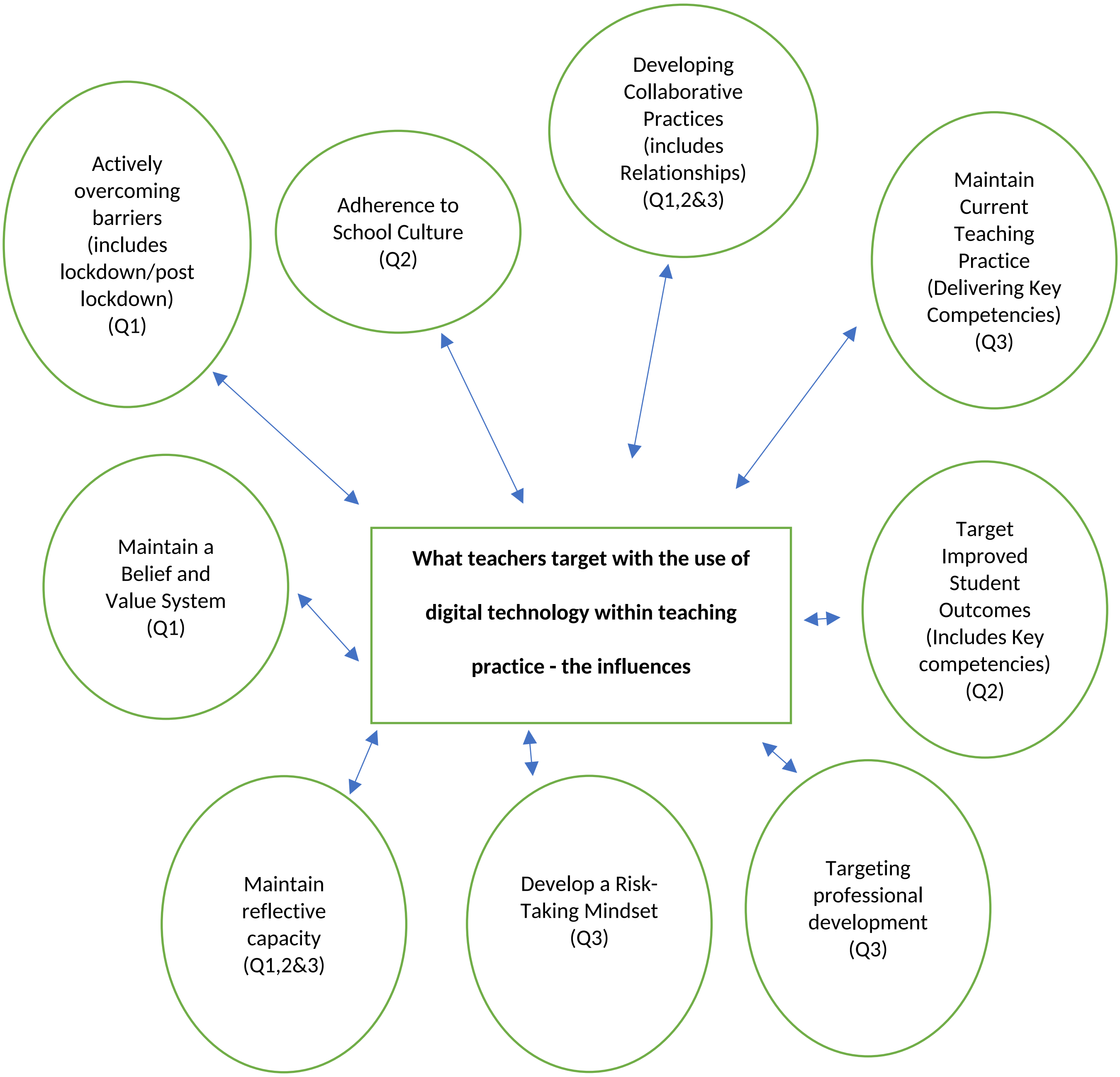
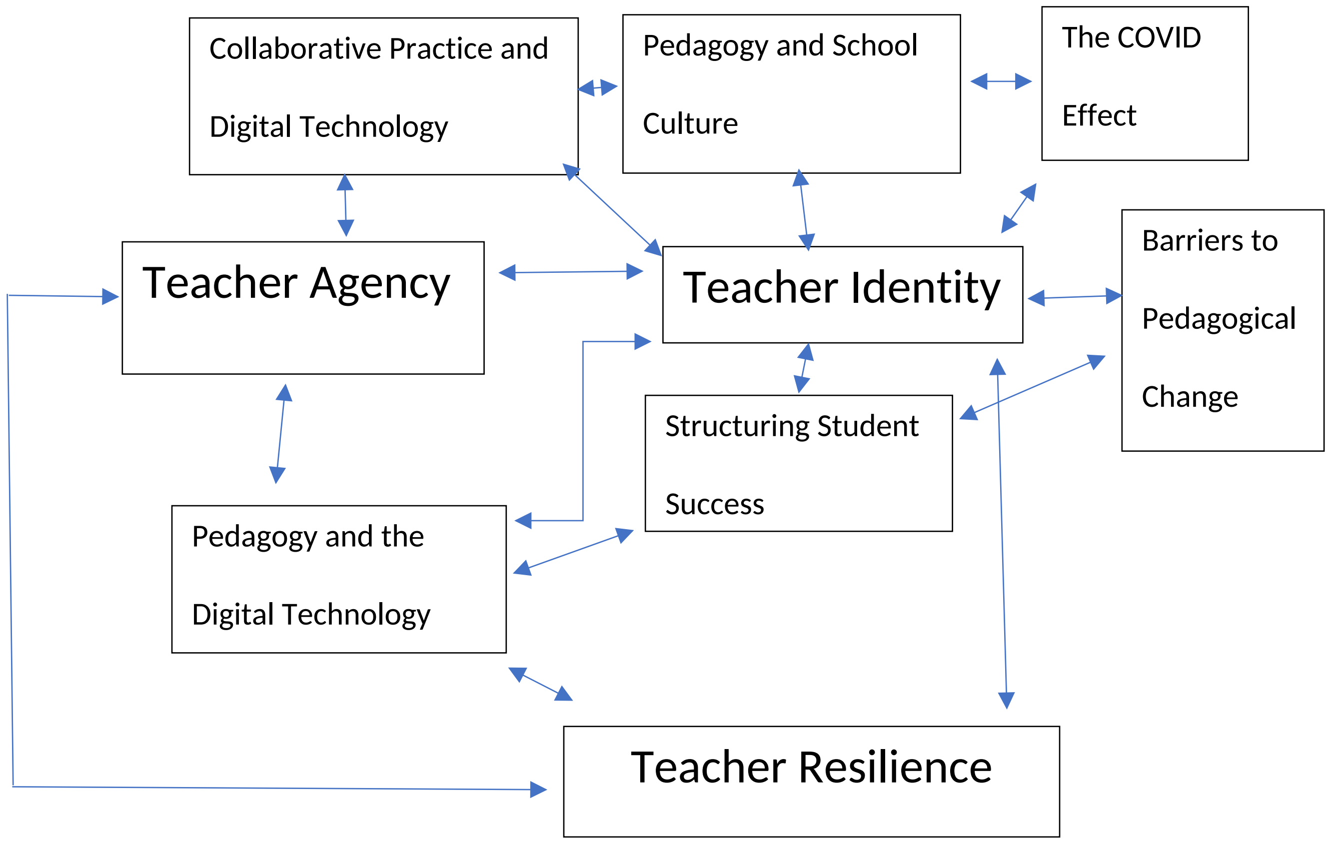


Figure 8

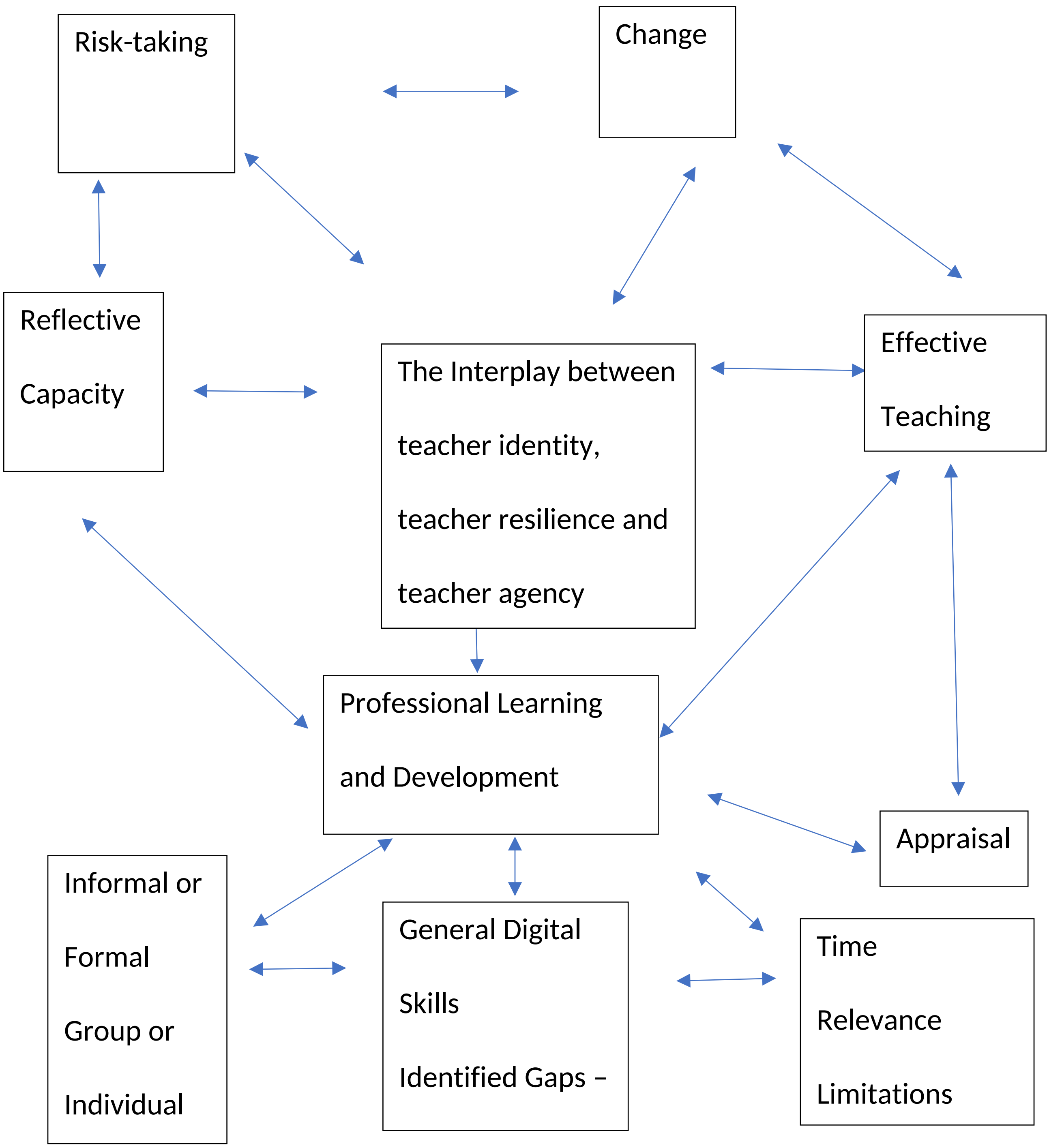
FINAL THEMATIC MAP FOR THIS STUDY – TEACHER AGENCY, RESILIENCE AND IDENTITY



Note. The diagrammatic form of the relationships that impact upon the interplay between teacher agency, resilience and identity

Figure 9

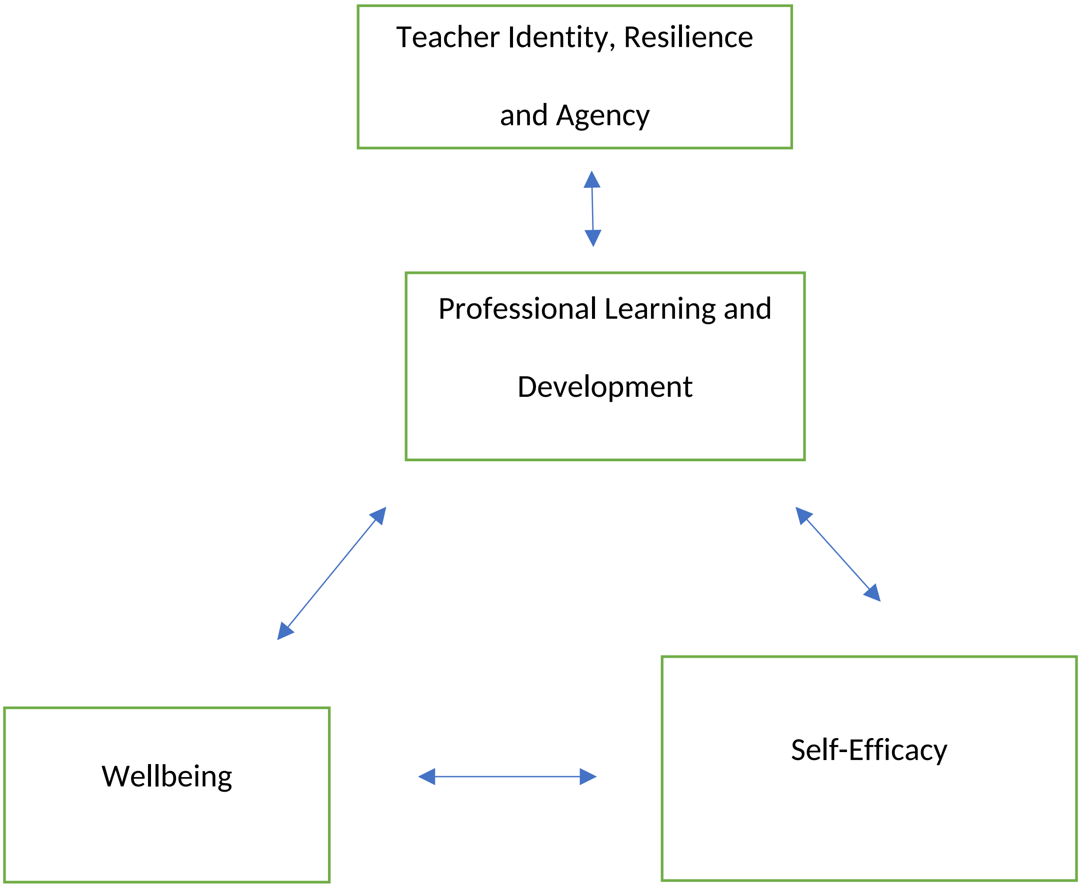
FINAL THEMATIC MAP FOR THIS STUDY CONTINUED – THE INTERPLAY BETWEEN PLD AND TEACHER IDENTIY, RESILIENCE AND AGENCY



Note: Influences at play when undertaking Professional Learning and Development.

Figure 10

THE INTERPLAY OF WELLBEING, SELF-EFFICACY, AND PLD ON TEACHER IDENTITY, RESILIENCE AND AGENCY



Note. Influences at play when undertaking professional learning and development.

3.14.5 Phase five - moving to the next participant

Having taken the above steps with my participant, I have repeated this process with each participant. Each participant's unique perception has identified new themes throughout. As I processed each transcript I looked for the similarities and the differences. I am happy that this process was iterative, which allowed me to move backward and forwards through the data, to confirm and identify existing and new themes as they appeared. The iterative process is a reflection of the IPA methodology (Smith et al., 2009).

3.14.6 Phase six - looking for patterns across cases and, defining and naming the theme

This process is creative, as I stood back and looked down upon my data, this allowed connections across participant analysis to appear. It may be that higher-order thinking and concepts can be illuminated with an overview of one participant analysis by comparison to another. I was able to look at the similarity of themes and differences across themes, to gain a better understanding and increase my familiarity. I was able to actively engage in grouping my data in different ways to provide a more significant analytical evaluation of the issues at hand (Smith et al., 2009).

3.14.7 Phase seven - taking it deeper

It is here that I was able to relate and reflect on my questions for my initial research. However, I was trying to be more than descriptive and allow the strengths of IPA methodology, which is about interpretation, to occur. As I have worked from the part to the whole, I was then able to work from the whole to the part as befits IPA. An in-depth analysis of the part can be related to the analysis of the whole (Smith et al., 2009). As my study has been about my overall aim and subsequent research questions, my report, interpretations, and descriptive text was situated to respond to these and information presented within my literature review (Braun & Clarke, 2006).

3.15 Overview of my process

I believe that undertaking a manual process with a small group of participants, undertaking the interview process (18 in total), typing, confirming, reading and rereading the content of each interview was an advantage as it gave me familiarity. The interviews were initially taped, so some time was taken with audio transcription.

The coding process for me, as a relatively novice researcher, was open and I allowed the interview data to fall where it lay, meaning I did not have a preconception of where it was at for teachers within this study with their use of digital technology within their practice. My initial step was to split the questions/interviews into 1,2 and 3. From this I tried for major common themes. Refer figure 7, my initial thematic map.

I had no control of any data outcome, and I was significantly surprised and unaware when the issue of teacher resilience, agency and identity began to appear. There was no direct questioning around these areas. I felt the data revealed itself. I felt that this supported the thematic analysis approach, I had no connection or preconception prior to this study of subject matter aligned to teacher resilience. My subjectivity was related to being too pro-teacher, as in I am presently and have been in the past, a practicing mathematics teacher within a secondary environment. I believe having a background as a teacher made me reflexive. And I was critical of my thought process throughout.

When looking at my initial and final thematic maps they differ greatly and an obvious shift has taken place, beyond the classroom use of digital technology, to an analysis of what is occurring for this teacher, at this school, that is shaping their teaching practice and their use or not of digital technology. The final thematic mapping supports the analysis undertaken and what I believe has occurred for teacher participants of this study. I initially thought I was just looking at the use of digital technology.

I found this process of analysis to be fluid and flexible, visiting the data, revisiting the data, my study floor and bed were covered with cut up strips of dialogue as I changed the nature of my thematic mapping as I gathered more insight, reflected – much like a brainstorm only with paper strips to be moved around, grouped, rejigged, until I was happy with the clarity of the analysis. I found this entire process time consuming as thoughts about themes occur at the oddest of moments, (walking, in the shower, driving, shopping). When referring to literature, I can see this process being referred to as messy, with messiness, and it was (Joy et al., 2023).

I feel that if this process had not been one where I could visit and revisit and move my data around, and largely let go of the digital technology focus and actually analyse my participant data, I would not have been able to produce my final thematic map. I am hopeful that throughout this process I have told a story, not one that I have invented, but one that has been told to me.

3.16 Trustworthiness

Issues like reliability and validity are treated separately in quantitative studies; however, these terms are not viewed separately in qualitative research, and instead, terms like trustworthiness, rigour, and quality are used in the qualitative paradigm (Golafshani, 2003). Hence reliability and validity are replaced by the idea of trustworthiness. Trustworthiness, for example, is an illustration of a view to obtaining quality within qualitative research (Smith et al., 2009). To ensure the practice of quality utilised with data collection and analysis, four principles have been identified that can be applied in qualitative research. These four principles are: sensitivity to context; commitment and rigour; transparency and coherence; and impact and importance (Yardley, 2000). These four principles are an approach that suggests broad-ranging criteria focused upon achieving quality in qualitative research (Smith et al., 2009). This section discusses each of these considerations concerning my study. Refer Table 7 below.

Table 7

CHARACTERISTICS OF GOOD QUALITATIVE RESEARCH

CHARACTERISTICS
SENSITIVITY TO CONTEXT Theoretical; relevant literature; empirical data; socio-cultural setting; participants' perspectives; ethical issues.
COMMITMENT TO RIGOUR In-depth engagement with the topic; methodological competence/skill; thorough data collection; depth/breadth of analysis.
TRANSPARENCY AND COHERENCE Clarity and power of description/argument; transparent methods and data presentation; fit between theory and method; reflexivity
IMPACT AND IMPORTANCE Theoretical (enriching understanding); socio-cultural; practical (for the community, policymakers, health workers).

Note. Reprinted from Dilemmas in Qualitative Health Research, by Yardley, L, 2000, *Journal of Psychology and Health*, *15*, p. 219. Copyright 2000 by the OPA (Overseas Publishers Association) N.V.

Sensitivity to context is a criterion which, when applied to phenomenology, is used to question assumptions made from data gathered. Conflicts that are revealed with existing understandings held are deeply investigated. The participants are seen as having a powerful role as opposed to being a subject of research. An awareness of the socio-cultural setting of the study is undertaken. As a novice researcher, I have worked, researched, and have a good theoretical background within this environment, before undertaking data collection (Smith et al., 2009; Yardley, 2000).

Commitment refers to prolonged engagement with the topic. I immersed myself within the data and exercised the methodology in place that supported the competency of data collection and analysis. "Rigour refers to the thoroughness of the study, the appropriateness of the sample to the question in hand, the quality of the interview, and the completeness of the analysis undertaken" (Smith et al., 2009, p. 181; Yardley, 2000). Commitment and rigour in combination should be able to support intuitive and imaginative analysis beyond superficial understanding (Yardley, 2000).

Transparency and coherency illustrate clarity and cogency (Yardley, 2000). This relates to the ability of the researcher to create a reality that is meaningful to the reader. "Transparency refers to how clearly the stages of the research process are described in the write up of the study" (Smith et al., 2009, p. 182). Transparency also incorporates reflexivity on the part of the researcher indicative of the impetus to undertake the research. Coherence is reflected by how well the research question and methodology undertaken complement the findings of the study. Ideally, if the perspective of teachers who decide to use or not, digital technology within their teaching practice is sought, then the methodology required is one that allows expression of their perspective.
The real test of impact and importance will be if the research tells the reader something of importance, something exciting, or something useful (Smith et al., 2009). This can be referred to as impact and utility (Yardley, 2000). The answer

to this will rest with the wider educative community and any interest shown in the findings of this research study. I have been aware and alert to these criteria, as summarised in table 7 above throughout the timeframe of this study.

3.17 Ethics

The ethics for this study, have been approved under FEDU 077/19 on 04 November 2019. The ethics approval is attached in appendix five. The critical elements of ethical practice that were relevant for this study are: informed consent; anonymity or confidentiality; potential harm to participants; the participants right to decline to participate or their right to withdraw data; the obligation of the researcher to provide information to the participants, and cultural safety. These aspects are discussed below, and it will be important to take a reflexive approach to ethics as the study takes place.

I have gained informed consent from the principals of the respective schools before approaching any teachers. The principal's consent form covers the request for permission to approach the Head of Department (HOD) Mathematics as a courtesy and the staff of the mathematics department to take part in this research project. Refer appendix three. Given the COVID constraints, once the power point presentation was undertaken, volunteers made contact. I emailed an information letter together with a signed consent request to each participant. Refer appendix four. I clearly stated voluntary participation, right of consent, right to withdraw consent, and contact details for my chief supervisor in case of any personal conflicts. Subject to this meeting times were arranged. Prior to interviews taking place I sent in advance a copy of the interview questions, refer appendix two. I provided journals and possible questions to be asked to prompt thought, refer appendix one.

I stressed the value of anonymity of responses to protect teachers from the power relationships that exist within schools. My approach to the principal was undertaken in confidence, forwarded to the Head of Department Mathematics and thereafter courtesy contact only has been maintained. This was minimal. Disclosure of volunteers will not take place, and pseudonyms will be used throughout, for both schools and participants. I have minimised any opportunity for the identification of volunteers to take place.

The time allocated to the reflective process, in addition to an existing workload, may be considered harmful to participants. It may be that the benefit of taking the time to reflect upon practice, which will inform teaching, may offset this.
It may be that as a result of the reflective process involved in the interviews participants may feel vulnerable within their teaching practice. I am looking at an anonymous reflective process. This process has an emphasis on the value of teacher perception where there is no wrong answer and where there is a considerable value placed upon honest responses. Given these factors, I believe room to allow improvement of practice without judgment can only assist in the development of teaching practice, which could be a benefit.

The written informed consent form details the research project and contains the clause that participants have the right to withdraw at any time of the study up until they have approved their transcripts or data analysis commences. Participants can also decide not to answer any questions asked.

All teachers have been provided transcripts of their interviews for checking, for accuracy of interview data recorded. The teachers will have the right to comment on the transcripts and withdraw, amend, or clarify anything within two weeks of receiving the transcripts. At the end of the research project, the teachers were provided with the links to the research report and any other journal articles from the research.

I have undertaken this study with an awareness of cultural identity, for both myself and the participants involved. With the desire to protect the cultural identity of my participants and myself I have approached and gained approval for Deputy Chief Judge Caren Fox to act as my cultural supervisor. I have not had to refer to Deputy Chief Judge Caren Fox at any time within the boundaries of this study.

3.18 Summary of the Methodology and the Methodological Process

Interpreting and describing human lived experience where we acknowledge multiple versions of reality to enable sense and meanings of the particular to be shared, supports the reasons for the use of IPA as the chosen methodology of this study. This is detailed in the descriptive sections of phenomenology, hermeneutics and idiography (section 3.4).

As a novice researcher I was not interested in proving a hypothesis, gathering facts or testing an existing theory. The interest I had for this study lies within the participatory role of people as part of the research process. The participants are the knowledge creators, and the use of IPA has supported an inclusive and empowering process for the participants of this study. This has enabled a people-in-context approach, where the provision of teacher perception, has allowed for equally authentic multiple realities (section 3.5).

The limitations attached to IPA have been discussed (section 3.6), but it could be that in targeting the objectivity of the methodological process, we may negate the subjectivity of interpretation; or that existing power structures are negated by the IPA approach which facilitates a shared power process, or that knowledge can be unveiled by structured and open-ended analysis, all features that can facilitate the minimising or negating of the limitations attached to an IPA approach.

The recruitment process and participant details are depicted (see sections 3.7 and 3.8), and both show the impact of the COVID circumstance and how this study had to work around this circumstance. Participant and school details have been summarised in table form for ease of reference. Confirmation of the data gathering process is given (section 3.9), with the need for a pilot interview to be undertaken, necessary for highlighting final adjustments needed for questions asked and researcher practice for the interview technique undertaken (section 3.10).

The use of semi-structured interviews is an accepted means of data gathering within the methodology of IPA (section 3.11). Strategically within an interview scenario, information that may relate to each question may appear in more than one context and the interconnecting nature of this data and how it is treated is discussed (section 3.12). The support for research practice with the undertaking of the reflective diaries for both participant and researcher has allowed for naïve stranger status to be maintained in an objective sense for the researcher and, could have aided contextualisation of interview data collected from the participant (sections 3.13 and 3.14), (Denscombe, 2014; Lincoln & Guba, 1985). However, the keeping of a reflective diary for the participants did not eventuate due to participant choice, with the researcher only undertaking the keeping of a reflective diary. Participants reflected upon the questions in thought, which came through within the interview process but not with a diary entry.

Data analysis is undertaken (section 3.15), with in depth evaluation of the thematic analysis process, clarified and illustrated by figures seven, eight and nine. Clearly a movement within the identification of themes has taken place resulting in emerging knowledge hitherto unconsidered. As the results of the thematic mapping undertaken have become visible an overview of this process is provided confirming the manual process undertaken by the researcher (section 3.16).

Trustworthiness is a term applied to a qualitative research method (section 3.17). This is identified within the four sections of: sensitivity to context;

commitment and rigour; transparency and coherence, and impact and importance. The adoption of trustworthiness allows for the quality to be maintained within the research process. Our final section (section 3.18) looks at the ethics of our research endeavours, where we do our utmost to safeguard out participants, ourselves and our processes.

The next four chapters represent the results of this study, beginning with the findings, discussion and then conclusions and implications. The two findings' chapters are divided into sections relative to major themes identified, each detailing the questions identified as one, two and three. These questions are targeting an understanding aligned to a response to the overall aim of this study.

CHAPTER FOUR: FINDINGS

Digital Technology in the Junior Mathematics Classroom and the Influences at Play

4.1 Introduction

In Chapter One the significance of this project was discussed, highlighting the following aspects for investigation based upon the perceptions held by the teachers of this study. These were: Digital technologies may change the potential ways to engage with mathematics; Changes in pedagogy may be associated with this; Issues with recruitment in provincial cities are compounded by the lack of specialised mathematics teachers resulting in teachers teaching out-of-field, highlighting the changing nature of professional learning and development and the potential that digital technology may have to support and assist teachers to improve their delivery of the learning process.

The literature review in Chapter Two gave impetus to three pedagogical theories which were teacher-centric, student-centric and learning-centred. Of interest, after the study had begun in 2020 the outbreak of COVID and the associated lockdown initiated the total immersion of digitilisation within teaching pedagogy, allowing for identification of the enablers and inhibitors attached to the use of digital technology, which would otherwise not have been so readily identifiable.

Section Two advanced the understanding of effective pedagogy by the descriptions of the models that are in play for teachers of mathematics. An understanding of these models by the teachers of this study can assist in pedagogical change and if pedagogical skill is developed can support the effective mathematics teacher profile when integrating digital technology within teaching practice.

The aim of this study was to better understand year 7-10 mathematics teachers perception of the aspects that influence whether they use digital technology when teaching mathematics. The three research questions undertaken that allowed an examination of this aim were:

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

The findings from the first two questions will be discussed in this chapter. Chapter Five presents the findings for question three. The findings presented below are representative of question two, which was: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

This chapter presents the major findings of this study. This chapter has been divided into eight sections. These findings were discussed in the following order: subsection 4.2 School management practices, school culture and digital technology; subsection 4.3 Relationships; subsection 4.4 Digital technology and mathematics software; subsection 4.5 Digital technology – growing teacher practice; subsection 4.6 Enablers and inhibitors; subsection 4.7 The COVID effect, and the final subsection 4.8 The summary of the findings from section 4.2 to 4.8 presented with text and by table form. The final thematic map for this study, referred to as figure 8, reflects upon these factors as they have an impact upon teacher agency, teacher identity and teacher resilience.

4.2 School management practices, school culture and digital technology

School culture can be thought of, in part, as the norms and beliefs attached to schools, so anthropological by focus. The culture of a school and its resulting climate must support reform or improvement will not occur (MacNeil et al., 2009). All the teachers of this study were positive in their acceptance of the use of digital technology within their teaching practice.

With the use of the dedicated software program of *MathsBuddy* and *Mathletics*:

> ***School culture is built upon by the leader of learning letting us know if usage is down – little reminders*** (Arihia, School Two).

School culture is built upon using a common platform and across the school competitions and monitoring of student placement (Arihia, School Two).

All of us coming together using the same platform is what brings the school together (Courtney, School Two).

Putting together a standard practice with the use of MathsBuddy (Taylor, School Three).

A resource that has been developed across the school over time (Arihia, School Two), (Courtney, School Two), (Taylor, School Three).

With the use of a resourced software program, *Education Perfect*, and an innovative learning environment:

School culture has made it easier to adopt a new teaching approach … I don't think it would have changed as much if the classrooms were left as they were … we would have made some changes, but I think it would have been slower … because I think in those bigger spaces (classrooms without walls) you had to try new things and had to try and do things differently (Laurell, School One).

School culture supports a digital focus … really heavily digitally focused (Matiu, School One).

With restrictions in device usage with a resourced *Education Perfect* software and an adherence to Maths Mate – a tear out page book.

… for juniors where we come, I suppose in a list of priorities we are at the bottom … so after all the seniors have used all the chrome books for whatever they need to then we are allowed to use them and that

> ***informs how we structure our topics for learning, and we design our courses and therefore what we learn …***
>
> ***… so the devices we had for mathematics are gone … they are all assigned to students and students bring them and take them home …***
>
> ***… but we haven't had an expectation that juniors need to have a device to learn at school …*** (Joelle, School Four).

School management practice has driven the changes in the uptake of digital integration within teaching practice. This has occurred both with a change in the physical environment (ILE) with one school and with generous resourcing of hardware and software across three of the four schools. By contrast, one of the schools experienced restrictions with resourcing which had a significant impact upon classroom delivery at some points in time over the school year. This suggests for the teachers of this study that the opportunity for imaginative and innovative practice is present, with only one teacher unable to freely develop at a junior level a digital redefining of all areas of the curricula.

Research tells us that the context a teacher finds themselves in has impact upon teaching pedagogy (Bremner, 2019; O'Sullivan, 2004). If we apply this to the integration of digital technology to teaching practice, resourcing has become a consideration that has had impact for one of the teachers of this study. Equally in the context of ILE's, there is consideration here for the promotion of pedagogical as opposed to material movement and incorporation of the widespread use of digital technologies (Fletcher et al., 2020; Smardon et al., 2015).

Analysis of the teacher perceptions from the teachers of this study, detailed above, suggested that for three of the four schools sustaining changes to pedagogical practice with the integration of digital technology involved the three facets of: management practices, school culture and a collective endeavour.

4.3 Relationships

There are four relationship aspects that I have discussed in this section. They are as follows: Teacher-to-student; Teacher-to-teacher; Student-to-student, and the Teacher, student, whānau triangle.

For the teachers of this study the use of digital technology within the classroom enabled a sharing of teacher perceptions in consideration of the positive and negative aspects of this use of digital technology upon the teacher/student relationship. The teachers of this study provided this feedback for consideration:

> ***Teacher beliefs impact upon digital technology use as a disconnect between student and teacher*** (Joelle, School Four).
>
> ***I prefer me*** (Arihia, School Two).
>
> ***I think that teachers have to work pretty hard with certain kids to get a relationship … I do not think it is just down to digital technology*** (Courtney, School Two).
>
> ***The use of digital technology is one of the ways to support relationships beyond the classroom*** (Joelle, School Four).
>
> ***Both negative and positive aspects of relationship building – negative being monitoring off-task behaviour and positive being reward systems***

with math programmes (certificate, across school competitions) (Arihia, School Two).

I normally set them targets and that if they get to that target with digital tech they know they get me off their back … I think that I am probably more of a stick than a carrot. They come out not only having learnt the skills with digital technology but also how to apply those skills (Matiu, School One).

The teachers in this study have worked hard to promote positive relationships with their students, with their choice of digital technology. The use of digital technology is not seen as a replacement of human interaction, but a way of creating an environment that augments student academic achievement (Mensah & Koomson, 2020). Teacher comments support the effort to establish and maintain positive student relationships to achieve the desired student outcomes(Mackey et al., 2015). The teachers of this study have where possible, transformed their teaching practice to reflect the uptake of digital technology, enabling change to existing teacher practice. School and teachers have undertaken innovative change.

The first two comments respond to a disconnect, in the first instance, relative to a lack of face-to-face interaction. This is understandable as face-to-face interaction formulates the closest bonding for human interaction (Hadley et al., 2022). Secondly, the impact is felt as teachers use contact to guide behaviours, to provide direction, to dialogue, and to maintain their relationships with their students (Mensah & Koomson, 2020).

The third teacher comment reveals that relationships with students are works-in-progress and require effort on behalf of the teacher, with digital technology another means within which to engage or improve the quality of the learning relationship if possible. This includes, supported by the fourth teacher comment, that communication and hence learning can now take place, and hence learning outside of the classroom. The fifth and sixth teacher comments refer to the way in which the sticks and carrots are used with digital technology, to pursue the desired student outcomes. For the teacher of this study this was a manipulation of the tools available to teachers and a reminder to students of teacher expectation, both behaviours based, and outcomes focused.

For the teachers of this study teacher perception was shared as they revealed their experiences on collaborative undertakings with their colleagues within their own school. The three teachers below report on the advantages attached to teacher-to-teacher collaboration with digital technology use:

> ***The math department is not that big, so I think it is quite reliant on those of us that do have the resources to share them around (web sites)*** (Matiu, School One).
>
> ***With the use of new software … me personally I value collegial support knowing that there is someone within the school that can help me with it*** (Laurell, School One).
>
> ***The supports I identify for developing facilitation, small groups, and using digital technology are my colleagues … finding out what others are doing … primary schools are dabbling … we carry it on … I don't know of any secondary school in this area who teach maths with digital***

> ***technology … the kids have got these skills … they learn and engage this way … at the other end it is not doing the same*** (Courtney, School Two).
>
> ***It's normally the more IT literate that get asked the questions. We teach cross curricular here … mathematics/science … digital technology assists in employing collaborative practices with that*** (Laurell, School One).

Collegial interaction can be used as a mechanism to support quality teaching and, for the teachers of this study, it formed an active part of their practice. It was not uncommon for the expertise of a colleague to be sought when developing the quality of individual teaching practice. Improving the quality of teaching assists with the development of the desired student outcomes.

However, working in the same environment does not guarantee individual compatibility with workmates. When teachers have differing ideas on teaching then conflict can emanate (Hertzog et al., 2000). The contrast here is that collegiality and collaboration are sometimes affected by subjective factors relating to human interaction.

The findings below indicate the subjective nature of human interaction from these two teachers:

> ***Collaborative task design across colleagues works, (but) not all colleagues. We have collaborative hubs and collaborative classrooms*** (Courtney, School Two).
>
> ***The use of digital technology does not mean that collaborative practices are undertaken collegially*** (Joelle, School Four).

