Investigating primary school teachers' pedagogy belief change about the use of ICT through a bespoke model of teacher CPD – The 4D model.

A Thesis Submitted in Fulfilment of the Requirements for the Award of Doctor of Philosophy, Trinity College Dublin, the University of Dublin

2024

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Declaration

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04 December 2023

Summary

A bespoke teacher Continuous Professional Development (CPD) model – The 4D Model – was designed to investigate teacher pedagogy belief change about the use of ICT at school. It incorporates elements of effective teacher CPD – content focus, active learning, collaboration, modelling, coaching and expert support, feedback and reflection and sustained duration – into its design along with activities where teachers raise implicit interconnected beliefs, experience multi-dimensional and bi-directional use of ICT, and engage in the co-creation, implementation and evaluation of teaching and learning activities at school while working as part of a team (Darling-Hammond, Hyler, & Gardner, 2017, p. 36; Ertmer, Ottenbreit-Leftwich, & Tondeur, 2015; Girvan, Conneely, & Tangney, 2016; Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2017). The research questions that guided this investigation are:

1. Do teachers' pedagogy beliefs change following their experiences with the 4D model? If so, then
2. How do teachers' beliefs change?
3. Why do teachers' beliefs change?

An interpretivist, constructivist paradigm guided the methodological decision-making, which ultimately resulted in Case Study being employed to develop an understanding of the participants' lived experiences with the model and to erect spatial and temporal boundaries around the participants' experiences with the model as they continued with their day-to-day teaching and learning at school (Merriam, 1998; Merriam & Tisdell, 2015; Reimann, 2011). An exploratory–explanatory case study design was employed. The exploratory element involved identifying the research questions and the procedures for the study. The explanatory element explains how or why teacher pedagogy belief change occurred. Eight primary school teachers participated in the main study in 2021–2022 and formed three teams. The participants – 6 female and 2 male - met online only and came from different sized primary schools across Ireland.

Qualitative data was collected and took the form of participants engaging in metaphor construction and reconstruction pre- and post-each of the two cycles of the 4D Model they engaged in across one school year (Leavy, McSorley, & Boté, 2007). Lesson(s) plans were also collected. After each cycle, each team engaged in a group interview, and each participant took part in an individual interview with the researcher, where they discussed changes in beliefs and practice in light of their experiences with the 4D Model.

Data analysis consisted of analysing teachers' metaphors against a pedagogy rubric (Beetham, Newman, & Sarah, 2018; Greeno, Collins, & Resnick, 1996; Leavy et al., 2007). The teams' lesson(s) plans were analysed for their alignment with the criteria set out in the UNESCO ICT Competence Framework for Teachers (UNESCO, 2018b). Group and individual interviews were coded, and categories were developed through open and axial coding (Bryman, 2016; Corbin & Strauss, 2014; Merriam, 1998; Strauss & Corbin, 1998).

The major findings indicate:

- Teachers strengthened or reconstructed beliefs about the use of ICT at primary school level. In this instance, teachers' reports indicated that their belief change involved a continuous process of resolving conflicts between new and pre-existing practice.
- Metaphor construction and reconstruction enables teachers to raise deeply held beliefs, and there is some evidence of interconnectedness between the six sub-categories of beliefs the participants submitted their metaphors under - learning theory, lesson design, student progression, assessment and feedback, design of the learning environment, and example activities.
- The 4D Model serves as an effective framework for teacher CPD, particularly in facilitating the belief change process – raising, experimenting, reflecting, and refining beliefs. This model incorporates a cyclical approach to experiential learning, where teachers engage in abstract conceptualisation, active experimentation, concrete experience, and reflective observation through a series of activities – reflect, design, develop, deliver, debug, and revisit – across multiple iterations.
- Teachers hold multi-dimensional pedagogy beliefs about learning theory, lesson design, student progression, assessment and feedback, design of the learning environment, and example activities. Engaging teachers in activities where they co-create, implement, and evaluate teaching and learning using ICT from multiple orientations causes them to integrate and differentiate between pre-existing and novel practice as a precursor to changing beliefs.
- The bi-directional relationship between teachers' pedagogy beliefs and their use of ICT can be leveraged as a strategy to enable teachers to change their pedagogy beliefs when working as part of a team.
- Working as part of a teacher design team can enable teachers to develop persistence with the implementation of novel ICT use at school.

Acknowledgements

Firstly, I would like to thank my supervisory team, Professor Brendan Tangney, and Assistant Professor Tim Savage, for their guidance, experience and understanding throughout this journey, without which it would have been impossible to have reached its conclusion. I would like to thank them for pushing me far beyond the boundaries of what I thought I was capable of, for emphasising the standard required to reach this level, and for their patience in working with a primary school teaching principal and all that entails.

Secondly, I would like to thank Dr Richard Millwood, my initial supervisor who sent me on this journey and who has become and remains both a critical friend and friend in earnest.

Thirdly, I would like to thank the 'Jollyologists' WhatsApp group for their humour, support, time, and know-how which has been invaluable.

Most importantly, I would like to thank my family, my wife Barbara, my daughter Alexandra, and my son Louis who have either been with me every step of this journey or who have joined in along the way. Without your understanding, support, and sacrifice, it would not have been possible to achieve this goal. I promise that the skills I have attained will enhance our lives and enable me to enhance your capacity as learners.

It is acknowledged that ChatGpt was used during the latter part of this research. When it was used its use involved seeking feedback on the author's written paragraphs and sentences with a view to achieving more clarity in sentence and paragraph structure.

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List of Abbreviations

21CL	21st Century Learning
3 x 3	Three Times Three Model
4Cs	Communication, Collaboration, Creativity and Critical Thinking Skills
4D	Design, Develop, Deliver, Debug
AC	Abstract Conceptualisation
AE	Active Experimentation
CE	Concrete Experience
CPD	Continuous Professional Development
DES	Department of Education and Skills
DLF	Digital Learning Framework
DoE	Department of Education
DSS	The Digital Strategy for Schools
DT	Design Thinking
ELC	Experiential Learning Cycle
ELT	Experiential Learning Theory
ERIC	Education Resources Information Centre
ETS	Educational Testing Service
ICT	Information and Communication Technologies
ISTE	International Society for Technology in Education
JCF	Junior Cycle Framework
JSTOR	Journal Storage
LS	Lesson Study
OECD	Organisation for Economic Co-operation and Development
P21	Partnership for 21st Century Skills Framework
PDST	Professional Development Services for Teachers
PDST TIE	Professional Development Services for Teachers Technology in Education
RO	Reflective Observation
STEM	Science, Technology, Engineering and Maths
TBS	Teachers' Beliefs Scale
TDT	Teacher Design Team
TPACK	Technology, Pedagogy, and Content Knowledge
TV	Television
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNESCO ICT CFT	The UNESCO ICT Competence Framework for Teachers

1. Introduction

1.1 Research Context

Internationally and in Ireland, there is a push towards 21st Century/transversal competency development at primary school (R. E. Anderson, 2008; Asia & Education, 2015; Voogt, Knezek, Christensen, & Lai, 2018). While this is a broad topic, there is consensus that it involves students' development of competencies - including communication, collaboration, creativity, critical thinking, and the use of ICT – by engaging in tasks such as planning strategies and procedures, choosing appropriate ICT tools, collecting, and organizing data, analysing and synthesizing, and disseminating and communicating (R. E. Anderson, 2008; Asia & Education, 2015; Voogt et al., 2018). Notwithstanding the efficacy of traditional pedagogy approaches for knowledge acquisition, it is argued that teachers should also approach 21st Century competency development through constructivist pedagogy and engage students in creative and innovative active experiences with ICT (Resnick, 2008).

Research literature indicates that students are more likely to use ICT as consumers rather than as creators, which does not lend itself to developing transversal skills (Asia & Education, 2015; Voogt et al., 2018). It is argued that one of the reasons for this is that teachers use ICT from prevailingly traditional rather than constructivist pedagogy orientations, which limits students' experiences of using ICT creatively and innovatively (Cuban, 2009). Such practice is misaligned with national and international policies such as the UNESCO ICT Competence Framework for Teachers (UNESCO) and the Irish Digital Learning Framework (DLF), which prescribe 21st century teaching and learning involving constructivist pedagogy and students using ICT creatively and innovatively (DES, 2015a; UNESCO, 2018b).

There are a range of barriers to teachers' constructivist use of ICT at school (Ertmer, 1999; Ertmer, Ottenbreit-Leftwich, & Tondeur, 2014; Tam & Trzmiel, 2018b). First-order barriers, such as access, infrastructure, school culture, and parents' expectations; second-order barriers, such as teacher knowledge, skills, attitudes, and beliefs along with operational, systemic, and definitional challenges are reported to limit teachers' and students' 21st Century teaching and learning at school in Ireland and abroad (Bray, Banks, Devitt, & Ní Chorcora, 2021; Ertmer, 1999; Ertmer et al., 2014; Tam & Trzmiel, 2018b). While there is support for teachers for overcoming first-order barriers, including funding towards the procurement of robust ICT infrastructure, and there is provision of teacher CPD aiming to address teachers' knowledge, skills and attitudes, there is less focus on CPD aiming to address teachers' beliefs, which have been identified as a key factor influencing teachers' use of ICT at school (Fives & Gill, 2014).

Continuous Professional Development (CPD) is the main way teachers' ICT practice is being addressed. However, traditional approaches that are off-site and one-shot in nature are not providing teachers with opportunities to make their pre-existing beliefs explicit or opportunities to experiment with those beliefs at school before reflecting on their outcomes as a precursor to refining their beliefs and adapting new practice (Guskey, 2000, 2002b). Moreover, they are lacking in support for teachers to enable them to overcome conflict with the traditional school environment (Somekh, 2008). Recent approaches to CPD, which have aimed to address these weaknesses have implications for CPD designers in the area of the relationship between teachers' pedagogy beliefs and their use of ICT. It is argued that effective CPD involves content focus, active learning, collaboration, modelling, coaching and expert support, feedback and reflection and is of sustained duration (Darling-Hammond et al., 2017). Moreover, team support is reported to enable teachers to overcome conflict between their new beliefs and practices and the traditional school environment (Girvan et al., 2016).

The literature about the relationship between teachers' pedagogy beliefs and their use of ICT to support 21st century teaching and learning reveals interesting insights for designers of teacher CPD (Tondeur et al., 2017). It is argued that beliefs are interconnected, and raising and challenging deeply held beliefs has more ramifications across the belief system (Ertmer, 2005; Rokeach, 1968). The belief change process involves raising, experimenting, reflecting, and refining beliefs. This is in alignment with an experiential learning cycle involving abstract conceptualisation, active experimentation, concrete experience, and reflective observation (Kolb, 2014). Teachers' beliefs are multi-dimensional, so CPD design should incorporate activities where teachers experience lesson design from multiple pedagogy orientations (Tondeur et al., 2017). The relationship between teachers' beliefs and ICT is bi-directional, so teachers can change beliefs through teacher-pedagogy-led and technology-pedagogy-led educational experiences (Tondeur et al., 2017).

This thesis describes a bespoke model of teacher CPD, the 4D Model, which engages teachers in raising, experimenting, reflecting, and refining beliefs. It was designed to investigate primary school teachers' pedagogy belief change about the use of ICT. It builds on effective CPD design by enabling teachers to make their deeply held pedagogy beliefs explicit through metaphor construction. Moreover, teachers experiment with their deeply held beliefs by co-creating, implementing, and evaluating teacher and technology-led use of ICT from multiple pedagogy orientations while working as part of a team online, across multiple iterations.

1.1.1 Research Aims

The research explored the 4D Model of teacher CPD for changing teachers' pedagogy beliefs about 21st century teaching and learning. The researcher sought to understand the participants' experiences and to identify and elaborate on elements of the CPD design that contributed to belief change. The researcher also sought to determine whether the 4D Model process is worthy of further study.

1.1.2 Research Questions

- Do teachers' pedagogy beliefs change following their experiences with the 4D model? If so, then
- How do teachers' beliefs change?
- Why do teachers' beliefs change?

1.2 Research Methodology

An interpretivist, constructivist paradigm underpinned the methodology, as it involved developing an understanding of the participants' lived experiences with the model at school (Bryman, 2016; Denzin & Lincoln, 2017). A case study approach was employed to erect spatial and temporal boundaries around the participants' experiences with the model as they continued with their day-to-day teaching and learning at school (Bassey, 1999; Merriam, 1998; Yin, 2018). Moreover, it enabled the explanation of an experience from multiple perspectives, the generation of theoretical understanding from the in-depth analysis of a small number of participants, and the analysis of belief change grounded in the data.

1.2.1 Research Methods

Qualitative methods were deemed most appropriate for investigating the participants' experiences with the 4D model. Reflection involved metaphor construction and reconstruction of teachers' beliefs before iteration one and after iterations one and two (Leavy et al., 2007). Lesson plans were collected that included evidence of teachers designing, implementing, and evaluating knowledge acquisition, knowledge deepening, and knowledge creation approaches to using ICT as outlined in the UNESCO ICT Competence Framework for Teachers (UNESCO, 2018a). Group and individual interviews were employed to dig deeper into the participants' experiences with the model (Gubrium, Holstein, Marvasti, & McKinney, 2012).

1.2.2 Research Design

The research sought to determine the 4D Model's efficacy and to generate a deeper theoretical understanding of which elements, if any, impact teacher belief change. An exploratory–explanatory case study design was employed. This involved a pilot and a main study. The main study involved 8 in-service primary school teachers working in three teams who met online only and implemented the 4D model across two iterations at multiple schools during one school year.

1.2.3 Data Collection and Analysis – Qualitative

A novel metaphor construction and reconstruction process was employed to enable the participants to raise their deeply held beliefs about teaching and learning using ICT. Pre-iteration one, participants submitted metaphors under several headings explained in section 6.4, using an online form. They revisited the metaphors post iterations one and two to reflect on whether there had been any changes in their beliefs. The participants either reconstructed their metaphors, submitted responses about changes that occurred, or indicated no change in their beliefs. The metaphors and responses were compared for their alignment with pedagogy orientations using a rubric adapted from Theory into Practice: Approaches to Understanding How People Learn and Implications for Design (Beetham & Sharpe, 2019).

The teams' lesson plan(s) were analysed for their alignment with the UNESCO ICT Competence Framework for Teachers (UNESCO, 2018b).

The group and individual interviews, which took place at the end of each iteration of the main study, were held online using Zoom conferencing, and they were audio recorded only. These data were analysed using qualitative methods, including focused and open coding, to construct categories grounded in the data (Corbin & Strauss, 2014; Merriam, 1998). The constant comparison method was applied to each of the categories that emerged for further insights.

1.3 Findings, Contributions, and Conclusions

1.3.1 Findings

From the research questions, the following findings emerged:

RQ 1: Do teachers' pedagogy beliefs change following their experiences with the 4D model?

Finding 1: Teachers self-reported strengthening and reconstructing their pedagogy beliefs about the use of ICT at school.

RQ 2: How do teachers' beliefs change?

Finding 2: In this instance, teachers' reports indicated that their belief change involved a continuous process of resolving conflicts between new and pre-existing practice.

RQ 3: Why do teachers' beliefs change?

Finding 3.1: The six sub-categories under which participants submitted their metaphors – learning theory, lesson design, student progression, assessment and feedback, design of the learning environment, and

example activities – displayed some interconnectedness. This indicates that metaphor construction and reconstruction enable teachers to access their deeply held beliefs. Moreover, there is some evidence of changes in one sub-category impacting upon changes in other sub-categories.

Finding 3.2: The 4D Model serves as an effective framework for teacher CPD, particularly in facilitating the belief change process – raising, experimenting, reflecting, and refining beliefs. This model incorporates a cyclical approach to experiential learning where teachers engage in abstract conceptualisation, active experimentation, concrete experience, and reflective observation through a series of activities – reflect, design, develop, deliver, debug, and revisit – across multiple iterations.

Finding 3.3: Teachers' pedagogy beliefs are multi-dimensional, including beliefs from a range of pedagogy orientations – traditional, individually constructivist, socially constructivist, and socio-cultural. There is evidence that teachers hold multi-dimensional beliefs about how students learn, lesson design principles, student progression, assessment and feedback, the design of the learning environment, and example activities. Engaging teachers in co-creating, implementing, and evaluating from multiple orientations is an effective strategy for changing teachers' beliefs as it engages them in activities where they integrate and differentiate between pre-existing and new practice.

Finding 3.4: The bi-directional relationship between teachers' pedagogy beliefs and their use of ICT can be leveraged and used as a strategy to enable teachers to change their pedagogy beliefs when working as part of a team.

Finding 3.5: Working as part of a teacher design team can enable teachers to develop persistence with the implementation of novel ICT use at school.

1.3.2 Contributions

The study makes two contributions to the literature. The first is the 4D Model of CPD for changing primary teachers' pedagogy beliefs about the use of ICT. The second is an enhanced metaphor construction and reconstruction process that can be applied to teachers' pedagogy beliefs about the use of ICT.

1.3.3 Conclusion

In conclusion, the findings of this study strongly suggest that elements of the CPD design contributed to belief change and that the 4D model is worthy of further study in the area of teachers' pedagogy beliefs and 21st century teaching and learning.

1.4 Structure of the Thesis

Chapter 2, The Literature review discusses primary teachers' use of ICT to support 21st Century teaching and learning at school, barriers to teachers' constructivist use of ICT at school, and CPD aiming to address this issue. The chapter highlights five propositions from the literature on teachers' beliefs that can inform CPD design in this area. Then, it discusses the Irish context before finishing with a set of propositions to inform the design of a model of teacher CPD aiming to change teachers' pedagogy beliefs. It concludes with the statement of the research questions.

Chapter 3, Design, outlines the design principles underpinning the 4D Model, it provides an overview of the model as used in this study.

Chapter 4, Research Methodology, outlines the interpretivist, constructivist paradigm the research sits within, it discusses appropriate methodologies in this area before ultimately deciding that Case Study is appropriate. Next, the research design outlines how an exploratory explanatory case study approach was employed across a pilot and main study.

Chapter 5, Pilot and Main Study, first describes the context within which the pilot study and the main study took place. It then reports on the learnings from the pilot that influenced the redesign of the model and the data collection tools. Following this, it reports on teachers' experiences during a main study with the model at school.

Chapter 6, Data Analysis, outlines how the data set made up of the participants' pre- and post-iterations metaphor construction and reconstruction, lesson plans, and group and individual interviews were analysed using qualitative methods, including open and focused coding.

Chapter 7, Findings, presents the findings of the study and describes how and why changes occurred in the participants' beliefs.

Chapter 8, Conclusions, reviews the findings. It discusses the contributions in relation to the relevant literature and the research questions. The chapter also addresses the strengths and limitations, the scope and transferability, and the ethical challenges encountered. It makes suggestions for future research. Finally, it concludes with a personal reflection.

2. Literature Review

2.1 Introduction

This chapter describes the literature search that was employed to understand the field of research and to contribute to the formation of the research questions. Section 2.2 reports on the literature search. The key concepts that were explored were 21st century teaching and learning, teacher Continuous Professional Development (CPD) Design, and the relationship between teachers' pedagogy beliefs and their use of ICT.

Section 2.3 reports how the push for 21st century skills and the use of ICT to enhance teaching and learning is impacting upon primary schools and teachers' classroom practice. Moreover, strategies for addressing barriers to teachers' ICT use at school have been employed in areas including digital infrastructure, teacher knowledge, skills, attitudes, and beliefs. It is argued that in the area of teachers' pedagogy beliefs and their use of ICT, further investigation is needed.

Section 2.4 explores teacher CPD in the area of teachers' pedagogy beliefs and their use of ICT. It indicates that situative, transitional models of teacher CPD may be more appropriate for changing teachers' pedagogy beliefs than transmissive and transformational models. Moreover, teacher CPD in this area can further support teacher belief change at school by engaging teachers in teacher design teams who co-create, implement, and evaluate novel ICT use at school.

Section 2.5 highlights recent research into the relationship between teachers' pedagogy beliefs and their use of ICT. It focuses on four elements argued to be valuable to teacher CPD design in this area. The elements include the following: (i) the need to raise deeply held implicit interconnected beliefs, (ii) alignment between an experiential learning cycle and the belief change process, (iii) pedagogy beliefs are multi-dimensional and engaging teachers in activities where they experience designing, implementing, and evaluating novel ICT use from pedagogical orientations that align and misalign with their pre-existing beliefs and practices is a potential precursor to change, and (iv) the bi-directional nature of the relationship between teachers' pedagogy beliefs and their use of ICT may be leveraged to enable change.

Section 2.6 sets the Irish context, the country in which this study takes place. In this section, it is argued that the Irish reform initiatives in the area of 21st century teaching and learning at school and the use of ICT to support students' development of 21st century skills have followed a similar path to the international context. Additionally, there is scope for the investigation of a bespoke model of teacher CPD aiming to change primary school teachers' pedagogy beliefs about the use of ICT at school.

Section 2.7 summarises the literature report, outlines the propositions for designing a bespoke model of teacher CPD aiming to change teachers' pedagogy beliefs and practice with ICT, and states the research questions to guide the study's goal.

2.2 The Literature Search

This literature search identified relevant research literature related to teachers' pedagogy beliefs and their use of ICT. Webster recommends focusing on concepts to develop the literature review (Webster & Watson, 2002). The concepts that were determined by the researcher to be explored in this study were 21C Skills, Teacher CPD, and the relationship between teachers' pedagogy beliefs and their use of ICT. Several approaches were employed to identify research literature about these topics. Webster recommends searching established research databases to gain access to the field (Webster & Watson, 2002). Electronic search engines, including Google Scholar and ERIC, and databases relevant to the field, including JSTOR, were used to develop a bank of literature relevant to the respective domains. To enhance the literature search's scope, synonyms and Boolean logic were used (Alzahrani, 2020). Examples of which are presented in Table 1.

Table 1: Search Terms and Synonyms

Key Word(s)	Synonyms
Teachers' pedagogy beliefs	Teachers' pedagogy/pedagogical beliefs, Teachers' beliefs about teaching and learning, the belief change process, multi-dimensional beliefs, bi-directional beliefs
Teachers' use of ICT	Educational use of technology, Technology enhanced learning, ICT*
Teacher Professional Development	Continuous professional development design, *PD, transformative CPD, evaluating teacher CPD, Teacher Design Team*
21st century learning	21st century curricul*, Knowledge Society, 21st Century workplace, 21st Century skills
School	"Primary School," "K-12" "Elementary"

A review of abstracts returned from the literature search established an initial set of relevant literature. The articles were stored electronically in Endnote and organised into themes using folders. Key information and summaries were recorded in the Endnote templates, which provided for quick access at

later stages. Webster also recommends creating a concept matrix that includes articles and concepts that crossover. A sample concept matrix is presented in Table 2.

Table 2: Concept Matrix

Articles	**Concepts**		
	21st Century Teaching and Learning	Teacher CPD Design	Teachers' Pedagogy Beliefs
Ertmer (2005)		X	X
Ertmer (2015)	X	X	X
Tondeur et al, (2017)		X	X
Guskey (2002)		X	X
Voogt & Roblin (2012)	X	X	
Mishra & Koehler, (2006)	X	X	

Levy, et al, (2006) recommend backwards and forwards searching. Backwards searching involves starting with seminal papers and working backwards through their list of references to identify the prominent authors in the field (Levy & Ellis, 2006). Forwards searching involves searching for literature that references the key papers previously identified. Literature mapping software (e.g., litmaps.com) was employed to generate seed maps of influential articles in this area. Seed maps connect titles of journal articles and books with the authors they reference and the authors who reference the relevant literature. This approach enabled the exploration of the interconnection of research literature not often possible with traditional search methods. Figure 1.

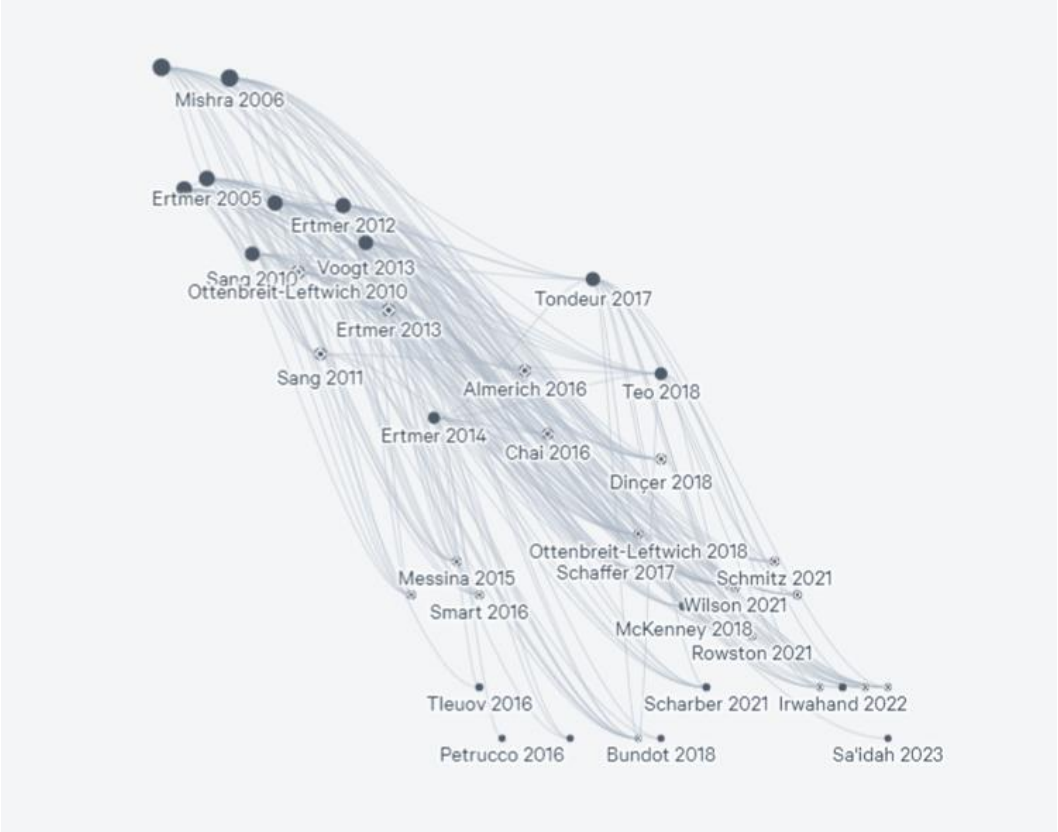

Figure 1: Seed Map of Interconnected Papers

To refine and specify the focus of this literature review, terms outside the research scope—such as higher education or pre-school teachers, teachers who typically work with students aged 2–4 years—were identified. This involved using more precise keywords and search parameters. Additionally, a set of inclusion and exclusion criteria was devised to streamline the incorporation of theoretical literature and empirical studies into this review (Machi & McEvoy, 2021; Petticrew & Roberts, 2008). The literature search was iterative and involved a continuous cycle of searching and reviewing established and up-to-date available research. Having described the literature search and review process, the following section reviews primary school teachers' use of ICT to support 21st Century teaching and learning at school.

2.3 21st Century Learning and Teachers use of ICT to Support it

This section explores three areas: The first discusses the impact of the push for 21st century teaching and learning on primary schools. The second discusses the impact of the push for 21st century teaching and learning on teachers' practice. The third argues that even though other barriers towards teachers'

adoption of ICT use at school exist, the alignment between teachers' pedagogy beliefs and practice indicates that the relationship between teachers' pedagogy beliefs and their use of ICT is a promising area for investigation.

2.3.1 The Impact of 21st Century Teaching and Learning on Primary Schools

Within the context of the push towards 21st century skills development at school, primary schools need to adapt to prepare students for legitimate participation in the 21st century. Internationalisation and globalisation are impacting upon primary schools. Internationalisation refers to adapting products and services to cater for multiple countries or cultures. Globalisation refers to the processes by which businesses, ideas, cultures, and lifestyles are becoming more integrated and interconnected across the world (Care, 2018). These concepts are impacting higher and post-primary education sectors, and they also have implications for primary schools (Chalkiadaki, 2018; González-Salamanca, Agudelo, & Salinas, 2020; Voogt et al., 2018). At primary school level, new policies and updated curricula now prescribe adaptions to the subjects being taught and to the visions and aims of schooling in the 21st Century. Countries, including Australia, Belgium, Ireland, Sweden, and the USA, have all responded to the impact of globalisation and internalisation. They have invested in schools' ICT infrastructure to support digital transition and introduced new policies focusing on quality, equity, inclusion, and gender equality, to support their emerging multi-cultural populations (Commission, Directorate-General for Education, & Culture, 2022; OECD, 2023). New policies and their emphasis on digital transition are requiring schools to rethink their traditional organisational structures. They have to integrate new nationalities and cultures into their student populations and new tools into their existing infrastructure. Primary schools are experiencing a period of transitional change that is further complicated by growing demands from industry for graduates with skills that traditionally receive less emphasis during class time.

Internationalisation, globalisation, and the rapid advancements in digital technologies are also changing the way people work, which is contributing to calls for students to develop new skills at school (Care, 2018). Although unevenly distributed, countries investment in digital infrastructure has enhanced access to ICTs across the world (UNESCO, 2023a). Enhanced access to digital technologies has increased global communication. Consequently, employees across various industries are now interacting more frequently with colleagues from different countries and cultures than in previous decades. Coupled with the growing trend of artificial intelligence technologies being employed to automate many of the tasks that employees have traditionally carried out, current primary school students will require new skills as they will be

competing for jobs that are not yet in existence (Forum, 2023; Frey & Osborne, 2017). For instance, jobs in traditionally high employment sectors such as transportation and material moving, production, sales, and office administration are under more threat of automation than jobs relying on higher levels of social intelligence, creativity, and perception and manipulation such as fashion designers, surgeons, and public relations specialists (Forum, 2023; Frey & Osborne, 2017). Moreover, rapid developments in technologies are impacting these areas meaning employees will have to be more adaptive than in the past; they will have to be lifelong learners, and the ability to learn, unlearn, and relearn will be a critical factor that shapes their future careers (Dunlap & Lowenthal, 2013; Forum, 2023). Primary school education has a role to play in developing students' capacity to live and learn in the real world, and there is a need for primary school education to prepare students for working and living in contemporary society alongside digital technologies. The new demands being placed on graduates entering the workforce are contributing to pressure being placed on both post-primary and primary schools to contribute to the new toolkit demanded by the 21st century. Alongside those challenges, primary schools are being tasked with adapting to students' use of ICT in their everyday lives.

However, there is a significant contrast between ICT use in everyday life and at school (Shapiro, 2019). Whereas outside of school, both teachers and students live in a digitally interconnected world, at school, ICT use is less prevalent. Outside of school, teachers and students are active users of social media applications such as Facebook, TikTok, and Instagram, along with videogaming using Xbox, PlayStation, and Nintendo Switch; smartphones; and artificial intelligence. At school, students' and teachers' use of ICT prevailingly involves using interactive whiteboards to communicate information, or presentation software to deliver content (UNESCO, 2023a). While those strategies enhance the delivery of content knowledge, there is a growing disconnect between living and learning in the real world and at school (Shapiro, 2019). For instance, whereas students are the primary users of ICT outside of school, at school the teacher is the primary user. Gomez-Fernandez (2021) argues that this is important to address, as there are links between students' use of ICT at personal and school levels and academic performance in areas such as mathematics, science, and reading comprehension (Gómez-Fernández & Mediavilla, 2021). For instance, students who learn to use ICT to support their learning at school and for homework perform better than students who prevailingly use ICT outside of school for entertainment (Gómez-Fernández & Mediavilla, 2021). Teaching students how to use ICTs to support their learning can reduce the disconnect between students' experiences inside and outside of school, and it can have a positive impact upon students' academic achievement.

2.3.1.1 21st Century Learning Policies and Criticisms

Globalisation, internationalisation, the way we do work, and ICT use in everyday life necessitate changes at primary school level. In response to trends in globalisation, internationalisation, and the rapid development of ICT - and its impact on life, work, and learning - the push for 21st century teaching and learning (21CL) at school is evident in several influential policies that have implications for primary school education (Chalkiadaki, 2018; Mishra & Mehta, 2017; Voogt & Roblin, 2012). While not without its critics, there is general consensus that students should develop more sophisticated communication, collaboration, creativity, critical thinking, use of ICT, and life skills. Those skills are prescribed in a wide range of policies, including the Partnership for 21st Century Skills Framework (P21, 2006); the EnGauge Framework from Metiri/NCREL (2003); the Organization for Economic Cooperation and Development (OECD, 2005); American Association of Colleges and Universities (2007); the International Society for Technology in Education (ISTE, 2007); the Educational Testing Service (ETS, 2007); and the UNESCO ICT Competence Framework for Teachers (UNESCO, 2018). Although many of those skills are not new to primary school teaching and learning, they have traditionally received less emphasis than foundational skills such as reading, writing, and mathematical skills (Chalkiadaki, 2018). Now there is an expectation from policy makers that 21CL skills will be given more emphasis (Mishra & Mehta, 2017). Integrating 21st century learning skills into primary school teaching and learning is proving challenging particularly in the area of teachers' use of ICT.

The 21st century learning (21CL) policy initiatives are placing new expectations on teachers. For instance, the UNESCO ICT Competence Framework for Teachers lists the types of changes primary school teachers need to make to prepare students for living and working in the 21st century (UNESCO, 2018b). It defines the needs of contemporary societies to put in place mechanisms to build workforces with ICT skills that are reflective, creative, and adept at problem-solving; to enable people to be knowledgeable and resourceful to make informed decisions; to encourage all members of society to participate fully in society; and to foster cross-cultural understanding, tolerance, and the peaceful resolution of conflict (UNESCO, 2018a, p. 7). Moreover, it states that '*teachers need to be equipped to guide the next generation to embrace and be able to achieve these goals*' (UNESCO, 2018a, p. 7). The UNESCO outlines six aspects of teachers' professional practice that require adaption: understanding ICT in education policy, curriculum and assessment, pedagogy, application of digital skills, organization and administration, and teacher professional learning (UNESCO, 2018a, p. 8). Moreover, it outlines successive stages of teachers' development in making pedagogical use of ICT: Knowledge Acquisition, where teachers acquire knowledge about using technology and basic ICT competencies; Knowledge Deepening, where teachers

acquire ICT competencies enabling them to facilitate student-centred, collaborative, and cooperative learning environments; and Knowledge Creation, where teachers acquire competencies in modelling good practice and designing learning environments that encourage students to create the kinds of new knowledge required for more harmonious, fulfilling, and prosperous societies (UNESCO, 2018a, p. 9). The UNESCO policy, like others, prescribes the types of changes primary schools are being asked to implement: it makes a clear statement that schools should focus on responding to the challenges that globalisation and internationalisation are bringing to contemporary societies. Moreover, it prescribes distinct stages of pedagogy-informed ICT use that incorporates both traditional and 21st century learning skills; however, it emphasises that progression involves teachers acquiring the skills necessary to design teaching and learning environments that support students' knowledge construction.

While it may be argued that changing teachers' practice can enable students to be better prepared for living and working in the 21st century, others are not as convinced that 21st century teaching and learning is clearly communicated to teachers at school (Hussin, 2018; Mishra & Mehta, 2017).

Mishra (2017) argues that the push for 21st century teaching and learning has led to three myths (Mishra & Mehta, 2017): that disciplinary knowledge is easy and is about memorizing and retrieving facts; that communication, collaboration, critical thinking, and creativity are content neutral; and that there is a simple answer to learning in the 21st century (Mishra & Mehta, 2017). They investigated practitioners' beliefs about the types of knowledge that are important for 21st century teaching and learning through the lens of the '3 x 3' (three times three) model of 21st century learning proposed by Kereluik et al, (Kereluik, Mishra, Fahnoe, & Terry, 2013). This model was built upon a synthesis of 15 key documents related to 21st-century learning that indicated a convergence onto three categories and nine sub-categories presented in Table 3.

Table 3: Categories and Subcategories

Category	Domains
Foundational Knowledge	Digital / ICT literacy Cross-disciplinary knowledge Core-disciplinary knowledge.
Meta Knowledge	Creativity and Innovation Problem-solving Critical Thinking
Humanistic Knowledge	Life / job skills Ethical / emotional awareness Cultural Competence

Foundational knowledge includes digital/ICT literacy, cross-disciplinary knowledge, and core-disciplinary knowledge; meta knowledge includes creativity and innovation, problem solving and critical thinking, and communication and collaboration; humanistic knowledge includes life/job skills, ethical/emotional awareness, and cultural competence (Kereluik et al., 2013). From a survey of 518 educators, they reported that practitioners valued meta knowledge over humanistic knowledge and rated foundational knowledge as the least important of the skills for students to learn to adapt to the 21st century (Mishra & Mehta, 2017). According to the authors, this view is narrow and reflects the popularisation of 21st century teaching and learning catchphrases, such as 'the 4Cs'. Moreover, there are several assumptions practitioners are making that are overlooking core skills students need to advance in professional communities (Mishra & Mehta, 2017).