Collegial relationships can enhance critical thought, encourage the sharing of ideas, the practice of reflection, and develop respect for other viewpoints. However, they are also subject to personality problems that can impact upon the expectations of professional relationships (Hertzog et al., 2000). The implication is that professionalism is maintained within the working relationship, with a suggestion for a preference to work with those whom we work well with, which was reflected for the teachers of this study in the teacher perceptions above.

Within the boundaries of collegiality and collaboration there exist the wider networks that support professional learning and development, the pooling of expertise and the desired skills needed to support and advantage student learning. Teacher perceptions from three teachers relayed the following:

> ***A wider math focus group is supported as opposed to a focus of digital technology use and collegial interaction*** (Joelle, School Four).
>
> ***Because Manaiakalani is running the three Communities of Learning (COL) as one … the numeracy one … there were five of us …*** (Matiu, School One).
>
> ***Within the COL we have a meeting … once a term … and talk about Kahui goals as a collective and … ummm … building those connections between the schools … I am part of the numeracy group … and we are looking at how we can embed learner agency … that we have a consistent understanding of numeracy … what level four looks like …*** (Laurell, School One).

> ***Collaborative task design, illustrated by Mathletics, you can get into the top five in New Zealand – appealing for the competitive aspect.*** (Arihia, School Two).

The impact of professional learning communities upon teacher practice is considered to strengthen existing practice, as it allows for the sharing and pooling of expertise. For the teachers of this study, the discussion above relates to the acquisition and sharing of knowledge, for example, learner agency. This finding identified individual upskilling, but also mutual decision-making, information sharing and collaborative undertakings (Luyten & Bazob, 2019). For the teachers of this study, these findings supported their involvement in communities of teachers beyond their own individual schools.

The use of digital technology within teaching practice due to the teacher incorporating the features offered by *Mathletics*, shared above, takes advantage of competitions and rewards. For some students this could be motivating, enjoyable and engaging. However, you cannot be successful all of the time. For some students it may be that failure may serve to help to teach them how to deal with poor performance. What is known is that mathematics competitions, with and without software, are increasing in popularity (Kenderov, 2022). The findings support the enhanced nature of teaching and learning with the use of digital technology within the wider focus of achievement together with the discipline of mathematics and as a collaborative undertaking. Digital technology in this instance has additional features that look to enhance the competitive factor as student outcomes are targeted, which for one of the teachers of this study formed a part of her practice.

As we look to collaborative communities, and enhanced features available with digital platforms, the expectation with initiatives undertaken is that they will support increases in student motivation, engagement and achievement enhanced through shifts in teaching pedagogy. Reflected within these findings and this dialogue is an understanding of the impact of cultural identity, and how this was influenced by shifts in pedagogy with the use of digital technology. This is illustrated by student-to-student interaction. Across-the-school approaches were adopted where teachers were supported with shifts in pedagogy related to the features of the software in use.

This study took place within an isolated provincial New Zealand locale. This has allowed a unique perspective to be portrayed of New Zealand classrooms depicting indigenous world views within multi-cultural diversity. The New Zealand classroom has obligations to the Treaty of Waitangi, illustrating the place and value placed upon the indigenous world view of Māori. As an expression of the Māori world view, one of the values is whakawhanaungatanga (making and maintaining relationships), expressed with peer support and the use of digital technology. This is worthy of discussion as “a student’s cultural identity, in terms of attitudes, beliefs, values, languages and practices, also affects engagement, motivation, learning and academic achievement” (Zajda, 2023; 2024, p. 34).

The indigenous value of whakawhanaungatanga portrays a person’s relationship to others, to life, and to the world. The Māori worldview and values are strongly expressed in the geographical area of this study, from within the student body, due to the location and culture of many of the students. The use of digital technology has enabled support of whakawhanaungatanga, in this example meaning the ability to establish relationships and work well together. From the teacher perspective the role of digital technology within the student-to-student relationship was as follows:

> ***Year 8's help the year 7's … there's a lot of that going on … when digital technology is introduced … some students have had it before in primary school*** (Courtney, School Two).
>
> ***An example of social justice would be students helping out other students who are not as confident as they are … co-operating to share resources … if a student has forgotten their device … borrowing devices from the library*** (Courtney, School Two).
>
> ***If they are sat next to someone, they are still trying to help each other out so it's not maybe now like an expert, but it is the person next to you that can help you. Because when they are sat individual with pen and paper, I find that they get more in sync with each other, … when they are using the software there is a variation and a randomisation of the questions … I don't think they co-operate as much*** (Matiu, School One).

Within an individualised digitised program, group learning can be supported but the pace and timing of individual learning was the priority. There was no wait time as students attain at differing time intervals. Group learning of the same material, undertaken at the same time, as everyone moves over the material at the same pace, becomes indicative of pen and paper and formal instruction.

Greater freedoms within learning occurred for students with digital technology usage reflecting the individual pace of learning, the freedom to help others and the ability to share devices to enable learning for all. Digital technology can be thought of here as assisting relationship building practices of student-to-student teaching and learning expressive of student identity and autonomy. This could be expressed as the pace of learning, the people they choose to interact with, and the nature of the dialogue undertaken. Equally the value of pen and paper equivalents cannot be ignored, as student interaction occurred here with greater synchronicity as expressed by one of the teachers of this study.

The last relationship that we will discuss now, supported by our findings is the parent/whānau (family), student, teacher relationship. The quotes below suggest that online access supports visibility of student learning beyond school hours enabling whānau awareness and participation. The greater the whānau involvement with the school the more it suggests to the teacher that support will come from home that will enable learning gains to be maintained or increased.

For the teachers of this study from the teacher perceptions expressed below, the role of digital technology and how this usage facilitates the teacher, student, and whānau triangle, was as follows:

> ***Online access for students at home keeps whānau involved*** (Arihia, School Two).
>
> ***Visible to all and so visible to parents, visible to whānau, visible to anyone who wants to look at it, … whānau can see it too and they can email and ask any questions … I use the comments function a lot on Google docs, in that kind of thing to help to give students feedback*** (Courtney, School Two).

> ***They have just got to go in here to find out that there is nothing overdue on it … that's the way I would do it with the parents … keep them in the loop on it*** (Matiu, School One).

Visibility was seen to increase whānau involvement with student learning, which the software program in use supported. Keeping in contact with home, involving home in the learning undertaken, enabled relationship building. For the teachers of this study, it may be that teacher identity is supported as the interaction between parties prevails.

4.4 Digital technology and mathematics software

The impetus to change existing teaching practice is nested within individual belief, school support, and school management practices. The development of the skills needed reflecting those of a lifelong learner are thought to support the employable attributes desired by the job market of tomorrow. Presently digital technology is widely used within society. As technological changes continue to advance, the use of digital technology within the mathematics classroom then supports the reality of everyday living. Presently it has given teachers the opportunity to reshape learning.

This reshaping occurs where packages like GeoGebra enable multiple graphical illustrations to happen within short time frames. Conceptual understanding is thus advanced, and software then takes the place of pen and paper which cannot deliver learning opportunities, within short timeframes, over multiple opportunities, in the same way. Digital changes to pedagogy also bring changes to the way knowledge is acquired. Previously in Chapter Two, examples were given of the qualitative gap that can result with the use of technology (Haspekian et al., 2023). In this instance a symbolic to functional comparison when using Geogebra to teach algebra.

The teachers of this study suggest that there were advantages in using digital technology in their mathematics practice. The reflection can be administrative and supportive of pedagogy for teachers but also developmental for students. One of the considerations was the development of the key competencies. The findings show the following:

> ***Our numeracy programme reflects the use of digital technology, embedded within this are the development and support of the key competencies (MathsBuddy)*** (Taylor, School Three).
>
> ***Intentional engagement supported with digital technology*** (Taylor, School Three), (Joelle, School Four).
>
> ***Targeted responsible, purposed use with a clear intention*** (Taylor, School Three), (Joelle, School Four).
>
> ***Students can demonstrate growth across a developing skill base*** (Taylor, School Three).
>
> ***Digital technology supports 24/7 access to mathematics, not only at maths time*** (Courtney, School Two).
>
> ***I think it's … using digital technology takes a lot harder to set up initially but it's a lot more reusable so once you have created it, it's a lot easier to reuse and adapt potentially for the next year*** (Laurell, School One).

Monitoring work completed easier and faster with digital technology (Arihia, School Two).

For the teachers of this study administration duties, inclusive of marking were supported using digital technology. Connections to learning extended beyond the physical boundaries of the classroom. The learning process was supported. Although the initial investment of time required for set up necessitated a well thought out approach, long term there was potential for time in lieu opportunities.

The instructional capacity of the teacher can be supported with the use of digital technology, additionally the desire to enhance knowledge content development in mathematics is integral to the assessment-prone nature of most educational environments globally (Lu, 2006). The educational environment of New Zealand is focused upon knowledge content which is echoed within assessments undertaken targeting NCEA success (Ministry of Education, 2007). Four teachers of this study had the following to say:

Allows for the development/support of teacher knowledge content as a reflection of a second or different explanation attached to learning (digital resource/teacher explanation), advantaging the student (Arihia, School Two), (Taylor, School Three), (Joelle, School Four).

Mathematical knowledge assumes greater importance then using technology (Courtney, School Two).

Greater teacher flexibility required/not teaching at one level/supports 25 different levels if 25 different students (Taylor, School Three).

For the teachers of this study increased teacher instructional capacity, with different explanations and the use of a second teacher voice through video tutorials, may lead to increased student understanding and may enhance student learning outcomes that are focused upon mathematical knowledge.

For the teachers of this study the flexibility to cater to differing levels of learning illustrates a personalised learning approach which supports individual student learning levels and knowledge content development. This teacher has identified that learning support is required simultaneously across differing knowledge content areas as students undertake learning at an individual level and pace with the use of digital technology. What is alluded to here is that student choice may be accommodated within a programme of learning.

For the teachers of this study the advantages of mathematics software (beyond the use of free apps), are inclusive of and could reflect accountability, opportunity and subsequent advancement of student motivation and engagement. Dedicated mathematics software as a rule does not allow for changes to the software interface and is structured in a preformatted sense. The delivery therefore is standard but enhanced with various features like embedded video instruction, blinking cursors, the use of colour and so on. The findings below expressed by four teachers of this study discuss other aspects applicable to dedicated mathematics software:

> ***Worksheets fill in time, digital technology keeps them on task and becomes a continual record*** (Arihia, School Two).

Monitoring work completed easier and faster with digital technology (Arihia, School Two).

Supports online assessments (Arihia, School Two), (Taylor, School Three).

The introduction of a new concept and showing a digitised clip, I think the engagement is better (Courtney, School Two).

Mathletics takes the learning outside of the classroom (Courtney, School Two).

Teacher dashboards allow supervision to occur in real time (Arihia, School Two).

Mathematics software that does allow changes to the interface still comes with the same enhanced features. The findings below discuss further aspects applicable to mathematics software:

Tracking and monitoring is easier … it is very easy to identify which students need that extra help and support (Laurell, School One).

For them core skills it is just the repetition of the small little things, it is a lot easier to do online (Matiu, School One).

I do think it is a lot more difficult to go over and have a look at why they are getting it wrong … it does help you identify their progress (Laurell, School One).

For the teachers of this study mathematics software that allows changes to material content but is set up in the same manner as dedicated mathematics software also identifies accountability, opportunity and subsequently student progress with tasks undertaken. One of the teachers of this study who used mathematics software that can allow changes to the interface found that backtracking to check on errors was harder, and therefore how to correct the thought process attached to this was harder too. Identifying the written recording of the problem and the error made and therefore the process was more difficult to track. For the teachers of this study digital technology appeared to facilitate shifts in teaching pedagogy.

4.5 Digital technology – growing teacher practice

The use of dedicated mathematics software might facilitate a shift from teacher-centric toward student-centric teaching practice. Three of the teachers of this study used dedicated mathematics software, representing two different software programs. The resources were provided and funded in an ongoing manner by the respective schools and allowed for strategic responses across the school to be undertaken. These schools targeted successful outcomes with a focused approach led by a numeracy team, with a numeracy team leader. These moves were of course supported by school leadership. The teacher quotes below reveal some of the strategies undertaken:

> ***Our new teachers would have no idea about teaching maths without Mathletics*** (Courtney, School Two).
>
> ***I have become more of a facilitator so more student-centric versus teacher-centric and I think that digital technology has been the biggest single factor in helping me make that shift*** (Taylor, School Three).
>
> ***… striving for them to be independent, self-directed learners I think that digital technology for me is the best tool for them to do that effectively*** (Taylor, School Three).

> ***A good balance is achieved with a structured programme … for a lot of teachers it is the first thing that gets missed as they have maths anxiety themselves … they didn't like maths themselves at school so it's the first thing off … so I think with having a tool like Mathletics for our new teachers having a really structured programme, they know that those kids are getting core learning while they are dealing with this group over here that have this new need.*** (Courtney, School Two).

There has been some guarantee of programme delivery, regardless of the experience of the teacher and some guarantee of time allocation spent teaching mathematics, given the monitoring features of the software program used. In addition, identified by the teachers of this study were the multiple software platforms available to teaching practice.

> ***Each teacher has a closed face book page, 99% of the teachers celebrate Mathletics through their face book pages … you get a bronze, silver or gold medal or you get in the top ten of New Zealand students and whānau can clearly see what we are doing to enhance that*** (Courtney, School Two).
>
> ***Mathletics provides a teacher platform, so you can do all of your planning at home, whole lot of resources there, available 24/7*** (Courtney, School Two).

One of the schools of this study has utilised technology within a social networking platform to enhance visibility and student outcomes, inclusive of whānau visibility. The Facebook page is closed to the wider community, so classroom focused only. The positive results achieved with the competitive rankings are based upon a nationwide *Mathletics* community. *Mathletics* is a dedicated mathematics software. The school and subsequently the teachers have an additional tool to use to enhance learning. This is not the only tool in use or the only programme, but a part of the mathematics programme for this school and these teachers. Equally for those who are not experiencing success, as one-size-fits-all is not possible, other facets of the existing wider mathematics programme may appeal.

The teachers of this study have found that digital technology advantages the ability of a student to gain a deeper understanding without overloading cognitive processes. Inherent to this deeper understanding is how the program has been designed and whether the program selected fulfils the use of visual and aural stimuli simultaneously to advantage learning. In addition, pedagogy and the use of digital technology has been the focus and hence has shaped how questions have been presented to the participants of this study. Teacher perceptions show clear advantages of software use.

> ***Conceptual understanding is advantaged with the use of digital technology/a million hand drawn graphs over years to one hour with technology to advantage learning*** (Joelle, School Four).
>
> ***… like a lot of online resources … you don't have to go and reinvent the wheel*** (Laurell, School One).
>
> ***Instant feedback provided by the technology allows greater high-quality contact time with students*** (Taylor, School Three).
>
> ***You can watch at your own speed/they can go back and have a look*** (Taylor, School Three).

> ***More responsive to student queries with digital technology use*** (Arihia, School Two), (Joelle, School Four).
>
> ***… will roam the classroom with my laptop – helpful videos – group work*** (Arihia, School Two).

These four teachers of this study created learning opportunities to advantage student engagement, with the overriding purpose here being one of student motivation, engagement and achievement. Teacher pedagogy dictates how digital technology and software are used. Conceptual understanding refers to understanding the mathematical concepts presented by supporting student understanding with repeated and differing examples of the same concept, within a small pocket of time (1 lesson), previously not possible with hand drawn graphs, for example. Given the desire to achieve student outcomes with the created learning opportunities, motivation became the first step in this cycle.

For the teachers of this study, the findings show that the combined effort of the teacher and their use of digital technology helps to fulfil the MUSIC model for academic motivation (Jones, 2009).

Although there are obvious advantages of software use, there are also disadvantages and these can relate to the software idiosyncrasies of a particular package. One of the teachers of this study found:

> ***I think it is really hard to do an assessment digitally at present*** (Laurell, School One).
>
> ***… for anything higher level there is no adaptability for the technology to be able to explain it different ways*** (Laurell, School One).

The teacher that expressed these thoughts was an experienced teacher with the use of digital software. The comment about digital assessment reflects digital assessment designed by the teacher, as opposed to preformatted, which is reflective of a digital platform like *asttle.* This teacher was commenting upon the desire to enter into explanations reflective of the methodology of mathematics and the need experienced by the teachers of this study to explain something several ways, in order that one of those ways was effectively enlightening for the student. This teacher had *Education Perfect* as one of the resourced software platforms utilised in class.

Student familiarity with digitally-based assessment may act to advantage student outcomes and give digital technology use in assessment increased relevance. This is evident with the introduction of the Common Assessment Activities (CAA's), available from curriculum level four and above, which are digitally presented. This could reflect year 9 students and beyond.

Asttle is a testing regime that gives an online option, which could act as a practice with a digital platform in readiness for the CAA's. *Asttle* is the preferred option for use within year 9-10, with the PACT tool, a reflection of past practice (2024). When asking about the fit of digital technology for assessment, NCEA assessments for CAA's and end-of-year external exams give the option of hard copy or digital.

Junior schools generally report on knowledge content and the key competencies. The following teachers report:

I guess we would make sure they could use it (digital technology) before they sit the assessment (Matiu, School One).

The assessment itself gets the weighting not the use of digital technology (Matiu, School One).

Digital technology use is not represented in reporting functions (Joelle, School Four).

I don't usually use digital for assessment, you can't see the working out, you'd have to have more like tablets and pens, devices that were touch screen (Laurell, School One).

Do not see it as a necessity to use digital technology in assessment (Courtney, School Two), (Joelle, School Four).

Except for the reporting that Mathletics gives us digital technology is not reflected in school assessment (Courtney, School Two).

The teachers of this study saw a limited role for digital technology use within an assessment regime, with pen and paper the preferred choice. The reality of choice is apparent within the comments made. The new testing regime will suggest to teachers of junior mathematics that familiarity with digitally-based assessment would be reflective of the changes that are being made to the mathematics environment.

Where teachers control the teaching and learning processes that occur, this could be thought of as one end of a continuum of teaching practice. Representative of the opposite end of this continuum is where students have agency and autonomy over the teaching and learning processes that occur. The following depicts the adoption of either theory within teaching practice for the teachers of this study:

> ***No particular theory that I follow when using digital technology*** (Matiu, School One).
>
> ***Over three years, as I have switched between teacher and student-centric practices, I have come to believe in the blended learning approach, due to student and teacher circumstance*** (Courtney, School Two).
>
> ***Not worried about the application of educative theory, neither teacher-centric or student-centric, more the relevance to learning and the connections to learning previously undertaken*** (Joelle, School Four).
>
> ***Combination of teacher-led facilitation then student-led with digital technology*** (Arihia, School Two).
>
> ***But I just think … trying to go with a blanket approach … I would just hate that*** (Laurell, School One).
>
> ***Easy shift between teacher-centric and student-centric practices – a blended learning scenario with digital technology*** (Taylor, School Three), (Joelle, School Four).

The teachers of this study have looked to the motivate, engage and achieve cycle, a fit-for-purpose approach as they employ blended learning, with the use of online and face-to-face practices, transitioning between teacher and student-centric methodology, referred to as a hybrid pedagogy, within their lesson delivery (Bremner, 2019). The teaching of junior mathematics has then become learning-centred, with the teachers of this study hybrid practitioners freely moving between teacher and student-centric models to achieve the targeted learning outcomes they have identified. Digital technology has then become a means to achieve this shift in teaching pedagogy, within and over lessons.

The flexibility of teaching pedagogy enhances the motivate, engage, and achieve opportunities available to the student. The learning-centred approach has come to represent the combination of teacher and student-centric practices. This is achieved with the transferring between the use of digital technology or pen and paper, and the use of visual and physical manipulatives within this study. The teachers of this study had the following to say:

> ***My first preference is to do that student-led one because it is working so … why would I change it*** (Matiu, School One).
>
> ***Blended, there's nothing that ever works 100%, otherwise it would be done, I always think that you have always got to evolve, you have always got to change*** (Laurell, School One).
>
> ***Heading toward student-centric, but there is still some teacher-centric practice that still goes on … so many technological options available to make it more student-centric I think and collaborative … students working collaboratively in groups*** (Matiu, School One).
>
> ***Kids have different learning styles we have the blended approach of paper and digital*** (Courtney, School Two).
>
> ***Combination of teacher-led facilitation then student-led with digital technology*** (Arihia, School Two).
>
> ***Both ways should really be the same … there shouldn't really be a difference between that … in anything there is no correct way of doing***

it … but you've got to adapt it, if you don't then you are not doing it correctly … it is the blended learning scenario (Laurell, School One).

The teachers of this study target the motivate, engage, achieve cycle as opposed to formally structuring a lesson within a theory or theories. The teachers of this study are fluid within changing pedagogical models that occur within the classroom and look to match pedagogy to differing student need. This links to teaching beyond a blanket one-size-fits-all approach, as teachers work toward quality instruction within a learning-centred approach. The following shows the findings from teachers of this study indicating shifts in pedagogy with the use of dedicated mathematics software.

The teachers of this study indicated the following teacher perceptions of the learning in relation to dedicated mathematics software:

Personalised learning targeted at the level of the student, students select the next stage, driving their own learning, pushing themselves, tailored to their own needs (Arihia, School Two).

Personalised learning is an option long term with digital technology (Courtney, School Two).

Independent learning programmes are easier to support (Arihia, School Two), (Taylor, School Three), (Joelle, School Four).

A personalised learning programme looks like kids know what they know, what they need to get to next, and how they are going to get there (Courtney, School Two).

The opportunity for developing personalised learning for a student is easier with the use of digital technology (Courtney, School Two).

> ***Using the same platform in maths helps redress any disparity in digital technology usage*** (Arihia, School Two).

The use of dedicated mathematics software here suggests that personalised or individualised approaches to teaching and learning are supported and easier to facilitate with the use of dedicated mathematics software. What the teacher perceptions above suggest is self-regulation of student learning. The following shows the findings from teachers of this study without dedicated mathematics software, where a shift in teaching pedagogy was also achieved.

> ***The resources that help personalise it for the students so for example Education Perfect we can, you can put all kinds of resources on, but you could just make them available to certain students so someone needs extra help we could put extra resources on there*** (Laurell, School One).
>
> ***It does require a lot more planning time because you are planning an individual programme for that student plus group work, do a lot in groups, … 75 to 80 kids in class*** (Laurell, School One).
>
> ***Where you've got a big group of seventy kids, where generally there's not necessarily maths specialists in it as well, that is a lot harder to do, the individualised or personalised learning*** (Matiu, School One).
>
> ***Could normally assign a class task (digital technology) to the majority of the kids and in one of the classes I assigned sometimes a different one, to one or two of the students who are generally quite low level*** (Matiu, School One).
>
> ***Targeted social grouping, getting away from ability grouping, focusing more on student agency, personal learning programmes … reading and observations that support student agency*** (Arihia, School Two).

Some of the teachers of this study face large class sizes and employ different strategies or pedagogical approaches to cater to these large class sizes. Two of the three teachers above are in ILE's in combination with the use of *Education Perfect*. One of the strategies employed is a group response, as in small group work, with individualised or personalised responses for those that are outside of the group boundaries because of either high or low achievement. One of these teachers is in a single classroom setting engaged in a school-wide approach for the use of a dedicated mathematics software program.

Within ability grouping is the social and academic stigma of high to low ability levels, most obvious in streamed environments. Ability grouping is subject to physical placement of low ability students with other low ability students, reflected at all levels. A move away from ability grouping is social grouping.
The teachers of this study advocate for the use of digital technology when faced with large numbers of students and time restrictions. In addition, in a dedicated mathematics software scenario students could self-regulate and drive their own achievement. This is a second dimension attached to personalised learning as work set is based upon completion and individual targets, or sustained effort regardless of ability levels, supporting self-regulation.

The desired attributes of a lifelong learner of tomorrow suggests the ability of an individual to apply the skill of learning throughout their working life, irrespective of the changing horizons that are depicted by the passage of time. The teachers of this study believe that knowledge construction is advantaged with the use of digital technology, as is the ability to build on learning routines. As discussed previously, among the key competencies to be taught are thinking and managing self.

> ***Supports independent and autonomous learning*** (Arihia, School Two).
>
> ***Effective use reflects self-direction and independent study time*** (Taylor, School Three).
>
> ***Digital technology is part of the process of building student identity*** (Joelle, School Four).
>
> ***Targeted social grouping, getting away from ability grouping, focusing more on student agency, personal learning programmes … reading and observations that support student agency*** (Arihia, School Two).
>
> ***The dedication you see students put into Mathletics now, because of the opportunity of obtaining Mathletics - gold – through consistent effort over a long time – establishing those work patterns*** (Arihia, School Two).

The teachers of this study believe the use of digital technology is supportive of the development of the key competencies. The use of digital technology is seen to enhance self-regulation, which supports student outcomes and assists in the development of individual learning skills.

The teachers of this study aligned their teaching practice to the digital resources provided. The decision made to undertake the use of a school-wide digital platform, which is appropriately resourced, is supported by leadership practice and filters down to classroom practice. It may be that the initiation or want or need is teacher driven, but targeted student outcomes dictate changes driven by school management. Schools are aligned to digital technology as an expression of the real world, and the desire to promote student achievement. Three of the teachers of this study had the following to say:

> ***We are targeting success, we look at outcomes, we want to make sure that they are going to be successful for the next stage of the educational journey*** (Arihia, School Two).
>
> ***It is not just a one-person decision to use Mathletics, it is a leadership decision*** (Courtney, School Two).
>
> ***For some students it (digital technology) definitely increases student engagement because it is their whole world and that is how they are used to doing things, for others not so much, so we offer choices*** (Laurell, School One).
>
> ***Student outcomes guide my practice*** (Arihia, School Two).
>
> ***Making sure that it is being used for the right reasons rather than just because it is technology, you've got to actually add something*** (Laurell, School One).
>
> ***Control of the class is as effective with digital technology as without it*** (Arihia, School Two).

The support structure in place illustrated by leadership practice enabled changes to existing teaching practice with the use of digitised platforms. The teachers of this study utilised digital technology to guide and enhance student outcomes and not simply to be seen to be using a software package resourced by the school. The targeted outcomes of improved and enhanced student outcomes were adhered to. The selection of the use of digital technology was made based upon advantaging student outcomes in line with targeted school goals.

One key benefit of using digital technology to develop and support teaching pedagogy, inclusive of task design, was to enhance student motivation and hence engagement. This formed a part of the overall skill development and focus undertaken by the teachers of this study. Lesson design refers to how the learning objective of a lesson focus is expressed and how a student would know if they have been successful in a lesson. Task design are the tasks undertaken that have been repackaged digitally within a software package and are used to achieve the learning outcome of the lesson. For one of the teachers in this study, this could occur spasmodically at certain times of the year. In consideration of task design, findings of four teachers show:

> ***Task redesign is not necessary with a program like Mathletics (dedicated mathematics software)*** (Courtney, School Two).
>
> ***We try and do collaborative task design here (software that allows changes)*** (Matiu, School One).
>
> ***Collaborative task design over department/school a bonus/magic (no software)*** (Joelle, School Four)
>
> ***Tasks are all mainly based upon Education Perfect, extension knowledge is pen and paper (software that allows changes)*** (Laurell, School One).

The varied circumstances of the teachers of this study show that tasks are preformatted with the use of the dedicated software programs and cannot be changed. *Education Perfect* software may be modified to personalise learning undertaken. The use of software has not replaced the overall mathematics programme delivery for the teachers of this study.

With *Education Perfect* the teachers of this study could choose to alter the program to reflect extension activities or utilise other means to engage students. Whether digital technology was used or not, the findings of this study suggested that collaborative practice at some level for task design was favoured by the teachers of this study.

The teachers of this study have targeted programme design to motivate students and increase engagement, in the hope that targets set will be achieved. In addition, the attributes of the lifelong learner are desired. The challenge for the teachers of this study is to fulfil this brief and make learning for students interesting. Task design is then a reflection of more than knowledge content transfer. When evaluating dedicated mathematics software findings show:

> ***Student autonomy is a process or learnt skill undertaken over time with digital technology*** (Arihia, School Two), (Taylor, School Three).
>
> ***Students are independent when using digital technology which has been built around the scaffolding at the start of the year*** (Courtney, School Two).
>
> ***Targeted social grouping, getting away from ability grouping, focusing more on student agency, personal learning programmes ... reading and observations that support student agency*** (Arihia, School Two).
>
> ***I can assign tasks, monitor these tasks a lot more easily, check, reassign and this is me reflecting with digital technology*** (Courtney, School Two).
>
> ***Can vary the lesson content – make it lighter – make it more fun*** (Arihia, School Two).

> ***Becomes a flexible but accountable resource for teacher and student – the digital resource supports me, and I support the digital resource*** (Taylor, School Three).

The use of a dedicated mathematics software program represented three of the six teachers concerned. These teachers found that developing the key competencies with students within their classroom was undertaken in a progressive manner and in a measurable timeframe. The teachers of this study found that digital technology was able to provide a second teacher voice within the classroom, dependent upon the features available with the software package. This was enabled with explanatory video clips, repetition of the video clips, and repeat opportunities to undertake worked examples.

The use of these software features assisted with the instructional capacity of the teacher and classroom. Teacher administration was assisted, together with the flexibility to move beyond ability grouping. The software used was either a whole lesson or formed part of the lesson, at teacher discretion. The digital technology utilised served as a support to the classroom by the teachers of this study.
When evaluating digital technology, findings by two teachers of this study without dedicated mathematics software, but still with mathematics software have led to suggestions by the following teachers:

> ***It's the same structure … space invaders timetables, where they shoot the answer … so just a little bit of fun for a buy in*** (Matiu, School One).
>
> ***Given the class size sometimes it becomes harder to teach a new digital skill or a new digital tool because of class size, but then sometimes we***

> ***would split them up and teach a group at a time … sometimes it is just easier to use the whiteboard*** (Laurell, School One).
>
> ***I would find the online resources to go to, create some sort of like revision or a page where they got like videos, where they can access them online at any time, or they've got access to online questions and answers, … I use it more for teaching them rather than me teaching them*** (Matiu, School One).
>
> ***It depends on the context … with some tools it is more about the process of using the technology and then overtime would become more about the maths or the content for an across curricular module … for others I think it is more of a balance straight away like Education Perfect, some things are much more user friendly*** (Laurell, School One).

The two teachers who have reported these ideas did say they spent more time finding digital content that would allow skill development for their students. At times their choice became more a reflection of the pressure of class size or time constraints when further time was needed to teach the new digital tools. The teachers of this study utilised digital technology as a support for existing teaching practice, with their long-term vision targeting the development of digital technology skills (knowledge of the software) alongside the development of mathematical competency. The time spent developing the digital technology skills was dependent on the user-friendly nature of the software in question. The digital technology utilised served as a support to the classroom by way of a lesson component, but also a revision practice that could be accessed beyond the confines and timeframes of the classroom and school hours.

The teachers of this study have found that with the provision of accessibility of a digital nature beyond the classroom confines, key competencies of managing self, thinking, and knowledge content were further developed.

When evaluating pedagogy without the use of digital technology findings show:

> ***Working their way through the paper-based programme with enthusiasm is the ideal – goal oriented and self-motivated*** (Arihia, School Two).
>
> ***It would be a lot harder to teacher from level one to five across 30 or 60 kids, you would lose some of that 21st century learning (key competencies)*** (Matiu, School One).
>
> ***Students being engaged on a task that is at the right level of challenge for them … ummm … and being engaged for a whole lesson or as much of a lesson as possible*** (Laurell, School One).

The three teachers of this study responded with comments that support the value of the key competencies with or without digital technology. All six of the teachers in this study were aware of the need to develop the key competencies in line with mathematical knowledge content. The effective teaching profile supports innovation, with the use of digital technology an example. The teachers of this study targeted student motivation and engagement with or without digital technology use and were aligned to the employment of practices that enhanced student outcomes.

4.6 Enablers and inhibitors

The findings below target the first research question listed above, which was: Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

In mathematics education there have been both enablers and inhibitors to the use of digital technology within teaching practice, referring to the discussion of both in Chapter Two. Enablers and inhibitors can be thought of as internal and external factors. One of the enablers to the use of digital technology is professional learning and development this discussion will take place in Chapter Five. Over time there have been obvious historic inhibitors of hardware and software shortages, given the uptake of digital technology within society. These enablers and inhibitors have changed in nature as time has progressed.

What is concerning is the perceived slow uptake by teachers within the education environment of the transformative potential of digital technology use, adding to the impetus to undertake this study. Digital technology use may assist in the delivery of quality instruction and assist teachers to fulfil the characteristics of an effective mathematics teacher. It has then become timely to undertake research on digital technology use reflecting the above.

The findings below are reflective of the first research question, mentioned above. Within this context reference is made to devices, wi-fi connectivity and software. Devices refer to chrome books, tablets, and phones. Wi-fi is the broadband connection that enables the online nature of teaching and learning to occur. Software refers to the instructional packages in use within the mathematics classroom, that are either freely resourced, which means available at no cost, or needing to be paid for by the school, which means available at cost. This availability of hardware and software resourcing impacts upon teaching approaches and student skill development. In line with a roll out of digital technology usage undertaken over time, the present snapshot that was reflective of the current timeframes, reveals the following:

Wi-fi connectivity and hardware shortage is an issue that the teachers in this study have experienced and managed across the spectrum of generous resourcing to limited resourcing. Examples taken from findings of three teachers revealed the following:

> ***Classroom use of digital devices is split, to cater to wi-fi and device constraints. Half of the class are on a device half are working in small groups with XXXX (paper based). Connectivity in itself does not prevent the use of digital technology*** (Arihia, School Two).
>
> ***I have twelve devices for my classroom, four of the twelve devices cannot play everything that we want to access, so that is restrictive*** (Arihia, School Two).
>
> ***Hardware replacement/update (2-year cycle – then they just start getting slower), timely undertaking of maintenance with devices becomes a feature*** (Arihia, School Two), (Taylor, School Three), (Joelle, School Four).

The teachers suggest that there is a shortage of devices for all the class to use at one time. This appears to be compounded by poor servicing of the bank of devices in use, meaning a slow turn around and replacement of these devices. Once out of circulation there are then fewer devices to use, compounding the shortage of devices for classroom use overall. It can be related to a decision to retain a defective device, to not seek repair, given the compounding issue of device shortage and replacement issues both long and short term.

> ***Wi-fi connectivity is an issue still, given the increased traffic as schools move closer to one-to-one devices*** (Arihia, School Two), (Taylor, School Three), (Joelle, School Four).

As the schools in this study move towards one-to-one device usage, the impact upon connectivity is felt, with simultaneous use across the school placing restrictions on the ability of classroom teachers in this study to work with certainty that every student in class can sign on at the same time and access work that has been set. The strategy used by teachers in this study was to work in groups, which would allow for this uncertainty with connectivity.

> ***There are no inhibitors to digital technology use in this school*** (Laurell, School One).
>
> ***Digital screen pads that you can write on … they brought me it … really good during lockdown*** (Matiu, School One).
>
> ***Insufficient number of devices as seniors take priority over juniors*** (Joelle, School Four).

The teachers in this study experienced a range of resourcing, with some generously resourced, given the school's digital focus within mathematics and other teachers having to prioritise student use given the shortage of devices for use within mathematics.

The enablers here are the generous resourcing of laptops for each teacher, each school had consultant ICT experts that maintained the school ICT system overall, with some schools having their own added ICT experts on staff assisting where possible. Additionally, mentioned throughout this study was the access to PLD, discussed in Chapter Five. Also mentioned in dialogue undertaken was the positive attitude the teachers of this study consistently displayed in their responses for the use of digital technology within their teaching practice, which is an internal enabler (Beltman, 2021).

Software resourcing for the teachers of this study was uncertain from year to year, with resourcing ranging across the spectrum of generous supply to limited supply, where the usage of software was restricted to only that which was free, known as free apps. The digital technology available for use was dependent upon the investment the respective schools were prepared to make, with their short-term and long-term planning. Examples taken from findings revealed the following:

> ***No access to software, free apps the norm*** (Joelle, School Four).
>
> ***Usage is influenced by the resourcing the school is prepared to make available*** (Arihia, School Two), (Taylor, School Three), (Joelle, School Four).

Funding decisions impact upon teacher commitment to software use given the funding got pulled at Board level after 4/5 years of teacher and student skill development (Joelle, School Four).

One funded resource has to fit both juniors and seniors across the learning streams (Taylor, School Three), (Joelle, School Four).

Some of the teachers of this study have experienced significant restrictions with digital technology usage, as a reflection of school resourcing and low prioritisation of a digital focus within junior mathematics. The teachers in this study desired greater support that allowed for the development of their teaching practice with the use of digital technology, in addition to enhancing their existing pedagogy. School policy is an enabler when supporting digital technology use, illustrated with the commensurate resourcing equally in some instances it is the barrier to desired shifts in pedagogy (Beltman, 2021).