More recently, there are arguments that 21st century skills are outdated, and instead, there needs to be focus on Education 4.0 to adapt to the demands of Industry 4.0 (Hussin, 2018). Education 4.0 refers to the anticipated future of education when it adapts to the fourth industrial revolution. It is anticipated that increased focus on smart technology, artificial intelligence, automation, and data exchange in industry will have an impact on education in much the same way as previous industry iterations (González-Pérez & Ramírez-Montoya, 2022). For instance, Industry 1.0 involved the use of water and steam use to mechanize production. Industry 2.0 involved using electric power to create mass production. Industry 3.0 involves using electronics and information technologies to automate production. Industry 4.0 involves

modern technologies blurring the lines between physical, digital, and biological worlds (Hussin, 2018). Each of these industrial revolutions has had influence on education and schooling. From the perspective of Industry 4.0, nine trends have been identified related to Education 4.0. These include (i) anytime, anywhere learning; (ii) personalised learning tailored to individual students; (iii) students choice in determining how they want to learn; (iv) increased exposure to project-based learning; (v) enhanced exposure to hands-on learning through field experience; (vi) the need for students to develop data interpretation skills by applying their theoretical and reasoning knowledge to make inferences based on logic and trends from given data sets; (vii) students will be assessed differently and conventional platforms may become irrelevant or insufficient; (viii) students will have a voice in curriculum design and review; and (ix) students will become more independent in their learning (Hussin, 2018). These trends will see more of a shift in the major learning responsibilities from the instructors to the learners (Hussin, 2018).

Notwithstanding the concerns about 21st century skills, it is evident that primary schools need to adapt to teaching and learning in the 21st Century. The impact of globalisation, internationalisation, and ICT use is contributing to more multi-cultural environments than in previous generations and while students are experiencing ICT use outside of school there is a disconnect with how they are using ICT at school. The disconnect between teachers' and students' use of ICT at school and outside school is leading critics to question the appropriateness of teachers' established practice for students' development of 21st century skills at school. Hence the need for this research's proposal for new CPD.

2.3.2 The Impact of 21st Century Teaching and Learning on Primary Teachers' Practice

Against the backdrop of the push towards 21st century teaching and learning at school, it is argued that there is a growing need for teachers to create innovative teaching and learning activities with ICT (R. E. Anderson, 2008; Care, 2018; Voogt et al., 2018). Anderson (2008) argued that teaching and learning 21st century skills involves knowledge-related task phases and skills, and existing curricula and teaching and learning practices were insufficient for their development (R. E. Anderson, 2008). Whereas knowledge-related task phases involve planning, strategies, and procedures; choosing appropriate ICT tools; collecting, and organising knowledge; analysing, synthesising; and disseminating and communicating, the prevailing teaching and learning at school at that time focused on transmission approaches and knowledge acquisition (R. E. Anderson, 2008; Voogt & Roblin, 2012). Moreover, knowledge-related skills - including accessing, assembling, re-organizing knowledge; interpreting, analysing, and evaluating; collaborating on projects and teamwork; complex problem solving; generating knowledge products;

communicating, presenting, and disseminating; and selecting appropriate tools and evaluating impact - were being given less emphasis at school than 'routine cognitive tasks' (R. E. Anderson, 2008, p. 12).

Following on, the discussion turned towards the adequacy of teachers' use of ICT to support 21st Century teaching and learning at school (Voogt et al., 2018). It became apparent that teachers' prevailing use of ICT was oriented more towards enhancing teacher productivity and efficiency than towards enhancing students' knowledge-related skills through knowledge-related task phases (Voogt et al., 2018). Whereas students' proficiency in 21st century skills was deemed necessary for citizenship in the 21st century, at school, students were mastering routine cognitive skills.

Emphasis on teachers' use of ICT to support 21st Century teaching and learning at school shifted away from knowledge-related skills and task phases towards the influence of ICT. on learners (Sumardi, Rohman, & Wahyudiati, 2020; Voogt et al., 2018). The change in focus towards students' experiences with ICT has further implications for teaching and learning at school. When it became apparent that students were prevailingly consumers rather than creators with ICT, and they were becoming anxious and overwhelmed by technology, it was argued that emphasis needed to be placed on students' emotions, motivation, creativity, grit, and attitudes, along with 21st century skills and task phases (Lamb, Maire, & Doecke, 2017; Voogt et al., 2018). Moreover, it was deemed critical that students develop knowledge creation and innovation skills with ICT to combat their tendency to be consumers rather than creators with technology (Voogt et al., 2018).

2.3.2.1 Teachers' Pedagogy and ICT

In turn this has led to a focus on teachers' pedagogical practice when using ICTs. Fullan (2014) reports that students' brain activity is nearly non-existent during traditional teaching and learning, when the teacher is at the front of the classroom transmitting knowledge and students are passive (Fullan & Langworthy, 2014). Fullan argues that new pedagogies are necessary to provide students with creative and innovative learning experiences with ICT at school (Fullan & Langworthy, 2014). New pedagogies can lead to deeper learning that enables students to develop 'the creating and doing dispositions' necessary for living and learning in the 21st century (Fullan & Langworthy, 2014). While the skills that are the focus of new pedagogies are not new, what is new is the focus on developing active learning partnerships between teachers and students, and shifting educational responsibility from the teacher to the student (Chalkiadaki, 2018; Hussin, 2018). While there is much evidence of active, constructivist teaching and learning at primary school level, traditionally, it has involved a clear line between the teacher and the

learners. What is being proposed by authors, including Fullan, is more of a partnership between teachers and students. For instance, it is argued that teachers and students can learn together when using ICTs for teaching and learning at school, and such practice can aid bottom-up change. This change can help to overcome the discrepancies between policymakers' visions of new practice and practices that teachers can achieve at school.

Even though primary school teachers incorporate constructivist practice into their day-to-day teaching and learning (Chalkiadaki, 2018), the research literature reports that when it comes to their use of ICT, it is misaligned with the aims and goals of national and international policies, such as the UNESCO (UNESCO, 2023a; Voogt et al., 2018). Whereas the aims and goals of policies in this area prescribe creative and innovative use of ICT, teachers' practice focuses on enhancing established practices that are more teacher-directed than student-centred (UNESCO, 2023a; Voogt et al., 2018). Watson (2012) argues that, instead of attempting to improve the existing education system, there is a need to move towards a learner-centred paradigm that supports individualized learning (W. R. Watson, Watson, & Reigeluth, 2012). For instance, instead of teaching students about the component elements of content knowledge using presentation software, students should be creating their own understanding of content knowledge and sharing it with their peers (Watson, 2001).

Inservice teachers' use of ICT at school has been reported on in several studies (OECD, 2015; O. OECD, 2015). The OECD (2015) investigated the skills students have acquired, and the learning environments teachers have designed, to support students' skills development at school (O. OECD, 2015). It was reported that, while 96% of students had access to and used ICT outside of school, the figure dropped to 72% at school. Moreover, it was reported that students' learning outcomes from using ICT at school were mixed, and that using ICT has potentially harmful effects. Furthermore, students used ICT on weekdays outside of school, on average, four times more than they used it at school (O. OECD, 2015). Whereas 96% of students were using ICT outside of school, only 54.9% of students reported browsing the internet for schoolwork at least once a week. The report indicates that there is low-level use of ICT at school in comparison with ICT use outside of school on schooldays; and where students are using ICTs outside of school, just over half are using them for school-related learning at least once a week.

Teachers' practice with ICT at school has not been fully addressed, and the implications of teachers' and students' limited ICT use for learning became apparent during the COVID-19 pandemic school closures (Azevedo, 2021). During the COVID-19 pandemic most international countries closed primary schools in adherence to public health recommendations (UNESCO, 2023a). The continuation of school learning was

prescribed, and teachers pivoted to remote learning using several strategies, including '*online, TV, and radio education, as well as print materials and instant messaging*' (Azevedo, 2021, p. 4). The quality of remote learning was mixed, and in many cases, it exacerbated inequality in education. Teachers and students from prevailingly higher-income backgrounds had more interactions than those from lower-income backgrounds (Azevedo, 2021). However, even where interactions were frequent, teaching and learning were prevailingly limited to transmissive practices. This involved teachers prescribing units of work and students completing textbooks, rather than practices aimed at facilitating deep learning experiences (Azevedo, 2021). While many teachers responded to the challenges of remote teaching and learning, their practice with ICT was prevailingly limited to knowledge acquisition strategies, and there was limited evidence of innovative and creative ICT use for teaching and learning.

While enhancing knowledge acquisition is an effective use of ICT, there is a need for teachers to practice more creative and innovative ICT use at school to better prepare students for living and learning in contemporary society.

The push for 21st century teaching and learning is not without its critics. Viewed through the lens of ICT use at school, Cuban has argued that computers are oversold and underused (Cuban, 2009). Cuban (2009) argues that there is much more visibility of computers at school than any tangible evidence of teachers using them in ways that enhance teaching and learning (Cuban, 2009). It is argued that the consequence of increased funding in education to support 21st century teaching and learning, and the use of ICT, led schools' decision making to focus on reducing computer–student ratio as a measure of success. Despite the success of this objective, students' computer use was relatively low. While there was significant funding made available to schools for procuring ICT, there was less advice for teachers about how to use it than pressure put on school leaders to spend it (Cuban, 2009). These factors contributed to schools hurrying to spend money on measurable gains, such as reducing the student-computer ratio at school, rather than spending time on enhancing teaching and learning (Cuban, 2009).

The trend of investing in ICTs rather than teachers' use of it for teaching and learning has been prevalent in the subsequent decades. The 'Global Education Monitoring Report: Technology in education: A Tool on whose Terms?' does little to dispel concerns of authors such as Cuban, highlighting little progress over time (UNESCO, 2023a). Following two decades of significant investment in ICTs in education, the report highlights how technology has yet to transform education, how its application varies by community and socioeconomic level, by teacher willingness and preparedness, by education level, and by country income (UNESCO, 2023a, p. v). Instead of preparing students for living and working in contemporary society, there

is a danger that traditional divides between lower-income and higher-income citizens are being reinforced (UNESCO, 2023a).

The emphasis on 21st century teaching and learning in schools has drawn critical attention to teachers' utilisation of ICT in their practices within the educational setting. Prevailingly, ICT is employed for knowledge acquisition rather than for knowledge deepening and knowledge creation, which is misaligned with the aims and goals of 21st century learning policies. Critics of the 21st cl movement have cautioned that there is more emphasis on procuring ICT infrastructure than on its use for enhancing teaching and learning at school. Furthermore, there are concerns that the variety of ICT use by community and socioeconomic level is widening, rather than eradicating, traditional socio-economic barriers to educational attainment at school. Despite these concerns, teachers' practice with ICT at school can help all students be better prepared for living and working in the 21st century, provided it equips students with the skills and competencies to use ICT in innovative and creative ways. Even though there has been significant funding towards developing ICT infrastructure at school, there are several barriers to teachers' adoption of technology for teaching and learning. These barriers are the focus of section 2.3.3.

2.3.3 Barriers to Primary Teachers' Adoption of ICT at School

Transforming teachers' practices and their utilisation of Information and Communication Technology (ICT) at school involves reconstructing teachers' beliefs about how ICT should be used during educational practices. Numerous obstacles hindering teachers' adaption of innovative and creative ICT usage, outlined in national and international policies, have been documented in existing literature (Ertmer, 2005; Tam & Trzmiel, 2018a). In the past, Ertmer (1999) outlined first- and second-order barriers to change. First-order barriers to change include: extrinsic factors such as lack of access to computers and software, insufficient time for planning and designing, and inadequate technical and administrative support (Ertmer, 1999). On the other hand, second-order barriers to change include: intrinsic factors such as teachers' knowledge, attitudes, skills, and beliefs about teaching and learning with ICT (Ertmer, 1999). Several strategies to address first-order barriers have been implemented. Significant investment into ICT infrastructure has enhanced access to computers and software for teachers and students, although there is uneven distribution amongst high-income and low-income regions, and students have less access to computers at school than teachers (UNESCO, 2023a). Curriculum reform in several countries (e.g., Ireland, US, Sweden), has taken steps towards providing teachers with more realistic planning expectations. There have been fewer solutions for providing schools with technical and administrative support outside of

education teacher CPD specialist organisations (e.g., The Irish Professional Development Services for Teachers – Technology in Education). Governments and ministries of education have provided investment, support, and solutions for enabling schools to overcome first-order barriers that are extrinsic to the teacher. It is argued that in most countries, the appropriate infrastructure is in place to enable teachers to use ICT effectively for supporting students' development of 21st century skills at school (UNESCO, 2023a).

There has also been significant emphasis on addressing second-order barriers such as teacher knowledge, attitudes, skills, and beliefs about using ICT at school (Ertmer, 1999; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). Developing teachers' Technological, Pedagogical, and Content Knowledge (TPACK) (Mishra & Koehler, 2006) about using ICT at school has become a key goal of many reform initiatives (DES, 2022). TPACK involves teachers developing technology knowledge, pedagogy knowledge and content knowledge as a precursor to changes in teachers' practice with ICT (Mishra & Koehler, 2006). The TPACK model has underpinned many studies exploring teachers' digital competence and how teachers integrate digital technologies into teaching and learning (Starkey, 2020). Despite its use and reports of teachers having enhanced their knowledge of the intersection of pedagogy, content, and technology knowledge, there is limited evidence of teachers' progress in this area (UNESCO, 2023b). Even though teacher knowledge about pedagogy, content, and digital technologies is important, it is only one of several second-order barriers to teacher change.

In addition, there has been considerable attention on teachers' attitudes regarding the use of ICT in schools. Several studies (Bond, 2020; Bouta, Retalis, & Paraskeva, 2012; Kostaris, Stylianos, Sampson, Giannakos, & Pelliccione, 2017) emphasise that teachers' observations of heightened student involvement and enjoyment during ICT-supported teaching and learning activities, have a favourable influence on their attitudes towards employing ICT in schools. These studies suggest that enhancing teachers' positive attitude towards ICT is a factor that leads to changes in teachers' practice. Moreover, several studies have indicated that students show greater engagement in their learning when ICT is part of the process (e.g., Carstens, et al, 2021, Hilton, et al, 2018). Carstens et al, (2021) surveyed Turkish teachers about their experiences of using ICT at school, and teachers reported that even though they primarily used ICTs for teacher-directed teaching and learning and administrative tasks, there was a notable increase in student engagement when they used ICT for project work or collaboration. This increase in student engagement, in turn, was a factor in teachers developing positive attitudes towards ICT use at school (Carstens, Mallon, Bataineh, & Al-Bataineh, 2021).

Hilton (2018) investigated the impact of iPads on primary students' attitudes and engagement in mathematics (Hilton, 2018). Hilton reported that initially students' attitudes towards mathematics increased following their use of iPads, and in a follow-up study, it was reported that iPads had a positive influence on students' engagement (Hilton, 2018). Dele-Ajayi, et al. (2019) also report that ICT usage enhances students' attitudes and engagement in the classroom (Dele-Ajayi, Strachan, Pickard, & Sanderson, 2019). In their study into the effectiveness of a digital education game, they report that students actively engaged in collaboration, creative problem-solving, and were co-creators of their own knowledge (Dele-Ajayi et al., 2019). By enhancing student engagement and enjoyment, it is argued that teachers are more likely to adopt ICTs for teaching and learning (Carstens et al., 2021; Dele-Ajayi et al., 2019; Hilton, 2018). While the focus on teachers' attitudes and knowledge is important, another second-order barrier - changing teachers' pedagogy beliefs about the use of ICT - is also a significant factor to address to align teachers' practice with the aims of contemporary policy initiatives.

2.3.3.1 Teachers' Pedagogy Beliefs Influence Teachers' Practice with ICT

Teachers' pedagogy beliefs refer to teachers' beliefs about teaching, learning, and assessing, and the practices that support those behaviours, such as lesson design, student progression, and designing the learning environment to support teaching and learning (Ertmer et al., 2015; Fives & Gill, 2014). Beliefs influence the type of teacher an individual perceives themselves as and have a significant impact upon the types of teaching and learning and classroom management practices teachers implement at school (Kagan, 1992; Shulman, 1986).

Fives & Buehl, (2012) argue that teachers' beliefs act as filters, frames, and guides. When presented with ill-structured situations, teachers filter incoming information through the lens of their past teaching and education experiences. The beliefs raised during the filtering phase are used to frame the problem space, such as recalling strategies learned in teacher education programmes (Mellati, Khademi, & Shirzadeh, 2015). Teachers evaluate the beliefs raised and how they apply to the problem space they are presented with. After weighing up the success and challenges of previous strategies they employed in similar situations, teachers' beliefs guide their subsequent actions (Fives & Buehl, 2012). Teachers' beliefs impact upon the general type of teaching and learning they perceive as being appropriate in the classroom. The impact of beliefs on teachers' reactions to ill-structured situations in the classroom indicate they are a fertile environment for investigation into changing ICT practices to align with 21st century learning.

Academic research regarding teachers' pedagogy beliefs about the use of ICT further support the argument that teachers' beliefs are a critical factor in changing teachers' practice (Ertmer & Glazewski, 2015; Prestridge, 2012; Tondeur et al., 2017). There is a weight of research literature indicating that teachers with constructivist beliefs use ICT in more complex, innovative, and creative ways than teachers' with prevailingly traditional pedagogy beliefs (Ertmer et al., 2015; Kopcha, Neumann, Ottenbreit-Leftwich, & Pitman, 2020; OECD, 2015). Whereas constructivist beliefs refer to students as active students in the process of acquiring knowledge and involve teachers designing lessons that facilitate student inquiry, opportunities to develop solutions to problems, and being actively engaged in the learning process; on the other hand, traditional or direct transmission views are more teacher-directed, where the teacher communicates the knowledge to be learned concisely, and students' replication of the communicated knowledge and skills is evidence of learning (OECD, 2015).

It is argued that there is more evidence of alignment than misalignment between teachers' beliefs and practice with ICT (Buehl & Beck, 2015). Hence, it is contended that teachers with constructivist beliefs are more likely to engage students in creative and innovative teaching and learning activities, where they are active and use digital technologies for complex problem solving and as tools to support self-directed inquiry (Ertmer & Glazewski, 2015; O. OECD, 2015; Prestridge, 2012). Moreover, there is alignment between constructivist pedagogy beliefs and approaches to creative and innovative use of ICT prescribed in the UNESCO ICT Competence Framework for Teachers (UNESCO, 2018a).

The UNESCO outlines three orientations of ICT use: knowledge acquisition, which aligns with traditional and teacher-centred use; knowledge deepening, which aligns with constructivist use; and knowledge creation, which aligns with socio-cultural use (UNESCO, 2011, 2015, 2018). There are parallels between knowledge acquisition use of ICT and traditional or direct transmission views. Whereas knowledge acquisition ICT use involves activities such as *'using presentation software and digital resources to support instruction*' (UNESCO, 2018a, p. 29), direct transmission views involve *'teachers communicating knowledge in a clear and structured way to explain correct solutions'* (OECD, 2015, p. 92). Moreover, knowledge deepening and knowledge creation approaches involve '*designing learning activities to engage students in reasoning with, collaborating on, and solving real-world problems*' (UNESCO, 2018a, p. 36) and '*helping students design project plans and activities that engage them in collaborative, problem-solving research or artistic creation*' (UNESCO, 2018a, p. 44), constructivist beliefs involve teachers scaffolding activities that '*emphasise facilitating, student inquiring, prefer to give students the chance to develop solutions to problems on their own, and allow students to play active role in instructional activities*' (OECD,

2015, p. 92). Given the alignment between constructivist pedagogy beliefs and complex and innovative uses of ICT at school prescribed by national policies such as the UNESCO, it may be argued that reconstructing teachers' pedagogy beliefs about constructivist practice with ICT can align teachers' practice with the aims and goals of 21st century ICT use to support students' development of 21st century skills. Furthermore, it is plausible that reconstructing teachers' pedagogy beliefs regarding the use of ICT for knowledge deepening and knowledge creation in teaching and learning can bring about changes in teachers' practice and provide students with experiences that support 21st century skills development at school.

Even though there is support for pedagogy beliefs as a critical factor in determining teachers' practice, there are many mismatches between teachers' espoused beliefs and actual practice, calling into question how measurable and how accurate beliefs are (Fives & Gill, 2014). Buehl and Beck (2015) argue that the relationship is more complex than simply changing teachers' beliefs from traditional to constructivist (Buehl & Beck, 2015). The authors cite several studies, Lim and Chai (2008) and Jorgensen et al. (2010), that report on inconsistencies between beliefs and practices. Lim and Chai (2008) reported inconsistencies between 80% of teachers' espoused beliefs and observed practice, whereas Jorgensen et al. (2010) identified inconsistences in some areas and consistencies in others (Jorgensen, Grootenboer, Niesche, & Lerman, 2010). Ertmer and Ottenbreit (2012) also reported inconsistencies between teachers' espoused beliefs and enacted practice (Ertmer et al., 2012). In their study involving twelve K-12 classroom teachers purposively selected for their ICT expertise, they reported that eleven out of the twelve teachers demonstrated close alignment between their beliefs and practice (Ertmer et al., 2012). Despite most teachers being observed using ICTs in ways that were consistent with their espoused student-centred beliefs, one teacher's practice differed, aligning more with using technology to deliver content and skills (Ertmer et al., 2012). Although there are many reports of mismatches between beliefs and practices there is more evidence of their alignment (Fives & Gill, 2014; Kopcha et al., 2020).

Alternative views to first- and second-order barriers are also critical factors in teacher change (Asia & Education, 2015; Tam & Trzmiel, 2018b). For instance, barriers also include definitional, operational, and systemic challenges (Tam & Trzmiel, 2018b).

- Definitional: lacking clarity in scope of transversal competencies, and the desired outcomes of the teaching of transversal competencies,

- Operational: lack of assessment mechanisms, insufficient teaching/learning materials and teaching guides, lack of incentives, insufficient capacity of teachers, lack of budget and placing an additional burden on teachers, and
- Systemic: large class sizes, overloaded curricula, pressure to achieve academic success, inconsistency with high-stake exams, lack of understanding among parents and other stakeholders, and the overall school/community culture (Asia & Education, 2015; Tam & Trzmiel, 2018).

This means that even for teachers with constructivist beliefs about ICT use, there are potentially several other challenges and barriers to constructivist ICT use at school. Despite the prevalence of other barriers that also impact upon teachers' constructivist ICT use, constructivist beliefs have been a reliable indicator of teachers' practice even when significant barriers to practice are present, such as limited access to ICTs (Ertmer et al., 2012; OECD, 2023).

Another challenge in investigating teacher pedagogy belief change is that teachers can proactively resist change regardless of the presence of barriers or enablers, which slows the implementation of education reform (Snyder, 2017). In a study of veteran teachers – teachers with more than 20 years' experience - Snyder (2017) reports that veteran teachers chose to resist change because of decreasing instructional time and the increased use of technology (Snyder, 2017). Some of the teachers in this study reported how they were frustrated with new policy initiatives that demanded instant change and a shift from teaching instruction to constant assessment of students' learning. While small in scale, this study reveals that in some cases, teachers are choosing to resist the changes in new policies and are unwilling to engage in professional development initiatives about shifting towards student-centred learning and providing on-demand access to information – two elements of contemporary society that are often referenced as factors driving change. While teachers' frustration at the pace and continuity of change is understandable, the research literature also demonstrates that those teachers with positive beliefs about the need for change are more likely to realign their practice with the aims and goals of national and international policies (Fives & Buehl, 2012). Hence, the potential for investigating teacher belief change as a precursor to changing practice.

Although teachers' pedagogy beliefs are only one of a number of obstacles to teachers' aligning their practice with contemporary education policies, their impact on teachers' behaviour indicates they are a fertile domain for investigating changing teachers' practice with ICT. Although teacher knowledge and attitudes about ICT use are also critical factors to consider in the area of teacher change, alignment

between teachers' pedagogy beliefs and practices is significant. It may be argued that teachers with positive beliefs about the effectiveness of knowledge deepening and knowledge creation ICT use are likely to engage students in innovative and creative ICT use, aligning with the aims and goals of national and international policies such as UNESCO (2018).

2.4 Teacher Continuous Professional Development Design

In this section, there are two sub-sections: the first argues that through the lens of teacher pedagogy belief change, situative transitional models of teacher CPD may be appropriate for designing bespoke models of teacher CPD aiming to change teachers' pedagogy beliefs about the use of ICT at school; the second argues that teacher design teams that engage in the co-creation, implementation, and evaluation of novel teaching and learning using ICT can support teachers to persist with belief change at school.

2.4.1 Situative Transitional Models of CPD Appropriate for Teacher Pedagogy Belief Change

According to Kennedy, models of teacher CPD can be categorised as transmissive, transitional, and transformative (Kennedy, 2005, 2014). Transmissive models aim to fulfil the function of preparing teachers to implement reforms and include models such as training models, award-bearing models, deficit, and cascade models. Transformative models aim to support teachers in contributing to and shaping education policy and include action research and transformative models. Transitional models such as standards-based, coaching/mentoring, and community of practice models have the capacity to support underlying agendas compatible with either the transmissive or transformative aims of CPD (Kennedy, 2005). While transmissive models aim to enhance teachers' efficacy with pre-existing practices, transitional and transformative models can provide teachers with more agency to discover new ways of teaching and learning with ICT.

Despite the need for transformative change, effective transitional CPD models may be more appropriate for scaffolding teacher pedagogy belief change. It is argued that effective CPD involves content focus, active learning, collaboration, modelling, coaching and expert support, feedback, and reflection practices. Moreover, it is recommended that professional development should be sustained over a considerable duration (Darling-Hammond, Burns, Campbell, Goodwin, & Low, 2018; Darling-Hammond et al., 2017). Content focus supports teachers' learning within teachers' classroom contexts. Active learning involves teachers directly in designing, implementing, and evaluating new initiatives. Collaboration provides

teachers with opportunities to share ideas and to support one another during the transformational process. Models of effective practice provide teachers with a clear vision of what new practice looks like. Coaching and expert support involves sharing expertise and evidence-based practice. Feedback and reflection enable teachers to engage in iterative cycles of implementing and refining new practice. Sustained duration provides teachers with more adequate time to develop their professional capacity with new practice (Darling-Hammond et al., 2017, p. vi). Effective teacher CPD provides teachers with opportunities to experiment with new practice at school, experience the impact of their design, implementation, and evaluation, and observe student learning outcomes.

Zepeda outlines a number of teacher CPD models that are effective for enabling teachers to develop new practices at school. These include (i) learning communities, (ii) coaching, (iii) collaborative teacher development, (iv) critical friends, (v) lesson study, (vi) action research, and (vii) portfolios (Zepeda, 2019). In contrast to often seen traditional professional development programmes that focused on honing teachers' individual skills, a (i) learning community involves the collective capacity of all people in the organisation. Moving to (ii) Coaching, this may consist of cognitive coaching, instructional coaching, or peer coaching, and it involves supporting teachers in the development of deeper understanding of content knowledge, extending thought process needed to see different points of view about strategies, helping develop critical thinking skills through problem posing and problem-solving focusing on the impact of instruction on student success, helping teachers boost student performance, providing translations of research, and assisting teachers in making connections with classroom practice, and providing feedback on performance (Zepeda, 2019).

(iii) Collaborative teacher development is a response to reports that teachers too often work in isolation. It involves teachers in regular, frequent, and structured opportunities to work together to develop curricula and lesson(s), to design learning experiences, create experiences, enhance individual practice, analyse student work, and help each other with questions related to content, pedagogy, or cultural experience. They can consist of small sized teacher study groups and larger whole-faculty study groups that engage in meetings where they brainstorm, leading to topic formation, narrow the topic to a question they wish to explore, extended meetings where the group addresses questions specific to the topic, and reflection on process and content (Zepeda, 2019).

(iv) Critical friends involves members of a critical friends group engaging in important, key, and necessary talk that carefully confronts and inquires into the issues being explored. (v) Lesson Study is an iterative cycle consisting of four basic steps: study curriculum and formulate goals, plan, conduct research, and

reflect. (vi) Action research involves examining real-life practices and experiences in the classroom using a systematic approach that is cyclical and continuous, developing deeper meanings about practice with the assistance of colleagues, experimenting with practices based upon extended reflection and analysis of data, and implementing change. (vii) Portfolios are a formative way for teachers to examine practices over time; they chronicle growth and development, and capture learning through artifacts that are representative of practice (Zepeda, 2019).

The models and effective elements of teacher CPD described above are key considerations for designers of teacher CPD aiming to change teachers' practice. As the next sub-section discusses, teacher CPD aiming to change teachers' beliefs has specific requirements that are also considerations for designers of teacher CPD in this area.

2.4.1.1 Teacher CPD Aiming to Change Teachers' Beliefs

While there are several teacher CPD models that are reported to be effective for changing teachers' practice, it is argued that transitional rather than transformative models may be more appropriate for changing teachers' pedagogy beliefs about the use of ICT. According to Ertmer (2005), CPD aiming to change teachers' pedagogy beliefs about the use of ICT requires personal, vicarious, and socio-cultural experiences (Ertmer, 2005). Because beliefs are formed through personal experiences, providing teachers with personal experiences of new practice can enable teachers to change beliefs. Vicarious experiences provide teachers with examples of models and modelling and opportunities to learn about successes and challenges associated with new practice. Socio-cultural influences impact upon teachers' pedagogy beliefs because teachers are continuously exposed to the impact that new practice has on the values, opinions, and traditions of the school community, including feedback from teachers, school leaders, and parents' expectations about their children's learning at school (Ertmer, 2005). Key to understanding these experiences' impact on teachers' pedagogy beliefs is that beliefs are transitional, and it is important to provide teachers with multiple iterations of personal, vicarious, and socio-cultural experiences as a precursor to change.

Guskey also argues that belief change is a transitional process (Guskey, 2002a). Guskey argues that belief change comes after observing student learning outcomes. In contrast with transmissive models of CPD that focus on off-site, one-shot CPD sessions as precursors to changes in beliefs and practice, Guskey argues that the change process requires teachers observing student learning outcomes as a precursor to change. Guskey argues that whereas traditional CPD models follow a change process with the following

steps: changes in teachers' beliefs and attitudes, changes in teachers' classroom practices, and changes in student learning outcomes, in practice, it follows a process where changes in teachers' beliefs and attitudes follow teachers observing changes in student learning outcomes. According to Guskey, the critical element in the change process is the situated experience where the teacher learns about the practice in context and observes whether positive student learning outcomes are achieved rather than the professional development intervention (Guskey, 2002b).

Even though transmission and transformational models are effective in changing practice, from the perspective of teachers' pedagogy beliefs and their use of ICT, transitional approaches can enable teachers to make links between their existing practices without ICT and the constructivist practices with ICT prescribed in national and international policies. From a theoretical lens, Vygotsky's zone of proximal development furthers the case for transitional CPD approaches. The Zone of Proximal Development (ZPD) refers to the area of maturing intellectual processes which are emerging and form the domain of transitions to higher levels of thinking (Gredler, 2005; Wertsch, 1985). Teacher CPD design often includes models, modelling, and expert advice as mechanisms to enable teachers to transition from pre-existing practice to new practice and where they develop new forms of thinking (Darling-Hammond et al., 2017; Kennedy, 2005; Zepeda, 2019). The ZPD refers to those types of changes as transitional before becoming transformative. For instance, 'readiness' refers to emerging cognitive functions (Gredler, 2005). According to Vygotsky, those emerging functions should be understood as 'buds' or 'flowers' rather than the 'fruits' of development (Wertsch, 1985, p. 67). In light of this, it may be appropriate for CPD design in this area to aim for transition between teachers' existing practice and the types of practice specified in policies as a precursor to achieving transformative change.

There are several arguments against transitional approaches, including: (i) the system needs transformation, (ii) deeper shifts in beliefs are possible, and (iii) primary school teachers are ready for change. One argument against taking an effective situated transitional approach to teacher CPD is that the system needs transformation rather than transition. As previously discussed, many authors argue that 21st century teaching and learning requires the transformation of classroom practices, schools' organizational structures, and teachers' use of ICT (Voogt & Roblin, 2012, Dede, 2010). These authors argued that schools in their current form are relics from the industrial age of education. The systems that are underpinning schools are still focusing on developing students' capacity to individually succeed within the parameters of what positive student learning outcomes are. Moreover, prevailing assessment practices focus on individual attainment measured against narrow curriculum objectives rather than

rewarding students for working collaboratively and producing innovative and creative novel solutions to complex problems. Taking a transitional situated effective approach does not preclude these outcomes; instead, this approach is a more gradual approach that takes into account that teachers' actual developmental level may not be ready for continuous constructivist ICT use at school and instead there are transitional steps that need to be taken while education reform is ongoing.

A second argument used against taking a transitional approach is that purposively designed transmission-based models can result in a gestalt shift in beliefs. A gestalt shift involves experiencing a sudden change in perception or understanding and seeing things in a new way (Nespor, 1987). Transmissive models that are appropriately designed regularly report shifts in teachers' beliefs and practices (Kennedy, 2005). However, according to Kolb this type of shift is not deep enough for long lasting shifts in beliefs. Instead, where the reported transformation arises from a prevailingly transmissive experience, belief change in these instances consists of substitution rather than integration. Whereas changes that evolve through integration tend to become stable parts of individuals' beliefs systems, beliefs that change through substitution are less stable, and the possibility of reversion to a previous state of beliefs is more likely (Kolb, 2014).

Additional reasoning against transitional approaches is that primary school teachers are ready for transformative change. Primary teachers are considered to be believers in constructivism as an approach for teaching and learning at school (Dennen, Burner, & Cates, 2018). In working with children aged 4–12 years teachers are typically working with students who are at early stages of development where they learn pre-number and pre-literacy skills before developing more complex understanding over time. Embedded in their practice is a constructivist philosophy that students learn through active exploration of the concepts rather than through direct instruction (Gredler, 2005). Moreover, departments of education regularly report consistent alignment between the aims of teaching and learning policies and their observation of teachers' constructivist practice at school when they are not using ICTs (e.g., DES, 2020). Despite observations that primary school teachers prevailingly engage in constructivist teaching and learning when they are not using ICT, it is also reported that primary school teachers prevailingly engage in traditional teaching and learning when they are using ICT (DES, 2020).

Despite reports that primary school teachers prevailingly employ constructivist teaching and learning approaches at school, that transmission-based teacher CPD models can lead to gestalt changes in beliefs, and that the system needs transformation rather than transmission, research literature in the area of teacher CPD belief change indicates that persistent changes in beliefs and practices are more likely to be

achieved through teacher CPD design that aims for transition from pre-existing to novel practice rather than transformative changes that are beyond teachers' potential level of development. The research literature also indicates the potential for team support as an enabler for teachers' persistence with changes in beliefs and practice, and this is discussed in the next sub-section.

2.4.2 Team Support as an Enabler for Teachers' Persistence with Pedagogy Belief Change

Team support can enhance the likelihood of teachers persisting with changes in pedagogy beliefs about the use of ICT at school. Even though teachers report that CPD is effective, it does not mean the reports result in teachers' changing their practice at school. Further strategies for teacher persistence are often required to support teachers' newly budding beliefs to become persistent at school. Somekh (2008) reports how teachers' beliefs often do not survive in the school environment, that there are several socio-cultural factors that affect teachers' ICT integration into classroom practice, and these include students, local communities, regulatory frameworks, policies of education systems, and national cultures (Somekh, 2008). Even though teachers may experience CPD aimed at integrating ICT into classroom practice, those socio-cultural influences can limit its transformation into changes in practice.

Windschitl, et al. (2002) highlight this point. In their study, teachers were introduced to CPD aiming to integrate laptops into their daily practice. While initially, the teachers who were new to the school used the laptops regularly, over time the practice dissipated. The participants reported that conversations with their peers, who were more established at school, led them to develop beliefs that laptops were not part of the school culture, and so in their attempts to fit in with their peers and the traditional teaching and learning that was established at the school, they phased out the use of laptops, even though they believed they enhanced students' learning (Windschitl & Sahl, 2002).

Lim and Chai's 2008 study provides further evidence of the impact that socio-cultural influences can have on teachers' practice (Lim & Chai, 2008). In their study, teachers' constructivist practice with ICT became less frequent over time, particularly when high-stakes exams were on the horizon. The participants reported that they felt the need to prioritise covering content that was likely to be on the exams over deep learning episodes that were afforded by spending more time on digging deeper into areas of the curriculum. The participants further explained that parental expectations that students achieve high marks on state exams were a factor in their rationale for changing practice, even though they argued it facilitated deeper learning experiences.

Ajzen and Fishbein provide further arguments that belief change is often subject to socio-cultural influences that are present in the individual's environment (Fishbein & Ajzen, 2011). The authors argue that individuals can change or resist change to their beliefs on account of their compliance with perceived social pressure (Fishbein & Ajzen, 2011). They refer to five types of power that others can be perceived to possess: (i) reward power, (ii) coercive power, (iii) legitimate power, (iv) expert power, and (v) referent power. (i) Reward power involves the belief that social agents may have the power to reward behaviour. (ii) Coercive power involves a social agent's ability to mete out punishment for noncompliance. (iii) Legitimate power refers to social agent's right to prescribe behaviour due to their role in a particular group, network, or society at large. (iv) Expert power refers to a social agent's expertise, skills, or abilities. (v) Referent power refers to an individual's sense of identification with the social agent and their interest in either acting like or unlike them (Fishbein & Ajzen, 2011, p. 130). Within schools, perceived power to comply with social pressure comes from students, peers, school leaders, boards of governance, the inspectorate, and parents and guardians (Voogt et al., 2018). Moreover, those factors can limit or enhance teacher belief change (Fives & Gill, 2014). From this perspective, it may be argued that primary school teachers require sustained support to facilitate changes in beliefs and practices concerning the integration of Information and Communication Technology (ICT). The design of teacher Continuous Professional Development (CPD) that integrates Teacher Design Teams (TDTs) can empower educators to sustain innovative and creative ICT use within the school environment. Such teams can play a crucial role in supporting teachers' persistence with implementing novel practices with ICT at school.