It appears that if teachers were unable to access pre-formatted software and were designing their own structured lessons with different software packages this became a pedagogical challenge. The use of technology within mathematics is designed to allow conceptual skill development in line with the key competencies. Teacher perception revealed the following:

Task redesign is not necessary with a program like Mathletics (Courtney, School Two).

Acquiring masses of video clips etc. without being shown how to use it is an accumulation of a bank of sxxt - will not touch it (Joelle, School Four).

> ***I guess our whole curriculum has been redesigned … it is hard to say whether that was as a result of the use of digital technology or with all of our other changes …*** (Laurell, School One).
>
> ***Curriculum redesign is hampered by the lack of availability of devices*** (Joelle, School Four).
>
> ***It is harder to alter, Education Perfect, so it takes a bit longer, I feel then pen and paper*** (Matiu, School One).

For the teachers of this study task redesign was not an issue with dedicated mathematics software, which does not allow for alteration of the software interface. The teachers of this study worked within the boundaries of the resourced software provided and followed a consecutive lesson roll out to a designated programme. However, in general, they incorporated a learning-centred approach, as befits hybrid practitioners (Bremner, 2019). It appeared that the teachers of this study can control the work set by digital means and can monitor work undertaken and work completed.

The teachers of this study that did not have resourced software programs discussed the challenges of changes and pressures of curriculum planning to suit the learners' needs. Teachers of this study recognised the redesign process of tasks and pedagogy necessary due to the use of digital technology. The teachers hampered by the lack of devices redesigned selected curriculum areas applicable to the timeframes within the year where devices were available. Effectively this was a partial redesign to fit when they were able to access digital devices.

Building a bank of digital resources for some teachers of this study was seen as ineffective, as lesson construction enabling the effective use of these resources required additional support. In addition, the use of digital technology for consecutive lessons was uncertain, meaning the use of a video clip in isolation occurred which supported traditional practice, but did not enable teachers to align to consistent changes to existing practice with the use of digital technology. Some teachers from this study were able to alter the software resource itself, to include teaching points of importance.

Teaching to the resources available seemed to dominate the approaches to teaching and learning undertaken by the teachers of this study. For those teachers who were adequately resourced this was not an issue, for those that were not it was an obvious point of frustration as they were limited in their opportunities to change existing teaching practice.

For the teachers of this study, teacher beliefs had an impact on digital technology usage within the classroom and subsequently pedagogy. Teacher perception revealed the following:

> ***Teacher belief is influenced by the resources available to them*** (Taylor, School Three), (Joelle, School Four).
>
> ***Student autonomy is not guaranteed with the use of digital technology as teachers have to believe in the benefits of facilitating student autonomy and structure the learning to support*** (Joelle, School Four).

All the teachers of this study were influenced by the digital resourcing available to them. Those that were generously resourced were able to enjoy the flexibility within their teaching practice that this enabled. Adequate resourcing allowed for a reflective response to student outcomes. Those teachers in this study that taught with restrictions were less able to develop their teaching practice in this way. Teacher beliefs that are positive to the use of digital technology are considered enablers and equally negative beliefs are inhibitors to the use of digital technology within teaching practice (Beltman, 2021).

Teacher beliefs in general showed that there exists an awareness of where numeracy is ranked across the school. Teacher perception revealed the following:

> ***Literacy assumes a higher focus, numeracy needs an equal commitment*** (Arihia, School Two), (Joelle, School Four).
>
> ***There is a need for a strong numeracy advocate within the management team*** (Joelle, School Four).

The teachers of this study were aware of the supports available to them and were looking to school management to advocate on their behalf to overcome restrictions to better develop and enhance student outcomes. The teachers of this study believed in the importance of mathematics within the education profile of the students within their classrooms. The teachers of this study were emphatic in their desire to enhance existing student outcomes with the use of digital technology.

Within individual teacher practice the differences related to the use or not of digital hardware revealed the following:

My practice would be assisted if every student had a one-to-one device (Courtney, School Two).

We have a one-to-one device use (Matiu, School One).

Some students miss out … so I guess the idea would be that each student had their own permanent device (Laurell, School One).

We use their phones, a lot of group work or partner work anyway or they have the option to do it on paper, less of a problem then it was when we first became BYOD I think (Laurell, School One).

The teachers of this study desire a one-to-one device usage to enhance student learning outcomes and their personal teaching practice and perceive an impact on their teaching practice when this is not achieved. This assists with the ease of transition within teaching practice, reflecting the desire to engage with shifts in pedagogy, supporting the learning-centred focus (the switch between teacher and student-centric models). The school policy of bring-your-own-device (BYOD) for some of the teachers in this study still did not overcome the lack of one-to-one device usage. The decile ranking of the school was not a factor in device availability, but rather management decisions reflecting school policies in play.

A second point, beyond the availability of resourcing, yet integral to individual teaching practice and group work, was identified by some participants as a barrier:

Independent use easier to facilitate then group or pair with digital technology (Taylor, School Three).

Nothing prevents small group usage with digital technology (Courtney, School Two).

> ***Need PLD to develop knowledge on how to support group work with digital technology*** (Joelle, School Four).

With some of the teachers in this study, effective group usage with digital technology was harder to achieve than for others. Teachers within this study identified the desire for professional learning and development to overcome the gaps they saw within their teaching practice. Teachers within this study were comfortable with the individual student use of digital technology within their classrooms. To only have individual use with digital technology limits the flow of teaching and learning as the transitioning between individual to group work within lesson structure is impacted. Teachers of this study measured the student outcomes gained with their use of digital technology, and in general teacher satisfaction with student outcomes dictated the digital technology usage for the teachers of this study.

The teachers of this study were not resistant to the use of digital technology within practice, but with the integration of digital technology comes the changing role of the teacher. A preference to teach in familiar ways has been expressed, but indicators of changes to student characteristics and the need to meet these characteristics within teaching practice added impetus to sustained change, in addition to physical factors within the classroom. Teacher perception confirmed:

> ***Quite a big school push like generally across the board … every single kid has a device available to use in every single classroom*** (Matiu, School One).

… it is a slightly different pedagogy that you are looking at, your screen to see where the progress is (Matiu, School One).

… the more you use it the more you are helping them become independent learners, so I think you are giving them ownership (Matiu, School One).

… we needed to do this in the sense of, this is the day and age, and our students are coming in with all of these skills, and if teachers aren't upskilling themselves … kids are wired differently than we were … like everything is digital for them (Courtney, School Two).

… so, our new teachers will have no idea about teaching without it (Courtney, School Two).

The teachers of this study accept the changing teacher role, where facilitation of learning is starting to become a regular aspect of their teaching practice, a learning-centred approach has become the norm.

The teachers of this study looked to employ both teacher and student-centric practice, regardless of enabling factors, which reflects internal teacher beliefs, which can be either positive or negative.

… it depends on where the students are at, so if we feel like there is more teaching that needs to happen, then and there, we might … and across the board … we might stop that and give them some work in class with our devices … (Joelle, School Four).

… and the kids will use their results from their pretests we do to judge what gaps they have and where to go from there, so then they manage with the facilitated resource or the hyperlinks to help them go

> ***and work on the skills they need to fill those gaps … that is really the essence of what we use the devices for in the junior syndicate*** (Joelle, School Four).

When asked directly if they could flick easily from teacher to student-centric practice as the resources are available, the responses were as follows:

> ***Yeah and what learning needs to be covered depending on the student responses*** (Joelle, School Four).

Can you see yourself using student-centric practice only?

> ***No, I believe there needs to be a blended approach*** (Courtney, School Two).

> ***… that we do switch in between where they can take control of their own learning*** (Arihia, School Two).

> ***… so you know there's structured portions of our lesson where it's teacher-centric …*** (Taylor, School Three).

> ***… really good for students who need to focus on their core skills and are aiming to get some core grades, but … I am still sceptical about the higher-level stuff*** (Matiu, School One).

Do you find if you have difficulty with a student who lacks motivation that you move back into traditional mode?

> ***I think once you get to know your students, you know which ones respond well to that and which ones don't … yeah I think there are some students that works for …*** (Laurell, School One).

What dialogue within the semi-structured interview supports is the belief that teachers' hold on the value they place on digital technology use, is high, but inherent knowledge of their individual student base reinforces for them the need to use learning-centred practices.

4.7 The COVID effect

At the time this study was undertaken the COVID pandemic took place. The obvious impetus for an increased usage of digital technology given the contactless scenario employed across New Zealand society assumed relevance within the education environment. With the advent of COVID the teachers of this study revealed the following:

> ***Introduction of resourced software (MathsBuddy, Education Perfect, beyond the use of free apps)*** (Taylor, School Three), (Joelle, School Four).
>
> ***Increased demand for PLD for teachers. Thrown at us. Learnt on the fly*** (Taylor, School Three), (Joelle, School Four).
>
> ***Placed increased emphasis on capacity building for teachers*** (Joelle, School Four).
>
> ***We have had to adapt, dramatically … but how we delivered that and how we taught that, it's a lot harder to do remotely*** (Matiu, School One).
>
> ***But the learning curve was pretty immense, steep*** (Laurell, School One).
>
> ***Teaching practice advantaged in lockdown with established use of digital pre lockdown*** (Taylor, School Three).

For those teachers of this study that did not have an established digital presence the learning curve was immense; coupled with the expectation that what they did not know reflective of digital skills, would be developed under pressure within expedient time frames. New software was employed, enhanced by software companies making free usage available, and training undertaken across departments, using the whole school approach. Collegial support was vital to enable a digital transition to occur.

For those schools whose digital footprint was already established the workload undertaken by teachers of this study was less extreme, with opportunities to try other software taken advantage of given the free nature of the trial period. The student skills of self-management were already in existence, which meant the teaching and learning undertaken with a digital presence was familiar, for both teachers of this study and their students.

Within a scenario of high anxiety as society faced these extraneous pressures and with teachers being front line for some of this roll out, the compounding nature of the development of digital skills and technical knowledge became an additional pressure to manage. Supportive frameworks by school management, who kicked in with both professional learning and development forums and additional digital resources reflecting both hardware and software, were integral to a success scenario, to enable student outcomes to be advantaged.

As the COVID lockdown came to an end and schools reopened enabling student presence within the classroom, a post lockdown scenario with a greater focus on digitally enhanced approaches became apparent. The teachers of this study commented on the following:

> ***Post lockdown, PLD initiatives ended, back to pre-COVID practices*** (Joelle, School Four).

> ***Everybody's skills improved over lockdown as a result of jumping in together as a culture*** (Taylor, School Three).
>
> ***This is the first year we have had allocated a time slot for PLD … every week … since lockdown*** (Laurell, School One).
>
> ***We got student voice and parent voice after lockdown, to reflect on our digital technology use, but I do not recall any reflection prior to lockdown on digital technology use*** (Arihia, School Two).

For one of the teachers of this study, teacher responses reveal that if school policy was not aligned to a digital presence in mathematics with sufficient device availability throughout the year, the provision of resourced software cannot be taken advantage of within teaching practice at a junior level post COVID. The push for increased PLD also diminished post COVID. Digital practice is restricted within teaching pedagogy.

For one of the teachers of this study PLD undertaken with regular time intervals occurred post COVID, supporting digital expertise and shifts in teaching pedagogy to achieve quality instruction. For one of the teachers of this study the momentum felt with a whole of school approach was a positive experience, assisting in the building of individual and group expertise. For one of the teachers of this study, school reflective practices on digital technology use, with the sourcing of parent and student voice, were initiated.

Teachers and students within this study that are not digitally aligned will again experience immense pressure at a junior level with the next pandemic wave. For those schools who have taken the COVID presence as an impetus to keep abreast of digital change, continued support of teachers within this study is ongoing. The teaching response is aligned to the resourcing made available to the teachers of this study. Not all teacher responses have been detailed above, but the responses that provide confirmation of major themes have been portrayed.

One of the concerns expressed by one of the teachers of this study looked at life without personal contact, given the COVID scenario and what she felt. This was portrayed in her comments below:

> ***I think one of the struggles experienced by students during COVID lockdown was the lack of peer interaction, … less scope for those kind of peer interactions that happen in the classroom all the time*** (Laurell, School One).
>
> ***… but lots of people are there ten or fifteen minutes before and sit down and have a chat beforehand and that can be when reflective conversations happen … it can be when planning conversations happen … or people swap ideas with each other … building friendships … building collegiality … personal interaction … that didn't happen when we were online*** (Laurell, School One).

The teacher perception expressed here is the need to be human. By this I mean the desire to interact personally with others, whereby informal interaction comes into play. Teacher perception considers face-to-face interaction as valuable, both within the classroom, staffroom and beyond. Digital technology is seen to enhance existing pedagogy but not to replace the human interface.

The summary of findings targeting the discussion above is presented below in Table 8. Following the table, a detailed discussion reflects the summary of findings, and the information presented in the table form.

4.8 Summary of the Findings for the Teachers of this Study

Table 8

SUMMARY OF THE FINDINGS

Pedagogy, Opportunities, Inhibitors, and Digital Technology Use in the Mathematics Classroom of year 7-10	Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?
SUMMARY OF THE FINDINGS PEDAGOGY, OPPORTUNITIES, INHIBITORS, AND DIGITAL TECHNOLOGY 4.2 SCHOOL MANAGEMENT PRACTICES	IMPLICATIONS FOR THE TEACHERS OF THIS STUDY
For 3 of the 4 schools within this study sustaining changes to school pedagogical practice involved the three facets of: school management practices, school culture and a collective school-wide endeavour.	For 3 of the 4 schools of this study, school management and school culture support teacher practice reflective of the adoption of digital technology. For one of the schools this included ILE's.
School culture is driving the usage of dedicated mathematics software which is driving school culture.	Teacher-led initiatives now reflect a digitised environment.
There were advantages and disadvantages to the use of digital technology; teachers are required to negotiate both to enhance student understanding.	The use of digital technology did not support a response to errors in thinking for wrong answers.
For one of the four schools within this study, changes to existing pedagogy with the use of digital technology reflecting imaginative praxis, has been enabled with a partial redesign, when digital devices are no longer	For 1 of the 4 schools of this study, school management have been unable to consistently resource software to include junior mathematics pre and post COVID. For 1 of the 4 schools of this study,

needed for senior school use. Junior mathematics outside of COVID lockdown was not resourced with software. Teacher practice is siloed within individual classes.	teacher practice that indicated the use of digital technology, inclusive of imaginative praxis, has not been developed across curricula areas given the restrictions faced. Collective endeavour is negatively impacted.
School culture and the use of digital technology were not synchronised. The use of a digital device was not available throughout the year. School culture was not able to promote the adoption of shifts in pedagogy with the use of digital technology. One could not build or sustain the other.	The teacher had a desire to respond to the effective teacher profile but was confined by the resourcing available.
For the teachers of this study shifts in pedagogy have been influenced by the context they find themselves within.	The teachers of this study employ practices that support the learning-centred classroom and are hybrid practitioners.
Teacher Resilience	Risk Factor – Lack of Resources Protective Factor – School Administrative Support (Beltman, 2021).
Teacher Agency	Classroom Practice - (Hiver & Whitehead, 2018).
Teacher Identity	Pedagogy - (Mockler, 2011)

COLLABORATIVE PRACTICE AND DIGITAL TECHNOLOGY 4.3 RELATIONSHIPS	IMPLICATIONS FOR THE TEACHERS OF THIS STUDY
Teachers are aware of the need to work toward positive relationships with their students with the tools available to them. Digital technology can be manipulated to assist with relationship building.	Teacher to student contact is needed to support feedback, guidance, dialogue, and relationship building. Human bonding necessitates interaction.
Teachers continue to work on relationship facilitation with the use of digital technology.	Digital technology is another means/tool to support the quality of the learning relationship between student and teacher. Aspects of digital technology use can be used as both stick and carrot for desired student outcomes.

Teacher Resilience	Risk Factor – Behaviour Management Protective Factor – Working with the students (Beltman, 2021).
Teacher Agency	Collaborative Practice (Hiver & Whitehead, 2018).
Improving the quality of teaching can be assisted by collegial interaction. Collegial support is valued.	When teachers are required to make changes to existing teaching practice, task design, or module of learning, the ability to access the expertise of a colleague can assist and support.
The teachers of this study that employed collaborative strategies within their practice with the use of digital technology targeted opportunities to enhance teacher and student capacity as they presented.	The sharing of resources (knowledge, tasks) is a collaborative practice that supports the pooling of expertise and assists with a uniform delivery of knowledge content.
Communities of Learning can assist with enhanced opportunities for student outcomes if pedagogy is effective.	Teaching practice was influenced by community membership nationwide aligned to individual student achievement.
Opportunities to include competitions as part of teaching practice were utilised to support student motivation and engagement.	Teaching students how to cope with failure.
Teacher Resilience	Protective Factor – support from peers and colleagues; working with the students. Risk Factor – behaviour management (Beltman, 2021).
Teacher Agency	Facilitating Student Learning (Hiver & Whitehead, 2018).
Subjective factors influence collegiality.	To be collaborative does not indicate a desire to be collegial as the personal dynamic is a consideration within the reality of collegiality.
Teacher Identity	Individualism – traditional teacher identity (Diniz-Pereira, 2003).
Teacher Resilience	Risk Factor – reluctance to seek help (Beltman, 2021).
Teacher Agency	Collaborative teacher learning (Hiver & Whitehead, 2018).
The teachers of this study within their use of digital technology have validated student identity.	The indigenous value of whakawhanaunagatanga is expressed within peer support as an expression of community togetherness with the use of

	digital technology. Student relationships were supported with the use of digital technology, reflecting the individual pace of learning, the freedom to help others and the ability to share devices to enable learning for all.
The teachers of this study when reliant on pen and paper have worked to validate student identity.	Pen and paper supported student-to-student synchronicity.
Teacher Resilience	Protective Factor - Working with the students (Beltman, 2021)
Online access supports visibility of student learning beyond school hours enabling whānau awareness and participation.	The teachers of this study have targeted visibility of mathematical progress as a key gain for whānau involvement with student learning, which the software program in use supports.
Teacher Resilience	Risk Factor – Relations with students' parents
Teacher Identity	Protective Factor – Altruistic Motives (Beltman, 2021)

STRUCTURING PEDAGOGICAL SUCCESS WITH DIGITAL TECHNOLOGY 4.4 DIGITAL TECHNOLOGY AND MATHEMATICS SOFTWARE	IMPLICATIONS FOR THE TEACHERS OF THIS STUDY
The teachers of this study have found the advantages of mathematics software, could reflect administrative efficiency, increased teacher instructional capacity, flexibility to cater to different learning levels, and student choice.	The teachers of this study valued the dimension of the second teacher voice in consideration of knowledge content development with the use of digital technology. Teacher knowledge content is required simultaneously across different levels of learning as students learn at different individual levels and pace.
The teachers of this study found advantages with accountability, monitoring of work and enhanced lesson delivery The teachers of this study were opportunistic with their selection and use of digital technology.	Delivery of software even when standard is enhanced with various features like embedded video instruction, blinking cursors and so on. These features increase student engagement by advantaging working memory capacity (CTML Theory).
The teachers of this study created opportunities to provide feedback to enable	One of the teachers of this study has identified that it is harder to track errors made by students with digital technology.

student learning, and increased student understanding with repeat examples.	
Teacher Resilience	Protective Factor – working with the students (Beltman, 2021).
Teacher Agency	Facilitation of student learning (MUSIC Model) - (Jones, 2009).

PEDAGOGY AND THE DIGITAL TECHNOLOGY RATIONALE 4.5 DIGITAL TECHNOLOGY – GROWING TEACHER PRACTICE	IMPLICATIONS FOR THE TEACHERS OF THIS STUDY
The use of dedicated mathematics software could facilitate a shift from teacher-centric toward student-centric teaching practice, supporting a learning-centred environment.	The use of a common software platform gives some guarantee of program delivery regardless of the experience of the teacher and some guarantee of time allocation spent teaching mathematics given the monitoring features of the program.
The wider mathematics programme can be designed to move beyond a one-size-fits all delivery of mathematics instruction. Social networking enhanced opportunities for communicating with whānau to allow the opportunity for increased support for student outcomes.	The utilisation of technology within a social networking platform enhanced visibility and student outcomes, inclusive of whānau visibility whilst networking within a wider dedicated mathematics community supporting student outcomes.
The teachers of this study have found that the transformative potential of digital technology can enhance learning opportunities for students.	Learning opportunities can be created that advantage student engagement. Different programs can be used to achieve different outcomes. The teaching and learning environment can have increased flexibility.
The teachers of this study have identified the limitations of a lack of adaptability of technology to be able to explain problems in different ways. Pedagogical shifts are utilised supporting the learning-centred classroom.	The limitations of digital technology impact upon teaching pedagogy as teacher knowledge content is utilised to supplement multiplicity of explanation.
Student familiarity with digitally based assessment may act to advantage student outcomes and give digital technology use in class increased relevance. Wider exam conditions will prevail (*asttle, CAA's)*. Classroom based practice will be within teacher discretion.	The use of digital assessment and digital technology within assessment gives relevance to the use of digital technology. The teachers of this study were aligned to the use of a paper-based approach to assessment.

Easy shifts are achieved between teacher-centric and student-centric approaches to teaching and learning with digital technology usage, resulting in a learning-centred approach to teaching and learning.	The teachers of this study were not aligned to either behaviourist or constructivist theory but utilised a learning-centred approach reflective of both theories. As they utilised a learning-centred approach, the focus was on the motivate, engage, and achieve cycle.
The flexibility of teaching pedagogy with a learning-centred approach enhances the motivate, engage, and achieve opportunities available to the student.	The learning-centred approach has come to mean three things: 1. the combination of teacher and student-led practices the tools of which are; the transferring between the use of digital technology, and the use of pen and paper and the use of visual and physical manipulatives. Teaching pedagogy is matched to student need.
Multiple sensory representations advantage student outcomes, indicative of the CTML theory, aiding the delivery by teachers of quality instruction as they move beyond the one-size-fits-all approach to teaching and learning.	Personalised learning is easier to support with the use of digital technology when faced with large numbers of students and the time factor. Students have the opportunity to self-regulate and drive their own achievement with a dedicated software package. Personalised learning allows for work to be set based upon individual attainment and completion. The disparities experienced by both teacher and student with their use of digital technology are overcome with the use of a common platform and the building of expertise.
The use of digital technology was seen as a reflection of student identity and aids in the development of individual approaches to teaching and learning.	The teachers of this study believe the use of digital technology is aligned to be supportive to the development of student capacity, inclusive of the key competencies, more so than teaching practice without the use of digital technology.
The teachers of this study aligned their teaching practice to the resources provided.	Advantaging student outcomes dictate changes made by school management. Teachers adopted the use of digital

	technology to guide and enhance student outcomes. Leadership mandate supported changes to teaching practice with the use of digitised platforms.
Task design is altered by degrees as it is influenced by software choices. Changing software will change task design.	Task design is not considered when using preformatted dedicated software, as it is already designed and cannot be altered. With software that allowed change, the alterations reflected extension activities or used resources that did not reflect digital technology.
Collaborative practice was favoured by the teachers of this study in consideration of planning activities beyond their immediate classroom to align subject delivery.	Whether digital technology was or was not used collaborative practice at some level for task design was favoured by the teachers of this study.
The digital technology utilised served as a support to the classroom by the teachers of this study, given its synchronous and ubiquitous nature.	Teacher discretion utilised software as a representation of either the whole lesson or part of the lesson. More time was spent hunting for digital resources when dedicated software was not in use, to illustrate lesson structure.
The key competencies had relevance for the teachers of this study, who supported self-regulation to achieve student outcomes.	Accessing learning programmes beyond the confines of the physical classroom assisted student engagement and student outcomes.
The teachers of this study were flexible in their choice of tools, beyond the sole use of digital technology, as a response to class size, and expedient delivery.	Student engagement was key to teacher practice, with or without the use of digital technology.
Teacher Agency	Facilitation of student learning (MUSIC Model) - (Jones, 2009).
Teacher Resilience	Risk Factor – Difficult schools or classes, lack of resources, heavy workloads and time required for non-teaching duties Protective Factors – working with the students, support from peers and colleagues, support from school administration, mentor relationships (Beltman, 2021).
Teacher Identity	Pedagogy - (Mockler, 2011).

ENABLERS AND INHIBITORS TO DIGITAL TECHNOLOGY USE IN THE JUNIOR MATHEMATICS CLASSROOM	Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?
ENABLERS AND INHIBITORS TO PEDAGOGICAL CHANGE 4.6 ENABLERS AND INHIBITORS	IMPLICATIONS FOR THE TEACHERS OF THIS STUDY
Teachers remain flexible within their lesson intentions to accommodate the shortages they experience. Leadership support that is aligned to a digitised teaching practice is paramount.	Junior mathematics, in some schools assumes a lesser priority to senior mathematics in consideration of hardware resourcing. Timely servicing of chrome books for quick turnaround has created a wariness to have chromes withdrawn from classroom circulation. Within the movement to one-to one devices for every student wi-fi connectivity remains an issue.
The teachers in this study desire the supports that allow the development of their effective teaching profile**.**	The teachers of this study desired adequate resourcing with flexibility of software selection across this age bracket. The teachers of this study are aware of the impact of resourcing and subsequently what they can do with what they have got within a teaching practice and student skill development context.
The use of technology within mathematics is designed to allow concepts to be taught with ease, enhancing the desired changes to teaching practice reflective of learning-centred approaches. Restricted resourcing restricts teaching practice.	The teachers of this study that did not have resourced software programs had to engage in redesign of their lessons reflecting digital technology use. This was further restricted to only those modules where access to hardware devices would be possible. This reflects as an opportunity for partial redesign of the mathematics curriculum only. Teaching to the resources available dominated the approaches to teaching and learning undertaken by the teachers of this study.

	Significant frustration was experienced by those teachers whose desired changes to practice were limited by a lack of resourcing.
Adequate resourcing reflecting digital technology use allowed the reflective capacity of the teachers of this study to be enhanced and developed.	Teacher beliefs have been influenced by the resourcing made available to them. Teachers can only advocate for change if they are able to experience it. The teachers of this study desired exposure to enhanced resourcing to support targeted improvements to existing pedagogy and student outcomes.
The teachers of this study desired a one-to-one device usage and policies of BYOD did not compensate for this within the classroom.	Management decisions reflecting school policies impacted upon teacher pedagogy. The ease within which to transition between teacher-centric and student-centric practice, reflecting the learning-centred scenario is restricted.
For some teachers of this study professional learning and development attached to pedagogy was desired in consideration of teaching practice with digital technology when undertaking group focused learning.	Teachers within this study desired the appropriate professional learning and development to support the gaps they felt that they had within their own practice. Teacher satisfaction with student outcomes dictated digital technology usage for the teachers of this study.
For some teachers of this study acceptance of the changing teacher role, to incorporate facilitation of learning has become another component part of teaching practice in a learning-centred teaching approach.	Student ownership of independent learning is structured to occur within a teaching and learning programme. Facilitation of learning has become part of teaching practice, when targeting student outcomes.
Teachers knowingly employ a learning-centred approach to cater to student identity and their belief in what they consider to be best practice.	Teachers can employ a range of theory-based approaches and choose to be flexible with this to support their belief about best ways to advantage student outcomes.
Teacher Resilience	Risk Factors – lack of resources (Beltman, 2021)
Teacher Identity	Pedagogy - (Mockler, 2011)
Teacher Agency	Facilitation of student learning (MUSIC

	Model) - (Jones, 2009).
COVID LOCKDOWN 4.7 THE COVID EFFECT	
The COVID impact necessitated the increased use of digital technology.	Those teachers who have not been adequately resourced with digital technology at a junior level, (hardware and software), face significant restrictions to undertake teaching and maintain learning within a COVID scenario.
The teachers of this study desire personal interaction as a reflection of the need to be human within their professional sphere.	Digital technology is seen as a means to enhance existing pedagogy but not as a means to replace the human interface. Both formal and informal interaction allows collegial support to be expressed.
Teacher Resilience	Protective Factor – tenacity and perseverance, proactive problem-solving skills, support from peers and colleagues, working with students Risk Factor – Heavy workloads (Beltman et al., 2011).

The references in Table 8, above will allow the reader to analyse figure 11, page 274, with an ability to see where the findings have taken the researcher and give the subsequent discussion chapter relevance to the findings.

The findings above are further referred to in this discussion to allow further thought. For the teachers of this study, the use of online mathematics instruction programs (OMIP's) is worthy of discussion as two of the schools and three of the participants of this study had these in use. The reflection became one of school culture, which in turn has related to collective efficacy or belief within respective schools of this study.

School culture that values the use of digital technology within the junior mathematics department enabled the development of a digitised identity for the teachers of this study. The transitioning of teaching practice to include a dedicated digitised mathematics program became a cyclical undertaking, representing school culture, and supporting changes in teaching practice, with changes in teaching practice supporting school culture. The image of a ‘digitised’ teacher became a component part of each teacher’s practice, regardless of the existing skill base of each teacher. Teacher identity grew and further enhanced student engagement by targeting the motivational factors attached to the use of digital technology, not previously easily and readily available without the use of a dedicated mathematics software program. Independent student learning dispositions were actively encouraged supported by a digitised environment.

The reflection of a digitised environment inclusive of ILE’s affected one of the schools and two of the teachers. For the teachers of this study, who had the use of software that could be changed, it was easier to transition to and cope with classrooms without walls, that had breakout rooms, team teaching, and large student numbers. These factors were easier to manage than if digital technology had not been adopted within this environment. This supports the intention of ILE’s, which is to promote pedagogical shift.

The restricted use of digital technology within a junior mathematics classroom meant that the teacher, taught in isolation from school culture, did not drive the use of digital technology or have it as a prime focus. One of the teachers of this study could not advocate for increased digital technology use, as within the immediate past the resourcing of a dedicated mathematics software program had been withdrawn by leadership at junior level.

For the teachers of this study positive student relationships were worked toward, regardless of whether digital technology was in use or not. However, when digital technology was in use there were both positive and negative aspects. Key to the teachers of this study was the value placed on face-to-face communication and how active facilitation of learning altered the degree of face-to-face interaction. The teachers of this study strategised to compensate for this alteration within their pedagogy.

The facilitation of collaborative practice, in consideration of teacher-to-teacher relationship building, became easier for the teachers of this study. However, within the reality of collaboration, the desire to be collegial was not guaranteed due to the personal dynamic. The use of digital technology allowed networking within a wider mathematics community to take place, which had advantages and were optimised by a positive school culture.

For the teachers of this study student to student relationships were enhanced, and individual student cultural identity was validated as it was allowed to be expressed in a natural classroom environment, reflective of the community, and specifically related to the values of whakawhanaungatanga (making and maintaining relationships) and tuakana-teina (the more experienced and the less experienced).

For the teachers of this study the visibility of student progress undertaken with the use of social media, reflecting restricted access for classroom use only, allowed dialogue to be undertaken, creating a community that was inclusive of whānau (family). Student achievement was celebrated here. This study is limited within the knowledge of how this achievement is portrayed. The focus on repeat opportunities to learn and try, as opposed to ability ranking, allows for motivational practices to be developed and become a part of structuring student success, discussed below.

The teachers of this study were pro digital technology use and as such utilised the digital technology available to them and were happy to take part in this study. The opportunity presented with the use of digital technology was utilised to advantage student engagement and therefore student success, inclusive of both the key competencies and knowledge content. Monitoring of knowledge gains continued within the framework of existing accountabilities, either assessment-related or overall teacher judgment based.

For the teachers of this study support with instructional capacity, 'teacher' voice within the classroom, was highly valued for the users of dedicated mathematics software, which also included instructional video tutelage. "I support the technology, and the technology supports me" became a comment which highlighted the value placed upon instructional teacher supports echoing lesson content. Indicative of the necessity for increased support for the teacher, was the multiple learning levels undertaken simultaneously, reflecting student autonomy within their programme of learning. For the teachers of this study, the teacher as a facilitator of learning negated the need to control learning undertaken if core learning had been achieved. This allowed for some individualisation of the learning programme.

Aspects of the design of digital technology, specifically software related, support the Cognitive Theory of Multimedia Learning (CTML), where student achievement can be advantaged. Equally, the teachers of this study support the use of different programs to achieve different outcomes. The facilitation of ease of movement between teacher-centric and student-centric teaching practice was acknowledged by the teachers of this study. Classrooms were uniformly learning-centred by confirmation undertaken within the interview scenario. The teachers of this study were not, however, keen on the use of digital technology with assessment, reflective of modules learnt within class. Point of contact here became important (marking) and comment was made on the difficulty in tracking student errors when a digitised approach was undertaken.

The transformative potential of digital technology could be manipulated to achieve targeted student outcomes. Of common practice, for the teachers of this study with access to digital technology, was the learning-centred approach undertaken to support teaching and learning. Both paper-based and digitised options were undertaken dependent upon the relevance within the programme of learning. Theories of teacher-centric or student-centric approaches did not occur, but rather learning-centred classrooms depicting differing combinations of teacher and student-led practices, digital technology and paper-based practices, and the use of visual and physical manipulatives. Teacher agency was advantaged with choice, as was student learning, with a selection of different learning approaches to cater to student outcomes.

Personalised learning was achieved with the use of digital technology and enhanced the ease of social grouping as opposed to ability grouping. Group work was supported if the teacher knew how to employ group strategies and the use of digital technology. Student autonomy and how this is supported within the classroom with digital technology was highlighted as a positive benefit. The interplay between student autonomy and motivation targeting student outcomes assisted with the movement toward achieving set school goals. The use of digital technology, in particular the two dedicated mathematics software programs was visible in its promotion of student autonomy, supported by teaching practice.

Regardless of whether digital technology was in use or not, teaching pedagogy favoured student outcomes, within a myriad of available resourcing. Teachers aligned themselves to the use of the resourcing made available to them, inclusive of digital technology. Enhancing student outcomes was always a key focus. However, all the teachers of this study were pro digital technology based within their mathematics classroom practice, which necessitates discussion below of the inhibitors that may still exist that prevent digital technology use within the classroom for the teachers of this study.

Task design has been thought of as a barrier, given the need to redesign existing tasks to better reflect digital technology use within the classroom. This became less of an issue when using dedicated mathematics software, as design was unable to be altered. This also applied to modified mathematics software delivery to a large degree. However, the use of mathematical apps also featured, and it was apparent that these fulfilled the illustration of mathematical concepts, the process of which was made easier with the use of digital technology, even if it was used in the sense of augmentation. When the opportunity presented, across modules within programmes, collaborative task design was favoured overall. Collaborative task design illustrated the pooling of expertise for teachers.

Wi-fi connectivity remains an issue as schools move toward one-to-one device usage. The policy of device servicing, predominantly chrome books within the schools of this study, became an issue for some of the teachers of this study, with a slow turn around, necessitating split classes (some on chromes, some not), or devices not serviced, to cope with classroom demand. The teachers of this study desired software that was resourced and made available to them, as the advantages of the support to teaching practice were considered equally as relevant at junior level as they were at senior level. Some of the teachers of this study also desired a flexibility of software selection, differentiating between senior and junior students, a movement beyond blanket resourcing.

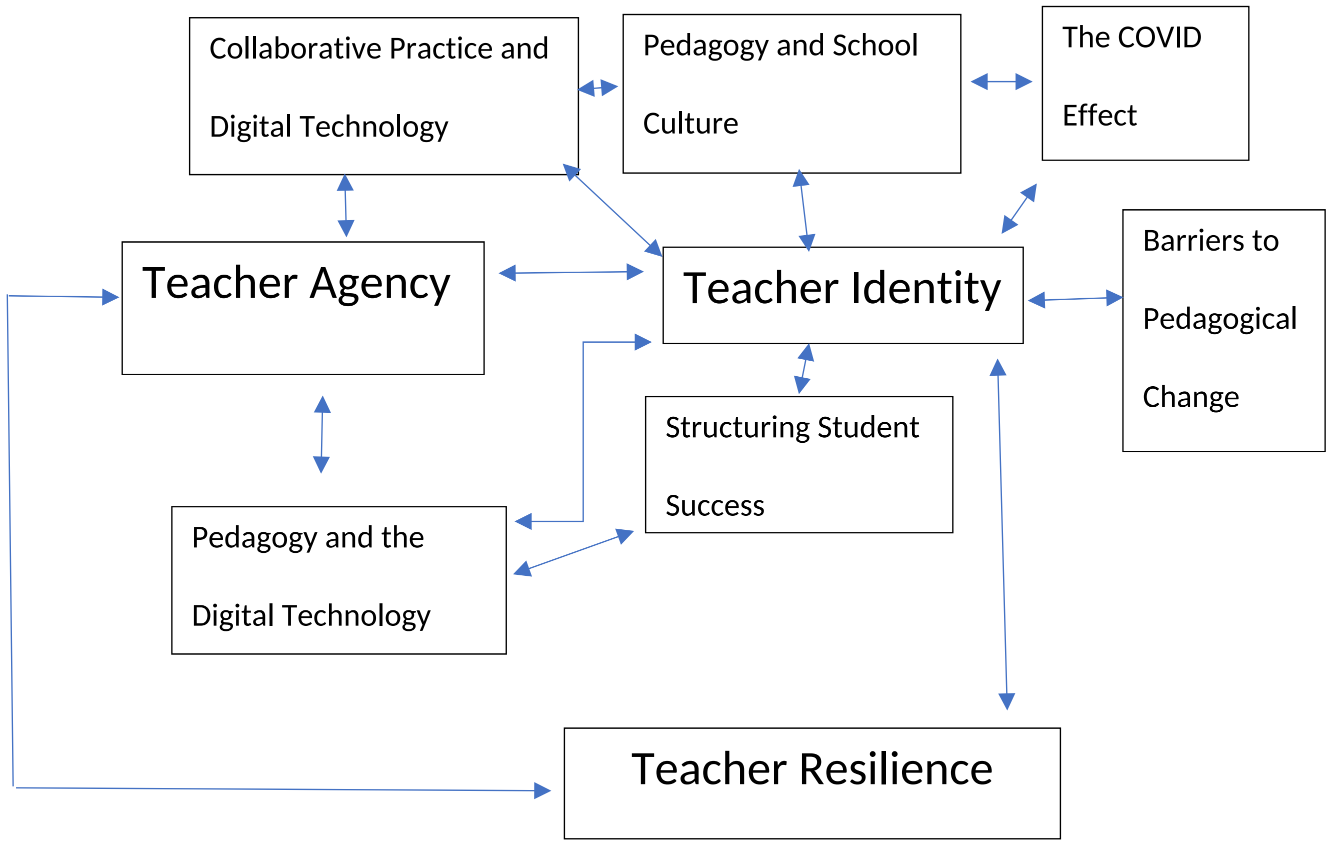
Teaching to the resources available dominated the approaches within the classroom. The teachers of this study who were not adequately resourced experienced frustration and felt restricted within their teaching practice. The querying of leadership decision-making and associated resentment coloured the progressive nature of desired reform to existing teaching practice. When teachers were adequately resourced within their teaching practice, reflective capacity was enhanced as they targeted improved student outcomes. Restricted resourcing restricted teaching practice. Teachers can only undertake and advocate for change within their own practice if they experience the opportunity to enable change. Developing expertise in the use of and the ways in which digital technology can be used can only occur if confirmation of ongoing support for resourcing is undertaken as a prime focus within junior mathematics by school leadership. This concept became inclusive of developing independent student learning within structured classroom lessons, where the changing teacher role included facilitation of student learning.

The overall impact of the pandemic COVID-19 necessitated increased usage of digital technology to maintain learning programmes. Teachers who had not been adequately resourced initially with digital technology within their junior classrooms were placed in extreme circumstance of extensive PLD, compounded by personal anxiety due to the pandemic, and compounded further by the necessity to maintain the “business as usual” facade for students. The impact of a lack of resourcing at a junior level, reflective of poor leadership decision-making was never more strongly felt. The teachers of this study looked to leadership for honourable decision-making reflecting the scenario of post pandemic circumstance. Long-term face-to-face contact was desired overall with digital technology perceived as a second choice within the context of spontaneous conversation, the sharing of ideas, and the need to be human.

As seen in figure 8 and repeated in figure 11 the diagrammatic conceptualisation of the findings from Chapter Four.

Figure 11

TEACHER AGENCY, IDENTITY AND RESILIENCE



Note. The diagrammatic form of the relationships that impact upon the interplay between teacher agency, resilience and identity.

There was a consistency in the data that identified the relationship between the influences at play, teaching pedagogy with the use or not of digital technology, and the three areas of teacher agency, identity and resilience. It was apparent that choice and the desire to develop pedagogy did not rest with the individual teachers alone, but also within their external environment.

Literature supports the interplay between the three areas of teacher resilience, agency and identity. If teachers and schools had not already made a shift in their teaching models, with the advent of COVID the change was forced upon them, as online became the teaching choice and mode.

As the teaching model has changed to reflect the incorporation of the transformative potential of digital technology use within teaching pedagogy, so too has the method of delivery, role and form of professional learning and development undertaken. This is discussed in the next chapter.

CHAPTER FIVE: FINDINGS PART TWO

The role of professional learning and development as an influence on digital technology use

5.1 Introduction

As teachers are encouraged to change their pedagogical practice to better reflect shifts toward the adoption of a student-centric model the role of professional learning and development (PLD) is thought of as an enabler for change (Beltman, 2021). Within the findings of this study the PLD that occurred took the form of leader driven or individual driven approaches. Leader driven approaches to PLD were formal /structured or whole school approaches. Individual approaches reflected the classroom need of the teacher but did not need to occur in isolation and could include group collaboration (Barton & Dexter, 2020). The obligation to undertake PLD became driven by the school and individual need to support the desired student outcomes with the delivery of quality instruction.

The aim of this study was to better understand year 7-10 mathematics teachers perceptions of the aspects that influence whether they use digital technology when teaching mathematics. The three research questions undertaken that allowed an examination of this aim were:

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?
Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

The findings for this chapter relate to question three with emphasis on the role of professional learning and development. This applies to both pedagogy and knowledge-content. Identified within this study is the circumstance of teachers teaching out-of-field who may lack knowledge content, which can impact upon the effectiveness of their teaching practice. This highlights the changing nature of professional learning and development and the potential that digital technology may have to support and assist teachers to develop and improve the overall delivery of the learning process. These findings were discussed in the following order: subsection 5.2 The nature of professional learning and development; subsection 5.3 PLD and professional competency; subsection 5.4 Opportunities and constraints with PLD; subsection 5.5 Summary of this findings chapter with an overall summary presented in subsection 5.6. The final thematic map for this study as shown in figure 9, reflects upon PLD as it relates to the major themes identified.

5.2 The nature of professional learning and development

The findings of this study reported in this section show that the teachers of this study did not prefer either form of PLD, leader or teacher-driven, but instead valued expertise of PLD delivery and time apportioned to PLD. These had more impact on the form preferred. An approach incorporating both group and individual approaches appeared to be desirable.

Teachers and schools prefer an effective delivery of PLD related clearly to the desired outcomes targeted by either the school or the individual. These findings show teacher perception and relate to mathematics specific PLD with an equal preference for both leader driven (formal) and teacher driven (informal) approaches. The following teacher quotes showed an emerging pattern of a blended PLD preference:

> ***Prefer both structured and being allowed to get on with it myself*** (Arihia, School Two).
>
> ***Structured school-wide learning if a school goal – otherwise personal needs based – source it yourself*** (Courtney, School Two).

Teacher perception portrayed that both these teachers saw both teacher driven (informal) and leader driven (formal) PLD as being valued and valuable given the applicability of the scenario, for example meeting school goals or meeting individual goals.

> ***Peer to peer PLD highly valued in a structured forum – valued what they were already practicing. (This was structured PLD external to the school and was GeoGebra based)*** (Joelle, School Four).
>
> ***I would like a bit of both … getting on with it but structured time and perhaps time with someone who is an expert …*** (Laurell, School One).
>
> ***Sit down style gives you that allocated time for PLD*** (Arihia, School Two).

These three teachers found value in structured PLD as it was allocated time with an expert, with both time allocation and expertise valued.

> ***Structured professional learning and development preferred (planned)*** (Taylor, School Three), (Joelle, School Four).
>
> ***I like to learn about PLD at a time when I am not immersed 'in it', meaning 'just-in-time' not ideal*** (Joelle, School Four).
>
> ***… It is definitely the just-in-time training … it would be nice to have some planned, orchestrated, timing … umm … as a maths department, but we don't currently*** (Laurell, School One).

These three teachers undertook PLD within the timeframes available to them, which on occasion meant that time was restricted, even though the desire was for a time allocation specific to their PLD. The 'just-in-time' PLD eventuated due to necessity but was not considered ideal. The issue here was time availability within a working environment. Further to this teacher perception supported:

> ***Ideal PLD would be introduction by someone with expertise, then create compensations and colleague style professional development from there, then having the opportunity to go back and refresh, learn or extend something*** (Arihia, School Two).

This was perceived as the ideal scenario of PLD delivery. Here we have structured PLD delivered by an expert, with peer-to-peer PLD thereafter, followed up with the opportunity by the individual to extend the learning undertaken. This is a blended PLD scenario and appeared from the perspectives articulated by most participants to be a desirable PLD delivery, related to digital technology and software use specific to mathematics software.

In summary, teacher perceptions of this study supported the value placed upon the need for PLD. Teachers have identified and integrated school and individual targets for PLD. The expertise of instructional capacity increased the value placed by teachers on the PLD. Whole of school PLD delivery may not satisfy individual goals, given individual circumstances, as it relates to existing teacher digital competency.

Individual need may not be met by group targeted PLD only, as group targeted PLD can reflect school targets, which may not concur with individual targets. However individual teachers are aligned to school targets. What could occur, which is not allowed for in a blanket approach, is that the expertise level of the individual teacher may be in excess or different from the PLD on offer. The findings below showed the perception of one very digitally literate teacher:

> ***They run the ManaiaKalani programme for all staff members which is quite good for all staff with low level digital skills*** (Matiu, School One).
>
> ***It is tailored to individual need but only to a certain level, so if you have already passed that, you still have to do it*** (Matiu, School One).

This was targeted PLD focused upon digital literacy. Whole of school delivery may not satisfy individual goals set reflecting PLD, given the individual's focus on classroom delivery and individual skill bases. This disconnect is apparent for this teacher, who had digital technology skills beyond more than what was offered for group PLD.

The perceptions of the teachers of this study indicated that the cycle of PLD was never ending given the software interface of constant change and update, and new things to learn within the software being used. This is further evidenced by new software applications, as teachers align their practice to what is made available to them. Within the environment of software, both mathematics aligned and software generally, teachers confirmed the ongoing nature of new applications and versions of software which emerge.

This means that teachers are maintaining their teaching practice within an environment of prospective change, which often is not within their control. The expertise, or the development of expertise with software is ongoing in nature for teachers, which provides the impetus for the requirement for PLD, which is also ongoing. Teacher perception revealed:

> ***Teacher awareness of the need to maintain an awareness of better software/maintaining familiarity with current software inherent to support existing teaching practice (forever changing)***, (Arihia, School Two),(Taylor, School Three), (Joelle, School Four).
>
> ***You know there is always something more to learn, there might be other things out there that I just do not know about, they need to go out and find that information*** (Courtney, School Two).
>
> ***Proficiency with software will be ongoing as a teacher I think … and I guess different packages work better for different year levels too …*** (Laurell, School One).

Whether leader driven (structured) or teacher driven (not structured) PLD was undertaken. The data was consistent with the ongoing nature of PLD occurring in response to software changes or the existence of new software. Teachers are aligned to multiple software packages, which reflect differing student age levels and goals targeted. These goals can be both individual and schoolwide. Both individual and schoolwide goals targeted the effective teacher profile, which illustrates competencies relevant for teacher registration undertaken with the Teachers' Council.

5.3 PLD and professional competency

The findings of this study show that the effective teacher profile became an illustration of digital competency, when used as an innovative teaching methodology. As teachers grew their digital technology knowledge, they accepted the ongoing nature of PLD and the impact of this upon the development of innovation within their teaching practice. The effective teaching profile became a reflection of the effectiveness of teaching practice with digital technology use, as teachers undertook flexibility of software selection, adaptation, and competency with existing software. As teacher agency was developed, teacher perception showed:

> ***Growing competency with digital technology*** (Taylor, School Three), (Joelle, School Four).
>
> ***As the digital resources become apparent*** (Arihia, School Two), (Taylor, School Three).
>
> ***I am always finding new ways to use it*** (Arihia, School Two).
>
> ***I just continually see what other options are available with digital technology*** (Arihia, School Two).

The exploration of digital technology developed teaching practice within a cycle of constant PLD. The teachers of this study no longer saw the changing software scenario as unusual or separate to teaching practice.

The teachers of this study reinforced their teaching practice as they developed their competency with digital technology use.

> ***Competency is an attitude that builds proficiency with digital technology over time***(Courtney, School Two), (Joelle, School Four).
>
> ***Working across software packages reflects digital competency in my teaching practice*** (Arihia, School Two).
>
> ***There is not one bit of magical software that does everything for us*** (Matiu, School One).
>
> ***I don't think I will ever get there (laughter), because I think that the digital technology we are using, is always changing … I think we are always learning, and we will always need to help each other …*** (Laurell, School One).

It was apparent that over time competency and proficiency with the use of digital technology had become, for the teachers of this study, an accepted aspect of teaching practice. The more digital technology was used, the greater the awareness by the teachers of this study of their need to become more proficient with their use of digital technology.

The teachers of this study have recognised that as their competency levels have grown this has enhanced existing practice which has in turn enhanced the targeted student learning outcomes, that have been either schoolwide or classroom based.

> ***The effective use of digital technology means you are needs based – meeting student needs*** (Courtney, School Two).
>
> ***With the use of digital technology, I am ahead of my students*** (Matiu, School One).
>
> ***My use of digital technology is on a par with my students … students knew more before the website Mathletics was updated … with the new website we are on a par*** (Arihia, School Two).

The teachers of this study have been committed in their approach to the use of digital technology to satisfy their own and their students identified needs and to growing competency in a constant cycle of PLD. As teachers were exposed to changes in software delivery, so were students, and teachers were the major source of navigation for students when change occurred, or new software was introduced. This then becomes a reflection of perceived teacher competency in the eyes of individual students. Teacher identity is then affected.

The findings of this study reflect an individual sense of wellbeing from within a professional lens, in response to PLD that was appropriate to the individual. The teachers of this study had an awareness that PLD was ongoing and a constant aspect of their practice whilst simultaneously reflecting upon their proficiency in relation to their use of digital technology. The findings from this study showed the value that the participants perceived in the PLD:

> ***PLD allows me to feel self-directed, reinforced, it has been positive*** (Courtney, School Two).

> ***PLD makes me feel supported and enthusiastic*** (Joelle, School Four).
>
> ***It is probably the only PLD that I like, it is going to observe other maths teachers teach … observing and talking to other maths teachers, across schools, my school is beneficial to me … it is not formal*** (Matiu, School One).
>
> ***Self-directed PLD makes me feel empowered but also a little frustrated because it probably takes me a long time to get my head around something when perhaps if there had been a formal opportunity it might have been easier … I quite like finding things out for myself*** (Laurell, School One).

Although undertaking PLD is a challenge, the outcome of undertaking PLD has been seen as having positive outcomes. One of these outcomes reflected a sense of individual wellbeing from within a professional lens.

The findings show the teachers of this study have found that existing teacher workload amplifies the constraints and challenges of time availability for PLD. Time availability can impact upon the nature and type of PLD undertaken. The teachers of this study were conscious of the effect of time restrictions, often indicative of teacher workload, and the impact of this upon the targeted individual learning needs reflective of the desired PLD. Sometimes, what is desired just does not take place.

PLD can become something else that has to be undertaken within a limited timeframe on top of existing teaching and administration workloads. PLD can include many aspects of teaching both mathematics specific and environmentally based, in addition to being group and individually focused. The findings below looked at PLD with a wider lens, beyond just the use of software and indicated what teachers' experience and their rationale for undertaking PLD was and when they did it:

> ***Routine of professional development to be established*** (Taylor, School Three).
>
> ***No time for PLD within a normal day, do that at home*** (Courtney, School Two).
>
> ***… the biggest barrier is time*** (Laurell, School One).

Teacher perception showed that time can be a constraint to the desired PLD undertaken. The establishment of a routine, which reflected time spent outside of a working day can be the chosen option, which was a reflection of a time shortage.

> ***Workload dictates time spent on PLD that I do myself, gaps I need help with assume priority*** (Arihia, School Two).
>
> ***We have a mixture of just-in-time PLD (colleague to colleague) and preplanning for PLD*** (Matiu, School One).

Teacher perception illustrated the prioritisation of PLD to support the immediate need of the individual teacher. This reflected the existence of the just-in-time PLD undertaken out of necessity within the short-term. Outside of this came the preplanning with leader driven (structured) PLD supporting longer term and external goal setting.

> ***Change to existing teaching practice is always needed, different literature comes out all the time, and different research too …*** (Courtney, School Two).

> ***You always feel as though there is more that you could be doing or should be doing and then you just have to go actually, I am doing my best in the time that I have got … yeah*** (Laurell, School One).

The availability of PLD provided by the school was undertaken within a structured timeframe. Outside of this, to fill gaps, to construct lessons, to enhance existing teaching practice PLD was undertaken where there are no other distractions, which can require an individual space. This may mean at the end of the day and at home.

The teachers of this study have an awareness of the ideal PLD scenario, but functioned to available timeframes. The reflection of this can be an individual need as opposed to a group need. The flexibility of time is advantaged by the asynchronous, (enabling learning to your own schedule) and ubiquitous, (everywhere) nature of software and the need for teachers to keep abreast of updates as they occur, as time allows. The relevance of decisions made, reflecting what is considered important PLD to be undertaken, is important as teacher acceptance and the ability to undertake change rests upon the effectiveness of the PLD that is delivered.

The teachers of this study have been more inclined to apply themselves to PLD that was driven by a targeted individual need. This reflected what was occurring or has occurred within individual classrooms. In addition, software changes become an additional driver for PLD and take precedence given the impact upon teacher proficiency. Some of the teachers of this study have expressed less enthusiasm for PLD that is not in response to their individual needs.

External obligations to the wider education environment also have a presence within the PLD framework. These are often undertaken as school-wide initiatives. The question can be asked who decides what relevant PLD is, within an environment that offers a wide arena of PLD possibilities, in consideration of a digital technology focus.

> ***I decide and my students decide what is relevant for me with the use of digital technology in the classroom*** (Arihia, School Two).
>
> ***Different needs for different teachers*** (Taylor, School Three).
>
> ***ManaiaKalani is not adaptive to individual teacher need – they just run everyone into it*** (Matiu, School One).
>
> ***When it changes, you reteach yourself*** (Courtney, School Two).

Schoolwide PLD has been provided to enable teachers to achieve a common level of expertise within the wider digital technology programme on offer. This is not adapted to individual need. The teachers of this study responded to the needs of their classroom which became a driver for the PLD undertaken. As a reflection of this, greater enthusiasm for PLD that directly supported their classroom practice had been expressed.

The teachers of this study have identified that mathematics specific PLD, that develops teaching practice with the use of digital technology, had not occurred and was greatly desired. Teacher perception supports this could also be included in teacher education programmes. In addition, making mathematics an equal priority with literacy within schoolwide PLD was echoed by some.

Teacher perception has identified that within the teacher education programmes undertaken there is an absence of digital technology skills applicable to those needed for the mathematics classroom, specifically mathematics software. The following teacher perceptions were indicative of this:

> ***No exposure to digital technology when in teacher training*** (Arihia, School Two).
>
> ***Acquiring masses of video clips etc. without being shown how to use it is an accumulation of a bank of sxxt, will not touch it*** (Joelle, School Four).
>
> ***You don't really get maths specific PLD*** (Matiu, School One).
>
> ***Literacy is the main focus, everything we have done (PLD), has been on literacy*** (Arihia, School Two).

Teacher perception was revealing regarding supports within PLD that are both required and desired as indicated above. The mathematics teachers of this study see mathematics achievement as being valuable enough to be expressed within a PLD framework schoolwide, as an echo of similar approaches undertaken with literacy. As well as the predominant focus being on literacy, the teachers in this study identified other limitations of their PLD, which are discussed below.

The teachers of this study have a range of PLD wants and needs which reflect the limitations they have experienced. The participants of this study have identified the limitations of their environment, the impact of these limitations and how PLD could assist. This has been expressed with a multitude of PLD desires that all relate to the desire to grow proficiency and competency within their practice.

Their usual teaching practice as a norm is an illustration of individual teachers within their classrooms. Individual teachers target PLD which they believe to be valuable to their practice and therefore their students. Teacher perception showed the following:

> ***Need an underlying knowledge of programming to negotiate software*** (Joelle, School Four).
>
> ***As the digital resources become apparent*** (Arihia, School Two), (Taylor, School Three).
>
> ***No PLD on offer that marries the key competencies and student-centric practices*** (Arihia, School Two), (Joelle, School Four).
>
> ***Would like access to University Library search engine to allow access to up-to-date research, a place to go to research teaching practice*** (Arihia, School Two).

The teachers of this study were aligned to skill development which was required within their employment. The gaps in PLD above look at the limitations that face teachers and the resourcing identified as missing.

The teachers of this study have taken advantage of the PLD opportunities as they have been made available to them to increase their instructional capacity. Teachers are limited within their teaching practice by the resourcing made available to them generally, inclusive of PLD. Teacher perception illustrated the following:

> ***We are well, really well resourced, but your teachers are your biggest resource, aren't they?*** (Courtney, School Two).
>
> ***Kahui Ako funds my PLD – I can choose*** (Joelle, School Four).
>
> ***Manaiakalani is funded by the school*** (Matiu, School One).

We have structured professional development time every Friday … this is the first year that we have had this structured professional development … once a week (Laurell, School One).

The teachers of this study have been supported with the PLD opportunities presented to them by their schools. This assists them to maintain and build teaching capacity. The conditions of employment undertaken by a certified practicing teacher echoed the necessity to maintain teaching practice to the required standards which were evidenced by the wider collective agreements, in addition to the ongoing monitoring undertaken by school management.

5.4 Opportunities and constraints with PLD

The teachers of this study reveal that digital technology usage is an implied as opposed to an explicit aspect of teacher registration within the schools of this study. In some schools, accountability of digital technology use has greater transparency when attached to fiscal and time tracking processes. Further to this, individual teachers may be targeted for digital technology use within appraisal.

Accountability is an aspect of employment. Teachers are held to account with professional standards like those expressed within various wider collective employment agreements and fixed term contracts. The areas of individual development that are identified as needing to be worked upon are picked up by classroom observation practices undertaken by the school. These areas of individual development then form a part of the appraisal process. The appraisal process supports teacher registration. Without registration teachers face limitations for employment. Once an area of need is identified within teaching practice PLD becomes the avenue for teacher skill development. Teacher perception revealed the following:

> ***The use of digital technology does not feature in existing appraisal systems*** (Taylor, School Three), (Joelle, School Four).
>
> ***The school does have an ethos of using digital technology, it might be commented that you weren't using it*** (Matiu, School One).
>
> ***Not kind of like a part of the appraisal process or a part of the observation process or anything like that … they do make digital technology a focus … I don't think so …*** (Laurell, School One).
>
> ***As always with maths teachers I think if you are a maths teacher everything else (digital technology) is a bonus is the honest answer*** (Matiu, School One).

Teacher perception supported that an expectation exists that teaching practice reflected the use of digital technology without external impetus being applied. However, in certain schools differing methods reveal other drivers for accountability of digital technology use. These drivers are simultaneously monitored with digital technology use and time spent teaching mathematics. With resourcing funded by respective schools the expectation is if funding is made available the resource must be used.

> ***Constantly checking how we are using Mathletics and how we are incorporating it, linking into the professional learning goals – with your lead teacher looking over things reflects digital technology use*** (Arihia, School Two).

> ***Not using Mathletics would highlight accountability issues – tracking processes*** (Courtney, School Two).
>
> ***It is a focus area of our school … the use of digital technology and so for us our inquiry and our appraisal are tied in together and each year the school has certain things that they are focusing on … for a number of staff their appraisal would reflect that …*** (Laurell, School One).

Schools have the option of making PLD a schoolwide targeted approach with specific software applications as evidenced using dedicated mathematics software and others. Even if this is not the circumstance, it may be that schools identify individuals who may require additional PLD support, whether collegial or external, to better fulfil the effective teaching profile.

The teachers of this study planned for positive student outcomes when undertaking change to existing practice with the use of digital technology, regardless of what form the drivers for change took. The teachers of this study undertook risk to facilitate change based upon the expectations of their external environment as opposed to individual desire. The potential negative impacts of risk-taking were alleviated by school culture which gave permission for teachers to take risks. Group support and interaction became a vehicle for teacher driven (not structured) PLD to manage risk-taking. PLD drove change for the teachers of this study, who also sought PLD in response to change (software).

To undertake a change to existing teaching practice represents a risk to teachers who are looking to maintain existing engagement and enthusiasm within the short and long term to sustain and enhance student academic and key competency development. If teachers change existing practice and the result does not reflect improvements in these areas, and perhaps even a decline, then change will not be sustained, either at a group or individual level. When contemplating change to teaching practice, a gain, outcome, or benefit is targeted. Changing existing practice has, for some teachers, been undertaken in the light of external drivers within the education environment as opposed to the perceived need to change by individual teachers themselves. The use of digital technology may be thought of as one of these external drivers. Teacher perception showed the following:

> ***I wasn't a massive fan of using something like Education Perfect … I started doing the occasional one … now it is virtually every lesson … I would prefer it to be more traditional … but if it is working … it is working*** (Matiu, School One).
>
> ***You never know what their engagement is going to be like, that is the measurement of success or fail with risk-taking with digital technology*** (Arihia, School Two).

Within the environment of the classroom, each of these teachers has looked at the risk attached to using digital technology in different ways. One has used a program that can be enhanced, and one has used a program that cannot be altered. The enhanced program was not thought of as an attractive option by the teacher, but student feedback has meant the adoption of this program for use in this classroom. The teacher who is using the dedicated mathematics software which cannot be altered has gambled that engagement will be supported and increased, as has the school with a fixed delivery.

I guess the whole school is taking a risk really with all the changes, (break out rooms, cross curricular, digital technology, team teaching, classrooms without walls) (Laurell, School One).

I don't like to fail … so … umm … I would probably say I am more on the conservative side of it, to say that I wouldn't go and gamble like … I would rather that the lesson went okay like … than it go absolutely tits up and we get no progress (Matiu, School One).

The teachers of this study were aware of the accountabilities within their own practice and looked to implement change by undertaking calculated risks, on an individual basis. Risk-taking across several fronts was supported by leadership and therefore PLD was provided in light of changes undertaken representing as it does group change. However, the teachers of this study, although responding to their environmental changes, still look to maintain and sustain student engagement. Learning outcomes are planned for and targeted, regardless of changes undertaken.

When undertaking change to existing practice, teachers who believe they have been successful to date without the prospective change, can question the need to change as they are already obtaining good student results. The digitisation of society and hence the changing profile of student identity is key.

How the teacher identifies with the digitised world and hence their desire to reflect this within their own teaching practice can have an impact. Teacher identity is influenced by collegial perception about the quality of the teaching and therefore the expertise of the teacher in question. Competency and expertise with the use of digital technology became an aspect of teacher identity.

> ***If a teacher came into my classroom and my lesson was a disaster, as long as I knew why it had failed, and reflect upon it, you are going to be in a much better position*** (Courtney, School Two).
>
> ***If risk-taking undertaken failed and was observed by a colleague, then you have tried that, and they do not need to*** (Arihia, School Two).
>
> ***I wouldn't want someone to perceive me being … not being able to teach the kids … all that type of thing, … so I am always thinking that if we do small incremental changes to our teaching it is a lot better for me*** (Matiu, School One).
>
> ***We definitely are given permission to take risks in class*** (Laurell, School One).

The school culture around risk-taking can act as a support for the teacher. If collegial interaction identifies for teachers where they went wrong and how they can rectify errors, then change becomes less of a threat and more of a way of doing things. Teacher identity is protected in an environment where it is safe to 'play' with digital technology and the changes to teaching practice that this will facilitate. Collegial interaction can become a vehicle for individual teacher driven PLD.

> ***I don't feel like a teacher … it's just that if it doesn't work you need to be in there to help and support them*** (Matiu, School One).
>
> ***Risk-taking with digital technology is a learning path that could open doors to new things*** (Arihia, School Two).

You need to fail sometimes to work it out a bit better in your own head (Courtney, School Two).

If it doesn't work, it doesn't work (Matiu, School One).

The teachers of this study were open to developing their teaching practice in line with the external drivers of their environment. PLD can drive change for teachers, who will also seek PLD in response to change (software).

The initiatives undertaken within schools do so with leadership approval.

Planning for success across timeframes is often undertaken in response to external drivers, among these are external exam results like PISA, TIMSS, asttle, NCEA and PACT. For the schools of this study leadership was identifiable within those schools that made the use of digital technology within the classroom the norm and, for some schools, a monitored accountability on behalf of individual teachers as referred to above.

… and had every class using it if we did not think it beneficial (Courtney, School Two).

… if it is spread across the whole school … it is not just put on one person it is a leadership decision … yeah (Courtney, School Two).

… using Maths Buddy as our prime platform (Taylor, School Three).

The main focus is just that one program really (Arihia, School Two).

Teacher perception shows the directive undertaken by leadership to fund and promote the use of one main mathematics software package. This occurred across three of the four schools, with two of these schools using two different dedicated mathematics software programs.

> ***The school fund it and they want to put all staff through it*** (Matiu, School One).
>
> ***Education Perfect was, had a trial last year on it and I think only Maths and maybe English had it last year and then for this year they decided to get it across the board, and I think they have agreed to extend it for next year as well*** (Matiu, School One).
>
> ***I think as a school we are very much into using digital technology*** (Laurell, School One).

Teacher perception showed the expectation by respective schools of digital technology use. Once funded the expectation is that the software will be used. The use in most cases was monitored by key senior staff.

> ***Having that role where there is somebody in charge of letting us know if there are updates and changes is definitely supportive of our development*** (Arihia, School Two).

Confirmation of updates guarantees every opportunity given for PLD to be undertaken to advantage teacher competency and proficiency. The provision of key staffing roles provided an accountability avenue within the school structure, in part reflecting fiscal responsibility but mainly teacher accountabilities of time spent teaching mathematics and skill development of the classroom. Although monitored by management, the responsibility of classroom results rests with the individual teacher, which requires enhanced reflective practice undertaken over time.

The teachers of this study undertook reflective practice when time constraints and workload allowed. Within this, a pattern of reflection was emphasised and established when teacher training had been undertaken and continued to form part of standard teaching practice. The teachers of this study sought to improve upon their reflective capacity and consequently the targeted outcomes identified both individually and collectively to further enhance and develop their teaching practice, inclusive of their use of digital technology. The PLD undertaken allows for the building and maintenance of reflective capacity within a teaching and learning mindset.

Within teaching practice, a key part of being professional is to be reflective. The art of reflection is ongoing for a teacher and occurs throughout a working day. This represents aspects attached to lessons, events, teaching points, or anything that necessitates a follow-up action by the teacher. The findings of this study show as evidenced by the data below:

> ***Digital technology allows for formal and informal reflection on teaching practice*** (Taylor, School Three).
>
> ***Formal and informal reflection are undertaken with or without technology use*** (Joelle, School Four).
>
> ***I do write weekly reflections as part of my beginner teacher process*** (Arihia, School Two).

Of concern to the teachers of this study was the impact of a lack of time upon reflective capacity which was seen as a limitation.

> ***Time a factor, a concern, allocating time, overload*** (Taylor, School Three), (Joelle, School Four).
>
> ***Reflective capacity is impacted upon by workload and time*** (Courtney, School Two).

Reflective capacity is undertaken with or without the use of digital technology. The teachers of this study supported this practice when assessing the success of their lesson.

> ***I am constantly asking … did I have success … did they understand … did I make it achievable … did they relate it to something to help them understand*** (Arihia, School Two).

> ***I always try and reflect all the time, like whenever I teach if that's went wrong, why did it go wrong … so I am always like … I hate it when that happens … so yeah … as much as possible*** (Matiu, School One).

Teachers of mathematics who employ reflective practice, can respond with alternative strategies to assist the targeted student outcomes, which may include the use of digital technology.

> ***Each and every lesson, during the lesson, then if it is not going well, then off … when I am talking to a group of students, if they just don't get it and I decide that they are off task and just don't get it and usually they are off task because they just don't know how to do it - stop the lesson - there is no point in trying to climb that mountain … or continuing with it … change it … you have to be confident in your own ability to be able to do that*** (Matiu, School One).

> ***I don't always achieve a shift in understanding with my student … sometimes you need to rewind … find the gap … look for physical resources … digital resources … try again*** (Arihia, School Two).

> ***I don't necessarily formally reflect but I will always at the end of a lesson think what would I change about that next time and what would***

I throw away from that lesson … that kind of thing … all the time (Laurell, School One).

Reflective practice can occur collegially, either team teaching or department wide. This can be both leader driven or teacher driven and allows for a pooling of expertise, to achieve a common goal or targeted outcome. Restructuring standard practice to include the use of digital technology necessitates reflection.

Because we teach together we reflect together to, so often at the end of a lesson, we just had a really brief chat about … you know, this student wasn't really working today, what could we do tomorrow (Laurell, School One).

Now that we teach collaboratively the reflection happens collaboratively to which is quite cool … not necessarily formal (Laurell, School One).

At the end of each course with junior students at the end of each trimester we do a more formal reflection where we actually look at the results and we do a really formal reflections at that stage (Laurell, School One).

To be reflective within a professional environment like this allows for a revisiting or a collegial dialogue to be undertaken, which becomes a norm within individual practice. This fills gaps in knowledge and in practice. Pooling expertise allows for the development of teaching practice, the pooling of ideas and the upskilling of teaching staff. The teachers of this study spent time looking at ways to improve on what it was they achieved with alternative strategies, which was acknowledged as a component part of standard practice.

> ***At teacher training college they would always say at the bottom of your lesson plan leave a space for your reflections, … we were encouraged to reflect on each lesson … we kept a reflective journal that we kept whilst we were on practicum … I think we had two … one while we were on practicum and one while we were at college … and here it has been a focus, not necessarily an explicit focus and I think it has probably come out more with the changes to working collaboratively*** (Laurell, School One).

The focus of reflective practice is undertaken within a PLD scenario, with much emphasis placed upon reflection utilised to improve teaching practice, as can be seen above. One of the tools used to improve and enhance existing teaching practice is digital technology. One of the mechanisms that support change in teaching practice is the use of reflective capacity.

The belief and value systems held by teachers are an expression of teacher identity within teaching practice. The key competencies are an illustration of the desired student skills targeted for development by teachers. The key competencies are defined as: thinking; managing self; relating to others; using language; symbols and texts and, participating and contributing. The findings of this study show that teachers believe in the value of digital technology as a support for key competency development and can be more flexible in their targeted responses because of this. Teacher perception within this study supported: thinking; managing self; participating and contributing; and relating to others (group structured).

As teachers can develop their teacher identity with their use of digital technology, they are able to facilitate a greater degree of independent learning with their students. Teacher perception showed:

> ***Student autonomy is not guaranteed with the use of digital technology as teachers' have to believe in the benefits of facilitating student autonomy and structure the learning to support*** (Joelle, School Four).
>
> ***Student autonomy is an ideal with and without digital technology*** (Joelle, School Four).
>
> ***If that's a method that works for that particular person in that particular group by all means do i****t* (Matiu, School One).
>
> ***We want the students to lead their own learning*** (Courtney, School Two).
>
> ***They're very independent on workspace … they are becoming more independent on Google sites*** (Laurell, School One).

Student autonomy, self-management and independence are considered by the teachers of this study as desirable, with the use of digital technology thought of as a means to support this development. The teachers of this study identified with multiple ways of enhancing the teaching space to cater to the differing learning needs of their students. Teacher identity is inclusive of flexibility and is not fixed within a traditional teaching approach or teaching space.

> ***I feel that my classroom has benefited from PLD that has targeted Google sites, giving my students multiple ways of someone explaining something to them*** (Laurell, School One).
>
> ***Student outcomes are advantaged with the use of digital technology*** (Taylor, School Three), (Joelle, School Four).

> ***It is still a very active role, but different … I focus on different things then what I would have done so in the past … digital technology has allowed me to be more flexible … we are still figuring out the best way to do all those kinds of things*** (Laurell, School One).

The use of PLD to facilitate change in existing teaching practice has developed the identity of the respective teachers in allowing them greater flexibility in their responses toward their students' learning needs. Teacher identity has been enhanced within a bigger picture of student capacity inclusive of the key competencies. The classroom has widened to include access to knowledge beyond the physical confines of the classroom and face-to-face interaction with the teacher. Learning continues with teacher monitoring and facilitation.

Teacher resilience, agency and identity has grown to reflect the inclusion of facilitation of learning undertaken for students structured to support targeted outcomes, which include the key competencies, supported by face-to-face teaching practice. It is the face-to-face interaction of teacher and student, and the appropriate structuring of expectations by the teacher for the student, that allows the development of the key competencies and facilitation to occur. The teachers of this study continue to drive the learning process.

In undertaking PLD, either at their own behest or that of the respective school, the teachers of this study have developed their identity to reflect change. This has occurred by responding to and implementing change to existing practice as it has been presented to them. The teachers of this study have looked at the need for change in the following ways:

Being open to teaching-as-inquiry, reaching students that might be underachieving, what can we do to change our practice, to investigate, to research, to look, to model, to???? (Courtney, School Two).