2.4.2.1 Teacher Design Teams

According to Voogt, teacher design teams provide opportunities for personal, social-cultural, and vicarious experiences, and they can support teachers to change beliefs and practices (Voogt et al., 2015). Voogt highlights the potential of collaborative design as a form of professional development, which involves teachers '*creating new or adapting existing curricular materials in teams to comply with the intentions of the curriculum designers and with the realities of their context*' (Voogt et al., 2015, p. 260). While the outcomes are typically in the form of curricular materials, the cases highlighted in Voogt's study indicate that teams can support changes in beliefs and practice. For instance, teachers reported continuing to use concepts and skills they learned during the professional development initiatives, teachers also changed beliefs about teacher collaboration and classroom practice, and teachers changed beliefs about using ICT

for enhancing student collaboration and inquiry, following their participation in teacher design teams (Voogt et al., 2015).

Kopcha et al. (2012) employed a situated professional development programme examining elementary school teachers' beliefs about barriers to technology integration (Kopcha, 2012). They reported that situated professional development activities, where a school upgraded their technology and employed a mentor whose role it was to provide teachers with skills and knowledge needed to integrate technology and to transition teachers to communities of practice to sustain technology use over time, was an effective mode of changing teachers' beliefs and practices and sustaining changes over time. However, the participants in the study reported that after the mentor had left the programme, it became more difficult for them to sustain their initial changes in ICT practice.

Other researchers aimed to harness the power of collaborative design to enable teachers to implement new common standards using the Lesson Study model (Ní Shúilleabháin, 2016; Takahashi & McDougal, 2016). Also referred to as 'Collaborative Lesson Research' by Takahashi et al. (2016), Lesson Study is the primary form of professional development in Japan. Most commonly, a Lesson Study takes place within a single school, and its common purpose is '*to seek practical ideas for the effective implementation of national curriculum*' (Takahashi, 2016). The Lesson Study consists of four phases: During phase one, teachers read the course of study, relevant research articles, and examine available curricula and other materials. During phase two, they design a lesson focused on a problematic topic the lesson study team has identified and link it to the broader research they uncovered during phase one. In phase three, one member of the lesson study team teaches the co-created lesson while the rest of the team members observe the lesson and the students' responses during the learning. During the fourth and final phase, the planning team and observers conduct a post-lesson discussion to gain insights into the teaching-learning process and how the course of study should be implemented (Takahashi & McDougal, 2016). In Ní Shuilleabháin (2016), teachers in the Lesson Study group noticed several salient outcomes during their observation of the lesson and made inferences that they could carry out such practice in their own classroom. Teachers reported that their observation of students discussing the mathematical concepts as opposed to just learning off algorithms was something that could bring extra value to their own practice (Ní Shúilleabháin, 2016).

A Design Thinking approach to 'collaborative design' has also been employed in other studies. Utilising the Design Thinking model with teachers, Koh et al. (2015), engaged teachers in the design,

implementation, and evaluation of novel pedagogy approaches to educational practice at school. The Design Thinking model is a non-linear, iterative process where participants, seek to understand end users' habits, redefine problems, suggest innovative solutions, and build and test artefacts to solve problems (Plattner, Meinel, & Leifer, 2014). The Design Thinking model's roots are in industry but has been used in education settings to enable teachers to design educational solutions to new policy initiatives. There are five stages to a Design Thinking cycle, although participants revisit stages during a full cycle: Stage one is the empathy stage, where participants seek to understand end users' habits and behaviours about the problem the team is trying to solve. Stage two is the define stage, where participants explicitly define the problem, they are trying to solve. Stage three is the ideate stage, where participants suggest solutions to the problem they are solving and try to challenge existing assumptions about the problem itself. Stage four is the prototype stage, where the design team builds artefacts to address the problem. Finally, stage five is the test stage, where the design team tests the solution to the problem in its authentic environment with its intended end users (Plattner et al., 2014). In Koh (2015), teachers who took part in a design thinking experience learned about control beliefs during the prototype stage. The teachers identified barriers and facilitating factors of their lessons through professional experimentation (Koh, Chai, Wong, & Hong, 2015).

Even though teachers may be taking part in Teacher CPD involving teams engaging in collaborative design, it does not always result in changes in beliefs. Liebech-Lien (2021) conducted a study on teachers who engaged in a professional development programme with a teacher team aiming to support their use of the pedagogical model cooperative learning at school (Liebech-Lien, 2021). In their study, they highlighted the potential of a teacher team to enhance teacher's cooperative learning practice, but also revealed how teams may be barriers to change. Their study follows a case of one teacher 'Daniel' through his initial experiences of working with a team and a follow up with Daniel when he moves to a new teacher team. From Daniel's positive experiences, the study highlights how discussing new pedagogy, experimenting with different lessons, implementing them in class before reflecting on the lessons' outcomes, were all reported as significant factors in changing the teachers' beliefs. Another key element was that the teachers' believed that the novel pedagogy met their needs as opposed to their feeling compelled to implement it in class. The study highlights how Daniel's newly formed beliefs about the effectiveness of cooperative learning pedagogy changed after he was transferred to another team at his school. His new teammates had little experience of implementing the novel pedagogy in class. Combined with curriculum pressure and limited time being available to Daniel, he stopped using cooperative pedagogy at school.

Firstly, this study presents a lens into what happens when teachers leave the safety net of their teacher team, and secondly, it reports that even though Daniel's new teammates were open to and interested in implementing the novel pedagogy at school, it did not match their immediate needs. The new team's readiness for implementing novel pedagogy was not there, and so the teacher changed their practice to meet the demands of what was in front of them and matched their practice to that of their new team (Liebech-Lien, 2021).

Even though teachers may change beliefs during teacher CPD initiatives, there are several socio-cultural barriers to teachers' persistence with new practice at school. Social referents exert power over individuals that can act as enablers or barriers to change. Teacher design teams, where teachers engage in the co-creation, implementation, and evaluation of new lessons, can enable individuals to persist with novel practice at school. Although changing teams can have negative effects where the immediate needs of the new team do not align with new beliefs and practice. Despite this, teacher design teams enable teachers to create shared beliefs about practice and can act as a motivator for teachers to persist with new practices at school.

Section 2.4 on Teacher CPD has asserted that transitional effective models for teacher Continuous Professional Development (CPD) are suitable for scaffolding initiatives aiming to change teachers' pedagogy beliefs. Moreover, teacher design teams can provide support for teachers to persist with changes in beliefs and practice at school. The subsequent section highlights critical elements concerning the relationship between teachers' pedagogy beliefs and their use of ICT, which are significant for designing teacher CPD initiatives in this area.

2.5 The Relationship Between Teachers' Pedagogy Beliefs and their use of ICT

This section includes four sub-sections related to the relationship between teachers' pedagogy beliefs and their use of ICT at school: Sub-section 2.5.1 discusses the need to raise teachers' deeply held implicit interconnected beliefs as a precursor to change; 2.5.2 outlines the alignment between the belief change process and an experiential learning cycle and argues that an experiential learning cycle is an appropriate scaffold for teachers to experience the belief change process; 2.5.3 discusses the multi-dimensionality of teachers' pedagogy beliefs and argues that engaging teachers in activities where they design, implement, and evaluate teaching and learning that aligns and misaligns with their pedagogy beliefs can be a precursor to change; 2.5.4 describes the bi-directional nature of the relationship between teachers'

pedagogy beliefs and their use of ICT and discusses how it may be leveraged in teacher CPD design in this area.

2.5.1 The Need to Raise Deeply Held Implicit Interconnected Beliefs

It is argued that teachers hold deep, implicit, interconnected beliefs that are rarely, if ever, made explicit. Rokeach argues that teachers hold deep, implicit, interconnected beliefs (Rokeach, 1968). According to Rokeach, individuals hold various levels of beliefs ranging from deeply to peripherally held. The author categorised by type the various levels of beliefs according to how deeply they are ingrained in the belief system in the following ways: Type A beliefs that are deeply personal and highly resistant to change; Type B beliefs are also deeply personal and are held privately; Type C, Type D, and Type E beliefs are more periphery and are less resistant to change (Rokeach, 1968). Periphery beliefs are less resistant to change, and they are less interconnected with other beliefs across the belief system. In contrast, Type A and Type B beliefs are considered to be more interconnected; hence, changing deeply held beliefs has greater ramifications across the belief system (Rokeach, 1968). Ertmer argues that teachers' beliefs act in the same way (Ertmer, 2005). It is contended that raising and changing deeply held interconnected beliefs can have greater ramifications for teacher belief change than raising and changing periphery beliefs.

Schon also argues that practitioners hold deep implicit beliefs (Schon, 1984). Moreover, individuals can hold implicit beliefs that differ from the types of activities they enact. Whereas individuals carry out actions that are explicit and observable, it is the implicit understandings of those actions the individual needs to reflect upon to criticise, restructure and embody in future changed practice (Schon, 1984). Schon carried out extensive research on reflection as a means of professional development. He made the following observation:

> "*Through reflection, he can surface and criticize the tacit understandings that have grown up around the repetitive experiences of a specialized practice and can make new sense of the situations of uncertainty or uniqueness which he may allow himself to experience*" (Schon, 1984, p. 61).

Hence, reflecting on deeply held implicit beliefs and criticizing them in light of new experiences can aid the belief restructuring process.

Kagan (1992) also argues teachers hold deep implicit beliefs they bring to pre-service training and their pre-formed perceptions of teaching and learning are highly resistant to change (Kagan, 1992). Kagan reported that teachers' pre-formed perceptions may be so deeply entrenched in their belief system that

they do not change during pre-service training and are instead carried through to in-service practice, where they are as likely to influence classroom practice as any knowledge accrued from formal professional learning experiences (Kagan, 1992). Heisner and Lederberg (2011) also hold this view. In their study with early childhood teachers, they identified that teachers come to professional development training with deep-rooted beliefs about the types of teaching and learning they believe are appropriate at school (Heisner & Lederberg, 2011). They reported that many teachers' beliefs contradict the practices prescribed in national and international policies. They implemented a professional development intervention aiming to change teachers' beliefs and practices to more student-centred teaching and learning, and they reported changes in some teachers' beliefs but resistance in others (Heisner & Lederberg, 2011). Key to their findings was the need to raise deeply held beliefs, have teachers engage in self-reflection with those beliefs, and for teachers to engage in experiences that can create dissonance with deep-rooted beliefs (Heisner & Lederberg, 2011). This suggests that teacher CPD designers, aiming to change teachers' pedagogy beliefs about the use of ICT at school, should include activities where teachers raise deeply held beliefs.

There is a concern that teacher CPD activities are not enabling teachers to raise deeply held implicit interconnected beliefs (Zepeda, 2019). Teachers may explicate beliefs that promote ideal versions of themselves that align with the espoused rather than the enacted goals of teacher CPD (Pajares, 1992). This means that teachers may be raising and explicating beliefs about the use of ICT that are in alignment with the aims and goals of national policies, but their deep-rooted beliefs may not be surfaced or challenged during teacher CPD reform initiatives. Moreover, because some deeply held beliefs are implicit and rarely made explicit, the beliefs that are being reported as having changed are less likely to be the deep-rooted beliefs that need to be addressed to reconstruct pre-existing practices.

Furthermore, there are concerns that CPD is not enabling teachers to engage in deep levels of reflection that are required to raise deeply held beliefs (Zepeda, 2019). Kolb argues that there are various levels of reflection (Kolb, 2014). Reflection at the elementary level, reframing at the mid-level, and reforming at the integrative level (Kolb, 2014). Reflection at the elementary level involves spontaneous reflective observation of direct experience. Reframing is more intense and involves a critique of reflective observations that may produce creative new perspectives. At the integrative level, individuals integrate critical reflection with spontaneous observations which produces a process where '*action is reformed by reflection and reflection is reformed and informed by action and its consequences in experience*' (Kolb, 2014, p. 59). While elementary reflection and mid-level reframing are important, deeper learning

experiences come from reflection that is integrative (Kolb, 2014; Schon, 1984). Raising deeply held implicit beliefs requires experiences where teachers themselves raise their personal implicit beliefs and critique them in light of new experiences as a precursor to change.

According to Argyris and Schon, belief change that does not involve deep reflection and iterative cycles of enaction and reflection can result in differences between an individual's theory of action and theory in use (Argyris, 2002; Argyris & Schön, 1978). Theory in action refers to a set of rules that individuals use to design and implement their own behaviour, whereas theory in use refers to the actual behaviours the individual enacts. There are often significant differences between professionals' espoused theory and their enacted practice (Argyris, 1991). And there are often significant differences between the pedagogy beliefs teachers espouse and the classroom practices they are observed enacting (Levin, 2014). In Ireland, for instance, a recent report from the Irish Department of Education highlights this issue (DES, 2020). The schools' inspectorate investigated schools' ICT planning and teachers' ICT use. The inspectorate reported that whereas 100% of schools had a digital action plan that was informed by the Irish Digital Learning Framework, only 71% of teachers reported being aware of the objectives of the Digital Learning Framework. Even though school policies were written to align their digital plan with departmental guidelines, in practice, teachers were not fully aware of the ICT practices they were reporting to be implementing in class (DES, 2020). It may be argued that raising and changing deeply held interconnected beliefs can enable teachers to address differences between their theory in action and theory in use.

One issue with attempting to raise deeply held implicit interconnected beliefs is that changing periphery beliefs may be sufficient. Even though Rokeach, and others, have outlined that individuals hold deep-rooted beliefs, they also contend that teachers hold periphery beliefs. Changing explicit periphery beliefs can be effective in changing practice (Woolley, Benjamin, & Woolley, 2004). Approaches to measuring teachers' periphery belief change have often involved employing quantitative measurement scales such as The Teachers' Beliefs Scale (TBS). The TBS consists of four factors: traditional classroom management, constructivist classroom management, traditional teaching, and constructivist teaching. Teachers are presented with a list of statements relevant to each of the four factors, and they indicate their agreement or disagreement on a scale ranging from 1 (strongly disagree) to 6 (strongly agree) (Woolley et al., 2004; Woolley & Woolley, 1999). While this approach has been employed to collect data about the types of beliefs teachers hold, and presented as evidence of teacher pedagogy belief change following CPD interventions, it doesn't take into account the deeply held implicit personal beliefs that other authors argue need to be raised to effect changes in practice (Ertmer, 2005; Pajares, 1992; Rokeach, 1968; Schon,

1984). For instance, Catalano et al. (2022) employed surveys to investigate relationships between teachers' beliefs about classroom management and pedagogy approaches (Catalano, Vecchio, & Perucchini, 2022). They reported the data revealed consistencies and inconsistencies between teachers' espoused beliefs and enacted practice. To address the inconsistencies, the authors contended that more attention needs to be placed on teachers' reflective practice as they argued teachers were not reflecting deeply enough about their survey responses (Catalano et al., 2022). While quantitative measurements accurately report periphery belief change, it is worth investigating if there are other mechanisms for raising and changing teachers' deeply held personal beliefs.

Another issue with raising deeply held beliefs is that teachers' beliefs are contextual, and teachers' personal beliefs may not be of much value outside of the context they are investigated within. According to Tschannen-Moran, beliefs differ from teacher to teacher (Tschannen-Moran, Salloum, & Goddard, 2014). At school, teachers hold different beliefs about the types of pedagogy that is appropriate in their classroom. This results in differences in teaching and learning practices across the school context, making it challenging to harmonise schoolwide approaches for adapting to new policy initiatives. For instance, Teaching Beliefs and Practice, an international study on the relationship between teachers' beliefs and practices, found that teachers held different beliefs about constructivist teaching and learning (OECD, 2015). Across several countries, teachers reported different beliefs about what is meant by constructivist teaching and learning. Whereas some teachers believed their teaching was constructivist, in other countries such practice would be considered traditional (OECD, 2015). Such reports make the investigation of teachers' deeply held beliefs challenging and reduce the likelihood of being able to generalize findings, meaning investigating periphery belief change may be more useful to the field. While this argument may shed doubt on the utility of investigating deeply held beliefs, it is argued that deeply held beliefs are interconnected with a greater number of beliefs than periphery beliefs. If deeply held beliefs can be changed – notwithstanding their contextuality – then it may be demonstrated what periphery beliefs they are interconnected with and reveal worthwhile insights into pedagogy belief change.

A further issue with raising deep implicit interconnected beliefs may be beliefs 'unboundedness.' Unboundedness suggests that beliefs within the belief system are '*loosely bounded with highly variable and uncertain linkages to events, situations, and knowledge systems*' (Abelson, 1979, pp. 359-360; Nespor, 1987). This view contrasts with Rokeach and Ertmer, who contend that there are interconnections between deeply held and periphery beliefs (Ertmer, 2005; Rokeach, 1968). Nespor argues that in the case

of beliefs unboundedness, '*people read belief-based meanings into situations where other people would not see the relevance of the beliefs*' (Nespor, 1987, p. 18). Hence, raising an individual's deeply held implicit interconnected beliefs may have little relevance to other teachers. However, while some beliefs are unbounded, Nespor concedes that others are interconnected (Nespor, 1987). Encouraging teachers to discuss both the successes and challenges of novel practice with ICT they have designed and implemented with their peers can be structured in a way that helps other teachers recognise the links between their beliefs and practice. This approach can effectively assist teachers in reconstructing their beliefs and practice concerning ICT use at school.

Section 2.5.1 has argued that raising teachers' deeply held implicit interconnected beliefs is advantageous for teacher CPD initiatives in this area. Section 2.5.2 discusses appropriate scaffolds for facilitating the belief change process.

2.5.2 Alignment between the Belief Change Process and an Experiential Learning Cycle

The alignment between the belief change process and an experiential learning cycle in the context of teachers' pedagogy beliefs and their use of ICT can be scaffolded and understood using an experiential learning cycle. Even though beliefs can change through gestalt shifts, there is general consensus that belief change is a continuous process that evolves over time (Ertmer et al., 2015; Fishbein & Ajzen, 2011; Tillema, 1998). Moreover, there is general consensus that the belief change process involves raising, experimenting, reflecting, and refining beliefs (Ertmer et al., 2015; Fishbein & Ajzen, 2011; Tillema, 1998). Because teachers often enact classroom practices that conform with their pre-existing beliefs even though they may be unaware of the beliefs that are guiding those practices, the belief change process requires teachers to raise beliefs to become aware of their impact upon their practice (Kagan, 1992; Pajares, 1992; Rokeach, 1968; Shulman, 2013). After teachers have raised their beliefs, it is important that teachers experiment with practices that both align and misalign with those beliefs. This enables teachers to view the outcomes of practices. When the outcomes of practices that align with beliefs are positive, teachers are more likely to retain such practices. However, when new practices contradict teachers' deeply held beliefs and pre-existing practices, dissatisfaction with pre-existing beliefs and practice occurs, which is argued to be a precursor to change (Nespor, 1987; Pajares, 1992; Prestridge, 2012, 2017). Additionally, reflecting with peers enables teachers to receive feedback about how important referents experienced new practice, which contributes to teachers making sense of new experiences as a precursor to change (Ertmer, 2005; Fishbein & Ajzen, 2011). Moreover, discussing the outcomes of new practice with peers

can enable teachers to interconnect other beliefs about practice they were not aware of (Nespor, 1987). Over time, teachers refine their new beliefs and practices and reconstruct the relationship between their pedagogy beliefs and practice. The process – raising, experimenting, reflecting, and refining – provides CPD designers with a scaffold for interventions that can focus specifically on changing teachers' pedagogy beliefs about the use of ICT at school. By providing teachers with experiences of practice that align and misalign with their pre-existing beliefs and opportunities to reflect with others, the belief change process can be scaffolded.