This is the day and age, … kids are wired differently than we were …, everything is digital for them, … the jobs these kids will go into have not been created yet, … helping them to develop the skills of the lifelong learner (Courtney, School Two).

The teacher is responding to the changing face of students of today, as an echo of their existing digital engagement occurring for most on a daily basis.

Reinforcing what they are learning, ability to access it anywhere, ability to be independent with it, ability for it to be fun and challenging at the same time (Arihia, School Two).

Valued most in teaching practice relevant learning, reflecting real life, inclusive of the use of digital technology (Joelle, School Four).

I see myself as a current practitioner … to keep doing it better and to keep teaching in a relevant way … also student outcomes (Laurell, School One).

I am focused on student outcomes, and I would always say, how is that going to benefit the kids? (Matiu, School One).

Teaching practice is not just the act of teaching, it is an expression of the individual teacher and the tools they teach with. PLD is a support to change and therefore supports the resilience of the teacher. The teachers of this study believed that:

Digital technology works alongside the teacher (Courtney, School Two).

> ***Digital technology has to flow with the stuff you are teaching, has to be appropriate*** (Matiu, School One).
>
> ***My teaching practice within mathematics improved over the last five years with the increased use of digital technology and the PLD that has allowed this to occur*** (Laurell, School One).
>
> ***Obvious role for digital technology … addressing the gap for students who enter the school with very low numeracy levels … assisting in lifting those learning levels of students at risk of continuing low achievement*** (Taylor, School Three).

The teachers of this study valued their teaching practice and the way that their use of digital technology has enhanced their teaching practice. The teachers of this study see the use of digital technology as advantaging targeted student outcomes. Teacher resilience is increased when the resourcing provided to them supports the changes to teaching practice, they are required to make.

5.5 Summary of the Findings Chapter - Part Two Table Form

The summary of findings targeting the discussion above is presented below in table form. The subsequent detailed discussion reflects the summary of findings, and the information presented in table form.

Table 9

SUMMARY OF THE FINDINGS – PART TWO

SECTION HEADINGS FOR PROFESSIONAL LEARNING AND DEVELOPMENT THE ROLE OF PROFESSIONAL LEARNING AND DEVELOPMENT AS AN INFLUENCE ON DIGITAL TECHNOLOGY	FINDINGS FROM THE TEACHERS OF THIS STUDY
5.2 SELF-DRIVEN INDIVIDUAL OR LEADER DRIVEN PROFESSIONAL LEARNING AND DEVLEOMENT (PLD)	
Teachers of this study did not prefer either form of PLD (leader or teacher driven) but valued a quality of PLD delivery and time apportioned to PLD as having an impact on the form preferred. Both group and individual approaches appeared to be desirable.	Time apportioned to PLD was valued by the teachers of this study. The expertise of instructional capacity increased the value placed by teachers on the PLD.
Individual need may not be met by group targeted PLD, as group targeted PLD can reflect school targets, which may not reflect individual targets.	Whole of school delivery may not satisfy individual goals set reflecting PLD, given the individual focus on classroom delivery and individual skill bases.
The teachers of this study have found the cycle of PLD as never ending given the software interface of constant change and update of existing software used.	Teachers are maintaining their teaching practice within an environment of prospective change, which often is not within their control.
The goals set reflecting PLD can be both school and individual based.	Teachers are aligned to multiple software packages, which reflect differing student age levels and goals targeted.

5.3 THE EFFECTIVE TEACHER PROFILE AND DIGITAL COMPETENCY	
The effective teacher profile becomes an illustration of digital competency.	The teachers of this study have been committed in their approach to the use of digital technology to satisfy the identified needs of their students and to growing competency in a constant cycle of PLD.
The effective teacher profile becomes a reflection of the effectiveness of teaching practice with digital technology use.	Although undertaking PLD is a challenge, the outcome of undertaking PLD has been seen as supporting individual development.
The findings of this study reflect an individual sense of wellbeing from within a professional lens, in response to PLD.	Individual development is extended to reflect a sense of individual wellbeing as PLD is undertaken.
The teachers of this study have found that existing teacher workload impinges upon time availability. Time availability can impact upon the nature and type of PLD undertaken.	The teachers of this study are conscious of the compounding effect of time restrictions, indicative of teacher workload, and the impact of this upon the targeted individual learning needs reflective of the desired PLD. The flexibility of time is advantaged by the asynchronous, (allowing for learning to your own schedule) and ubiquitous, (everywhere) nature of software and the need for teachers to keep abreast of updates as they occur.
The teachers of this study are more inclined to apply themselves to PLD that is driven by a targeted individual need.	The teachers of this study respond to the needs of their classroom which becomes a driver for the PLD undertaken. Software changes become an additional driver for PLD and take precedence given the impact upon teacher proficiency.
The teachers of this study have identified that mathematics specific	Teacher perception supports mathematics specific PLD with the

PLD, that develops teaching practice with the use of digital technology is greatly desired.	use of digital technology, inclusive of teacher training programmes is greatly desired. Making mathematics an equal priority with literacy within schoolwide PLD is desired by some teachers.
The teachers of this study have expressed a multitude of PLD desires that all relate to their desire to grow proficiency and competency within their practice.	The teachers of this study are aligned to skill development as a requirement of their employment.
Teachers are limited within their teaching practice by the resourcing made available to them generally, inclusive of PLD.	The teachers of this study have taken advantage of the PLD opportunities as they have been made available to them to increase their instructional capacity.

5.4 OPPORTUNITIES AND CONSTRAINTS WITH PLD

The teachers of this study reveal that digital technology usage is an implied as opposed to an explicit aspect of teacher appraisal within the schools of this study.	In some schools, accountability of digital technology use has greater transparency when attached to fiscal and time tracking processes. Individual teachers may be targeted for digital technology use within appraisal.
The teachers of this study planned for positive student outcomes when undertaking change to existing practice with the use of digital technology, regardless of what form the drivers for change took.	The teachers of this study undertook risk to facilitate change based upon the expectations of their external environment as opposed to individual desire. Risk-taking was alleviated by school culture which gave permission for teachers to take risks. Group support and interaction became a vehicle for informal PLD to manage risk-taking. PLD can drive change for the teachers of this study, who will also seek PLD in response to change (software).

The teachers of this study responded to PLD as a reflection of digital technology use.	The leadership of some schools of this study prioritised within junior mathematics the role of digital technology.
The schools that placed priority upon digital technology use with PLD support stabilised teacher identity in the face of change.	Digital technology was used by leadership as an accountability mechanism across teaching practice.
The schools that prioritised the use of digital technology, in particular dedicated mathematics software, increased school resilience and built upon individual teacher resilience.	The use of PLD which supported the use of a common software across some schools supported skill enhancement of all teachers. PLD became a cyclical driver for current teaching practice, particularly evident within the school culture of those schools that adopted dedicated mathematics software.
The teachers of this study look to improve upon their reflective capacity and consequently the targeted outcomes identified both individually and collectively to further enhance and develop their teaching practice, inclusive of their use of digital technology.	One of the mechanisms that support change in teaching practice is the use of reflective capacity. Reflective practice is undertaken within a PLD scenario, with much emphasis placed upon reflection utilised to improve teaching practice.
The belief and value systems held by teachers are an expression of teacher identity within teaching practice.	Teachers believe in the value of digital technology as a support for key competency development and are able to be more flexible in their targeted responses because of this. The teachers of this study identify with multiple ways of enhancing the teaching space to cater to the differing learning needs of their students. Teacher identity is inclusive of flexibility and is not fixed within a traditional teaching approach or teaching space.
In undertaking PLD, either at their own behest or that of the respective school, the teachers of this study have developed their identity by responding to and implementing	Teaching practice is not just the act of teaching it is an expression of the individual teacher and the tools they teach with. PLD is a support to change and

change to existing practice as it has been presented to them, to enhance student outcomes.	therefore supports the resilience of the teacher. The teachers of this study value their teaching practice and the way that their use of digital technology has enhanced their teaching practice.

5.6 Overall Summary

The value apportioned to effective PLD has been maintained by the teachers of this study. Key to this is the expertise of the delivery and the time allocated to undertake PLD. They indicated that the ideal scenario, were it possible within a school framework, would be delivery by an expert, peer-to-peer interaction thereafter, with an individual follow-up should it be necessary. The teachers of this study have identified that the cycle of PLD is ongoing, with the use of digital technology, reflecting the scenario of software use.

Innovation within teaching practice with the use of digital technology in the mathematics classroom becomes, for the individual teachers of this study, a reflection of competency and hence an aspect of their effective teaching profile. This enhanced its importance as it is subject to the external drivers of appraisal and certification. The more the teachers of this study have used digital technology the greater the awareness by these teachers of the need to be more proficient with their use of digital technology. Teaching practice confirms that the teachers of this study are the navigators for the students of their classroom with the use of software.

The undertaking of PLD has enabled individual teacher wellbeing to be developed from within a professional lens. The teachers of this study see PLD as an ongoing requirement attached to their profession. Management of this requirement identifies a routine to be established, and timeframes apportioned to this routine. This is driven by the individual teacher concerned.
Individual teachers have more enthusiasm for PLD that targets individual need. However, school-wide PLD is mandatory and satisfies school-wide goals. Mathematics specific PLD related to digital technology use is not readily available but is desired. General prioritisation of school-wide initiatives that are mathematics focused are overlooked for the teachers of this study. For those teachers of this study that had recently undertaken teacher training, no mathematics specific training with the use of digital technology was made available. The teachers of this study were expected to participate and contribute to school-wide literacy initiatives.

Teachers respond to the PLD resourcing made available to them. The appraisal system at play can identify for each respective school the areas that need further development for individual teachers. However, if school culture is driving proficiency and accountability of software use within respective schools, uptake in use, proficiency and competency is accelerated within the practice of the individual mathematics teachers of this study.

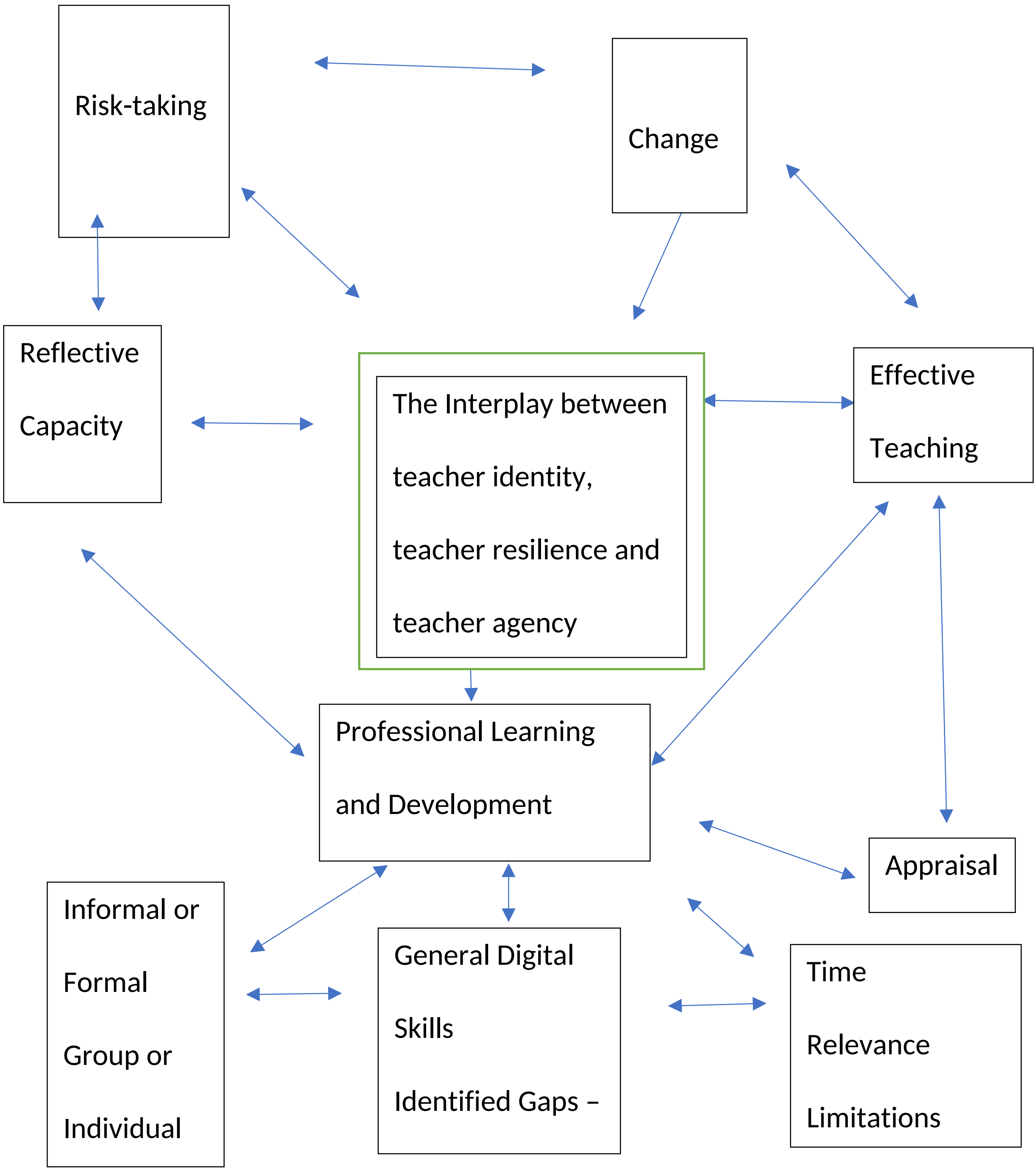
Student engagement and outcomes become agents of change within the practice of the individual teachers of this study. The use of digital technology and respective software packages are maintained if they are considered to enhance existing practice. Student voice and teacher reflection validate the ongoing use of digitally enhanced teaching and learning. When the teachers of this study have undertaken PLD with digital technology use, they have self-managed further PLD, to further enhance their practice. PLD is not seen as finite but rather as infinite.

Leadership practice that supported the role of digital technology within the school, strengthened school and teacher resilience. The role of PLD orchestrated across some schools to support the use of digital technology, specifically dedicated mathematics software, stabilised teacher identity in the face of change. Innovative leadership practice, and whole of school risk-taking became reflected within school culture, allowing value to be placed upon innovative teaching practice within junior mathematics. PLD was the support mechanism that allowed the success of these initiatives.

The teachers of this study believe in the value of digital technology use within their mathematics classrooms. This study supports the development and enhancement of individual teacher resilience, agency, and identity with the use of digital technology. This study supports the use of PLD as an effective tool in supporting innovation and change to existing teaching practice targeting the use of digital technology within the junior mathematics classroom. Refer Figure 12 and 13.

Figure 12

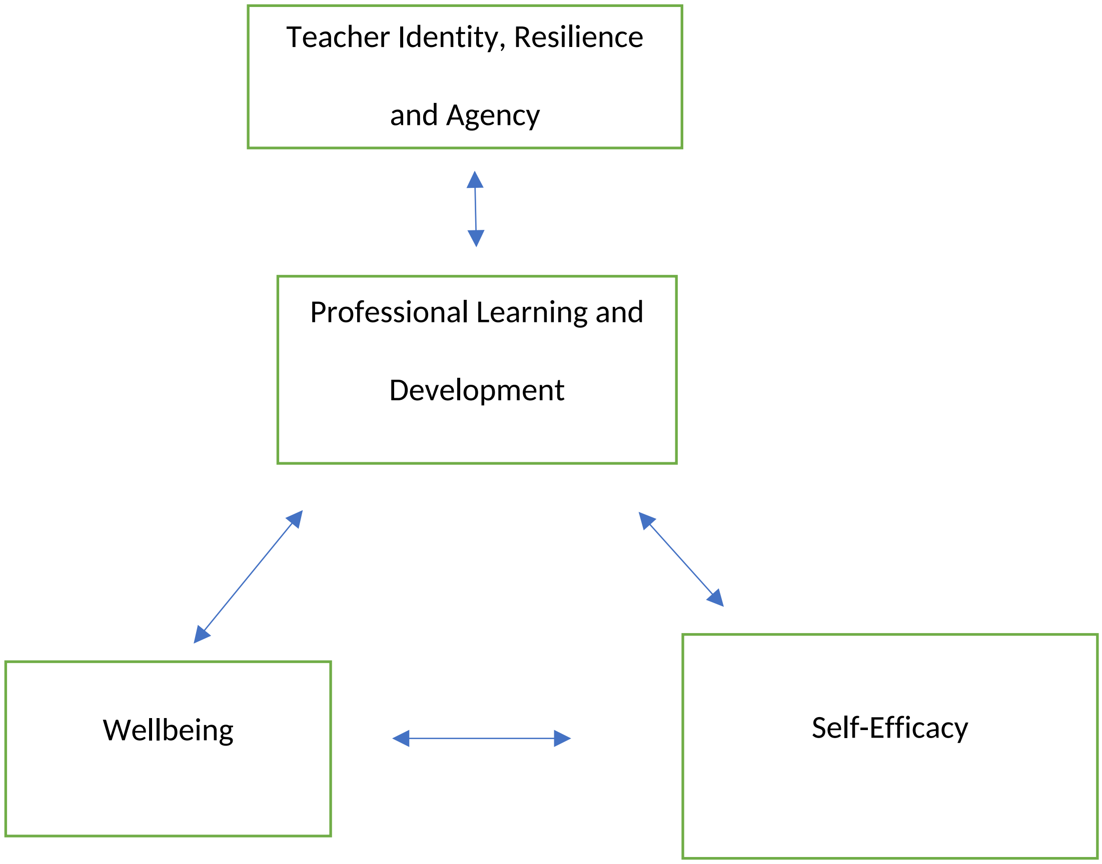
THE INTERPLAY BETWEEN PLD, AND TEACHER IDENTITY, RESILIENCE AND AGENCY



Note: Influences at play when undertaking Professional Learning and Development

Figure 13

THE INTERPLAY OF WELLBEING, SELF-EFFICACY, AND PLD ON TEACHER IDENTITY, RESILIENCE AND AGENCY



Note. Influences at play when undertaking Professional Learning and Development.

The findings were relatively consistent with the correlation of professional learning and development and increased teacher resilience when undertaking change in existing teaching practice with the use of digital technology. The targeted change has been to achieve the transformational potential of the use of digital technology as opposed to the use of digital technology as a tool only, within the changing landscape of what qualifies as PLD. Equally the teachers of this study were aware of the Generation Z characteristics which gave impetus to the desire to echo digital changes within existing pedagogy.

CHAPTER SIX – DISCUSSION

Introduction

This chapter discusses the findings of this research project based upon the in-depth understanding gained from the participating teachers' perceptions and experiences. The teachers of this study were open about their experiences when integrating digital technology within their mathematics programmes and hence the changes made to their teaching practice. Changes undertaken included collective approaches which helped to build resilient school and teacher practices. Additionally, findings revealed that teacher practice sought to illustrate the adoption of a learning-centred classroom model in response to student need and the desired delivery of quality instruction. The findings revealed that the adoption of a learning-centred model within the junior mathematics classroom by the teachers of this study appeared to be aided by the use of digital technology.

The impact of influences that resulted in targeted sustained change to existing teaching practice have revealed teacher resilience as influential within a changing teaching and learning environment. In addition, the findings of this study also revealed that there are multiple influences that have had an impact upon existing teacher practice.

The aim of this study was to better understand year 7-10 mathematics teachers perceptions of the aspects that influence whether they use digital technology when teaching mathematics. The following three questions underpinned the research and allowed an evaluation of responses from teacher participants of this study addressing this aim.

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?
Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?
Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

This discussion chapter will be undertaken in consecutive order of the questions asked, as they relate to the semi-structured interviews undertaken. These were split into three sets of analysed findings that related to the three interviews, one for each question, with responses that related specifically to the main question of each interview (Brown & Danaher, 2019).

The first subsection of this discussion chapter reflects question one, as detailed below. This is split into first to fourth order inhibitors and enablers. These inhibitors and enablers encompass the external environment reflective of: resourcing; school contextual and individual teacher factors; task, and lesson design, and finally the COVID-19 pandemic. The lockdown which occurred due to the COVID pandemic could be an identifier of a fourth-order inhibitor, but also an enabler in consideration of the immersive nature of digitilisation and the resulting PLD and software exposure that resulted (United Nations Sustainable Development Group, 2020).

Question One - inhibitors and enablers

6.1 Inhibitors and enablers to pedagogical change

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

Question one is focused upon the influences that may have had an impact upon the inclusion or exclusion of digital technology within teaching practice. The following inhibitors and enablers were identified and supported by literature as; first-order (Singhavi & Basargekar, 2019), second-order (Snoeyink & Ertmer, 2001), third-order (Tsai & Chai, 2012), and the enhanced digital divide relating to the COVID-19 pandemic (Lai & Widmar, 2021).

The first-order inhibitors and enablers were external such as resourcing, reliability of equipment, technical support, and time (Harrell & Bynum, 2018). The findings from this study identified these issues still exist for some of the schools of this study. Second-order inhibitors and enablers included both school level factors, such as school culture, and teacher beliefs in the value of the technology used, and openness to change (Snoeyink & Ertmer, 2001). This study linked school level factors to both enablers and inhibitors, dependent upon the school in question. Change presented with the advent of new tools to teach with and the subsequent changing teaching role due to the new tools; this change brought with it challenges to pedagogy (Dias, 1999; Hanif et al., 2023). The teachers of this study endeavored/aimed to maximise the potential for digital interactivity appealing to the student characteristics of Generation Z. The third-order inhibitors, or task design, reflected the design of the software which allowed no change or some change to the interface for most of the teachers of this study, for example OMIP's (Tsai & Chai, 2012). In addition, in consideration of the findings lesson design was also enhanced with digital technology use. The adoption of digital technology enabled the participants to generate lesson flexibility within teaching practice which gave the teachers of this study greater creativity within their pedagogical approaches (Hanif et al., 2023). Among the attributes of the effective teaching profile is the use of a range of dynamic, interactive teaching styles (Bishop & Berryman, 2009). In addition, the issues of acceptance and integration of technology to better reflect the 21st century pertain to education and therefore educationalists (Fadel, 2015). This is further reflected in the expectations of effective teaching referenced within the code of conduct (Teaching Council of Aotearoa New Zealand, 2024).

With the advent of COVID-19 a fourth-inhibitor was revealed which was the impact of the digital divide for those who were not digitally literate for various reasons, and did not have ready access to devices and the internet(Ramsetty & Adams, 2020). If we consider the circumstances of COVID-19 and the subsequent lockdowns as a result, then COVID also became an enabler as it forced the immersive nature of the adoption of digital technology within teaching practice. The next sections discuss these inhibitors and enablers with increased detail.

What was identified within the findings, section 4.6, reflective of contextual factors, were the aspects of resourcing, task design, teacher belief and the pedagogical impact expressed as student autonomy and shifts in pedagogy. Further to this, the impact of COVID was discussed. Section 6.2 will discuss first-order enablers and inhibitors.

6.2 External first-order inhibitors and enablers – resourcing, equipment, technical support, and time

First-order inhibitors and enablers reflect the shortages of hardware, software and connectivity. This is supported by the findings of this study as still being a current issue within the timeframe of this study. The impact of device shortages and lack of access to mathematics software was damaging to teacher identity and impacted upon teacher resilience. The teachers of this study had the following teacher perceptions to share:

> ***… so, after all the seniors have used all the chrome books for whatever they need to then we are allowed to use them … but we haven't had an expectation that juniors need to have a device to learn at school …*** (Joelle, School Four).

This was an illustration of an overview by school management that digital technology use was an option, as opposed to a part of a regular classroom experience, within junior mathematics. This view held by senior management in that school was not supported by research as the use of digital technology is seen as essential to achieve quality education (Abid et al., 2022). The advantages to having the use of digital technology for a low decile school (decile 3), with the aim of counteracting the socio-economic disadvantage and the larger drop in mathematics achievement (May & Medina, 2023), is that it could have helped to enhance student outcomes for this teacher and for this school.

Adaptation within teaching practice is not the construct of the teacher alone, but also the nature of the conditions within which teachers are expected to work (Ainsworth & Oldfield, 2019). The lack of adequate resourcing when considering teacher stress, lowers teacher resilience and adds to teacher attrition (Sutcher et al., 2016). It may be that school policy has to include the resourcing of devices and software as a routine requirement within the junior mathematics classrooms, much along the lines of textbook provision.

The pedagogical impact of this lack made it harder for this teacher to adopt shifts in teaching practice from teacher to student-centric practice without digital technology. A typical response was that it was:

> ***Not as easy … Not as easy …*** (Joelle, School Four).
>
> ***… the use of digital technology made these shifts easier*** (Joelle, School Four).

School leadership was not aligned to student identity indicative of Generation Z characteristics and their need for digital interactivity (Hashim, 2018). The role of school leadership is considered to be integral to the change initiative reflective of digitilisation (Barton & Dexter, 2020).

It appeared, confirmed by the findings of this study, that shifts in pedagogy occurred for this teacher with and without the use of digital technology however, it was easier to achieve shifts in pedagogy with the use of digital technology than without it. The shifts in pedagogy supported the adoption of a learning-centred classroom within teaching practice (Bremner, 2019; O'Sullivan, 2004).

For one of the teachers of this study decisions made by management around the resources provided for the mathematics classroom did not occur with consultation. Conversations that support teacher resilience did not take place.

> ***…. funding got pulled after 4/5 years of use …*** (Joelle, School Four).

One of the contextual factors that impacted upon teacher resilience was the involvement of teachers in the decision-making processes that occur in collaboration with others. Participative decision making did not seem to have taken place, impacting upon teacher choice and voice (Ainsworth & Oldfield, 2019; Johnson et al., 2014; Supovitz & Tognatta, 2013; Wilcox & Lawson, 2017). This impacted upon teacher identity, resilience and agency. It seemed that teacher shifts in pedagogy were now limited.

Also identified by the teachers of this study was that students expected that device availability was the norm for classroom practice.

> ***… we needed to do this in the sense of, this is the day and age, and our students are coming in with all of these skills, and if teachers aren't upskilling themselves … kids are wired differently than we were … like everything is digital for them*** (Courtney, School Two).
>
> ***… the kids have got these skills … they learn and engage this way … at the other end it is not doing the same*** (Courtney, School Two).

… it is part of their existence … it starts to build their identity (Joelle, School Four).

The teacher of years 7 and 8, above, revealed that within this district, high schools have not echoed the same approach of digital interactivity, with the resultant impact upon student identity. The teacher of year 9 and 10 confirmed the shortages, the lack of resourcing, and the need for digital interactivity to support student identity. Principals lead educational change (Mackey et al., 2015), and the teachers of this study required leadership support to undertake transformative change to teaching practice with the use of digital technology (Beltman, 2021).

The teachers of this study, tried to align themselves with pedagogical shifts to support the student characteristics of Gen-Z and subsequent generations (Hashim, 2018). It may be that an awareness has to be developed within the leadership team of the delivery of quality education, inclusive of the use of digital technology, together with the significance of Generation Z characteristics.

For the majority of the teachers of this study resourcing was generous, acting as enablers to teaching practice. Sustained change to teaching practice was enabled, reflected within the student choice of tasks undertaken, for example, identified by the following:

Personalised learning programmes are easier to support (Courtney, School Two).

Personalised learning is an option long term with digital technology (Courtney, School Two).

Supports independent and autonomous learning (Arihia, School Two).

Effective use reflects self-direction and independent study time (Taylor, School Three).

For some students it (digital technology) definitely increases student engagement because it is their whole world and that is how they are used to doing things, for others, not so much, so we offer choices (Laurell, School One).

I would find the online resources to go to, create some sort of like revision or a page where they got like videos, where they can access them online at any time, or they've got access to online questions and answers, … I use it more for teaching them rather than me teaching them (Matiu, School One).

Device usage allowed for ease of change occurring as shifts in pedagogy took place between teacher and student-centric approaches, indicative of the learning-centred classroom and the incorporation of creative pedagogy with the inclusion of multimedia learning (Bremner, 2019; Cremin & Chappell, 2021; Hanif et al., 2023; Mayer, 2005b). The use of multimedia learning is supported by the CTML theory which advantages working memory capacity (Mayer, 2005b). It appeared that the teachers of this study who were generously resourced were creative in their lesson design to maximise pedagogical flexibility with student autonomy, personalised learning and the provision of student choice.

The findings indicated that for the schools of this study educational contexts have influenced teaching pedagogy, illustrated by a lack of hardware and resourced software for one particular school at the junior level. Resourcing had an impact for all of these teachers upon teacher resilience, agency and identity, either negatively or positively (Beltman, 2021).

Throughout these findings the decile ranking of each school was not a barrier to the uptake of digital technology, with school management practices the influence which most impacted on change initiatives, both as an enabler and as a barrier. Further discussion on the internal inhibitors and enablers is undertaken in the chapter below. These are referred to as second order inhibitors and enablers.

6.3 Second order inhibitors and enablers – teacher beliefs and change

Change in education does not take place simply for the sake of change but is undertaken to add quality to some aspects of the educational environment. Drivers for change within education are: globalisation, technology, and research undertaken with developments in teaching and learning approaches (Burner, 2018). The changing role of the teacher is now perceived as being a facilitator of learning, which has meant that both teacher belief and teaching practice have undergone change (McLean, 2003).

The facilitation of digital interactivity becomes a reflection of the belief of the individual teacher and their targeting of quality instruction (Blömeke et al., 2016). Validation of the new ways of teaching mathematics with the use of digital technology reflect the changing nature of the mathematics classroom and the creative pedagogy that is taking place as teachers undertake risk attached to change (Abid et al., 2022; Attard & Holmes, 2020; Borba et al., 2021). The teachers of this study shared their perceptions below illustrating some of the enabling features complementary to teaching and learning with the use of digital technology.

This teacher used a gaming feature to advantage core skill development,

> ***core skills… a buy in for a bit of fun … …shoot 'em up times tables….*** (Matiu, School One).

This teacher used a free app to aid conceptual understanding identified by,

> ***…a million hand drawn graphs …*** (Joelle, School Four),

which enabled pedagogical shifts attached to learning.

This was about teacher belief responding to change and maximising the pedagogical advantages attached to imaginative praxis (Monaghan & Trouche, 2019). Positive belief was an enabler in consideration of challenges that were attached to changes to pedagogy (Beltman, 2021).

The following were examples of the inhibitors attached to teacher belief and digital technology use.

> ***… as a disconnect between student and teacher*** (Joelle, School Four).
>
> ***… I prefer me*** (Arihia, School Two).

The opportunity to provide feedback and develop a teacher-student relationship was prioritised. This becomes an illustration of human interaction and the need for face-to-face contact (Hadley et al., 2022).

This teacher had identified the student characteristics of Generation Z and beyond and looked to advantage student outcomes with the use of digital technology by appealing to student autonomy,

> ***… Taking away their agency …. lowers their engagement …*** Arihia, (School Two).

The teacher from this school supported the use of digital technology to support the development of student autonomy (Gueudet et al., 2021).

The SAMR framework features in consideration of:

> ***… you've actually got to add something …*** (Laurell, School One).

The meaning given here was not just using technology for the sake of using technology. The program in use here was Education Perfect which allowed further evaluation of teaching points, so a movement beyond creativity to critical thinking, indicative of the Modification and Redefinition end of the SAMR model.

What the above comments demonstrate is the desire by the teachers of this study to mix up their pedagogy to take advantage of what it is that technology had to offer in the discipline of mathematics (Attard & Holmes, 2020). It appeared pedagogical expertise was advantaged with digital technology use. It seemed that the one-size-fits-all for teacher instruction is not applicable as school contexts were not uniform, teacher ICT skills were not uniform, and creative pedagogy was an expression of the individual teacher.

The barrier of teacher role change, and resistant thought based upon role change (Mutch, 2012; Singhavi & Basargekar, 2019), was not a feature of this study. The resistance to role change can occur due to the implementation of digital technology without proficiency which impacts upon teacher identity (Day, 2018a). The teachers of this study were able to experiment with their teaching practice and the tools available to them to see if changes made were effective. The ability to reflect on existing teaching practice to achieve targeted outcomes is an example of the Teaching-as-Inquiry cycle employed within teaching practice. This relates to risk-taking and the acceptance of sometimes failing, in order to advance teacher practice (ERO, 2012).

As improved student outcomes are targeted, the teachers of this study were reflective of their teaching practice and looked for ways to support the delivery of quality instruction. Acknowledged here were the student characteristics attached to Generation Z and beyond (Hashim, 2018). The teachers of this study had taken risks to improve upon existing teaching practice (ERO, 2012; Timperley et al., 2014). For the teachers of this study, it appeared that teaching practice was aligned to digital technology use if benefits were perceived when digital technology was used. Overall, positive attitudes seemed to prevail (Beltman, 2021).

Our next point of discussion is lesson and task-design. With the use of digital technology, it became apparent that this was influenced by the software packages in use and made available to the teachers of this study. The two design related inhibitors and enablers are investigated in section 6.4.

6.4 Third order inhibitors and enablers – lesson and task design

The schools of this study existed on the continuum of no inhibitors to task and lesson design to some inhibitors to task and lesson design. This was largely a reflection of the types of software packages and software resourcing made available. With one of the schools, multiple changes had occurred resulting in a total curriculum redesign with technology use, and it was hard to isolate changes in teaching practice as being solely about the use of digital technology.

The physical configuration of one of the schools supported an ILE environment. The adopted approach for this school was STEM staffed with a mathematics specialist and a science specialist. This school used *Education Perfect* and the two teachers from this school worked collaboratively within this program to enhance the learning intentions and the desired teaching points of a module, inquiry-based approach, for example,

> ***… we try and do collaborative task design here*** Laurell, (School One).

Two of the schools, representing three of the teachers, used OMIP's and had this to say about collaborative practice with the use of digital technology:

> ***…putting together a standard practice*** (Taylor, School Three),
>
> ***… a resource that has been developed across the school over time*** (Arihia, School Two), (Courtney, School Two), (Taylor, School Three).

It appeared that having a program that enabled a collective approach became a strength for these schools, irrespective of the degree of alteration of the software.

When targeting task and lesson design with a focus on OMIP's for two of the schools of this study, task design became a reflection of lesson design and gave these teachers the opportunity to have flexibility within their approaches, for example,

> ***… I can run my program to have individual and group time with students …*** (Arihia, School Two).

This teacher could not change the nature of the software, but could change the lesson design to advantage the desired student outcomes (Hanif et al., 2023). This teacher has provided small group work and choice of task within the program available for use *(Mathletics)*, which appeal to the characteristics of Generation Z (Hashim, 2018).

Flexibility became,

> ***… roaming the classroom with my laptop …*** (Arihia, School Two).

It appeared, based on teacher perception that when constraints with task design had been experienced, lesson design had been manipulated to enable the desired student outcomes, indicative of pedagogical expertise. A teacher without resilience cannot overcome constraints, and the expectation is that teachers will role model and teach resilience to their students (Ainsworth & Oldfield, 2019).

One teacher was not resourced but had a bank of digital resources to refer to which could be used at strategic times of the year for whole-of-class activities, or digital clips via teacher laptop all year. It appeared for this teacher, that without the use of a resourced mathematics software program, individual practice was isolated to individual classrooms by comparison to the whole-of-school approaches undertaken by other schools.

Two factors stood out for the teachers of this study that impact upon task and lesson design, these were resourcing and creativity. One of the inhibiting factors for the teachers of this study appeared to be not having the use of digital technology and resourced software. A second inhibiting factor for those that had resourced software, became about the degree of change that could be undertaken to the software interface to achieve the desired outcomes. Equally, it seemed that the enablers within this discussion have been whole-of-school approaches to collective efficacy, the features of the software itself, and flexibility within lesson design, reflective of pedagogical expertise.

The use of technology at the right time at the right place by teachers is the reduction of the third-order inhibitor and to do this design thinking skills are required (Drijvers, 2015; Tsai & Chai, 2012). Within the approach to design, both task and lesson design featured (Hanif et al., 2023). For the teachers of this study who actively taught and reflected on their practice, the strengths of their pedagogy and the resources at their disposal were used to the advantage of their teaching practice, where possible.

For the teachers of this study resourcing became a reflection of leadership practice. Equally, prioritising gains in mathematical achievement became a whole-of-school approach within the tools made available. The ability of an individual teacher to buy-in to school or group goals became an issue of identity (Horn, 2015).

> ***… it is not just a one-person decision to use Mathletics, it is a leadership decision …*** (Courtney, School Two).

The reflection is one of both teacher and school resilience practices as change initiatives are undertaken (Beltman, 2021). It seemed that the change initiatives that have taken place have been reflective of lesson and task design.

For the teachers of this study risk-taking has occurred with the approaches undertaken to support change to existing practice with the use of digital technology to improve student outcomes. As some of these schools have undertaken collective approaches, the employment of collective efficacy has become instrumental in achieving sustained change to existing teaching practice, discussed in section 6.10.

With the total immersion in online learning that occurred due to the COVID lockdown, the adoption of an online learning model was undertaken, which did not include face-to-face interaction. The use of digital technology became the only avenue for teaching and learning to be undertaken and this is discussed in greater depth below in section 6.5. This became an illustration of teacher and school resilience practices.

6.5 COVID-19 and the immersion of teaching practice with digital technology

The pandemic COVID-19 brought with it social distancing, lockdown scenarios, and a heavy reliance on the internet. The inhibitors within education were multi-faceted, the most obvious relating to a lack of digital devices, and internet connectivity or availability (Lai & Widmar, 2021; Sosa Díaz, 2021). The impact of the circumstance of lockdown on education was immediate, given the overnight transition to online teaching and learning and the immediate requirement for teachers to display digital competency within a reduced timeframe. This circumstance was the reality for the teachers of this study. For those that did not have devices, hard packs (textbooks, tear-off pages) and shared devices (mobile phones, chromes, laptops) were utilised, with the expectation that home based devices could help fill the gap of device shortage. The expectation was that the home environment would be supportive of online teaching and learning as most families were in lockdown together (Darragh & Franke, 2022). Communication via digital means was a necessity for learning programme continuity. Teachers had to learn to teach digitally, effectively embracing a new online teaching model (Edelhauser & Lupu-Dima, 2021).

The adoption of changes to teaching and learning underwent intense digitilisation. School resilience practices, evident in a collective approach to change, became the response to challenges set. Professional learning and development became a means to support gaps in knowledge, reflecting a lack of digital competence for some. The barrier for all was the adoption of an online teaching and learning model, previously unknown and the impact of this upon quality instruction. Teacher perceptions revealed

> ***… Increased demand for PLD for teachers. Thrown at us. Learnt on the fly …*** (Joelle, School Four), (Taylor, School Three).
>
> ***This was particularly stressful for those who had not been exposed to resourced software previously. … introduction of resourced software …*** (Joelle, School Four), (Taylor, School Three).

The emphasis for teachers lay within the necessity to maintain a continuity of delivery of a learning programme, regardless of the pandemic scenario. This required a massive PLD undertaking, which for most schools was a school-wide approach to accountability.

> ***… We have had to adapt, dramatically … but how we delivered that and how we taught that, it's a lot harder to do remotely*** (Matiu, School One)
>
> ***… but the learning curve was pretty immense, steep …*** (Laurell, School One).

Teachers were entrusted to appear as they would normally within an online and COVID-19 scenario to support student wellbeing, regardless of how they were feeling. Teacher comment reflected:

> ***… scrambling to figure out what we were going to do …*** (Joelle, School Four).

Due to the compounding nature of the factors attached to an online learning process, illustrative of the greater part of teaching practice within a COVID scenario, the teachers of this study felt the personal and professional impact of their environment. The professional identity of a teacher requires both emotional as well as intellectual energy, so that teachers can teach well and to the best of their ability (Day, 2018a, 2018b).

With the easing of pandemic conditions, a greater degree of digital preparedness within the teaching and learning environment may remain (Edelhauser & Lupu-Dima, 2021; Sosa Díaz, 2021); however, for the some of the teachers of this study

> ***… post lockdown, PLD initiatives ended, back to pre-COVID practices …***
> (Joelle, School Four).

This reflects school management practices with individual PLD the only option thereafter, with free trials of software not renewed once COVID ended and device shortages prevailing at a junior level for this teacher.

The intervention of enhanced learning opportunities for students in the form of online teaching and learning, occurring under pressure, becomes an illustration of teacher resilience, teacher agency, and teacher identity. Teacher stress occurred during the pandemic because the teacher "energy resources were tied up in coping with new teaching demands that came with the pandemic" one of these being the introduction of new technology (McCarthy et al., 2022, p. 12). When evaluating quality instruction, participation in PLD and a teacher's sense of preparedness are strong predictors. It is thought that teacher quality predicts instructional quality which predicts student achievement (Blömeke et al., 2016). With the combined factors of teacher stress and the adoption of an online learning model previously unknown, with an immersion in PLD over a short timeframe, quality instruction became subject to communication and teacher and student demotivation (Kreydun et al., 2022).

The teachers of this study employed emotional and intellectual energy within a scenario of lockdown and were reliant on their individual and collective ability to be resilient in an extreme circumstance (Day, 2018a). Emotional wellbeing has an impact upon the authenticity of professional identity and for this to be sustained is due, in part, to the teachers' capacity to be resilient (Day, 2018a). Lack of teacher resilience can then be perceived to be a barrier to teacher agency expressed by innovation and adaptation (Day, 2018a).

For some teachers, collective endeavour was minimised given the COVID circumstance. The loss of collegial interaction that occurs as you sit in the staffroom and dialogue with others was commented upon, adding as it does to the picture of emotional wellbeing.

> … ***The loss of personal interaction was felt, which impacted upon friendships, building collegiality, planning, swapping ideas and being reflective*** (Laurell, School One).

It appeared for the teachers of this study that teacher stress had impact. Professional identity was maintained for each teacher, as they continued to teach within a COVID-19 lockdown scenario. It may be due to the nature of the lockdown and overall environment that quality instruction may not have been achieved.

6.6 Summary of Question One

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

To summarise my discussion above, in terms of how the findings and the associated research literature addressed research question one, the first order inhibitors and enablers identified a shortage of physical resourcing, related to devices and software for one of the schools. Equally teachers were enabled with generous resources for the majority of the teachers of this study. The key difference between those that were resourced generously and those that were not, was the alignment of management practices to the student characteristics of Generation Z and their need for digital interactivity. This aspect is supported within the research literature (Hashim, 2018). The decile rating of the school was not a limiting factor for the uptake of digital technology within teaching practice.

Teacher perception revealed that the use of digital technology to enhance student engagement, with the provision of student choice, became possible for five of the six teachers consistently. This was reflected in teacher belief as the integration of digital resourcing changed existing teaching practice. This meant that creative pedagogy was pursued with teachers experiencing greater flexibility within their teaching practice as a result. Teachers actively shifted between teacher and student-centric models, illustrating the learning-centred classroom (Bremner, 2019; O'Sullivan, 2004).

It was harder for the teacher that did not enjoy the benefits of resourcing to have the same flexibility and offer the same digital choices. Teaching practice was impacted here. However, this teacher still adopted shifts in teaching models but acknowledged it was harder to do without digital technology. The individual teacher belief was embracing of changes to teaching practice and again ran a learning-centred classroom (Bremner, 2019; O'Sullivan, 2004).

Student expectation portrayed by teacher perception supports the expectation of the norm of device use within the junior mathematics classroom, equally not identified by some school leadership structures (United Nations Sustainable Development Group, 2020). As each school context was significantly different, so too was the teacher's instruction, the one-size-fits-all approach to pedagogy was not applicable, given school context, individual skill levels with ICT, among other factors for consideration. Teacher belief in student choice allowed for student autonomy, which was supported by pedagogy (Gueudet et al., 2021).

Task design with resourced software was not an issue, as the structure of most tasks was provided, particularly with dedicated software. The fixed nature of the software became an opportunity for flexibility within lesson design, with teachers of this study employing pedagogical expertise to target the desired student outcomes (Hanif et al., 2023). As teachers employed pedagogical practices that took advantage of the software features available to them, they employed creative pedagogy with the complementary features available for student engagement, like entertainment (gaming, competitions) (Barber, 2021; Pazin et al., 2021). Lesson design was manipulated to support student outcomes with strategies of small group design when task design did not allow changes (Hanif et al., 2023; Hashim, 2018). Collective efficacy became a part of school culture and drove the digital approach to mathematics, strongly for two of the four schools of this study with their use of OMIP's, as teacher experts were developed, and mathematical competency was supported (Donohoo et al., 2018).

For the teacher that was not adequately resourced, individual practice was isolated within the classroom and although planning sessions would have taken place as part of normal practice, the feature of digital technology use did not add to school culture and enhance existing teacher pedagogy. Participative decision-making was not evident at this school.

With the advent of the COVID-19 pandemic, the barriers of a lack of existing digital competency and device availability presented themselves to the participants and their schools. Embracing an online teaching model became challenging for teachers and their students. The adoption of an online learning model was undertaken under pressure of time without face-to-face support and while experiencing escalating COVID stress. The teachers of this study experienced an increase in the resourcing of software, inclusive of free trials. PLD was undertaken within a scenario of high stress. Teacher stress had an impact upon teacher identity, agency and resilience (McCarthy et al., 2022). Quality instruction became harder to deliver due to the issues of communication and teacher and student demotivation (Kreydun et al., 2022). Increased inhibitors to a continuity of learning presented when management did not continue to honor online learning post COVID, with the prospect of further lockdowns looming; this situation occurred with one of these schools.

For the teachers of this study teacher perception reflected on digital competency as integral to the effective teaching profile as a means to facilitate student engagement and the development of an effective teaching practice that supported student identity depicting the Generation Z characteristics (Hashim, 2018). The focus for question two, which is discussed below in section two, moves beyond the inhibitors and enablers to investigate the role of digital technology within teaching pedagogy.

Question Two - the role of pedagogy

6.7 Introduction

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

It can be said that pedagogy assumes increased importance with the advent of the digital native (Ting, 2015), and that the majority of those born in the 21st century are considered to be digital natives (Buentello-Montoya et al., 2021; Hashim, 2018). Teaching digital natives becomes challenging as the learning tools have changed, indicative of technology use within society. The written word and hence the act of reading is no longer the first or only choice for many, with digital interactivity a primary need (Buentello-Montoya et al., 2021; Gu et al., 2013; Hashim, 2018). Hence educationalists, in general, are catering to a learning need with the use of digital technology, to motivate learning to occur. What was reflected is the Generation Z student characteristics, which necessitate a change in teaching approaches adopted within the classroom (Hashim, 2018).

Schools and teachers have worked toward appropriate and effective use of technology to produce the desired student outcomes. Using digital technology to better reflect the effective teaching profile became a part of pedagogy for teachers, and being effective with the use of technology, beyond “just using it” allows for key competency and conceptual understanding and development (Hoyles, 2018; Puentedura, 2006; Ting, 2015). The “transformational potential” of digital technology reflects changes to traditional teaching approaches with greater opportunity for knowledge construction (Hoyles, 2018). What is understood is that student outcomes are dependent upon all the strategies employed, separately or in combination, within the classroom (Attard & Holmes, 2020; Hoyles, 2018). A learning-centred approach, where movement occurs between teacher-centric and student-centric practices, is supported with pedagogical expertise, no matter what tool is in use (Bremner, 2019; O'Sullivan, 2004). Of special mention here is the pandemic scenario and the intense digitilisation within teaching and learning that occurred over repeat lockdown scenarios (Calder et al., 2021; McCarthy et al., 2022). When teachers are effective in their use of digital technologies, the stability of teacher identity and the continuity of learning are supported (Beltman, 2021; Beltman et al., 2011).

The following discussion is divided into sections that reflect the key findings undertaken within this study. These sections are numbered as follows: section

6.8 has discourse on Targeting improved student outcomes with online mathematics instruction programs (OMIP); section 6.9 similarly details Innovative learning environments and transformative practice; section 6.10 discusses Transformational change and collective efficacy; section 6.11 features Transformative practice and autonomous teaching methodology; with section 6.12 examining Social networking and collaborative practice. Our final summary section is 6.13, reflective of the above.

6.8 Targeting improved student outcomes – online mathematics instruction programs (OMIP)

The focus within this discussion for online mathematics instruction reflects five of the six teachers of this study, who to some degree employed programs of this nature, making this a worthy dialogue reflective of the above. The sixth teacher could only employ the use of digital technology when options of device use were available, for example, when seniors had study leave. This teacher could only access free apps thereafter, as resourced mathematics software was not funded by the school. The teachers of this study used *Mathletics and MathsBuddy* within their teaching practice, considered to be OMIP's. Also employed within teacher practice was *Education Perfect*, which enabled some adaptation to occur.

In making an informed choice to use online mathematics instruction programs (OMIP), the awareness exists for schools and teachers of the negative publicity attached to OMIP's (Darragh & Franke, 2021), as can be seen by the teacher comment expressed.

… Mathletics does not fit in with every bit of research around good mathematic practice but then you have got to choose one that is going to work and meet the needs of your students … (Courtney, School Two).

Schools endeavor to keep abreast of current literature in order to maintain a professional focus with an awareness here of negative and positive critique. One of the criticisms with the use of OMIP's relates to the individualised focus undertaken which is seen as teacher-centric as opposed to student-centric (Darragh & Franke, 2021). It may be for the teachers of this study that the use of OMIP's has advantaged their teaching practice as it has enabled the introduction of digital technology as a norm within classroom practice. It could be that the use of OMIP's may alleviate mathematics anxiety previously discussed in this study, due to weak knowledge content and aligned to teaching-out-field. The use of OMIP's could assist in the development of teacher pedagogy and knowledge content subject to the features of the respective software, for example, video tutorials.

What this study has found, supported by literature, is the learning-centred classroom is considered by the teachers of this study to be responsive to student need subject to the influences that occur within the mathematics classroom (Bremner, 2019; O'Sullivan, 2004). Expertise in shifting between teacher and student-centric models is thought of as an expected part of teaching practice.

… as I have switched between teacher and student-centric practices … (Courtney, School Two).

The learning-centred classroom, as discussed by this teacher, responds to the movement between digital technology and paper-based tools, and traditional teacher and student-centric practices. The teachers of this study look to advantage their teaching practice with the ability to shift easily between teacher and student-centric practices. This in turn builds teacher resilience, supports teacher agency, and stabilises teacher identity (Day, 2018a).

This is supported by the following teacher comment:

> ***… not worried about the application of educative theory, … more the relevance to learning*** … (Joelle, School Four).

Even without continuous use of digital technology, this mindset portrays a learning-centred practice with targeted learning outcomes, reflective of the continuity of a learning programme, which was teacher driven. Teacher beliefs were focused on the relevance of the learning undertaken and the ways this can be achieved (Kim et al., 2013). Further endorsement of this was made by the following teacher of this study:

> ***… trying to go with a blanket approach … I would just hate tha***t (Matiu, School One).

This teacher has been able to identify within a learning-centred approach that being able to change the way in which teaching has been undertaken facilitates choice for both teacher and student, with obvious advantages to teacher resilience, agency and identity. Equally:

> ***… if it is not working … it is not working … stop and try something else …*** (Matiu, School One).

Teacher beliefs are then about effective ways of teaching (Kim et al., 2013). Replacing teaching practice with an OMIP as a single line of delivery would illustrate a blanket approach, which does not illustrate a learning-centred approach. The teachers of this study have actively moved away from blanket approaches, as something they would prefer not to implement. In addition, this teacher has endorsed reflective capacity, aligned to the Teaching-as-Inquiry approach, with reflection-in-action, … “stop and try something else” …

One of the features of the use of digital technology is the ability to provide short bursts of learning, ideal for the multi-tasking short attention span, indicative of the digital native, (or generally those born in the 21st century) and this is less likely to occur when a digital alternative is not readily available (Hashim, 2018). It appeared the teachers of this study have adopted a learning-centred pedagogy as the norm of classroom practice reflecting pedagogy and the use of digital technology. It appeared that the teachers of this study have not adopted a blanket approach or one-size-fits-all model irrespective of the software in use.

The next section discusses ILE’s and how the physical design of ILE’s promotes pedagogical shifts with the adoption of digital technology within teaching practice.

6.9 Innovative learning environments and transformative practice

With the adoption of an innovative learning environment (ILE), School One worked toward building a collective, school-wide digitised identity. To do this they have changed the physical environment, adopted a STEM approach, advocated for team teaching, and resourced *Education Perfect* for teacher use, with a one-device-to-one-student policy. The effect of the physical environment of the ILE has fulfilled the intended purpose of promoting digital technology use as a consequence of the physical changes to the classroom structure (Starkey & Wood, 2021). Innovative learning environments allow for flexibility in teaching and learning approaches and enables collaborative, team teaching (Benade, 2015b). The STEM approach undertaken here was by module reflecting the combination of science and mathematics and pursued an Inquiry-based model.

Within this study teachers highlighted the reality of this change, which was as follows:

> ***… group work was undertaken, … where a lot more planning for individual programmes was needed, … plus the whole of class tasks set indicative of 75 to 80 students in class …*** (Matiu, School One).
>
> ***… when it is being integrated into the modules we have up to seventy kids in a classroom and it is really hard to do small group work … To keep it small and quiet … and then the space to be able to do it …*** (Matiu, School One).
>
> ***… we would split them up and teach a group at a time … Other barriers … probably time … sometimes it is easier to fall back on writing something on the board … instead of a digital tool …*** (Laurel, School One).
>
> ***… We are definitely not at the stage where every student is on their own individual plan, but we do have certain individuals on a plan …*** (Laurel, School One)

… I don't think it would have changed so much … because in those bigger spaces you have to try new things … it doesn't always work perfectly because you don't always have a subject specialist in both areas … (Laurel, School One).

Digital technology assisted with the setting of the task for the entire class. What was commented upon was the difficulty of having one mathematics specialist in this group, which made it harder to cater to the needs of the whole class within a scenario of team teaching (Benade, 2015b). Effectively if you do not have a subject specialist, you have a circumstance of teaching out-of-field (Du Plessis, 2020). Class size had an impact on available space and noise as a result of the increase in student numbers. The change in environment supported the shift in pedagogy toward student-centric models. School leadership with the implementation of ILE's has taken the risk that teaching practice will respond with the desired shift in teaching pedagogy, from teacher-centric to student-centric.

It could be that for student-centric learning to be more readily achieved with large student to teacher ratios, an increase in the number of teachers may be needed. Further to this, changing the physical design of classrooms to promote student-centric learning at the cost of traditional teaching had negated the value of lower student to teacher ratios, direct instruction, and class discussion (Starkey & Wood, 2021; Watson et al., 2013). Teacher resilience would have been supported by the whole school approach; however, teacher identity may not have been, as the nature of the physical change may have worked against individual teacher identity. Teachers may not have been able to identify with the group goal of ILE's (Horn, 2015), impacting upon teacher identity.

It appeared that the teachers of this study experienced an accelerated shift in pedagogy towards a student-centric model (group work), due to the change in physical environment, where the use of digital technology was promoted in response to classroom size. It appeared that achieving personalised learning to the satisfaction of the two teachers concerned was in transition. It appeared that digital technology was not always the preferred tool.

6.10 Transformational change with collective efficacy

Whole school approaches to the adoption of digital technology within teaching practice are considered to be innovative and involve risk-taking (Education Review Office, 2012). The risk for schools is that innovative undertakings may result in lower student achievement, so it is the risk of failure that schools face. The need to develop resilience is important for both schools and teachers as they contemplate change (Beltman, 2021; Forbes & Poultney, 2020).

The school focus is then structured to reflect success with innovative approaches which are used to target shifts in teaching pedagogy, thereby increasing positive student outcomes within junior mathematics (Rajaram, 2021). Teachers are expected to adhere to the set school-wide targets. Schools can employ the Spiral-of-Inquiry to revisit changes undertaken and the assessment of positive gains in desired outcomes (Timperley et al., 2014). Contextual factors can impact teacher resilience (Beltman et al., 2011).

Creating a school culture with high expectations for staff and students forms a part of strategies indicative of resilient schools that are faced with challenging circumstance (Pinskaya et al., 2019). School culture can support and assist with the achievement of school-wide targets. Distributed leadership can be supportive to change initiatives (Rashid et al., 2011; Supovitz & Tognatta, 2013).

The teachers of this study had this to say

> ***… Our new teachers would have no idea about teaching maths without Mathletics*** (Courtney, School Two).
>
> ***… it is the first thing that gets missed as they have maths anxiety themselves*** (Courtney, School Two).

School leadership has an awareness here of the issues that exist for the teaching of mathematics at this school. The need for teacher support within the years 7 and 8's resulted in management making conscious choices to provide OMIP's that supported monitoring of mathematics instructional delivery by time and as a response to mathematics anxiety experienced by teachers. Teachers can experience anxiety due to a lack of knowledge content expressed as mathematics anxiety, if mathematics is not their specialist area, and this can be projected onto students (Du Plessis, 2020; Peker & Ertekin, 2011). Mathematics anxiety, gaps in mathematical knowledge content or achieving uniformity of content delivery are issues which may continue even with staff attrition and replacement. Having a structured mathematics programme in place, with easy monitoring of usage by teachers, has been achieved with ease through the resourced OMIP's used by this school. The guarantee here is the monitoring of timeframes for instructional delivery and the building of teacher expertise over time, both with the digital technology in use and with knowledge content, if not already held.

The schools of this study actively strategised for success within their approaches for the promotion of student mathematical achievement.

> ***… Putting together a standard practice*** (Taylor, School Three).

PLD can now be supported in-house with the development of standard practice and consequently teachers who are experts in the use of the OMIP's. Features of the software program can offer a second voice in the classroom, supporting teacher knowledge content development. The schools involved have utilised school culture to support innovative changes that they hoped would lead to sustained change within teaching practice. This was subject to a process of critical review and evaluation.

> ***… All of us coming together using the same platform …*** (Courtney, School Two).
>
> ***… Across the school competitions …*** (Arihia, School Two)
>
> ***… Letting us know if usage is down …*** (Arihia, School Two).
>
> ***… A resource that has been developed across the school over time*** (Arihia, School Two), (Courtney, School Two), (Taylor, School Three).

The two schools, representative of the four schools involved, were not limited to individual teacher practice with the use of one software package, but utilised free apps to support where necessary. The teachers did not adopt a blanket approach in their teaching practice and “mixed it up,” if not with task design, then with lesson design, to advantage pedagogy and therefore student outcomes. Teachers need to believe in their own competency (Dimopoulou, 2012).

A leadership initiative that supports collective efficacy and drives innovative adoption of digital technologies targeting teaching and learning in the mathematics environment provides opportunities for the development of teaching practice reflective of a digitised identity for the teacher, allowing school identity to reflect 21st century expectations within their communities (Navaridas-Nalda et al., 2020; Rashid et al., 2011). Leadership within these schools have adopted strategies that have challenged staff to respond positively to meet the expectations held (Donohoo et al., 2018). The opportunity existed for all of the teachers of this study to extend their existing understanding with exposure to the Kāhui Ako and in-house training.

By contrast, restricted use for one of the teachers of this study meant that individual teacher practice continued with limited opportunities for the use of digital technology within the learning programme to occur, and therefore development of a digitised teacher identity was negatively impacted at a junior level. By comparison (Joelle, Teacher Four) was sent outside of the area for specific Geogebra training targeting senior achievement.

With a compromised digital identity at a junior level due to resourcing constraints, collegial support would also not be reflective of a school-wide (department wide) drive targeting mathematical attainment, transparent with the use of digital software. School Four lacked a presence within the leadership team of a mathematics professional, or a technology leader, one who was advocating for the mathematics department (Thannimalai & Raman, 2018). In addition, the need for digital interactivity for Generation Z and beyond has not featured (Hashim, 2018). Schoolwide initiatives were focused on literacy as a whole-of-school approach. This was also evident in School Two.

For the teachers of this study who used OMIP's, existing teaching opportunities were enhanced. However this was more at the substitution, augmentation level of the SAMR diagram (Ministry of Education, 2021b), with worksheet practice and online textbook reading. However, what was revealed was the need to start somewhere with the introduction of digital technology, and

> ***that … it goes against some of the theories …*** (Courtney, School Two).

so this school was very much aware of the risk attached to trialing a new approach, with OMIP's considered to reflect teacher-centric models, a move away from student-centric practice (Darragh & Franke, 2021). This was a leadership choice to undertake the use of OMIP's as a way of monitoring mathematics instruction.

> ***… if we are wanting students to lead their learning, we have to give them the opportunity to do so …*** (Courtney, School Two)

This school has undertaken a risk/benefit assessment and with the provision of an OMIP has aligned teaching practice to the use of digital technology, but also to uniform instruction and a monitoring of hours of instruction. The benefits that exist for students are seen as: student autonomy, the provision of entertainment, competition, student membership with larger groups, and involvement of whānau with increased visibility of learning. The benefits that exist for teachers appear to be collective efficacy and individual support with PLD as the school has structured their approach to the inclusion of this OMIP. It appears that with the use of OMIP's with fixed instructional delivery that although task design cannot be altered, lesson design can be, which assisted in enhancing teaching pedagogy (Hanif et al., 2023; Tsai & Chai, 2012). The benefits for the school were uniform knowledge content delivery and confirmation of time spent on the learning.

Social contexts and interaction within schools allow for teacher resilience to be supported. This involves the ability of the teacher to navigate challenges through the use of strategies, reflective of resourcing to enable engagement, growth, and the ability to meet outcomes set (Mansfield et al., 2016). Supported changes could illustrate a movement toward the development of facilitative teaching roles and student autonomy.

It seemed that collective school approaches enabled teacher resilience, measured by response to the change initiatives. It gave the impression that school resilience was also advantaged with in-house support developed to offset mathematics anxiety and instructional delivery for teaching staff. It appeared that the use of an OMIP enhanced the ease of a collective school approach for the teachers of this study.

6.11 Transformative practice and autonomous teaching

The continuum of an autonomous supportive teaching methodology is reflective of a facilitative, student-centric teaching style. An autonomous teaching methodology is considered desirable given the positive relationship to increased student engagement, thought of as a predictor for underlying motivation (Jones, 2020; Reeve et al., 2004). Autonomy-supportive teachers facilitate student learning opportunities to better reflect student needs, interests and preferences (Reeve et al., 2004).

Teacher perception showed:

> ***… striving for them to be independent, self-directed learners I think that digital technology for me is the best tool for them to do that effectively*** (Taylor, School Three).
>
> ***… instant feedback provided by the technology allows greater high-quality contact time with students …*** (Taylor, School Three).
>
> ***… Will roam the classroom with my laptop – helpful videos - group work*** … (Arihia, School Two).

Greater lesson flexibility has been generated with the use of digital technology, allowing individual student need to be identified with lessons structured to support student autonomy and teacher flexibility of lesson delivery. The ability of digital technology to support the development of student autonomy was considered to be advantageous to teaching practice.

> ***… Greater teacher flexibility required/not teaching at one level/supports 25 different levels if 25 different students*** (Taylor, School Three).

Within the age group of junior mathematics of year 7-10, the teachers of this study worked toward developing an understanding with their students of the need for autonomous learning. Teacher perception revealed the use of digital technology within pedagogy facilitated student-centred learning inclusive of the social identity of the student.

> ***… digital technology is part of the process of building student identity*** (Joelle, School Four).

The need for student autonomy to be expressed within teacher pedagogy becomes a reflection of the characteristics of Generation Z (Gen-Z) (Hashim, 2018).

The teachers of this study have identified that students come into classrooms with the expectation that digital interactivity will be a norm within their learning experiences. Personalised learning with digital technology is then about choices students can make within their learning. The provision of choice has been enabled with the use of digital technology, confirmed by this teacher participant:

> ***… students select the next stage, driving their own learning, pushing themselves, tailored to their own needs …*** (Arihia, School Two).

Three teachers of this study confirmed that:

> ***… independent learning programmes are easier to support …*** (Arihia, School Two), (Taylor, School Three), (Joelle, School Four).

Generation Z is a tech-savvy generation, who are more aligned to remaining within the education system at an older age than any other (Fry & Parker, 2018). A better need for student autonomy is reflected in student choice (Patall et al., 2013), which allows personalised learning to occur. Personalised learning with digital technology is then about choices students can make within their learning. With these traits, Generation Z are more “reflective and independent in their learning style than other generations” (Hashim, 2018, p. 2).

As technological advances have created digital natives, the response from all of the four schools to varying degrees, and all teacher participants, has been the use of a learning-centred approach, enabled with the use of digital technology, also inclusive of autonomous teaching methodology where possible. The provision of choice was supportive of student autonomy. The adoption of teacher practice which supports student autonomy assists with student engagement and motivation (Patall et al., 2013). It appeared that within this study teachers targeted student autonomy with their use of digital technology. It appeared that the use of digital technology by the teachers of this study made independent learning programmes easier to support.

Support for change to teacher practice can be developed within the larger picture of collegiality and collaborative undertakings with colleagues, not only within the physical confines of the classroom and school, but also across the wider professional groups of which that teachers are members. This is discussed below.

6.12 Transformative collaborative practice

Group expertise can assist with teacher development by way of teacher talk and group dialogue. For the teachers of this study, within their educational settings there was interaction that occurred by the common commitment of improved student achievement, and engagement within particular teacher groups (mathematics) with the use of a particular software. All of this contributed to what should be dialogue between colleagues that allows for gains in pedagogical understanding or new and better ways of teaching. Conversation could assist in collaboration and the building of group expertise. Teacher perception revealed:

> … ***Collaborative task design across colleagues works, not all colleagues*** (Courtney, School Two).
>
> … ***The use of digital technology does not mean that collaborative practices are undertaken collegially*** (Joelle, School Four).

What is revealed here is that selective interaction occurs within the workplace, and although aligned to a common focus, being human does not guarantee collaborative practices occur with all staff.

Within this study, episodes of pedagogical reasoning have occurred where the teachers of this study, through teacher talk, have looked at their teaching practice and planned for improvement and debated change through dialogue. Given the isolation factor within teaching, where classrooms are thought of as islands, and dialogue may be fleeting and spasmodic, collegial conversations may be limited (Horn, 2015). The use of digital technology, *Zoom*, *Microsoft Teams*, and other social media interventions may support teacher conversations beyond the limitations of the existing physical environment. This could allow “rich” conversations to occur. Teacher perception revealed:

> ***… a wider math focus group is supported as opposed to a focus of digital technology use and collegial interaction*** (Joelle, School Four).

Some of the schools of this study used *Facebook* as a medium to sustain relationship building, inclusive of students and family (whānau). Some schools used virtual learning communities to sustain student achievement, utilising nationwide membership. Teacher perception revealed the following:

> ***… Each teacher has a closed Facebook page, 99% of the teachers*** (Courtney, School Two).

For the teachers of this study, in addition to sourcing and providing supportive teacher dialogue about their teaching practice within their physical environment, the building and sustaining of relationships is also sourced in the virtual environment, as a reflection of professional commitment. Social media has now become an acceptable platform for communication and is used within classroom scenarios to develop and sustain relationships of a professional nature (Anggoro & Rueangrong, 2021). What was commented upon within this study was the role of *Facebook* as a means of communication, and in this instance a closed *Facebook* page reflective of one classroom. The role of social media then becomes a part of the learning-centred approach, with face-to-face and online instruction, which also became collaborative by design, meaning class membership, group dialogue, and the opportunity for participation by all. It may be that collegial interaction could be supported across digital platforms, where professional dialogue becomes the driver for conversation, with human interaction limited to chosen colleagues.

The use of digital technology, within some of the schools of this study, reflected an increase in commitment to developing expertise with the use of the digital technology and software in question. This was also discussed with collective efficacy, section 6.10. It appeared that within this study teachers targeted student autonomy with their use of digital technology, discussed in section 6.11. Teacher perception revealed the impact of the adoption of a school-wide software package and the impact upon teaching practice:

> ***… Structured school-wide learning if a school goal*** (Courtney, School Two).
>
> ***… School culture is built upon by the use of a common platform and across the school competitions and monitoring of student placement*** (Arihia, School Two).

The adoption of a common platform assisted in developing a group identity and group identity has sustained efforts made for improvements in teaching practice (Brown, 2017; Goddard et al., 2004; Horn, 2015). This was a school-wide goal.

Teacher perception shows that teachers were aligned to the use of digital technology as a collective within their schools, with targets set supportive to the common goal of increased student outcomes within junior mathematics (Donohoo et al., 2018). Applicable to collective undertakings within schools is individual teacher identity. The group identity sustained efforts in gaining expertise within teaching practice with the software packages in place. There was a commitment to an epistemic stance and, as a group, failure was not seen to be an attractive option when undertaking the risk of, for example, the use of OMIP's. Equally there was no choice attached to the adoption of the group resourced software. Group identity could therefore impact upon individual identity. Representational adequacy or a commitment to developing the necessary skills to achieve expertise with the chosen software could occur. Another example of this could be the adoption of the ILE's, impacting upon individual teacher identity. Group identity can restrain and inhibit individual teacher identity if the individual teacher is not able to align themselves to the group goal (Horn, 2015). This may lead to teacher attrition.

Teachers can now move outside of their immediate environment, either individually or collectively to enhance practice by membership within wider mathematics focused collectives, undertaking collaborative practice sustained online. Within this study this collaboration occurred nationwide, given the features of one of the software packages used, which was student focused. Further enhanced within this study is the visibility of classroom presence, involving teachers, students, and family (whānau). Teachers are no longer limited to the physical boundaries of their own class or school when seeking professional interaction with others. The teachers of this study confirm that social media now has an accepted presence within the professional sphere of schools and classrooms (Insorio & Olivarez, 2021). It appeared for the teachers of this study that teacher identity was developed and supported with a growing base of technological and communication-based software.

6.13 Summary of Question Two

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

All the teachers of this study employed shifts in teaching pedagogy from teacher to student-centric and vice versa illustrating the learning-centred classroom. Shifts from one model to the other occurred in response to the learning outcomes desired for the majority of the teacher participants of this study (Bremner, 2019). It appeared for the teachers of this study that learning-centred pedagogy has been adopted as the norm of classroom practice.

The use of *Mathletics*, *MathsBuddy and Education Perfect* allowed an easy transition between each teaching model. Pedagogical expertise was instrumental in the maximisation of the potential of the resources at hand (Hanif et al., 2023). With the use of resourced software programs, teachers and students could build expertise over time. OMIP's could reflect a good starting point for digital technology within teacher practice. The process of building student autonomy was facilitated with the opportunity for choice and multiple opportunities for mastery (Gueudet et al., 2021). This was a feature of the three software packages used. It appeared that the teachers of this study have aligned their teaching practice to reflect student autonomy but have not adopted a blanket approach or one-size-fits-all model.

For two of the six teachers of this study, ILE's and their impact upon their mathematics classroom practice reflected a STEM approach, with one of the two teachers a qualified mathematics teacher. Digital technology was used and given the impact of the size of the combined classes with these two teachers, it would have been hard to maintain teaching and learning without it. *Education Perfect*, which allowed alterations within lesson content, was available for use. Teacher comment supported the additional teacher planning undertaken to cater for the large class size. Both teachers commented on the increase in noise as a result of the class size. The shift in pedagogy toward student-centric practice occurred as a result of changes to the physical environment and as a response to large class sizes.

For the schools that have adopted schoolwide approaches with OMIP's, they have taken a risk but have guaranteed through management practice a uniformity of time spent teaching mathematics and instructional delivery. The issues mentioned within these schools are mathematics anxiety, time, and uniformity of instructional content. For the teachers of this study, collective efficacy became a strength with this whole-of-school approach. Leadership initiatives promoted a school culture which supported collective efficacy with the use of digital technology (Donohoo et al., 2018). This gave both teachers and the school a digital identity within the community. The use of OMIP's strengthened the focus on school achievement, which contributed to a digitised school culture and became a cycle that promoted sustained change in teaching practice. With the adoption of ILE's and OMIP's, group identity may impact upon individual identity, and the ability to represent the skills and knowledge needed (representational adequacy) may not result (Horn, 2015). With the adoption of these initiatives, sustained change to teaching practice has been achieved, with the negatives mentioned above to be considered. It seems that collective school approaches enabled teacher resilience, measured by response to the change initiatives. It seemed that school resilience was also advantaged with in-house support developed to offset mathematics anxiety and instructional delivery for teaching staff.

The teachers of this study have identified that students come into classrooms with the expectation that digital interactivity will be a norm within their learning experiences. Personalised learning with digital technology is then about choices students can make within their learning. The provision of choice has been enabled with the use of digital technology promoting autonomous teaching practices that reflect the Generation Z characteristics (Gueudet et al., 2021; Hashim, 2018). It appeared that within this study teachers targeted student autonomy with their use of digital technology.

Teachers can now move outside of their immediate environment, either individually or collectively to enhance practice by membership within wider mathematics focused collectives, undertaking collaborative practice sustained online. The role of social media then becomes a part of the learning-centred approach, with face-to-face and online instruction, which also becomes collaborative by design, meaning class membership, group dialogue, and the opportunity of participation by all (Insorio & Olivarez, 2021). It may be that collegial interaction is supported across digital platforms, where professional dialogue becomes the driver for conversation, with human interaction limited to chosen colleagues.

For the teacher that was not resourced adequately at a junior level with digital technology, teaching practice could not consistently reflect a digitised approach to the teaching of mathematics. Teaching practice, however, still reflected a learning-centred approach. Leadership at this school did not align itself to the characteristics of Generation Z and their requirement for digital interactivity. This leadership team did not have either a mathematics specialist or a technology leader on the leadership team. Both of the secondary schools of this study targeted literacy as their schoolwide goal.