Azjen and Fishbein describe a similar process when aiming to change individuals' beliefs (Fishbein & Ajzen, 2011). They argue that individuals need to develop behavioural, normative, and control beliefs as precursor to changing beliefs and behaviour. Behavioural beliefs refer to the positive or negative consequences individuals may experience if they enact the behaviour. There are two types of normative beliefs: Injunctive beliefs refer to important referents approving or disapproving the behaviour, and descriptive normative beliefs refer to important referents performing or not performing the behaviour. Control beliefs refer to the facilitating and inhibiting factors the individual believes will be present in the environment the behaviour is to be enacted within (Fishbein & Ajzen, 2011, pp. 20 - 21). Prochaska, DiClemente and Norcross (1992) refer to the stages of belief change as involving (i) precontemplation, (ii) contemplation, (iii) preparation, (iv) action, and (v) maintenance (DiClemente & Norcross, 1992; Fishbein & Ajzen, 2011). The (i) precontemplation stage is where the individual has no intention of changing behaviour and has not raised the beliefs necessary to begin the change process. During the (ii) contemplation stage, the relevant beliefs are brought into focus. During the (iii) preparation phase, the individual considers a range of behaviours that align with and misalign with their beliefs. During the (iv) action stage, the individual enacts behaviours designed to change behaviour. During the (v) maintenance stage, the individual engages in the behaviour consistently. The stages are not discrete, however, and do not indicate that individuals jump from one stage to the other; moreover, this is not a linear process, and individuals may cycle backwards and forwards through the stages in the sequence (Fishbein & Ajzen, 2011; Prochaska, Norcross, & DiClemente, 2013).

Tillema describes a similar belief change process involving the following four stages (Tillema, 1998): (i) A coherence check where the individual processes incoming information in light of prior experiences. If the information matches pre-existing beliefs there is coherence and beliefs may be strengthened; however, if there is incoherence between incoming information and pre-existing beliefs the individual may move on to the next stage. (ii) Discrepancy recognition may occur when the individual recognizes there is a

conflict between their pre-existing beliefs and new information they encounter. The need for (iii) reconstruction is the third stage, and it is here that the individual either rejects new ideas or accepts that a reconstruction of their existing beliefs is required. (iv) Searching for solution paths is the fourth stage in this belief change process model. It involves the individual either integrating new beliefs and reconstructing existing belief structures if a positive outcome is identified; however, adapting new beliefs or reconstructing beliefs is more likely to be rejected if the individual evaluates a negative outcome (Tillema, 1998). There are parallels between the belief change processes described above which may be argued to involve raising, experimenting, reflecting, and refining-and an experiential learning cycle involving abstract conceptualization, active experimentation, concrete experience, and reflective observation.

According to Kolb (2014), an Experiential Learning Cycle (ELC) includes two modes of grasping experience – Concrete Experience (CE) and Abstract Conceptualization (AC) – and two modes of transforming experience – Reflective Observation (RO) and Active Experimentation (AE), Figure 2.

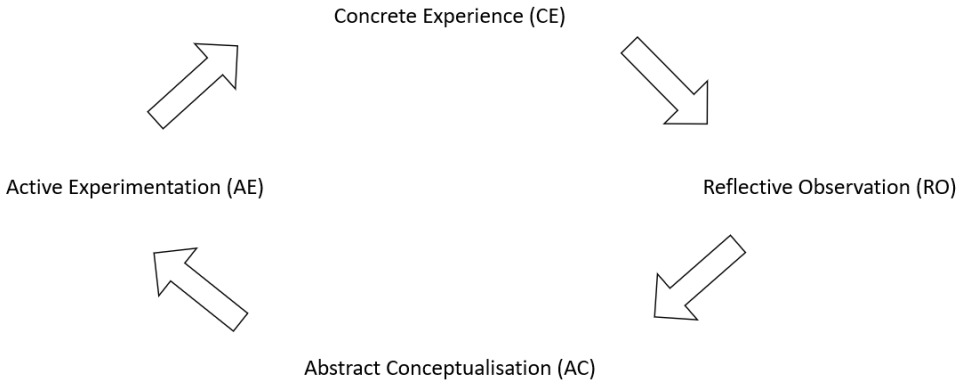

Figure 2: Experiential Learning Cycle (Kolb, 2014)

Learning is driven by the resolution of the dual dialectics of action/reflection and experience/abstraction and is defined as *'the process whereby knowledge is created through the transformation of experience'* (Kolb, 2014, p. 51). Moreover, learning arises from the resolution of creative tension among these four learning modes. The model is nonlinear and instead is a recursive process where the individual '*touches all the bases*' of experiencing, reflecting, thinking, and acting (Kolb, 2014, p. 51). There is synergy between the cycle and the belief change process, where abstract conceptualization is in alignment with raising beliefs. Active experimentation and concrete experiment are in alignment with experimenting with

beliefs. Reflective observation is in alignment with reflecting and refining beliefs, intimating that an Experiential Learning Cycle is an appropriate scaffold for teacher CPD design aiming to change teachers' pedagogy beliefs.

Teacher belief change about 21st century learning has been explored through the lens of Experiential Learning Theory previously. Girvan et al. (2016) encouraged teachers to plan, develop, and refine lessons based on new pedagogical approaches and implement them in their classroom before reflecting on their learning experience (Girvan et al., 2016). This project involved using the Bridge21 model of teacher CPD, an experiential CPD model (Girvan et al., 2016). Post-primary teachers observed student learning outcomes and experienced new pedagogical approaches as learners themselves, before adapting and implementing them in their own classrooms (Girvan et al., 2016). In this study, teachers developed both injunctive and descriptive normative beliefs. Teachers reported that they were motivated to persist with their new educational practice at school because they believed that other team members believed in the efficacy of the lessons they co-created, and they believed their teammates were persisting with the new practices at school (Girvan et al., 2016).

Sang et al. (2012) also scaffolded an intervention challenging science teachers' beliefs and practice utilizing Kolb's Experiential Learning Cycle (Sang et al., 2012). The Video-based teacher development project involved workshops where content ranged from theories of constructivist science teaching (AC), experience of watching class videos model designs (AE), practical activities where teachers designed and implemented teaching activities (CE), and reflective group discussion and reflection reports (RO) (Sang et al., 2012). Following their participation in an intervention that was scaffolded using an Experiential Learning Cycle, experimental group teachers reported fewer traditional beliefs and more constructivist beliefs about using ICT to support primary school students' learning of science (Sang et al., 2012). Despite the outcomes reported by the authors of this study, they conceded that there were no statistically significant differences between the experimental group and the control group participants. Sang et al, conceded that it was likely that they had not changed teachers' resistant beliefs which they had sought to address by employing a questionnaire – The Teacher Beliefs Survey (Woolley et al., 2004). This case highlights how primary school teachers' beliefs can change during teacher CPD interventions scaffolded employing an experiential learning cycle; however, it further highlights the need for employing deeper reflection activities than questionnaires to raise deeply held beliefs that are resistant to change. While it is acknowledged that some beliefs change during all types of teacher CPD and there is no one-size-fits-all model appropriate for scaffolding teacher CPD initiatives, utilizing Kolb's Experiential Learning Cycle

framework to scaffold the belief change process can be effective for changing teachers' pedagogy beliefs about the use of ICT.

Belief change could also be viewed through the lens of an expansive learning cycle. Figure 3. Expansive Learning Cycle.

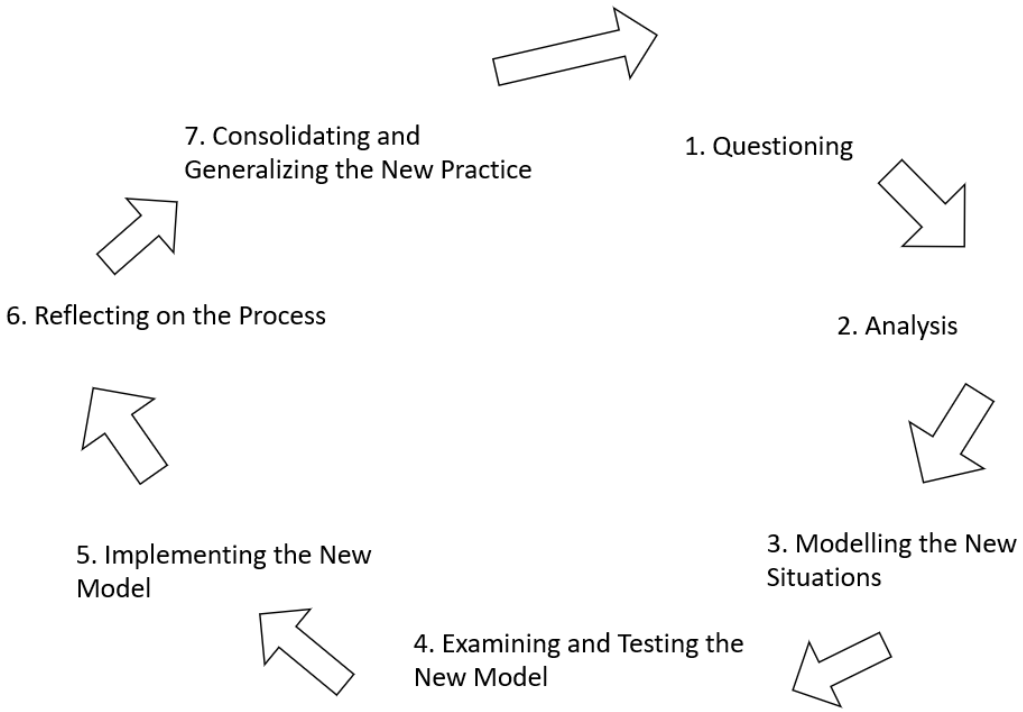

Figure 3: Expansive Learning Cycle (Engestrom, 2015)

An Expansive Learning Cycle involves 7 actions. These include (i) questioning, or rejecting some aspects of accepted practice and accepted wisdom; (ii) analysing the situation to find out causes or explanatory mechanisms; (iii) modelling the explanatory relationship by constructing an explicit simplified model of the situation; (iv) examining and testing the new model(s); (v) implementing the model in an authentic setting; (vi) reflecting on the outcomes; and (vii) consolidating outcomes into new practice (Engeström, 2015, p. xxi). While there are parallels between an Expansive Learning Cycle and the belief change process – raising, experimenting, reflecting, and refining,-there is more emphasis on reflection through abstract conceptualization in an Experiential Learning Cycle than an Expansive Learning Cycle, and deep reflection is argued to be important for changing beliefs, section 2.5.1.

A second lens through which the belief change process could be viewed is that of the principle of double stimulation. According to Sannino (2015), the principle of double stimulation indicates that teachers need to resolve conflicting motives about the different variables of the teaching and learning process as precursors to persistent change (Sannino, 2015). Double stimulation regards the formation of higher mental functions through a process in which the individual is faced with conflicting motives (Sannino, 2015). The first stimulus causes the individual to experience a paralysing conflict of motives. The individual resolves conflict by choosing an artefact which assists them to achieve their goals. The artefact serves the function of a meaningful sign. Through its use, the teacher believes they can achieve their teaching and learning motives. The method of double stimulation serves to make visible internal and unobservable psychological processes. Triggered by an initial problematic situation or first stimulus, a second stimulus is an artifact that has become a sign, i.e., a traceable link between the outside world and inner psychological functioning. The use of second stimuli, therefore, makes accessible processes which remain hidden when external resources are not mobilized. In this sense, double stimulation is a method of objectification of inner psychological processes such as teachers' beliefs (A. E. Sannino, Daniels, & Gutiérrez, 2009).

A third lens that belief change could be viewed through is coordination. When the organism/individual is faced with an indeterminate situation, the organism needs to readjust to achieve 'coordination' with its environment. Coordination is harmony between the organism and its environment, which are in a process of continuous readjustment (Biesta & Burbules, 2003). The process develops from an 'open' phase to a phase where the organism, through 'selection and assimilation' establishes a dynamic coordination with its environment (Biesta & Burbules, 2003). This moves to a closed phase where, once coordination has been achieved the organism can take a line of action. To bring this back to the literature on teachers' beliefs, coordination is the outcome of several minor coordinations, which are functionally connected with one another. In a similar vein, changing teachers' beliefs and practices with ICT involves interconnecting beliefs and practices that are in coordination with one another, such as how students learn, lesson design principles, student progression, assessment and feedback, and the design of the learning environment (Beetham & Sharpe, 2019; Greeno et al., 1996). As the teacher gains 'control' of the response to the stimulus by coordinating its actions, they coordinate other functions and develop new practices. The new practices are now something the teacher's developmental level has reached and achieved in the classroom environment. Moreover, the teacher has developed mental models of new practice they can revisit during the filtering, framing, and guiding process, section 2.3.3.1.

There are several lenses through which teacher pedagogy belief change may be scaffolded. While an expansive learning cycle, the principle of double stimulation, and coordination all offer alternatives to an experiential learning cycle (ELC) an ELC more closely aligns with the belief change process of raising, experimenting, reflecting, and refining. In particular, the focus of an ELC on abstract conceptualisation and deep levels of reflection is in synergy with the belief change process. While this is not to discount any of the other lenses as appropriate, it may be argued that an approach that employs an ELC can enable teachers to experience a holistic approach that interconnects each of the grasping and transforming elements as a precursor to belief change.

2.5.3 Multi-Dimensional Pedagogy Beliefs

Engaging teachers in designing lessons from multiple rather than single pedagogy orientations can change teachers' pedagogy beliefs and practices with ICT. According to Tondeur et al. 2017 who conducted a literature review regarding the relationship between teachers' pedagogy beliefs and their use of ICT, teachers' pedagogy beliefs are multi-dimensional (Ertmer et al., 2015; Tondeur et al., 2017). Multi-dimensional means teachers hold pedagogy beliefs ranging across multiple rather than single pedagogy orientations. Orientations include traditional, constructivist, and socio-cultural pedagogy beliefs (Greeno et al., 1996; Leavy et al., 2007; Martínez, Sauleda, & Huber, 2001). Traditional beliefs are more aligned with teacher-directed approaches. Constructivist beliefs include both individual and social constructivist beliefs that individuals construct rather than absorb knowledge, and that knowledge construction can be supported or triggered by social interactions. Socio-cultural beliefs include beliefs about people learning through participation in communities of practice that are closely aligned with the real-world setting in which the learner will eventually practice the acquired skills (Beetham & Sharpe, 2019; Greeno et al., 1996). The presence of multi-dimensional beliefs in a teacher's belief system adds to the complexity of addressing teacher belief change. It also calls into question to what extent teachers can become innovative and creative users of ICT at school if they hold equally strong beliefs about the effectiveness of traditional teaching and learning.

There are several cases that highlight the multi-dimensional nature of teachers' pedagogy beliefs. Lim, et al. report that the orientation of teachers' practice changes as the school year progresses (Lim, Tondeur, Nastiti, & Pagram, 2014). They highlighted how teachers are more likely to employ traditional teaching and learning when high stakes exams are on the horizon, even though the participants reported that

constructivist approaches enabled deeper learning experiences. In a similar vein, Becker reported that teachers hold both constructivist and traditional beliefs and practices with ICT (Becker, 2000). Even teachers whose pedagogy beliefs were more constructivist than transmissive used ICT in class for both transmission and constructivist teaching and learning (Becker, 2000). Ottenbreit-Leftwich et al. also report that teachers hold multi-dimensional beliefs (Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010). In their study with eight award winning elementary level teachers, they report that teachers used technology for both professional needs and student needs. Professional needs involved facilitating classroom operations and organisation, creating customised classroom materials, and engaging in professional development. Student needs involved engaging and motivating students, improving student comprehension, promoting higher-level thinking, and facilitating technology skills development that could transfer to future applications (Ottenbreit-Leftwich et al., 2010).

The multi-dimensional nature of teachers' pedagogy beliefs is also reported in larger scale studies. In an OECD report on Teaching Practices, the beliefs and attitudes of teachers from 18 countries were investigated, and alignment between beliefs and practices was evident in 15 countries. However, the report indicated that even though teachers with prevailingly constructivist pedagogy beliefs are more likely to engage students in stimulating and challenging learning environments, that are supportive of students' construction of knowledge, teachers with constructivist beliefs also employ direct transmission approaches involving transmitting information and demonstrating 'correct solutions' (OECD, 2015). The multi-dimensional nature of teachers' beliefs and ICT use is also reported on in Education at a Glance 2023 (UNESCO, 2023a). There it is reported that even though education systems may be ready for digital lifelong learning, and prevailingly teachers report their preference for student rather than teacher-centred teaching and learning, teachers still implement traditional approaches (UNESCO, 2023a). It is plausible that changing teachers' pedagogy beliefs about the use of ICT can be enhanced by multi-dimensional rather than uni-dimensional approaches.

While several international policies, such as the UNESCO ICT CFT outline multi-dimensional approaches to teachers' use of ICT at school, in some cases, national policymakers have removed objectives relating to traditional teaching and learning and emphasised constructivist use of ICT as a more effective approach (DES, 2015a). In Ireland, for example, the Digital Learning Framework (DLF) prescribes standards of effective and highly effective ICT use at school (DES, 2015a). Both standards prescribe ICT use that is constructivist in nature. The DLF makes limited reference to traditional use of ICT as an effective strategy for ICT use at school. From a pedagogy beliefs perspective, this approach does not consider the multi-

dimensional nature of the relationship between teachers' pedagogy beliefs and practice using ICT. While it prescribes innovative and creative use of ICT, it does not consider teachers' actual practice at school, which is not fixed in one orientation and instead involves teaching and learning practices that align with a wider range of orientations and shift from one orientation to the other as the academic year unfolds (Mama & Hennessy, 2013).

Kolb argues that individuals benefit from experiences that both align and misalign with their beliefs and behaviours (Kolb, 2014). While Kolb is not referring to teachers and their practices with ICT directly, he outlines the benefits of individuals learning through dialectically opposed modes of adaption to the world (Kolb, 2014). Kolb argues that learning is supported when individuals experience and reflect on conflicts between opposing ways of dealing with the world; moreover, '*the way in which the conflicts among the dialectically opposed modes of adaption get resolved determines the level of learning that results'* (Kolb, 2014, p. 42). Conflicts can be resolved by the suppression of one mode and/or dominance by another. This can be applied to the relationship between teachers' pedagogy beliefs and their use of ICT. By engaging teachers in both traditional and constructivist ICT use, teachers can experience teaching and observe student learning outcomes from orientations that are dialectically opposed. Resolving these conflicts can be a precursor to changing teachers' beliefs and practice.