The impact of group identity on individual identity is considered, reflecting the initiatives discussed above. As teachers undertake the use of wider mathematics groups, teacher identity is advantaged both within and beyond their school and classroom environments. It appeared for the teachers of this study that teacher identity was developed and supported with a growing base of technological and communication-based software.

Teacher identity is strengthened with both external and internal factors. One of the external factors is PLD which is undertaken to assist with the development of expertise with the use of digital technology within teaching practice (Beltman, 2021). The role of PLD is discussed in the next section.

Question Three - professional learning and development

6.14 Introduction

Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

As teachers work toward changing existing practice to further embrace changes driven by the external environment and the digitised nature of the student body, assistance with the development of expertise and digital technology can be supported with professional learning and development (PLD). Teachers may pursue this individually, or it may be a requirement of the school environment; in both cases this supports teacher registration and becomes evidentiary within the context of the professional growth cycle. Evidence of maintaining current practice assists teacher registration.

The sourcing of appropriate PLD may reflect qualifications related to knowledge content, which, if you become an out-of-field teacher, is an option, or knowledge related to the use of digital technology, or both. There are two types of PLD in action in schools. These are leader and teacher driven. Leader driven PLD is considered compulsory in nature, with teacher driven self-directed. Self-directed teacher driven learning does not necessarily reflect one individual only and can occur through group need (Barton & Dexter, 2020).

The shortage in mathematics graduates impacts upon instructional capacity in the classroom, with teachers placed in classrooms who are teaching out-of-field (Goos et al., 2020). The phenomenon of teachers who teach out-of-field is the lack of pre-existing specialist mathematical knowledge and the time needed for this knowledge to be developed, as teaching is already taking place. Equally this circumstance may apply to those teachers who have mathematics anxiety, which can negatively influence their students. This is thought to reflect insufficient content knowledge (Peker & Ertekin, 2011).

For a teacher who is teaching out-of-field, or a teacher with mathematics anxiety, considerable planning, and therefore time spent, is undertaken to prepare for lessons, where teacher identity is protected. When teachers undertake change to existing pedagogy, the perception of risk occurs due to the possibility that changes undertaken will not generate the perceived benefits targeted and, in addition, may result in a reduction of existing student outcomes. The target is to make changes to teaching practice that can be sustained.

Teachers enter into the teaching workforce with entry level qualifications appropriate to the school and classroom. Sourcing additional qualifications becomes an expression of commitment to the students they teach as a response to navigating change. The long-term target is enhanced student outcomes. The implication for teaching practice is an increase in pedagogical expertise. The implication for school policy is the contribution that can be made to assist leadership decision-making. The reflective capacity of teachers individually, and across the school, combined with the capacity to take risks, allows the identity of both the teacher and the school to be developed.

What is apparent to the teaching fraternity is the ongoing nature of change in education, as a response to changes that take place in society. An example of societal change is the megatrend of digitilisation. The impact of societal changes can impact upon teacher resilience and therefore teacher identity (Petersen & Steiner, 2021; Pfaffinger et al., 2020). The following discussion relates to how schools and teachers of this study have embraced the challenges that have confronted them and the role of PLD in supporting these changes to individual and collective practice. The issues of teacher self-efficacy and wellbeing are considered in a holistic PLD framework. This section and following subsections relate to the chapter of findings entitled "The Role of Professional Learning and Development as an influence on Digital Technology Use Within the Junior Secondary Mathematics Classroom", subsections 5.1-5.6.

6.15 Self-Efficacy and professional learning and development

When undertaking PLD, the ideal scenario, for example leader-driven versus individual-driven, is debated as quality PLD is a focus. Targeted school and individual teacher outcomes suggest improvements in teaching practice and make the undertaking of PLD significant. Teacher perception revealed the following desired delivery of PLD:

> ***… Ideal PLD would be introduction by someone with expertise, then create compensations and colleague style professional development***

from there, then having the opportunity to go back and refresh, learn or extend something (Arihia, School Two).

Self-directed PLD allows for teacher agency, whereas structured learning targets leader agency to achieve the desired school-wide outcomes. Self-directed PLD allows for informal and independent PLD. Teacher initiated collaboration with colleagues is described as informal PLD with independent teacher PLD sourced by the teacher beyond the school boundaries (Barton & Dexter, 2020). The practice of employing distributed leadership across teacher experts would enable leader-initiated but teacher-led PLD. This was the scenario for the teacher comment above, if we assume PLD expertise to be leader driven. The holistic application of all forms of PLD would be the ideal targeted, discussed above.

Self-driven, individual teacher PLD, which supports opportunities for individual collaboration, enables mastery to be achieved with the repeated use of digital technology. Independent PLD occurs where teachers include sources like the internet. An example here would be the wider mathematics focus groups sourced by some of the teacher participants of this study which added to the 'rich' nature of the dialogue needed. Leader-driven PLD has been described as verbal persuasion which lacks sufficient action orientation (Barton & Dexter, 2020). The holistic adoption of all forms of PLD has been identified as providing opportunity for reflective capacity to be incorporated, allowing the development of teacher self-efficacy for technology integration to occur (Barton & Dexter, 2020).

Without the leader-driven approach initiated by the school, the need of the individual teacher became instrumental in sourcing appropriate PLD. This was illustrated with the following teacher perception:

> ***… I just continually see what other options are available with digital technology*** (Arihia, School Two).

The teachers of this study have looked to employ reflective practices as they critically self-review and group-review their approaches to their use of digital technology within their classes and across their schools. Teacher perception revealed:

> ***… I don't always achieve a shift in understanding with my student … sometimes you need to rewind … find the gap … look for physical resources … digital resources … try again*** (Arihia, School Two).

When building self-efficacy, or believing in oneself, reflective capacity to understand where the ability of the teacher lies and therefore what must be undertaken to build mastery, plays a part. The reflective capacity of a teacher can be considered one of the cornerstones of professionalism in teaching practice, where past instruction informs future practice (Farrell & Jacobs, 2016; Luttenberg et al., 2016). Mastery experiences occur when teachers are engaged in teaching practice and experience competency with technology integration, which then becomes instrumental in building teacher self-efficacy, which builds competency and so the cycle is established (Angeli & Valanides, 2018; Tondeur et al., 2017). Leader-driven PLD alone may not increase self-efficacy, as reflective capacity and the time for this may not occur, given competing teacher workloads (Barton & Dexter, 2020).

Competency with digital technology supports the effective teaching profile, when evidenced by observation within class. Teacher perception illustrated the following:

> ***… Proficiency with software will be ongoing as a teacher I think … and I guess different packages work better for different year levels too*** (Laurell, School One).

The teachers of this study are pro digital technology use, and it can be seen they wanted to be competent and proficient, to illustrate a quality delivery of teaching content. The need to foster the use of digital technology in class relies on teacher proficiency with digital technology, as evidenced above. In consideration of the mindset of teaching with digital technology, the balance between the differing areas of knowledge, referred to within the literature review as TPACK, prevails. Teachers target the achieving of the desired blend of all skills expressed by TPACK. Teacher perception revealed this about the use of digital technology:

> ***… Greater teaching flexibility required/not teaching at one level/supports 25 different levels if 25 different students*** (Taylor, School Three).

Competency is needed in teaching practice, with the use of digital technology, but also with knowledge content, supporting the TPACK model, to enable the above approach. Teacher self-efficacy can be enhanced with mastery experiences, which build confidence and expertise, making the use of digital technology appear more attractive for teachers (Moreira-Fontán et al., 2019). Implicit in the above statement is an able teacher who can support this approach in their teaching practice.

Insufficient PLD contributes to teachers low self-efficacy (Harrell & Bynum, 2018). Those teachers who are seen to have high teacher self-efficacy are seen "as being more likely to persist with challenging yet effective strategies" (Bruce et al., 2010, p. 1600). The understanding of a blended TPACK approach with the integration of digital technology within the teaching and learning environment allows for the realisation that only after PLD has been undertaken, and with repeat experiences of professional relevance can a knowledge of the right way to integrate digital technology occur (Angeli & Valanides, 2018).

This mindset of success or failure presents as a personal issue for a teacher, whose stability of identity can suffer, given the loss of reputation as the end result impacting upon teacher resilience. It appears the teachers of this study have actively built upon existing digital literacy and have worked toward the learning-centred classroom, using digital technology to assist in the successful shifts between teacher and student-centric models of teaching practice.

Teachers took risks when they experimented with their practice, because they could be destabilising their identity, making themselves appear to lack competency. The flow-on-effect of failure impacts upon student buy-in, and the targeted student outcome becomes harder to achieve. Teacher reputation within school could also suffer. The importance of success and failure is revealed with the following teacher perception:

> ***… You never know what their engagement is going to be like, that is the measurement of success or fail with risk-taking with digital technology*** (Arihia, School Two).

Teacher perception supports the issue of success and failure as occurring in a lesson. If quality PLD is a desire for teachers, the complement in teaching practice is the desire to be perceived as being competent as a teacher and therefore with the use of digital technology in the classroom. Competency with digital technology use before it is introduced into the classroom, as part of existing teacher practice, is considered necessary. This is because the teacher is in the position of being required to be the expert in order to support the student in a learning environment.

With the overview of veteran versus beginner teacher assumptions, the thinking could be that veteran teachers may have greater hesitation with integration of technology within teaching practice, given the digital native illustration. However self-efficacy is also a constraint that applies to digital natives, who are just as susceptible to the need for PLD support. The issue identified here is one of risk-taking. A teacher's ability to undertake risk has an impact on self-efficacy and hence has an effect on a teachers ability to integrate digital technology within their teaching practice (Li et al., 2015). Literature reveals that a teacher's ability to take risks within teaching practice, is tempered by the understanding that as the technology and software change, so too do the levels of self-efficacy of the individual teacher concerned (Holden & Rada, 2011). The conclusion reached therefore is of the need for PLD to continue in an ongoing manner, subject to these changes. Teacher perception revealed:

> ***… I don't like to fail … so … umm … I would probably say I am more on the conservative side of it, to say that I wouldn't go and gamble like …*** (Matiu, School One).

The stability of teacher identity is supported with PLD, which is an external enabling factor for teacher resilience. The school-wide approaches undertaken within this study, to develop mastery with a targeted software program support the building of teacher self-efficacy as an initial step to the integration of digital technology in teaching practice and therefore stability of teacher identity.

Teachers would like to undertake quality PLD, supported by the comments made in this study. All of the teacher participants in this study were receptive to the need for PLD. To achieve competency with the digital tools that enhance pedagogical shifts, and therefore student choice, can be further identified as a lesson that was successful. Successful undertakings assist with teacher identity and wellbeing. It appeared that self-efficacy with the teaching of mathematics and the incorporation of digital technology is supported with PLD for the teachers of this study, who desired competency when they delivered quality instruction.

6.16 Wellbeing and teacher identity

The impact of change through digitilisation within teaching practice, and across society generally, brings with it anxiety (Chandel & Ratra, 2020; Pfaffinger et al., 2020). This was evident within the COVID-19 pandemic as teachers were forced to adopt new teaching models reflective of the online environment. For some teachers, in primary and secondary schools, this was a completely new model of teaching and learning, negating face-to-face contact. Outside of a lockdown scenario, the march of technology and the digitilisation of society has had ramifications for individuals who are faced with changes to existing work environments, much like the education sector. With the advent of digitilisation in society (Petersen & Steiner, 2021), anxiety specific to digitilisation and the changes that occur as a result of new ways of being has had an impact upon organisational outcomes (Pfaffinger et al., 2020).

One of the teachers of this study voiced this aspect within a future focus targeting a lack of opportunity for face-to-face conversation and collegial interaction. Teacher perception illustrated the following:

> ***… But lots of people are there ten to fifteen minutes before and sit down and have a chat beforehand and that can be when reflective conversations happen … it can be when planning conversations happen … or people swap ideas with each other … building friendships … building collegiality … personal interaction … that didn't happen when we were online*** (Laurell, School One).

Teacher perception here confirmed a long-term concern with the direction of a fully digitised approach upon social interaction, across both student and teacher fronts.

One of the teachers of this study commented on the fact that there was always more to do; this was in connection with the software in use, updates, professional development, keeping abreast of changes, and largely trying to do your best, as much as humanly possible. Teacher perception revealed:

> ***… You always feel as though there is more that you could be doing or should be doing and then you just have to go actually, I am doing my best in the time that I have got … yeah*** (Laurell, School One).

The teacher here has seen the advantages and also the disadvantages attached to the day that has no end. With the perception of a day with no end, the advent of PLD, or the time/no time for PLD, becomes another anxiety. Teacher perception confirmed:

> ***… No time for PLD within a normal day, do that at home*** (Courtney, School Two).

Schools are known to be busy places. In consideration of the day without end, the issue of teacher burnout and attrition are of concern within a compounding scenario of teaching out-of-field and poor student performance in mathematics, (Du Plessis, 2020; Goos et al., 2020), among other factors.

Anxiety attached to the use of digitalisation can be thought of as relating to differing anxiety triggers. Social triggers, evidenced by teacher perception, looked at the prospect of social exclusion, which relates to social isolation, reflective of digital communication and loss of face-to-face conversation and interaction (Pfaffinger et al., 2020). This occurred with the forced adoption of the online teaching and learning model within a scenario of lockdown.

In the teaching world, the need to give feedback, scaffold, build rapport and relationships, necessitates face-to-face interaction. The strategy to negate social isolation with the advent of digitilisation is participation in digital changes in the workplace, or becoming part of the process of change (Pfaffinger et al., 2020).

This has occurred in the schools of this study, as all the teachers of this study responded to the targeted school goals, with the adoption of ILE's, OMIP's and adherence to school outcomes and student characteristics indicative of Generation Z and beyond.

The second category of digitilisation anxiety looked at organisational triggers, one of which focused upon the expectations that an organisation has as a result of the introduction of digital changes (Pfaffinger et al., 2020). This concept related to the expectation of being constantly available for work duties given smartphone and other new technologies, described as a workday with no end. The teachers of this study, in adopting new approaches and models to teach with, are faced with the constraints of time and workload. The strategy to negate this is clarification of expectations (Pfaffinger et al., 2020). Time can be a negotiated circumstance for some, with digital availability moving beyond classroom hours. This then becomes autonomous to the teacher and class concerned. Individual boundary settings can be introduced to allow alleviation of anxiety.

The third category of digitilisation anxiety is described as individual triggers and relate to personal development, lack of time for training, and the internal pressure to comprehend new technological developments (Pfaffinger et al., 2020). Within the overview of differing expertise levels with the use of digital technology across teachers in schools, schools strategised to facilitate growth in this area. One of the strategies employed was a whole-of-school approach with a common platform available to all teachers. This enabled the development of in-house school experts and whole-of-school expertise to be developed. The age of teachers did not impact upon digital technology use, with all staff requiring PLD with the introduction of changes to existing practice. The strategy to negate the third trigger, described above as individual, was organisational training (Pfaffinger et al., 2020).

These anxiety descriptors are not comprehensive, as those mentioned relate to the teachers of this study and the comments made within the qualitative research gathering undertaking. In addition, these anxiety categories relate specifically to digitilisation anxiety. Within the scenario of the COVID-19 pandemic, intense digitilisation of education occurred. The significant impact of several forms of anxiety, discussed, due to the pandemic scenario and the existence of digitilisation anxiety, was teacher burnout and attrition. Added to this was the further obligation by teachers, supported by government mandate, to undertake vaccination, if employment was to be ongoing during the time of COVID 19. This was ameliorated in April 2022 two years after the initial lockdown had occurred.

When teacher burn out and attrition is applied to the discipline of mathematics, in conjunction with the global and local shortage of mathematics graduates coming into the teaching profession, strategies that allow schools some forward planning could be considered to be necessary. Within scenarios of extreme events organisational responsibility for the wellbeing of teaching staff, with school-wide resilience building strategies like distributed decision-making, could assume importance. It is apparent that the issue of teacher resilience has necessitated consideration given the hitherto unprecedented scenarios of megatrends and pandemics. It would seem that factors that enhance teacher wellbeing could assume an increased importance within school leadership practice as a result, given the discussion above.

6.17 Summary of Question Three

In consideration of the process of digital technology integration in teaching practice, self-efficacy can be considered to feature significantly. The building of self-efficacy can be enhanced with opportunities for mastery, or exposure to repeat undertakings with the digital technology in question. Whether a teacher is a seasoned veteran, or a digital native immersed in digital interactivity, risk-taking and therefore the need for PLD has become an ongoing cycle that is presented within teaching practice. The reflective capacity for the teachers of this study had been undertaken frequently as self-review was ongoing in an environment of development with digital technological proficiency and constant change. PLD provided an avenue for teachers to grow their personal capabilities to enable successful outcomes to be achieved. The success of targeted outcomes influenced existing teacher perception when reflection of ways to improve existing teaching pedagogy was undertaken. Personal capabilities and the individual need for further development reflective of PLD were further influenced by individual classroom need.

The holistic approach to PLD, reflecting leader, and individual teacher driven approaches, is illustrative of school and individual need, inclusive of social media as an avenue of collaborative support for skill enhancement. The value of individual skill enhancement should be included by schools within the PLD skill strategy.

Teacher wellbeing, a component of teacher resilience, has increasingly assumed importance in this study, as a reflection of pandemic and digitilisation anxiety. The triggers of digitilisation anxiety were social, organisational, and individual. This is not a comprehensive listing of digitilisation anxiety but reflects the content of the narrative identified in this study. In an environment of low graduate scenarios, mandatory vaccination, lockdown and digitilisation anxiety, teacher burnout and attrition has assumed an importance.

It appeared that self-efficacy with the teaching of mathematics and the incorporation of digital technology was supported with PLD for the teachers of this study, who wanted to be competent to enhance existing teaching practice. It appeared that the issue of teacher resilience had assumed an importance hitherto unprecedented within the scenarios of megatrends and pandemics. It would seem that factors that enhance teacher wellbeing could assume an increased importance within school leadership practice as a result.

6.18 Overview of the Discussion Chapter

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

With the first research question we can see that physical shortages are impacting upon the classroom practice of some teachers of junior mathematics, with some teachers generously resourced. Within this we had the impact of student identity, identified by Generation Z characteristics and their need for digital interactivity (Hashim, 2018). The analysis of second order inhibitors and enablers identified that leadership style became a feature (Navaridas-Nalda et al., 2020; Thannimalai & Raman, 2018). Here students' expectation of device use as a norm was identified (Hashim, 2018; United Nations Sustainable Development Group, 2020). The impact of this was highlighted within teacher resilience, agency, and identity (Ainsworth & Oldfield, 2019; Beltman, 2021). The interplay of student identity, reflective of Generation Z characteristics, the degree of numeric understanding, digital awareness, and a mindset of change within leadership of schools assumed relevance also.

Task design became dependent upon software in use, with preformatted design indicative of OMIP's negating this issue. Teachers manipulated the classroom environment by lesson design to manipulate the resources available to achieve the desired student outcomes (Hanif et al., 2023). Without the use of OMIP's, task design necessitated support in the form of PLD.

With the advent of COVID-19 the adoption of an online teaching and learning model was presented. The digital competency of both teacher and student had an impact on teacher resilience within a COVID scenario (Beltman, 2021). As schools came out of lockdown, some schools did not continue with online learning post COVID, with the creation of inhibitors for some teachers. The effective teaching profile was endorsed in the findings of this study as reflective of digital competency by the teachers of this study. Refer Table Three.

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

The use of digital technology assisted with the ease of transition between teacher and student-centric approaches, reflective of teaching expertise and the learning-centred classroom (Bremner, 2019; O'Sullivan, 2004). The blanket approach or one-size-fits-all delivery of a lesson was not supported by the teachers of this study. The use of OMIP’s assisted with the inclusion of digital technology within teaching practice, and built upon teacher expertise, whole of school collective efficacy, school culture and the building of teacher and student identity (Donohoo et al., 2018; Hashim, 2018; Rashid et al., 2011). Teaching without digital technology made student engagement with Generation Z harder to achieve. The illustration of Generation Z characteristics, reflective of student identity, looked at digital interactivity as a norm (Hashim, 2018).

ILE’s and OMIP’s were in use, reflecting both negative and positive factors. The use of OMIP’s generated and supported collective efficacy, driven by supportive school leadership (Donohoo et al., 2018; Supovitz & Tognatta, 2013). This in turn allowed the ongoing development of collective and individual teacher expertise. Teacher resilience, agency and identity were strengthened and supported with their use of digital technology (Bagdžiūnienė et al., 2022; Beltman, 2021). Collaborative practice inclusive of wider digital networks, social media and community were enhanced with the use of digital technology, reflective of the technological advances of the current times (Anggoro & Rueangrong, 2021). PLD became an important aspect of digital technology use.

Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

Whether a teacher is a novice or a seasoned veteran, the need for PLD becomes ongoing within the environment of digital technology reflective of software use for the teachers of this study. The building of self-efficacy is instrumental in the integration of digital technology within teaching practice. Opportunities for mastery with repetition of software use is integral to self-efficacy (Barton & Dexter, 2020; Tondeur et al., 2017). The teachers of this study were either provided with school-wide PLD, built expertise inhouse to provide staff PLD, or sourced PLD individually, as desired, for classroom need. Mastery for the teachers of this study was developed over time with exposure to the software at hand.

Emphasis on the ability of teachers to undertake reflective practice to enable improved student outcomes forms a component part of a PLD skill strategy (ERO, 2012; Timperley et al., 2014). Teacher wellbeing and the impact of pandemics and digitalisation anxiety on teacher resilience reflect the narrative of the times (Chandel & Ratra, 2020; Pfaffinger et al., 2020). The focus of teacher resilience assumes an increasing importance in an environment of a shortage of mathematics graduates and therefore teacher graduates within mathematics (Ainsworth & Oldfield, 2019). The increasing number of teachers who teach out-of-field and those that have mathematics anxiety, and the time taken to improve knowledge content as a result, provides incentive for additional PLD (Goos et al., 2020). One of the avenues for PLD is the support provided by classroom digital packages. Equally teachers need to know how to use the selected packages and PLD supports this need. This was evidenced by the findings of this study. With the advent of COVID, PLD became an immersive experience for the teachers of this study and their use of software to enable competency.

The effective teaching profile has become a reflection of competency with the use of digital technology in existing teaching pedagogy. The focus on teacher resilience assumes importance, illustrative of the above. The next chapter identifies the conclusions made from the findings of this study. Teacher perception gave insight into the responses formulated that answered the questions targeting the aim. The influences that have shaped teacher perception are revealed.

CHAPTER SEVEN: CONCLUSIONS

Overview of this Study

The conclusions are based upon the teacher perceptions that inform this study as befits a qualitative approach for an IPA methodology. The conclusions are a result of analysis of participant teachers voice and subsequent insights into their mathematics teaching and learning. These perceptions and insight address the aim of this study which was to better understand year 7-10 mathematics teachers perceptions of the aspects that influence whether they use digital technology when teaching mathematics. The flow of the conclusions is linked to the discussion chapter, reflecting the same sequential order for both.

These conclusions occur in the order of sections One, Two and Three. Section One gives a summary of historic and current enablers and inhibitors to pedagogical change. These enablers and inhibitors are categorised as first, second, third and fourth order. Section Two undertakes summaries of the role of pedagogy with respect to enhancing quality instruction within teaching pedagogy thereby improving student outcomes with the use of OMIP's, ILE's and transformative practice. In this section, the focus is on pedagogical change with the use of digital technology. Conclusions have been reached relative to: section 6.8 Targeting improved student outcomes – OMIP's; section 6.9 Innovative learning environments and transformative practice; section 6.10 Transformative change with collective efficacy; section 6.11 Transformative practice and autonomous teaching methodology, and section 6.12 Transformative collaborative practice. Section Three has drawn conclusions based upon the existing role of professional learning and development and the change to this niche with the advent of digital technology use, inclusive of self-efficacy, wellbeing, and teacher identity.

This study enabled an in-depth look using a qualitative methodology where discussion from participants is valued giving insight for analysis using an IPA lens. Feedback from practicing teachers was dialogic in nature, with semi-structured interviews allowing the sharing of thought. The dialogue undertaken between teachers and the researcher added to the interview content and hence the quality of findings. As with all studies, this study also had limitations which are discussed after the conclusions and implications have been shared.

Three questions were undertaken to enable examination of the factors that may provide answers to the aim, as mentioned above. These questions were:

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/or not digital technology within their teaching practice?

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

As can be seen, the differentiation of the questions allowed a separate semi-structured interview and gathering of rich text data based upon teacher perception for each question, with these focused upon individual teacher practice from within the classroom. This allowed for the sharing of teaching experiences and teacher worldviews, indicative of an IPA approach. Teacher perception revealed the impact of the educational environment and hence what has occurred within respective classrooms as a reflection of individual schools. Analysis of the discussion chapter allowed the perceptions of individual teachers to inform future teacher practice. This would enable an increased understanding of teacher practice with the use of digital technology in the junior mathematics classroom.

This study was based upon current teaching practice in New Zealand. All of the teachers of this study worked to enhance existing student achievement with their use of digital technology. The students of this study were Generation Z, due to digital immersion from birth, however generations subsequent to Generation Z are also immersed in digital media from birth and conclusions reached could equally apply here.

Generation Z assumes IT skills autonomously and prefers first contact to be digital. These students typically depict a stronger digital technological prowess. They are likely to be the most technologically savvy generation of students because they have only ever known the world with mobile devices. Almost all tend to have knowledge of computer gaming, therefore they tend to acquire IT skills with ease. The teaching and learning environment may work to engage these students further with digital interactivity, in a bid to support improved student outcomes.

The prioritising of future resourcing initiatives within classrooms now implies a changed focus where resourcing may be reflective of Generation Z and their requirement for digital interactivity. The resources required to support digital interactivity may assume higher priority with schools and teachers, as they work toward supporting and maintaining the desired student outcomes. Software platforms, like OMIP's, could be viewed along the lines of textbook provision, where replacement and maintenance of textbooks is parallel with software subscription renewals.

As the uptake of software platforms like social networking, gaming, and online shopping increase within society, the progressive uptake of digital technology by educational institutions may be a medium that could be used to effectively engage with Generation Z, and subsequent generations, in an effort to enhance the desired learning outcomes.

Schools and teachers work toward increasing and maintaining student outcomes. The motivation and engagement of students is illustrated within teaching practice, by the inclusion of differing teaching strategies. The use of digital technology can be one of these, reflected, amongst others, as a medium, a second teacher voice, a tool, or an aspect of teaching pedagogy. A resilient teacher has the capacity to keep abreast of change and maintain a reflective response within their teaching pedagogy. The provision of digital resources has become a support to teaching practice. Digital technology is now considered to be an essential tool for the delivery of quality education (Abid et al., 2022). The maintenance and development of teacher resilience is reliant upon several factors discussed above, key to this is the nature of resources made available to teachers.

Conclusions addressing question one

Question One: How do teachers of year 7-10 mathematics perceive what influences their decisions to use/not to use digital technology within their teaching practice?

7.1 External first-order enablers and inhibitors

Conclusion One: The availability of device use has now shifted to reflect one student to one allocated device on demand, facilitating digital interactivity as a component of classroom learning. This contrasts with accessing devices when or if devices can be made available to classes. Some schools within this study have targeted and achieved this, other schools continue to work toward this desire. Schools that resourced their teachers with digital technology assisted with their development of creative pedagogy and enabled easy shifts between teaching models, indicative of the learning-centred classroom.

The teacher's perceptions were strongly indicative that the requirement to use digital technology supports the learning-centred classroom that exists within the practice of the participant teachers of this study. The convenience of use supports the shifts in pedagogy when responding to classroom influences. The development of teacher resilience can be supported when resources are made available to be incorporated within teaching practice as needed. Inhibitors are presented when resourcing is not practical with one device to one student and hence, teaching practice is restricted by the resourcing availability. Adequate resourcing enables the provision of choice within teaching practice, which in turn supports teacher resilience. School policy may have to reflect the resourcing of devices and software as a routine requirement within the junior mathematics classrooms, much along the lines of textbook provision.

7.2 Second-order enablers and inhibitors – teacher beliefs and change

Conclusion Two: The schools of this study have made decisions based upon affordability and the ranking of expense priorities. Device and software resourcing in mathematics classrooms is still considered to be an optional choice for some schools' leadership. Teacher belief is aligned to the characteristics of Generation Z and their requirement for digital interactivity.

Some schools within this study have yet to acknowledge the alignment of digital interactivity to enable enhanced student achievement within mathematics indicative of the delivery of quality education. Some of the school management systems tended to lag behind the nature of student identity, depicted by the Generation Z characteristics where students have ability and capacity to learn with digital interactivity. Declining student outcomes within mathematics necessitate risk-taking on behalf of teachers and schools, where the use of digital interactivity is part of a uniform, regular classroom routine. Management of some schools do not have an expectation that student learning requires device use, by choice, each lesson, as part of a standard teaching and learning practice. The advantages attached to the use of digital technology for a low decile school counteracts the socio-economic disadvantage and the larger drop in mathematics achievement. Teacher belief supported the use of digital technology for the teachers of this study to enable shifts in teaching pedagogy to advantage intended student outcomes.

7.3 Third-order enablers and inhibitors – task and lesson design

Conclusion Three: The teachers of this study responded positively to the range of opportunities to increase student engagement with the use of both teaching models indicative of the learning-centred classroom. Teacher perceptions reveal that the opportunities for digital interactivity within teaching and learning were perceived as a choice that should be available in all lessons and that students tended to consider that the use of devices was expected as the norm in classroom practice. Teaching practice with the inclusion of digital interactivity was thought of as satisfying a student’s needs. The teachers of this study were not restricted by task or lesson design/redesign but became creative within their pedagogy to overcome any constraints that may have existed to achieve the desired student outcomes.

Conclusion Four: Taking risks involved moving beyond the status quo of traditional practices to take advantage of new opportunities in digital technology. This often required overcoming prejudices about digital spaces in learning. Opportunities such as the ability to entertain students to enhance engagement whilst assisting the teaching and learning process has allowed for the provision of games, which has provided opportunities to faster/deeper knowledge and understanding of mathematical concepts and rules. Subsequently lesson design can be enhanced by the entertainment factor that these games provide.

Equally the opportunity exists for living textbooks in the form of OMIP's. The opportunity to maximise a second teaching voice such as in OMIP's, assisted teaching practice, even though by design OMIP's are teacher centric with delivery. The features that advantaged teaching pedagogy became the immediate response of a second teaching voice allowing the one teacher to one student scenario. Student outcomes can be supported and enhanced. In addition, when teachers of mathematics are out-of-field or suffer from mathematics anxiety due to the lack of content knowledge, the opportunity to develop knowledge content and pedagogical understanding using OMIP's overtime exists and could shorten the timeframe needed for teacher development indicative of a paucity of knowledge content.

As the use of a digital space within the classroom becomes varied, reflective of the above, some of the teachers of this study looked to redesign existing tasks and lessons to incorporate the use of digital interactivity. As the teachers explored change, both success and failure occurred. Some teachers felt the need to be supported by the wider environment as they took risks with changes to existing practice.

Conclusion Five: Some schools in this study have adopted participative decision-making which has enabled school-wide risk-taking to occur. Collective efficacy has assisted the intended achievement of school goals, targeting increased student outcomes with the use of digital platforms. Participative decision-making involves teachers' shared beliefs in their joint ability to engage in these courses of action necessary to implement change with digital platforms.

Some schools had adopted a collective response to digital interactivity school-wide, inclusive of junior mathematics. This meant that across the teaching and learning platform, all teachers have been monitored for their usage of OMIP's, expertise and experts on staff have been developed, and managers are in place that are directly aligned to professional learning and development updates. These managers target teachers for individual support opportunities.
Some of the schools of this study have endorsed digital use with strong supportive school leadership which has assisted collective efficacy with school-wide responses occurring to enhance existing student achievement within the junior mathematics environment. This has reflected participation nationwide of school and student profiles in the form of competitions and rewards (*Mathletics*).

Some of the schools of this study have relied on participative decision-making to bring about positive change with the use of digital platforms (*Mathsbuddy*, *Mathletics*) and collective efficacy. An awareness exists of the impact of group identity on individual identity if the epistemic focus of the group was at odds with the individual.

7.4 COVID-19 and the digital divide – enabler and inhibitor

Conclusion Six: Teacher resilience was challenged with the advent of COVID-19, due to the adoption of a new online teaching and learning model. School resilience practices assumed a collective response. The immersion in digital technology occurred.

One of the challenges to the learning programmes undertaken by the teachers of this study was the continuity of learning with the advent of a COVID-19 lockdown scenario. School-wide approaches targeting accountability of learning undertaken required the adoption of new intensely digitised online teaching and learning models. For some of the teachers of this study the COVID-19 scenario induced increased teacher stress at a professional level, as a reflection of the accelerative nature of enforced sudden change. It may be due to the nature of the pandemic, subsequent lockdown and overall environment, that quality instruction may not have been achieved. Additional factors of communication difficulties may have become demotivating for both teacher and student.

The total immersion in digital technology due to the pandemic and lockdown scenarios enabled teaching practice long term as teachers were exposed to software platforms hitherto unavailable indicative of resourced software and free trials. This became an opportunity to improve existing skills, by accessing different software platforms, inclusive of those platforms assisting in communication.

7.5 Summary of Conclusions for Question One

My first question targeted my aim which was to better understand year 7-10 mathematics teachers perceptions of the aspects that influence whether they use digital technology when teaching mathematics. A summary of the conclusions I have reached regarding the content of the findings made is listed below.

The barrier of device use has shifted to reflect one student to one device as opposed to accessing devices only when they were available. Some schools within this study have targeted and achieved this, other schools continue to work toward this desire. A leadership process that is aligned to both mathematics and technology perspectives was desired, by some teachers of this study, as a reflection of student identity and hence student outcomes. All the teachers of this study reported their teaching practice was illustrative of a learning-centred classroom as a teaching norm, with the use of digital technology, where and when able. The teachers of this study have perceived the need to be supported as risk-taking occurs with new teaching and learning approaches. Some schools within this study have adopted participative decision-making which has enabled school-wide risk-taking to occur. Collective efficacy has assisted the intended achievement of school goals, targeting increased student outcomes with the use of digital platforms. Teacher resilience was challenged within COVID circumstances due to the adoption of a new online teaching and learning model. School resilience practices assumed a collective response. Teachers were immersed in different software platforms, indicative of free trials and inclusive of social media as communication was targeted as a priority.

Implications:

The following is a range of implications which may help to develop greater digital technology practice in classrooms:

1. The resourcing of junior mathematics classrooms in terms of digital technology could be supported by senior leadership decisions regarding alignment to school policy on digital resources with a one device to one student policy (including device maintenance programmes, Wi-Fi connectivity, one-to-one device availability).
2. Senior and middle leadership planning and decisions made regarding the interplay between mathematics and technology within schools could require representation from the teaching faculty of the mathematics department. This may help to allow the development of a greater awareness schoolwide of the understanding of student identity, declining student outcomes, and the need for digital interactivity characteristic of Generation Z, and hence subsequent generations in the junior mathematics context.

3. Leadership in schools could foster a greater global awareness of the need to support new teaching and learning approaches and hence build a school-wide reflective capacity in readiness to accept change, indicative of pedagogy and the use of digital platforms and teaching models.
4. Leadership in schools could adopt participative decision-making. This could minimise the development of inhibitors to change assisting collective efficacy perhaps enabling school-wide targets to be met.
5. School leadership could monitor and maintain professional learning and development that fosters the alignment of online teaching and learning models to current practice to assist teacher resilience in scenarios of lockdown. This will require targeted resourcing of digital tools, reflected within the context of school policy as more than a one-off cost. This means budgeting for digital platforms across time as opposed to one-off decisions made that may or may not be approved each budget cycle.
6. School leadership could align themselves to the requirements associated with the delivery of quality education. This could assist in advantaging student outcomes reflecting socio-economic factors indicative of low decile schools.

Conclusions addressing question two

Question Two: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

7.6 Targeting improved student outcomes – online mathematics instruction programs (OMIP)

Conclusion One: The teachers of this study shifted between teaching models of student and teacher-centric confirming the learning-centred classroom as their norm within teaching practice. This was achieved with the use of digital technology inclusive of OMIP's, to engage student learning and advantage key competency development. For the teachers of this study digital interactivity in a teaching and learning programme is a desired norm within teaching pedagogy as it made the shifts in teaching models easier to facilitate, thus advancing pedagogy.

The learning-centred classroom achieved with the use of digital technology has become an expression of expertise within pedagogy and is thought of as enhancing the effective mathematics teacher profile. Teaching pedagogy is focused upon providing choice to students targeting digital interactivity to enhance student engagement and autonomy. Teaching pedagogy does not support a one-size-fits-all approach recognizing that students have individual learning needs.

It appeared that the teachers of this study have not adopted a blanket approach or one-size-fits-all model irrespective of the software in use. It seemed that the one-size-fits-all approach for teacher instruction is not applicable, either between individual teachers or across schools as school contexts were not uniform, teacher ICT skills were not uniform, and creative pedagogy was an expression of the individual teacher.

7.7 Innovative learning environments and transformative practice

Conclusion Two: The teachers of this study have reported that the ILE environments involving large class numbers have made individualised and personalised teaching approaches difficult to facilitate in the learning programmes, even with the use of digital technology. There was a greater need to redesign programmes and plan for larger classes, to overcome the barrier of large classroom numbers. Teachers were constrained by their physical environment to some extent making shifts in pedagogy with teacher and student centric models harder to achieve, even with the use of digital technology.

By physical design ILE's support digital technology use, and facilitate/force change to traditional teaching practice, however large classroom numbers have detracted from teacher-to-student contact, which has made transitional changes within lesson design harder to manage, detracting from the desired student outcomes. It appeared that achieving personalised learning to the satisfaction of the two teachers concerned was in transition. It appeared that digital technology was not always the preferred tool.

7.8 Transformational change with collective efficacy

Conclusion Three: Some of the schools of this study have acknowledged the role of mathematics anxiety that exists for staff as an ongoing issue and have adopted whole-of-school approaches that involve OMIP's and collective efficacy.

The transformative approach by some schools of this study with the use of OMIP's has allowed some continuity of structure to the delivery of a mathematics programme, where a shortage of either mathematics specialists or enthusiasm for mathematics may exist. School culture has been advantaged with this adoption of a common resourced platform, building teacher and student identity.

7.9 Transformative practice and autonomous teaching methodology

Conclusion Four: Some of the teachers in this study have been supported in their professional development with their use of digital technology within their teaching and learning programmes. These opportunities provided by school leadership have supported the development and maintenance of teacher identity.

With the maintenance of a learning-centred classroom with the use of digital technology, teaching practice, teacher expertise and teacher experts have enabled a digitised teacher identity for all teachers. Leadership initiatives driving change here are reflective of 21st century expectations.

Conclusion Five: Teaching pedagogy for some of the teachers of this study, with the use of resourced digital platforms, enabled the facilitation of student identity, agency, and autonomy.

Some of the teachers of this study were able to move beyond ability grouping and ability levels of individual students and embraced the development of student identity. Student-centred learning then became about the provision of opportunities that supported student agency.

7.10 Transformative practice, social networking, and collaborative practice and the use of digital technology

Conclusion Six: For some teachers of this study digitalisation has meant the development of both expertise with digital technology and specialist knowledge content over a wider range of digital media. This has further supported their commitment to school and teacher identity. The teachers of this study reported expertise with the use of digital technology across software platforms was an important specific knowledge to develop. The array and usage of digital platforms has meant the development of teacher identity across a range of forums. These forums are diverse within the bigger picture of teacher identity.

7.11 Summary of Conclusions for Question Two

When undertaking interview two the question targeted was: From the perspective of year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice? The following summary reflects the conclusions that I have been comfortable expressing.

For the teachers of this study, expertise to do with teaching pedagogy has become an expression of a learning-centred classroom with the inclusion of digital technology and OMIP's. The blended learning scenario has been seen to enhance engagement with Generation Z and advantage student learning and key competency development, enabling a more personalised approach.
The use of digital technology alone does not guarantee effective pedagogy. The advent of ILE's physical design supports the use of digital technology. However, the teachers of this study have found that the ILE environment, reflective of large class numbers, has made individualised and personalised teaching approaches challenging to achieve, even with the use of digital technology.
Moving between teacher-centric and student-centric approaches to teaching and learning, or transitioning, became harder to achieve with larger class numbers.
To negate a lack of personalised or individualised teaching approaches they have planned around the impact of large class numbers irrespective of the physical design of an ILE.

The teachers of this study, within their teaching pedagogy have looked to maintain a learning-centred classroom, indicative of an illustration of teacher perception of what is considered to be effective teaching pedagogy.
Some of the schools of this study have acknowledged the role of mathematics anxiety that exists for staff as an ongoing issue and have adopted whole-of-school approaches that involve OMIP's and collective efficacy. This approach of

collective efficacy allows for participative decision making which is reflective of school and teacher resilience practices. The use of OMIP's has allowed group responses to student outcomes and the development of individual teacher identity within a supportive environment. The change in teaching practice with the adoption of digital technology is supported across every level of digital expertise.

Some of the teachers of this study are supported in their development of a digitised teacher identity with leadership decision-making. The introduction of changes to teaching pedagogy with the inclusion of digitalisation has resulted in collective group interaction and responses, for most. For those teachers experiencing shortages in resourcing individual isolation within classrooms resulted. For those teachers who may be unable to align themselves to the epistemic focus of the group due to individual factors they may experience isolation. Leadership involvement becomes defining, as a support, when change is introduced to individual teachers when undertaking change to existing practice.

Teaching pedagogy for some of the teachers of this study, with the use of resourced digital platforms, allowed the facilitation of shifts in pedagogy at teacher discretion, indicative of a learning-centred classroom. This enabled the development of student identity, agency, and autonomy to be supported. The ability to support student learning within a learning-centred classroom with the use of digital technology, indicative of a second teaching voice, beyond the physical confines of the school day and classroom equate to the removal of inhibitors for some schools, teachers and students and support teacher identity.

For some teachers of this study digitalisation has meant the development of teacher expertise over a wider range of digital media to support the commitment to school and teacher identity. This facilitates the development and support of teacher identity.

For the teachers of this study, competing factors across a breadth of circumstances can significantly impact upon teacher resilience, identity and agency affecting teacher pedagogy and decisions that can be made when deciding or not to use digital technology. No one factor can be considered in isolation as they are representative of an integrated set of circumstances as befits the complexity of human interaction within educational environments.

Implications:

1. School decision-making could plan to further develop resourcing of digital platforms within the junior mathematics classroom, in line with a one device to one student allocation, to support the learning-centred classroom approach reflective of Generation Z characteristics and pandemic events.
2. Leadership decision-making could foster ways to compensate for the negative impact of ILE's with large class numbers within a STEM approach. An example here would be increases in staffing numbers or the provision of PLD by external organisations.

3. Leadership decision-making could structure the use of OMIP's as an initial step to the creation and maintenance of a digitised teacher identity. This structure could be reflective of a learning-centred classroom with the use of digital technology.
4. Leadership decision-making could reflect the impact of intense digitalisation upon teacher identity across a variety of digital platforms. The resourcing of the variety of available digital platforms and the need to keep abreast of the necessary skills involved creates the need to maximise participative decision-making. This could enhance collective efficacy and could allow the building of a desired school culture.
5. Leadership decision-making could allow for the specialist nature of the mathematics classroom and subsequently the teachers that are in these classrooms and plan for the development and maintenance of digital pedagogy. Accepted within the framework of digital pedagogy is that which is teacher-driven and, a reflection of the maintenance of current teacher practice, where digital expertise is seen as an illustration of the effective mathematics teaching profile.

Conclusions addressing question three

Question Three: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development?

7.12 Self-efficacy and professional learning and development

Conclusion One: The teachers in this study felt the need for timelier and more considered PLD which is reflective of more than an initial exposure or one-off encounter, therefore a combination of leader and teacher driven PLD when approaching digital integration within their teaching practice. Teacher driven PLD is undertaken by teachers in response to their immediate classroom needs and allows for reflective capacity to be developed as skills are enhanced. Teacher driven PLD can be undertaken as an individual or as a group.

Conclusion Two: Reflective capacity is enhanced when mastery with digital integration is achieved, which necessitates more than a formal PLD approach. Multiple opportunities to develop mastery with software platforms are sometimes needed (software dependent). Formal PLD is sometimes required to be undertaken, firstly as an initial exposure and thereafter with consecutive opportunities.

Conclusion Three: Digital competency is now viewed by the teachers of this study as inclusive of working across software packages, ongoing with the advent of change, and reflective of proficiency within teaching practice to fulfil the effective mathematics teacher profile.

Conclusion Four: For some of the teachers of this study mathematical knowledge is considered to be more important than the use of digital technology which is dependent upon the building of software expertise supportive to teacher self-efficacy.

Conclusion Five: The teachers of this study like to be perceived as being competent, with digital competency coloring their own perception of competency within their own teaching practice. The teachers of this study perceive their lessons within a framework of success or failure and are conservative with risk-taking when using digital media due to this.

7.13 Wellbeing and teacher identity

Conclusion Six: Some of the teachers of this study expressed digital anxiety with the prospect of increased digital interactivity as society continues to move forward. The reflection of this is the preference of Generation Z to experience their initial social contact digitally. How this will develop over time and how this will impact upon physical social interaction, is a question posed reflective of teacher anxiety.

Conclusion Seven: The teachers of this study experience the day without end and undertake PLD outside of school, with digital platforms able to support this. PLD is no longer driven by teacher choice, but by necessity given the software update scenario and the need to maintain a reflective profile to fulfil the effective teacher profile.

7.14 Summary of Conclusions for Question Three

When undertaking this semi-structured interview, this question was asked: How do teachers of year 7-10 mathematics perceive and make sense of their experience with different types of professional learning and development related to the use of digital technology in mathematics teaching?

The teachers of this study desire quality PLD with digital technology integration, allowing for self-efficacy to be developed. Quality PLD for the teachers of this study is reflective of both leader and teacher driven opportunities. Within this, reflective capacity allows for the development of software expertise to be achieved.

The teachers of this study see their teaching practice reflecting competency when their use of digital media across software platforms shows expertise. To enable expertise to be maintained, due to the nature of software development over time, there is an identified need for ongoing PLD. For some of the teachers of this study mathematical knowledge content is prioritised as being the most important aspect of their teaching practice.

As lessons are delivered the reflective capacity of the teachers of this study evaluate the success or failure of each lesson and are therefore conservative with risk-taking within their lessons. Digital anxiety is a factor that the teachers of this study experience, in addition to the anxiety attached to the day without end, with software platforms contributing to this. PLD is often undertaken outside of school hours to maintain teacher competency within teaching practice.

Implications

1. For the teachers of this study quality PLD, where possible, was important and could be fostered by school management when available.
2. School leadership may need to convey expectations attached to workload in consideration of the ongoing nature of PLD aligned to technology use and the day without end.
3. School leadership may need to develop onsite teacher experts to generate mastery experiences to support teacher self-efficacy allowing for individual teacher perception attached to competency across software platforms.
4. School leadership may need to involve teachers in change initiatives, to alleviate digital anxiety. Participative decision-making reflective of school resilience practices could assist in building teacher resilience to facilitate change.

7.15 Overall Summary of Conclusions

The aim of this study was to understand year 7-10 mathematics teachers perceptions of the aspects that influence whether they use digital technology when teaching mathematics. My conclusion regarding this, when undertaking an evaluation of all the data, is the mitigating circumstance of a variety of sometimes simultaneous influences that occur within the educative, school, and class environments that impact upon the teacher's decision to use digital technology within their lesson. These influences include leadership style, support, and active resourcing to name a few. When looking toward the future, my thoughts from undertaking this study are focused upon teacher resilience, agency, and identity to support and achieve increased student outcomes. The development of thought supports teachers who are not able to sustain resilience without active support from school leadership. The norm of teaching practice identified by the findings of this study is the learning-centred classroom with the use of digital technology.

7.16 New knowledge and contribution to the field

This study is a contribution to the pool of knowledge on digital learning environments research, where mathematics teacher perceptions of practice have been investigated. Findings reveal the effectiveness of the learning-centred classroom, with the use of digital technology, student identity (Generation Z), the role of teacher resilience and the importance of school-wide resilience practices. Also, through comparing and contrasting the findings with a range of research in the general scope of the study, it contributes to an understanding of the area in the overall international context.

Although the scope and nature of the IPA methodology does not allow me to generalise the findings of this study, this research gives insights and understanding of this particular context. It, therefore, enhances the overall understanding of the field and contributes by enriching our understanding of using digital technology when learning mathematics within the New Zealand context.

Two themes stood out, the role of teacher resilience in secondary mathematics teaching/education and the nature of the support needed to sustain teacher identity to allow innovative practice. Overall, the inhibitors of the adoption of changes to existing teaching practice did not appear to be teacher driven.

Collective efficacy was instrumental in allowing changes to existing teaching practice, enhancing individual teacher capacity and therefore student engagement and achievement. When senior leadership made decisions relating to software options without seeking participative decision making with mathematics teachers, resentment and subsequently inhibitors to the use of digital platforms were created for some of the teachers of this study. The commitment toward a change mindset reflective of risk-taking, when undertaking the use of digital technology within teaching practice in the junior mathematics classroom, was thus affected.

The adoption of online teaching and learning models, new to teacher and student alike, became a feature of classroom practice within a COVID pandemic scenario. This meant that the collective response within education became focused upon digital delivery. The advent of digital anxiety for teachers, given these compounding factors contributes to new knowledge in the field.
The nature of enforced usage of digital technology undertaken under duress due to the acceleration of a delivery timeframe prompted school and teacher responses reflective of pre COVID, during COVID and post COVID practices. The opportunity for teacher perspectives inclusive of the above, to the present time, is unique. The nature of teacher perspectives under this set of circumstance,

within a New Zealand locale, assists the development of a growing understanding of what this meant for teacher identity, agency, and resilience. In this respect, this contributes to new knowledge in the field.

One key contribution to new knowledge in the field relates to insights and understandings gained due to the local context that the research took place in, a small provincial city in NZ. These insights and understandings enhance the overall knowledge in the field by combining and comparing with other contexts to build a more fulsome, robust understanding and insights. This is also due to the methodology being IPA.

There is very little research undertaken in the year 7-10 age group examining the use of school-wide digital learning apps in a consistent way across mathematics programmes, especially regarding schools with a proportion of mathematics teachers, that have mathematics anxiety inclusive of teaching out-of-field relative to a paucity of knowledge content. As well, within this context, the influences of leadership, teacher identity, motivation and engagement were made visible.

I am hopeful that this research project may support future studies targeting teachers and school resilience practices. There exists a possibility of future and current pandemics and given this the desire to support the building of resilience practices within education. It could be said that these resilience practices could be of some importance, given the above. It may also allow the development of existing pedagogy to enhance the learning-centred classrooms, that have become the norm of teaching pedagogy, supported by this study. The opportunity to support teachers with changes to existing teaching practice could enable the positive promotion of student outcomes within mathematics which are presently declining. The implications for the future reflective of all the above suggested that teacher resilience is of importance when there is greater reliance on the use of digital platforms.

7.17 Limitations

The qualitative nature of an IPA study was the preferred methodology of this researcher for this study, as it has become a natural fit for explorative understanding of shared teacher perception. It is the intention of an IPA study to gain rich, in-depth insights related to teachers' perceptions and worldviews, within an authentic, real-world setting. The small size of the group of teachers taking part in this study (six), supports the rich, in-depth sharing of real-world perceptions. It may be due to the small size of this group of volunteer teachers that further studies may lead to a bigger range of findings. The limitation of size is then considered, with conclusions drawn unique to this group of teachers, and relate only to this group of teachers. It can also be said that these teachers are representative of a mix of schools from within a provincial region of the North Island of Aotearoa, New Zealand. These factors confirm that extrapolation of these results to other regions of Aotearoa, New Zealand cannot be assumed.

Access to professional learning and development is not as readily available due to the isolation of this area and hence we are considered by some to be "off the beaten track". The region is not a part of the central North or South Islands. This may have had an impact upon the nature of the support in the form of available PLD, that would enable changes to existing teaching practice that would allow digital integration to occur within teaching practice.

The qualitative nature of this study has meant that there was a large pool of data to gather, sort and analyse. What findings have revealed has not been discussed in entirety, but as an indicator of major themes that have presented, revealed by teacher perception. Therefore, there are some findings that have not been brought into this discussion. The IPA methodology undertaken, does not encompass, nor encourage a breadth of knowledge content, but a depth of knowledge content, about the issues attached to the questions investigated. The aim of this study has been principal to this focus. With this in mind, major themes were central and were the focus of this study.

I did not undertake this study with any preconceived thought about either school or teacher resilience, teacher agency, or teacher identity. Teacher perception and worldview led the researcher (me) here. The interplay between the use of digital technology within teacher pedagogy and teacher resilience has since been revealed due to the methodology of an IPA approach. It appeared that a teacher who has resilience will undertake change and continue to employ reflective capacity to advantage the students they teach. It also appeared that change is continuous for teaching pedagogy. It was also apparent that the learning-centred classroom was the norm for the teachers of this study, as they easily shifted between the two models of teacher and student centric practice, with the use of digital technology.

All the teachers of this study were proactive in voicing the positive attributes associated with the use of digital technology within teaching practice as an expression of the learning-centred classroom, and this could be seen as a limitation of this study. Equally in discussions held teacher perception has identified existing staff within schools that did not take part in this study who were not proactive, where schools have employed strategies that have allowed development of digital skills within whole of school approaches. The targeted in-depth responses as befits an IPA approach have revealed this and added to the content of the study, supporting school resilience practices.

The COVID scenario occurred within the timeframe of this study. This limited the availability of a larger number of participants, as some schools felt that teaching staff were already experiencing anxiety, and additional duties would escalate this. What COVID did do, was plunge teaching staff and students into an online teaching and learning model. The benefits to this study were in-depth evaluation of previously unconsidered issues like digital anxiety. In addition, the teachers of this study were able to express their opinion on key issues like their preference for effective PLD and what it looked like to them. As there were limitations experienced there were also benefits.

As this is a qualitative methodology, in-depth responses were sought. What this does not provide for the reader is quantitative data reflecting large numbers of participants canvassed over time that may be valued by some. What quantitative data would not have revealed are the significance of multiple influences occurring simultaneously and the impact of this upon teacher resilience when contemplating change to existing teaching practice, revealed by a qualitative approach like IPA. This project has highlighted common themes worthy of consideration in their own right and as such opens up a wealth of possibilities for future research.

7.18 Further research

Further studies undertaken could help to grow the body of knowledge identified above. This has some bearing on teacher attrition within the New Zealand education environment and the decline in student achievement within mathematics overall. This study confirms a learning-centred classroom with the use of digital technology within the junior mathematics classroom.

A need to undertake a further study to look at the interplay between the characteristics of Generation Z and the use of digital technology within teaching pedagogy to enhance student engagement and therefore student outcomes could be highly beneficial.

The accelerative nature of change in education due to the accelerative nature of technological advances within society allows consideration for the need for change, which may occur within the short term. Further studies reflecting a New Zealand context, that identify factors impacting upon teacher identity, agency, and resilience could allow increased understanding to be gained to advantage the teaching and learning environment.

The above suggests the need for further studies to better inform educators on the impact of these two factors within the New Zealand Secondary mathematics classroom. The first factor being the characteristics of Generation Z, and what this means for student engagement and student outcomes. The second factor being the role that teacher resilience, agency, and identity play in enabling teachers to undertake change to existing teaching and learning models. With the decline in secondary mathematics achievement consistent across consecutive timeframes, the need to promote further studies can be seen to be both relevant and important. Research studies that include student voice and observation would also increase the scope of understanding in this area. Likewise those with a mixture of qualitative and quantitative data.

In summary the opportunity this study has given the teacher participants has been to allow a reflective inquiry into their own learning by gaining knowledge of their own pedagogical skills in terms of digital technology use. It has been apparent that the teachers of this study desire the use of digital technology within their teaching practice. They have been able to acknowledge the changes within student identity that the characteristics of Generation Z exemplify. They have been able to confirm the adoption of a learning-centred classroom, indicative of the use of digital technology, for ease of transition. This study has been a useful process in identifying the effects and influences to bring about change in the mathematics classes of four different schools with six different teachers in a provincial locale. This opportunity to analyse the different views from teachers of diverse learners has been a powerful mechanism to reflect on classroom practices and to make informed steps about future learning in mathematics. There have been clear comparisons undertaken within leadership of these four schools and the impact of these decisions on teacher practice. Further studies that employ this methodology can only assist in the facilitation of improved teaching practice reflective of increases in the growing body of knowledge attached to the education environment.

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Appendices

Appendix 1: Reflective Journals

Questions asked to prompt response for the reflective journal

The overarching aim of this study is to understand Year 7-10 mathematics teachers perceptions of the influences on their use of digital technology.

Reflective Journal Instructions: Please spend one hour each week, for each question in bold. Questions are marked as week 1 through to week 4. Beneath each question in bold are prompt questions to assist in stimulating your responses targeting the main question.
Please select one lesson each week, where you have used digital technology and with this lesson in mind, respond to the question/s presented. Please spend no more than one hour approximately each week on this task for this specific lesson. There is no wrong answer. Complete honesty is the targeted response.
A journal will be provided to you each week, which will be collected, with a new journal given in return. Questions will be glued into the journal. Handwritten responses are fine.
You may choose not to answer a question.

Question One: What influences Year 7-10 mathematics teachers use of digital technology within their teaching practice?

Week 1. Question One: What influences Year 7-10 mathematics teachers use of digital technology within their teaching practice?
What influences you to use digital technology within your teaching practice for this lesson?
Do you feel supported by practice? By others? with your digital technology use?
Are you where you want to be? In your classroom? Beyond the physical boundaries of the classroom? With your use of digital technology?

Week 2. Question One: What influences Year 7-10 mathematics teachers use of digital technology within their teaching practice?
What do you value within your teaching and learning environment? An ordered environment? Focused teaching and learning? Does the use of digital technology help you achieve this?
Who do you maintain meaningful relationships within your teaching and learning environment when using digital technology? Expert students within class? Whānau dialogue and interaction? Collegial support and advice? Student/teacher interaction?
What makes you feel positive when using digital technology?

Week 3. Question One: What influences Year 7-10 mathematics teachers use of digital technology within their teaching practice?
Are you working in small groups, now that digital technology use has been in place for some time? Please give examples. If not, why not?
When you work with technology, what assumes greater importance within your teaching, the knowledge of your discipline or the ways of using the technology? Initially/long term? How is technology introduced?
When you are using technology are you more or less involved with the teaching process?

Week 4. Question One: What influences Year 7-10 mathematics teachers use of digital technology within their teaching practice?
Has the teaching role with the use of digital technology enabled you to assume more of a facilitative role? Please give examples. If not, why not?
Is the opportunity available to you with the use of digital technology to develop personalised learning for individual students? Please give examples. If not, why not?
What supports can you identify that would allow these practices (facilitation, small groups, using digital technology) to be developed further?
How has the use of digital technology influenced changes to your teaching practice?

Question 2. From the perspective of Year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

Week 1. From the perspective of Year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?
What do you value within your pedagogical practice? Does this reflect the use of digital technology?
If you were to place yourself with within your practice, who are you? A current practitioner/an expert teacher/a teacher who keeps abreast of changes/a teacher who evaluates effort/industry/outcomes? Please give an example.
What is the ideal situation – the situation that you want to bring about? When using digital technology?
What are the limiting factors preventing the achievement of that ideal?

Week 2. From the perspective of Year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?
What guides your practice? Teacher evaluation/student outcomes/the desire to keep doing it better? A particular approach/theory used to teach with?
What are the benefits to your practice when using digital technology? Time saving/reaching students who have been out of reach?
What are the shortcomings to your practice when using digital technology? Stuck behind technology?
Who or what supports your pedagogical practice? Is change to existing practice needed? Why or why not?
How much time do you spend reflecting upon your practice/each lesson? How frequently does this reflection occur? What changes occur because of your reflection?

Week 3. From the perspective of Year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?
In what ways would you or have you contributed to curriculum redesign to support the use of digital technology within your classroom? Has this occurred?
What system of teacher evaluation have you in place to allow a reflective process to occur when using digital technology? Please give an example of when you have been happy with your outcomes for your lesson or when you have not been?
When using digital technology do you give yourself permission to fail, in order to develop better practice? Please elaborate.
Do assessment practices support the use of digital technology? In what way?

Week 4. From the perspective of Year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?
How does appraisal impact upon your use of digital technology within the classroom?
In order to maximise your teaching practice, so that you could be the best teacher you could possibly be, what would you require when using digital technology?
Are you more or less responsive to student learning with digital technology use? Please explain.
How has the use of digital technology within the classroom caused you to evaluate your teaching practice? Do you see a developing scenario of proficiency occurring over time? A refining of the process of teaching with the use of digital technology?
Are you more or less culturally responsive when using digital technology, within practice, within your student/teacher relationship?

Question 3. What role and type of professional development is perceived by Year 7-10 mathematics teachers as being needed to effect changes to teaching pedagogy with the use of digital technology?

Week 1. What role and type of professional development is perceived by Year 7-10 mathematics teachers as being needed to effect changes to teaching pedagogy with the use of digital technology?
What do you value within your professional development? Formal/informal? When using digital technology? when implementing digital technology within your classroom?
What learning theory do you target to allow you to undertake teaching and learning in class? With digital technology?
What causes you/provides the impetus for you to pursue/undertake professional development? Formal/informal?
What impacts upon your desire to undertake/complete/pursue professional development?

Week 2. What role and type of professional development is perceived by Year 7-10 mathematics teachers as being needed to effect changes to teaching pedagogy with the use of digital technology?
Using an example from professional development what did you learn? Did you feel that your classroom benefited from this professional development? Did you feel that your practice benefited from your professional development?
What helped your learning with this professional development and digital technology use? Collegial support/school-wide initiatives/personal reflection/the type of professional learning undertaken/follow up support via YouTube?
How did you feel? Comfortable when undertaking professional development? Self-directed? Ticking the box because you had to? Disappointed in the type of professional development offered? Reinforced?
What could be done that would help your learning more? More time/less time?

Week 3. What role and type of professional development is perceived by Year 7-10 mathematics teachers as being needed to effect changes to teaching pedagogy with the use of digital technology?
When is professional development rewarding to you? With the use of digital technology?
Who decides what is relevant for you and under what circumstance?
Does collaborative task design, with digital technology in mind, appear attractive to you? Across colleagues? (same school), across schools? Individually? Why/Whynot?

Week 4. What role and type of professional development is perceived by Year 7-10 mathematics teachers as being needed to effect changes to teaching pedagogy with the use of digital technology?
If you are a recent teacher trainee, did you receive adequate training with digital technology within your teacher training programme? Did you have a set of standards that could assess your competency with the integration of technology?
If you are not a recent teacher trainee, have you worked toward degrees of competency or timeframes of digital technology use to support competency?
What does digital competency look like to you as a practicing teacher? Working across software packages? Working with software packages? Being able to pick up new software use within the classroom? Identifying relevant software packages for use? Easy student implementation and use? Growing confidence levels? Targeting competency? Please give examples.
When using pedagogic tools, for example GeoGebra, who provides the training for this? Yourself, if you have designed the lesson? Yourself, and a colleague if you are both using the same program and teach the same level and content? YouTube out of necessity? Please give an example.
Is ‘just in time’ training where you go with colleagues when in a real-life scenario of software training?

Appendix 2: Interview Questions

Interview 1

What influences Year 7-10 mathematics teachers use of digital technology within their teaching practice?

Are there any barriers experienced within the school system for hardware or software use?
What programs do you use within class and why?
Do you feel that there is a general feeling of support for continued digital technology use within your department?
Are your colleagues supportive to your use of digital technology?
Are there any nominated key personnel who provide expert training in any of your software programmes?
Is the use of digital technology a part of school culture? Supported by initiatives undertaken school-wide?
Is mathematics in your opinion well supported as a department and financially adequately resourced to allow the use of digital technology as you would desire it to be?
Is homework a digital option?
What technology is available for your use within your classroom and school-wide?
Do you feel as though you are “there” in your practice, or could you develop your practice more, with digital technology?
Are students independent when using digital technology or still reliant on your instruction? Is this a step-by-step process?
Do you think that task design is necessary, specific to digital technology use?
Are assessment materials weighted to acknowledge and support the use of digital technology?
It would be my intention to discuss any questions that have been provided in the reflective journal if any of the answers were relevant to the above. If they have not been used (prompts) I would ask them here.

Interview Questions: Interview 2

From the perspective of Year 7-10 mathematics teachers, what role does digital technology play in pedagogical practice?

What prevents small group usage with digital technology in your classroom?
As a mainstream subject, which generally means large classes in a public school, do you see personalised student learning programs as an option long term? Could this occur in stages?
What advantages do you see to rewriting the curriculum for digital technology usage and focus? What are the disadvantages? What do you think the focus would be to rewrite the curriculum in this way?

Is digital technology a tool used to support classroom activities? Could these activities occur without digital technology? What would the impact of this be?
Do you see the necessity to include digital technology in assessment and weight the assessment to reflect technology use?
Are you able to control the class as effectively when using digital technology, then when you do not?
Is digital technology use reflective of every student using digital technology, or yourself only giving instruction by power point or similar within class?
Do you switch between teacher-centric and student-centric practices with the use of digital technology? Without the use of digital technology? Which do you favour?
What do 21st century practices look like to you within your teaching practice?
Does social justice play a part in teaching practice?
How much importance do you place upon reflection? Reflective practices? How much time realistically can you apply to reflection within a normal day? Did your teacher training place emphasis upon reflective practices?
Please give an example of reflection and how you changed something that occurred within your practice as a result.
Do you believe student outcomes are advantaged with the use of digital technology? Do you assess this simply as a knowledge-based question?
Does the opportunity exist to employ collaborative practices, across schools, departments, or with colleagues? Would you use someone else's lesson design? Rework someone else's lesson design to fit? Use the idea and leave the details?

Interview Questions: Interview 3

What role and type of professional development is perceived by Year 7-10 mathematics teachers as being needed to effect changes to teaching pedagogy with the use of digital technology?

Have you undertaken formal professional development over the last five years? What was it?
Have you undertaken informal professional development over the last five years? What was it? How frequently did this occur? Can you see this diminishing or increasing over time?
Is digital technology a static or dynamic requirement and will proficiency with software packages be an ongoing requirement for professional development as a teacher?
Do you see yourself as ahead of your students, just ahead of your students, on a par with your students, slightly behind with your students, with digital technology use? Please give examples.
What professional development do you find as most advantageous – formal (school-wide, tertiary) or informal? (software related).
Do you prefer to be allowed to just get on with it, or is structured professional development more to your liking?
Is there enough time within your normal school day for professional development? How do you cater to this?

Is there a colleague you can approach for support when it is needed? With software usage, learning theory, student-centric practices? Or are you “on your own”?
Is there a school-wide focus on professional development? Or is it very much an individual choice? Formal/informal?
How does school culture support professional development?
How does appraisal ‘fit’ with professional development? Is it reflected?
Do you have a good opinion of the developmental initiatives that take place within your school that support teacher registration and do these initiatives reflect digital technology usage? Have they in the past?

Appendix 3: Letter to the Principal of Junior Mathematics Schools

Year 7-10

Kerry N-Garrett
Faculty of Education
The University of Waikato
Private Bag 3105
Hamilton 3240

DD/MM/2020

The Principal
………………………… High School/Intermediate School

Dear ………………………

I would like to request permission to allow participation by practicing mathematics teachers of Year 7-10 to take part in this 'teacher voice' study. I am currently enrolled as a doctoral student at The University of Waikato, New Zealand. The title of my research project is "Exploring shifts in teaching practice through the use of digital technology in the mathematics classroom: a qualitative study".

The overarching aim of this study is to understand Year 7-10 mathematics teachers perceptions of the influences on their use of digital technology. For this study to be undertaken I would like your permission to approach your Head of Department Mathematics and Mathematics Department teachers to see if any of your staff would like to take part. This would necessitate an initial meeting with your HOD Mathematics to relay the overview of this study and to arrange to have a meeting with the mathematics department, to see if there would be any willing participants.

Participants would be looking at anonymity and confidentiality. I would be looking at one, possibly two willing participants of Year 7-10 mathematics. Participants would be required to:

- Participate in keeping a reflective journal for each question, of which there are three.
- Each question will take a time frame of 4 weeks of no more than one hour each week, reflecting a lesson which had a component of digital technology use. This would reflect a 12-hour commitment overall.
- Prompts for each question will be provided, in the form of open-ended questioning.
- At the end of each 4-week time frame, interviews will take place of a 45-minute duration. There will be three interviews in total, one for each question. These will occur on site.
- Once interviews are transcribed transcripts will be checked for accuracy by the participant which I have allowed 30-minutes for.

- A 15-minute interval will be utilized for any questions needed to be made to check upon the accuracy of the intended answer.

I do not need to observe teaching practice, but may need to sight a lesson plan, portfolio, or appraisal document, at the discretion of the teacher for objective three of this study. Participants have the right to withdraw at any time of the study up until they have approved their transcripts or data analysis commences. Participants have the right to refuse to answer any questions asked. Participants have the right to withdraw at any time. While every effort will be made to protect the anonymity of all participants, this cannot be guaranteed. At the end of this study, a copy of my research findings will be sent to your school.

I am available for contact on 0279232135 or my email kerryng68@gmail.com. Clarification on any of the above can be sought from Assoc. Prof. Nigel Calder at the Faculty of Education, The University of Waikato, Tauranga. Email nigel.calder@waikato.ac.nz. Clarification on any of the above can be sought from Dr Katrina McChesney at the Faculty of Education, The University of Waikato, Tauranga. Email kmcchesn@waikato.ac.nz.
Thank you.

Yours sincerely

Kerry N-Garrett

Informed Consent
I give my permission for an approach to be made to the mathematics department of this school to see if there are any teachers willing to volunteer to participate in this research project.

……………………………………………………………………………….
Principal
XXXXXXXXX School

Appendix 4: Information Sheet for Teachers of Year 7-10

Mathematics Teachers

Kerry N-Garrett
Faculty of Education
The University of Waikato
Private Bag 3105
Hamilton 3240

DD/MM/2020

Dear Teachers
I would like to request permission to allow participation by yourself, a practicing mathematics teacher of Year 7-10, to take part in this 'teacher voice' research project. Please refer to the informed consent form, to be executed by yourself.
I am currently enrolled as a doctoral student at The University of Waikato, New Zealand. The title of my research project is "Exploring shifts in teaching practice through the use of digital technology in the mathematics classroom: a qualitative study". The overarching aim of this study is to understand Year 7-10 mathematics teachers perceptions of the influences on their use of digital technology.
For this study to be undertaken I would like to request your participation. Participants would be looking at anonymity and confidentiality. I would be looking at one, possibly two willing participants of Year 7-10 mathematics, per school. Participants would be required to:

- Participate in keeping a reflective journal for each question, of which there are three. Reflection on one lesson per week would be considered to be adequate. Over 12 weeks a total time commitment of no more than 12 hours would be required.
- Each question will take a time frame of 4 weeks, reflecting a lesson which had a component of digital technology use for each week.
- Prompts for each question will be provided, in the form of open-ended questioning.
- At the end of each 4-week time frame, interviews will take place of a 45-minute duration on site. This would answer the main question asked, with open-ended questions presented as prompts.
- Once interviews are transcribed transcripts will be checked for accuracy by the participant which I have allowed 30-minutes for. This will occur on site.
- A 15-minute interval will be utilized for questions to be asked relating to accuracy of the transcript.

I do not need to observe teaching practice, but may need to sight a lesson plan, portfolio or appraisal document, at your discretion for objective two of this study.

Participants have the right to withdraw at any time of the study up until they have approved their transcripts or data analysis commences. This means that participants can withdraw but if raw data has been collected and transcribed at the point of participant withdrawal, it may still be used in this research project. Participants can also decide not to answer any questions asked. Participants can withdraw at any time. While every effort will be made to protect anonymity of all participants, this cannot be guaranteed. Participants and schools will be allocated a number and identified by this number throughout this study.

I am available for contact on 0279232135 or my email kerryng68@gmail.com. Clarification on any of the above can be sought from Assoc. Prof. Nigel Calder at the Faculty of Education, The University of Waikato, Tauranga. Email nigel.calder@waikato.ac.nz. Clarification on any of the above can be sought from Dr Katrina McChesney at the Faculty of Education, The University of Waikato, Tauranga. Email kmcchesn@waikato.ac.nz.
Thank you.

Yours sincerely

Kerry N-Garrett

Appendix 5: Ethics Approval

Te Kura Toi Tangata
Division of Education
The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240

DivEd Ethics Committee

fedu.ethics@waikato.ac.nz
07 8384500 ext. 7870
www.waikato.ac.nz/education

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

4/11/2019

Dear Kerry N-Garrett

Division of Education Ethics Application Approved FEDU077/19

I am pleased to advise you that your ethics application for the project entitled "Exploring Shifts in Teaching Practice through the use of Digital Technology in the Mathematics Classroom: A Qualitative Study" was approved by Te Kura Toi Tangata Division of Education Ethics Committee on November 4th, 2019.

Please be aware that the Te Kura Toi Tangata Division of Education Ethics Committee must be advised (by memo) of any changes to the details recorded in your ethics application. Please send any such advice to fedu.ethics@waikato.ac.nz. You will receive a memo of approval once the change(s) has been considered.

Kind regards

Co-chair
Te Kura Toi Tangata Division of Education Ethics Committee