Taking a dialectically opposed approach – where teachers engage in ICT use from both traditional and constructivist approaches – can create dissatisfaction in teachers' pedagogy beliefs as a precursor to changes in practice (Prestridge, 2017). In a small-scale study with three teachers, Prestridge examined the shaping of teachers' pedagogical orientation for the use of technology. Prestridge reports that even though teachers initially selected digital games that aligned with their pre-existing pedagogy beliefs, teachers' dissatisfaction, or satisfaction from the subsequent student learning outcomes they observed triggered changes in their beliefs and practice. Moreover, teachers' experiences of implementing new practices with ICT preceded change in beliefs as it caused tension between beliefs, pedagogy, technology, and student experiences (Prestridge, 2017). While small in scale, the study indicates that tension between beliefs and practices and student learning experiences and between pre-existing practice and novel practice may act as a precursor to reconstructing beliefs and practices from new orientations (Prestridge, 2017). Applying that reasoning to this study, it is argued that engaging teachers in designing teaching and learning from multiple orientations, including both traditional and constructivist approaches, may also trigger changes in teachers' pedagogy beliefs.

There are alternative views to taking multi-dimensional approaches. Firstly, the research literature in this area has focused on a dichotomous view of pedagogy beliefs, aiming to categorise teachers' pedagogy beliefs as either constructivist or traditional. Several studies have been guided by the assumption that because teachers with constructivist beliefs are more likely to use ICTs in creative and innovative ways that align with the aims and goals of national and international policies, professional development should engage teachers in constructivist practices with ICT (Buehl & Beck, 2015; Liu, 2011).

Secondly, it has been argued there may be no such thing as constructivist teaching, only constructivist learning (Biesta, and Richardson, 2003). Richardson reports that constructivist teaching is ideologically challenging as it involves translating a theory of learning into a theory of practice (Richardson, 2003). For example, whereas constructivism as a learning theory suggests individuals actively construct meaning around phenomena individual or within a social group through active experimentation, feedback, and discovery, when teachers employ constructivist pedagogy it involves the use of step-by-step models of constructivist teaching where the knowledge students are learning is already pre-determined by the teacher (Richardson, 2003). Moreover, constructivism as a learning, development or meaning-making theory suggests that individuals also learn from transmission models of teaching such as lectures, direct instruction, and non-interactive media (Bandura, Freeman, & Lightsey, 1999). Meaning, direct transmission teaching and learning strategies can also be part of a constructivist classroom.

Notwithstanding these concerns, the research literature indicates that teachers' pedagogy beliefs are multi-dimensional, and they include beliefs and practices that align with traditional, constructivist, and socio-cultural pedagogy teaching and learning. By engaging teachers in activities where they experience designing, implementing, and evaluating teaching and learning that aligns and misaligns with their beliefs and practices, teachers can observe student learning outcomes from different orientations as a precursor to change.

2.5.4 The Bi-Directional Relationship Between Teachers' Pedagogy Beliefs and their use of ICT

The bi-directional element of the relationship between teachers' pedagogy beliefs and ICT use is of interest to designers of teacher CPD. According to Tondeur et al. (2017), there is a bi-directional element to the relationship between teachers' pedagogy beliefs and their use of ICT. This means that teachers can use ICT to actualise pre-existing beliefs, and teachers' use of ICT can lead to changes in their beliefs (Chand, Deshmukh, & Shukla, 2020; Tondeur et al., 2017). According to Tondeur et al., teachers may use ICT to

engage students in learning and to give them more ownership, to introduce problem-based learning, to experiment with simulations, to access authentic learning episodes, to communicate and collaborate with peers, teachers, and parents, to provide scaffolds for self-regulated learners, and to accommodate individual learning (Tondeur et al., 2017). Moreover, the affordances of technology can support teachers' existing pedagogy beliefs about the use of ICT. Teachers' existing constructivist beliefs can enable teachers to use ICT in ways where it allows students to work in small groups, and to encourage students to explore and research new ideas (Tondeur et al., 2017).

Rowston et al. (2020) present further evidence of the usefulness of understanding the relationship as being bidirectional, rather than unidirectional (Rowston, Bower, & Woodcock, 2020). In their study into the lived experiences of career change professionals, they reported that career changers who had entered teacher training reported how their expertise using technology in the private sector was amongst their most valued and transferrable skill for teaching and learning. The authors argued that the participants' knowledge of the tools' affordances enabled them to use them pedagogically in their subsequent practice, even though they had little formal pedagogical training or classroom experience up to that point (Rowston et al., 2020).

Prestridge (2017, 2012) has conducted research on teachers' pedagogical decision making with ICTs. In her 2017 study referred to earlier, she also describes how teachers' dissatisfaction in pre-existing beliefs and practices arose as a consequence of the bidirectional relationship between teachers' pedagogy beliefs and their use of ICT. Although the author observed how her participants initially selected games to facilitate learning that aligned with their pedagogy beliefs, the participants' beliefs changed during the implementation phase (Prestridge, 2017). Prestridge reported how participants changed beliefs and practices to facilitate new learning during their use of ICT, even where the participants were initially sceptical about the affordances of the applications (Prestridge, 2017). This type of transactional relationship exists in the classroom. Teachers can use ICT for specific objectives, and ICT use can enable teachers to achieve surprising objectives.

Chand et al. (2020) have also discussed the bi-directional relationship between teachers' pedagogy beliefs and ICT use at school (Chand et al., 2020). Their 2020 study investigated the relationship among technology integration, teacher beliefs, and the interpretation by teachers of the computer application that was made available to them. They argued that well-designed educational technologies based on constructivist practices can enhance teachers' use of ICT at school for student-centred rather than teacher-centred teaching and learning. Moreover, the process takes time as teachers with teacher-

centred beliefs tend to use such educational technologies for teacher-centred rather than student-centred approaches during the early stages of adoption, even where education policies are prescribing a shift towards student-centred teaching and learning (Chand et al., 2020).

There are grounds for incorporating specific bi-directional strategies into teacher CPD. According to Kolb (2014), learning is conceived as a 'transaction' between the person and the environment. Moreover,

> *"The process of cognitive growth from concrete to abstract and from active to reflective is based on this continual transaction between assimilation and accommodation ' (Kolb, 2014, p. 34). Transaction implies a more fluid, interpenetrating relationship between objective conditions and subjective experience, such that once they become related, both are essentially changed (Kolb, 2014, p. 47)."*

Taking a perspective that the teacher and the ICT they are using in class change each other, rather than the perspective that it is the teacher and their pedagogy beliefs alone that are acting on the ICT, may be an important design feature for teacher CPD.

In a similar vein, Vygotsky argues that tools are mediating factors in human psychological development and that tools and signs make possible the transmission of culture (Wertsch, 1985). For instance, '*the ability to invent and use tools is a prerequisite for the historical development of humans*' (Wertsch, 1985, p. 28). Moreover, new uses of technical tools provide the foundation for new labour which grounds the development of mental functioning in qualitatively new principles from which higher mental functioning, or new beliefs, emerge (Wertsch, 1985, p. 28). This perspective underscores the importance of adopting a bi-directional approach for designers of Teacher CPD.

Engestrom et al. (2015), also argued that both technical and psychological tools play a significant role in humans' transformation of nature and in psychological development. While psychological tools include signs and symbols, it is argued that they *'are abstracted and generalized from the production and use of material tools and objects' (Engeström, 2015, p. 36)*. Instead of it being a unidirectional relationship, it is 'a *superindividual, collective process, based on the mediated, indirect interaction of subjects with symbols via objects'* (Engeström, 2015, p. 36). Moreover, the individual's '*grasp and use of symbols originate from practical encounters with the world of objects, which the symbols represent and from which they stem'* (Engeström, 2015, p. 36). While ICTs themselves are not teachers, they can play a role in teacher belief growth. Teacher CPD designers should be aware of this potential when designing initiatives. Even though

sophisticated pedagogy-first teacher-led practice is the goal of teacher CPD, there is also scope for teachers being guided by the technology.

Dewey (1997) also argues that human development emerges out of a transactive relationship between the individual and the environment in which the experience is enacted (Dewey, 1997). From this perspective, the individual and the environment are inseparable. The experience is not just made up of the individual and their beliefs and actions; rather, it is the transactional nature of the experience where the individual and the tools they use to enact the behaviour impact upon one another, which has consequences for the experience and the individual's learning from the experience (Dewey, 1997). In the case of the bidirectional element of the relationship between teachers' pedagogy beliefs and their use of ICT, teachers' pre-existing pedagogy beliefs and the functionality of the ICT they are employing in class involves transactions between the teachers pre-existing pedagogy beliefs, the pedagogical affordances of the ICT, and the subsequent learning experience that evolves. It may be argued that the bi-directional transactional element of this relationship can enable socio-cultural exchanges of pedagogy beliefs and practices during teachers' transactions with ICTs and peers.

In contrast to a transactional approach, Watson (2001) argues that the integration of ICTs at school should be teacher-directed rather than ICT-directed (Watson, 2001). In 'Putting the pedagogic horse in front of the technology cart' Watson argued that change *'has been too associated with the symbolic function of technology in society which sits uncomfortably with teachers' professional judgements*' (Watson, 2001, p. 1). Following on, the author argues that *'technology should not be the catalyst for change, but rather its tool'* (Watson, 2001, p. 264). From this perspective, authors have argued that teachers need to take a pedagogy-first approach towards embedding ICT in classroom practice. Watson contends that with technological innovation and new developments, attention will inevitably and necessarily fall on what constitutes good practice. By taking a pedagogy first approach, teachers can unlock more of the potential educational uses of the ICTs at their disposal and let their minds be made up about the utility of ICTs' role in the classroom, by observing the learning outcomes their design skills enable their students to attain. Following on, teachers taking a pedagogy-first rather than a technology-first approach to supporting 21st Century teaching and learning at school can better enable them to keep up with the continuous and rapid progress of ICTs, as it is the principles of learning theory, rather than the technology, that will determine ICT use at school (OECD, 2019). The research literature, however, indicates that when ICT is teacher-directed, prevailingly its outcome is traditional teaching and learning. Instead, a bi-directional approach,

where teachers are open to being guided by the pedagogical affordances embedded in ICTs, can enable teachers to reconstruct beliefs and practice.

Subsection 2.5.4 contends that the bi-directional element of the relationship between teachers' pedagogy beliefs and ICT use is of value to designers of teacher CPD in this area. Whereas one of the primary goals of ICT-enhanced teaching and learning is teachers enacting innovative and creative digital educational practice at school, the research literature indicates that when ICT use is teacher-led, it is prevailingly traditional in nature. From a theoretical lens, the bi-directional element of the relationship can be viewed as transactions between the teacher, the technology, and the learning context. Leveraging this relationship for CPD interventions can enable teachers to experience using ICT to realise pre-existing beliefs and experience ICT use that influences teachers reconstruction of pre-existing beliefs. Section 2.6 sets the Irish context, the country in which this study takes place.

2.6 The Irish Context

Within the context of the push towards 21st century teaching and learning at school, Ireland has followed international trends and there is a need for research into Irish primary teachers' pedagogy beliefs about the use of ICT at school (Butler, 2022). In the Irish context, McGarr and Johnston have discussed ICT policy reform initiatives during three phases (McGarr & Johnston, 2021). The first phase, 'Catching up and joining the international ICT race '1997-2003' involved government funding initiatives that focused on four primary areas: (i) technology infrastructure, (ii) training for teachers, (iii) pilot projects, and (iv) support services. The authors argue there was a lack of any real direction about how to embed ICTs within existing curricula, which meant that even though the provision of infrastructure and teacher professional development were more readily visible and achievable, and the attempts at bridging the digital divide between the haves and the have-nots were genuine, the fuzziness of early policies' educational intentions left them open to accusations of masking the social, political, and economic agendas they were being used to propagate (McGarr & Johnston, 2021).

The second Phase, '2008-2013' 'Responding to the changing lives of young people,' involved government funding aimed at seven primary areas of investment: professional development; software and digital content; ICT infrastructure; broadband; technical support; cohesive implementation structures and supports; and a research dimension (McGarr & Johnston, 2021). In contrast to the first phase, the second phase was aimed more towards enhancing student learning experiences with ICT at school, than schools

building visible infrastructure. It became more about preparing students for living and working in the modern world, rather than procuring ICT, as there was an understanding that the previous wave had not resulted in much of a shift in teachers' practice. Moreover, the second phase of ICT adoption became more about economic rationale such as preparing students for the 'knowledge economy,' than educational rationale (McGarr & Johnston, 2021).

The third phase, 'Towards Pedagogical Maturation'-included the release of the Digital Strategy for Schools and the Digital Learning Framework and sought to address four key areas: (i) Teaching, Learning, and Assessment using ICT; (ii) Teacher Professional Learning; (iii) Leadership, Research, and Policy; and (iv). ICT Infrastructure. During this phase, Irish policy also became more grounded in international policies such as the UNESCO and the TPACK frameworks, and policies prescribed constructivist pedagogy as an appropriate approach for teachers' use of ICT to support students' 21st century learning at school (Mishra & Koehler, 2006; UNESCO, 2018b). Critics persist with their argument, however, that this phase is still underpinned by an economic rationale which is *'as self-evident as any social rationale'* (McGarr & Johnston, 2021, p. 856). According to the authors, earlier phases of policy had more to do with spending school grant money on ICT infrastructure rather than developing teachers' capacity for teaching and learning using ICT. The most recent wave has sought to address those concerns by emphasising constructivist pedagogy approaches, even though reform is underpinned by economic rationale. Criticisms of Ireland's progress towards effective use of ICT at school are also present in other reviews.

Butler (2022), reviewing the successes of Ireland's digital strategies, reported that teachers' practice with ICT is very much in the embryonic stage (Butler, 2022). Upon review of their observations, the inspectorate's key recommendations included the need for teachers and students using ICT in innovative and creative ways at school, e.g., STEM activities for engaging students in real-world problem-solving experiences (DES, 2020). Among the reasons teachers have not reached the pedagogical maturation phase with their use of ICT at school are: there is confusion between teachers' and policy makers' understanding of effective and highly effective practice with ICT; moreover, there is a lack of assessment practices that are consistent with constructivist use of ICT, which is limiting teachers giving over curriculum time to teaching and learning outside of that which is assessed on the end-of-year standardised tests. Furthermore, at primary level, the reports indicated more need for greater focus on teaching and learning activities rather than whole-school approaches because primary teachers are behind their post-primary school peers (Butler, 2022). Butler's review of the adequacy of national and international CPD for developing teachers' use of ICT to support 21st Century skills development at school identified a number

of factors that can enhance teachers' realisation of 21st Century teaching and learning at school. These involve providing more in-school support for teachers during informal learning sessions and building on what is already available in the school's developing infrastructure and practice (Butler, 2022).

Since then, Ireland has published a new Digital Strategy for Schools - Digital Strategy for Schools to 2027 (DES, 2022). This document outlines three pillars addressing ICT integration in schools: Pillar 1: Supporting the embedding of digital technologies in Teaching, Learning and Assessment; Pillar 2: Digital Technology Infrastructure; and Pillar 3: Looking to the future: policy, research, and digital leadership. The policy has also reported on the successes of previous policy initiatives. It outlines how 100% of post-primary schools now have high-speed broadband with minimum connectivity speeds of 200 Mbps. Since 2020, Computer Science has been introduced as a leaving certificate subject in Ireland. And it reports that 23,000 high quality digital resources are available at www.scoilnet.ie - a site where teachers can upload and share digital educational practice. It claims that in the intervening period, a broad range of professional learning opportunities, including differentiated models of Teacher Professional Learning (TPL), are available to teachers and school leaders on the effective use of digital technologies in teaching and learning practice. That there is now extensive support and resources, including quality-assured exemplars of effective practice. Moreover, the new Digital Strategy for Schools (DSS) reports that all new and revised curricular specifications include clear statements that focus on the development of digital learning skills and the use of digital technologies as a resource in achieving specific outcomes across the curriculum. Furthermore, it claims as an achievement that the Junior Cycle Framework (JCF) continues to promote digital literacy skills through eight key skills and through statements of learning. The strategy also acknowledges that these developments were accelerated during the COVID-19 pandemic and that school closures drew attention to several challenges related to the digital capacity of schools, teacher professional learning, and overall levels of digital skills and competences for both teachers and learners alike, as well as the need for appropriate infrastructure and broadband connectivity in schools (DES, 2022, p. 9).

Despite these successes there is no mention of radical change in teaching and learning using ICT. The strategy recognizes that:

> *'Enabling real change requires policies and actions on several fronts, including infrastructure, strategy and leadership, teacher skills, learner skills, content, curricula, assessment and national legal frameworks*," (DES, 2022, p. 11).

The strategy is aiming to address the shortfalls in teaching and learning, and its stated vision is to:

> "*Empower schools to harness the opportunities of digital transformation to build digital competence and an effective digital education ecosystem so as to develop competent, critically engaged, active learners while supporting them to reach their potential and participate fully as global citizens in a digital world,*" (DES, 2022, p. 11).

Primary school teachers limited progress with ICT use for educational practice was observed during the COVID-19 school closures, where teachers from primary school level adapted less well to the provision of remote teaching and learning than post-primary teachers (Bray et al., 2021). Feerick et al. (2021) reported that even though primary school teachers responded better during the second school closure, their practice was less about constructivist use of ICT than enhancing their communication with parents and providing feedback on students' work (Feerick, Cosgrove, & Moran, 2021). According to teachers' self-reports about their use of ICT aligned with the Digital Learning Framework, approximately 85% or primary school teachers are either at the level of effective practice or below, and only 15% of teachers consider themselves to be either partly or wholly in alignment with highly effective practice at school (Feerick et al., 2021). Approximately 94% of teachers rate their level of practice embedding DTs in teaching, learning, and assessment between intermediate, developing, and emerging, with only 6% rating as advanced or highly advanced (Feerick et al., 2021, p. 90). Similar trends were evident prior to the pandemic school closures. The schools' inspectorate reported that during their observations of Irish primary school teachers' lessons, only 55% involved the use of ICT. Of those teachers who used ICT during their lessons, less than half used ICT in ways that are consistent with the approaches prescribed in national policies such as the Digital strategy for Schools (DES, 2020).

To address the deficit between teachers' practice and prescribed practice in national policies such as the Digital Strategy for Schools and the Digital Learning Framework, the Irish education ministry has developed the Cosán framework. Cosán – an Irish word meaning pathways – has identified the following interconnected elements as key to achieving its aims: (i) dimensions of teachers' learning, (ii) teachers' learning processes, (iii) teachers' learning areas, and (iv) standards to guide learning and reflection (Council, 2016a). Each of the four areas is aligned with a view that knowledge is distributed across the education system and reflects a wide range of different pathways teachers engage in, such as individual/collaborative, formal/informal, school-based/external, and personal/professional learning. Moreover, Cosán has identified the following learning processes teachers may engage in: mentoring and coaching, reading and professional contributions, research, practice and collaboration, immersive professional learning activities and courses, programmes, workshops, and other events. In alignment with

other such policy initiatives, Cosán identifies leading learning, inclusion, well-being, ICT, literacy and numeracy, and supporting other teachers' learning as the key learning areas teachers are to focus their professional development (Council, 2016).

There are similarities between Irish primary school teachers' progress with ICT use for students' 21st century skills development at school and their international peers. The Cosán framework calls for novel CPD approaches for enhancing teachers' ICT use, and a key recommendation from Butler's review of Irish teachers' progress in this area is the need for a focus on teachers' beliefs. Building on those calls, the Irish context is appropriate for investigating teacher pedagogy belief change about their use of ICT through a bespoke model of teacher CPD.

2.7 Propositions and Research Questions

This chapter has outlined the literature search and the literature report underpinning this thesis. Section 2.3 reported on the push for 21st century skills development at school, and it argued there is a need for primary schools and primary school teachers to adapt their current practices with ICT for teaching and learning. Moreover, it was argued that even though there are several barriers to ICT adoption at school, the relationship between teachers' pedagogy beliefs and their use of ICT warrants further investigation, as strong links between pedagogy beliefs and practice with ICT are consistently reported on in the relevant research literature.

Section 2.4 argues that effective situative transitional models of teacher CPD are appropriate for designing interventions aiming to change teachers' pedagogy beliefs about the use of ICT at school. Moreover, teams that co-create, implement, and evaluate novel teaching and learning using ICT can provide teachers with support to develop persistence with new beliefs and practice with ICT at school.

Section 2.5 discussed the relationship between teachers' pedagogy beliefs and their use of ICT in depth. Here, it was argued that raising deeply held implicit interconnected beliefs can have greater ramifications across the belief system. The alignment between the belief change process and an Experiential Learning Cycle (ELC) indicates that an ELC is an appropriate scaffold for pedagogy belief change. Pedagogy beliefs are multi-dimensional, and engaging teachers in the co-creation, implementation, and evaluation of teaching and learning using ICT that aligns and misaligns with their beliefs and practice may be a strategy for enabling teacher change. Moreover, the bi-directional element of the relationship is a component that can be leveraged by designers of teacher CPD as a precursor to change.

In section 2.6, it is argued that Irish reform initiatives in the push for 21st century teaching and learning at school have followed international trends, and the outcomes are much the same: more progress in ICT infrastructure than technology-enhanced teaching and learning.

The conclusion of this chapter is that there is scope for investigation into a bespoke model of teacher CPD aiming to change teachers' pedagogy beliefs about the use of ICT. One that incorporates effective situative transitional models and teacher design teams, that raises teachers' deeply held implicit interconnected beliefs, and scaffolds the belief change process aligning it with an experiential learning cycle. It engages teachers in co-creating, implementing, and evaluating teaching and learning that aligns and misaligns with teachers' pedagogy beliefs and practice, and aims to leverage the bi-directional element of the relationship as a precursor to changing pedagogy beliefs and practice. Finally, it employs the bespoke model in Ireland with Irish primary school teachers whose practice with ICT has followed similar trends to their international peers and is misaligned with the aims and goals of national and international policies such as the UNESCO ICT Competence Framework for Teachers and the Irish Digital Learning Framework.

Five propositions are developed from the literature review that underpin the design of a model of teacher CPD aiming to investigate changing teachers' pedagogy beliefs about the use of ICT. These are as follows:

- Team support can enable teachers to persist with new practices at school.
- Because beliefs are functionally connected to and in communication with one another, raising and changing deeply held beliefs has more ramifications across the belief system.
- The belief change process involves raising, experimenting, reflecting, and refining beliefs that align with an experiential learning cycle of abstract conceptualisation, active experimentation, concrete experience, and reflective observation.
- Teachers' beliefs are multi-dimensional, so CPD design can seek to interconnect beliefs from different pedagogy orientations by engaging teachers in lesson design from multiple rather than single orientations.
- The relationship between teachers' beliefs and ICT is bi-directional, so teachers can benefit from guiding and being guided by pedagogy-first, ICT-enhanced teaching and learning.

From those propositions, the following research questions about the design of a bespoke model – the 4D Model-emerged:

- Q1. Do teachers change and grow beliefs about 21st Century teaching and learning because of their experiences with the 4D Model? If so, then

- Q2. How do teachers change their beliefs about 21st Century teaching and learning because of their experiences with the 4D model?
- Q3. Why do teachers change their beliefs about 21st Century teaching and learning because of their experiences with the 4D model?

The next chapter describes, explores, and establishes the design of the bespoke model – the 4D Model- used in this study.

3. Design

3.1 Introduction

This chapter describes the development and design of a new model of teacher CPD. The 4D model- design, develop, deliver, debug-is designed to investigate changes in teachers' pedagogy beliefs and practice about 21st Century teaching and learning at school. First, this chapter discusses the international literature underpinning the design of the 4D model. Next, the theoretical principles and their influence on the design of the 4D model are discussed. Following on, the practical 4D activity model is presented, the materials used to scaffold the experience are presented, and a typical 4D model activity is described. Finally, guidelines for facilitating the experience are outlined as visually summarised in Figure 4 below: The 4D Model.

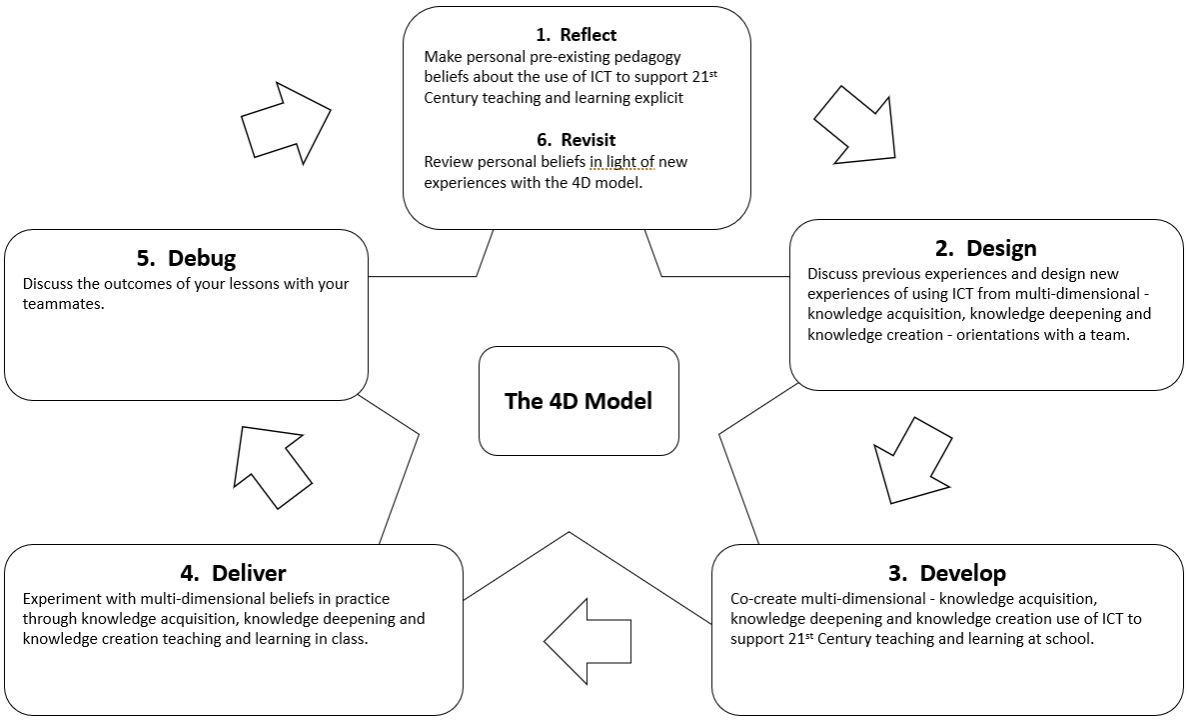

Figure 4: The 4D Model

3.2 Context

In the previous chapter, the literature review indicated that primary teachers' use of ICT at school is prevailingly traditional. This is at odds with the constructivist practices outlined in national and international policies aiming to embed digital educational practice into school curricula, e.g., (DES, 2015a;

UNESCO, 2018b). It has been argued that teachers' pedagogy beliefs can act as barriers and supports to 21st Century teaching and learning at school. Teachers whose pedagogical beliefs are principally constructivist are more likely to implement ICTs in creative and innovative ways, whereas teachers whose beliefs are prevailingly traditional are more likely to use ICTs to enhance previously established practice. It was also discussed how traditional models of teacher CPD were inadequate for growing teachers' beliefs about 21st Century teaching and learning. Whereas traditional CPD models have sought to change teachers' beliefs and practice through off-site one-shot initiatives, it is argued that change in beliefs and practice follows classroom experiences and takes time (Darling-Hammond et al., 2017; Guskey, 2002b). It was argued that there is a gap in the literature for a model of teacher CPD aiming to enable teachers to form new beliefs about using ICT to support students' development of 21st Century skills at school.

There are international calls for teachers and students to engage in innovative and creative use of ICT at school (R. E. Anderson, 2008; Voogt et al., 2018). Even though external and internal barriers to teachers' adoption of ICT at school are being addressed, the previous chapter highlighted how there is a lack of teacher CPD models that specifically aim to grow or change teachers' beliefs and practices about the use of ICT to support 21st Century teaching and learning at school (Ertmer et al., 2015). Synthesis of research literature on the relationship between teachers' pedagogy beliefs and their use of ICT to support 21st century teaching and learning have revealed that the relationship is bi-directional and multi-dimensional, and there is a need to support teachers' new beliefs and practice at school, especially when new practice comes into conflict with the existing school culture (Tondeur et al., 2017).

In teacher CPD, it is contended that offsite, one-shot CPD experiences do little to change teachers' beliefs. Instead, there is a need to engage teachers in authentic, situated experiences where they can observe student learning outcomes as a precursor to changes in their beliefs and practice (Guskey, 2002b; Guskey & Yoon, 2009). Moreover, effective teacher CPD involves content focus, active learning, collaboration, modelling, coaching and expert support, feedback and reflection, and sustained duration (Darling-Hammond, Burns, Campbell, Goodwin, & Low, 2018; Darling-Hammond et al., 2017). National and international policies seeking to address how and why teachers use ICT to support students' development of 21st Century skills at school argue for pedagogy-first constructivist approaches at school, which can provide students with innovative and creative experiences of using ICT for enhancing teaching and learning (DES, 2015a; UNESCO, 2018b).

However, it could be argued that there is a conflict between pedagogy-first constructivist approaches and the literature on the relationship between teachers' pedagogy beliefs and their use of ICT. Teachers'

beliefs play a significant role in determining teachers' actual practice at school; those teachers whose pedagogy beliefs are prevailingly traditional are less likely to engage in constructivist practice (Ertmer et al., 2012; Sadaf, Newby, & Ertmer, 2013). Moreover, the prevailing school culture, which has its roots in traditional approaches to teaching and learning, limits teachers whose beliefs are prevailingly constructivist from realising such practice at school (Chai, 2010; Somekh, 2008). Instead, it is argued that there is efficacy in providing teachers with opportunities to engage in the design, implementation, and evaluation of the use of ICT to enhance teaching and learning from multi-dimensional approaches, e.g., both traditional and constructivist. Moreover, there is efficacy in engaging teachers in technology-led experiences, especially where it engages teachers whose beliefs are prevailingly traditional in constructivist learning experiences supported by peers (Chen & Bonner, 2017). While this approach conflicts with national and international approaches, such as the UNESCO ICT Competence Framework for Teachers and the Irish Digital Learning Framework, it is argued that multi-dimensional and bi-directional approaches can enable teachers to form new beliefs by interconnecting core beliefs about teaching and learning with the periphery beliefs they are functionally connected to and in communication with as a precursor to realising constructivist ICT use at school.

In sections 3.3 and 3.4 the theoretical principles underpinning the model and the practical activity 4D activity model are presented. The model includes a multi-dimensional approach which is aligned with the goals of the UNESCO ICT CFT (UNESCO, 2018b), and it is also in synergy with the aims and objectives of the Digital Strategy for Schools (DES, 2015b, 2022) and the Digital Learning Framework (DES, 2015a) in Ireland. It is hypothesised that the 4D model could be a suitable teacher CPD model for facilitating teachers' transformation of their educational practice with ICT by enabling teachers to form new beliefs and practices about constructivist educational use of technology at school. The elements of the model, in combination with authentic situated experiences at school, could help teachers to realise the potential of constructivist use of technology at school and enable them to unlock more of the potential of ICT-enhanced teaching and learning. Thus, an investigation into the efficacy of this model of teachers' pedagogy belief change would first be necessary.

3.3 Theoretical Principles Underpinning the 4D Model

The literature review identified five propositions, see 2.7, that inform the design of the 4D model. The propositions are discussed in turn. In the literature review, it was argued that effective CPD involves content focus, active learning, collaboration, use of models and modelling, coaching and expert support,

feedback and reflection, and is of sustained duration (Darling-Hammond et al., 2017). Moreover, team support can enable teachers to persist with new practice at school (Girvan et al., 2016).

The literature review reported interesting insights from the literature pertaining to the relationship between teachers' pedagogy beliefs and ICT that can inform teacher CPD design. Teachers hold beliefs of different strengths in their belief system, and there are concerns that many teacher CPD initiatives fail to raise teachers' deeply held beliefs that are rarely, if ever, made explicit. It was also reported that beliefs are interconnected with one another (Ertmer, 2005; Pajares, 1992; Rokeach, 1968; Schraw & Olafson, 2015). Changing interconnected beliefs can have ramifications across the belief system.

In the literature review, it was also argued that the belief change process involves raising, experimenting, reflecting, and refining beliefs (Ertmer et al., 2014; Guskey, 2000). Moreover, there is alignment between the belief change process and an experiential learning cycle involving abstract conceptualisation, active experimentation, concrete experience, and reflective observation.

It was also reported that teachers' beliefs are multi-dimensional. This is taken to mean that within teachers' pedagogy beliefs systems, teachers hold multi-dimensional beliefs ranging from traditional, individual and socially constructivist, and socio-cultural pedagogy orientations (Tondeur et al., 2017). Teacher CPD initiatives often focus on changing teachers' practice from traditional to constructivist orientations by focusing on one orientation only, e.g., Girvan, et al. (2016). Meanwhile, national policies such as the Digital Learning Framework, outline practice that is constructivist only. This contradicts teachers holding multi-dimensional beliefs.

Further insights revealed that the relationship between teachers' pedagogy beliefs and ICT is bi-directional. This means that teachers can use ICT to achieve pre-existing beliefs about practice, and teachers' use of ICT can enable teachers to grow beliefs about novel practice. Moreover, working with peers who have experience of using ICT for constructivist teaching and learning can guide teachers towards growing constructivist beliefs.

Building on these insights into the literature, five theoretical propositions inform the design of the practical 4D model for changing teachers' pedagogy beliefs about the use of ICT. Each of these theoretical propositions informs the design of the practical 4D activity model in the following ways.

Proposition 1: *Because beliefs are functionally connected and in communication with one another, raising and changing deeply held beliefs has more ramifications across the belief system*.

Proposition one involved designing a task where teachers could raise deeply held beliefs that are interconnected with one another. The literature search reported that reflection is one activity that teachers can engage in to access deeply held beliefs. While many CPD initiatives employ questionnaires and surveys as media for teacher reflection, there are concerns such practices are only raising superficial beliefs. While changes in these beliefs are recorded, the lack of evidence of changes in teachers' practice has led some authors to question what levels of change are occurring and whether these changes are interconnected with other beliefs (Schraw & Olafson, 2015). To address this, the 4D model includes a reflection phase where the participants can raise their deeply held beliefs about teaching and learning using ICT. Moreover, the participants are tasked with reflecting on beliefs that are interconnected. This involves teachers reflecting on their pre-existing pedagogy beliefs about the use of ICT at school under the following headings: how students learn, lesson design principles, student progression, design of the learning environment, and example activities (Beetham & Sharpe, 2019; Greeno et al., 1996). Proposition one and its influence on the design of the 4D model is presented in Table 4.

Table 4: Proposition One

Proposition	Influence on Design
Because beliefs are functionally connected and in communication with one another, raising and changing deeply held beliefs has more ramifications across the belief system.	• Teachers deeply reflect on, raise, and revisit interconnected pedagogy beliefs under the following subcategories: how students learn, lesson design principles, student progression, assessment and feedback, design of the learning environment, and example activities.

Proposition 2: *The belief change process involves raising, experimenting, reflecting, and refining beliefs that align with an experiential learning cycle of abstract conceptualisation, active experimentation, concrete experience, and reflective observation*.

Proposition two involved scaffolding the practical activity model in a sequence that enables teachers to experience the belief change process, which is argued to involve raising, experimenting, reflecting, and refining beliefs. It is argued the belief change process aligns with an experiential learning cycle consisting of abstract conceptualisation, active experimentation, concrete experience, and reflective observation.

To address this proposition, the 4D model incorporates abstract conceptualisation into its reflection stage. Active experimentation is actualised into a design and develop stage. Concrete experience involves implementing the lesson into practice. Reflective observation involves a debugging phase, where the participants reflect on the outcomes of the lessons with fellow participants, and a revisit stage where the participants revisit their initial reflection and review their initial abstract conceptualisations about the use of ICT at school in light of their new experiences. Proposition two and its influence on the design of the 4D model is presented in Table 5.

Table 5: Proposition Two

Proposition	Influence on Design
The belief change process involves raising, experimenting, reflecting, and refining beliefs that align with an experiential learning cycle of abstract conceptualisation, active experimentation, concrete experience, and reflective observation.	• Teachers make abstract conceptualisations of deeply held interconnected beliefs. • Teachers actively experiment with their beliefs by designing and developing teaching and learning activities using ICT. • Teachers have concrete experiences with those beliefs by implementing the lessons in class. • Teachers reflect on the outcomes of the lessons with their teammates. • Teachers revisit their initial beliefs and refine where appropriate.

Proposition 3: *Teachers' beliefs are multi-dimensional, so CPD design can seek to interconnect beliefs from different pedagogy orientations by engaging teachers in lesson design from multiple rather than single orientations.*

Proposition three indicated that teachers' pedagogy beliefs are multi-dimensional, including beliefs about a wide range of pedagogy orientations and practices. Whereas many CPD initiatives have attempted to change teachers' beliefs and practices by engaging them in novel practice from constructivist orientations, there has been less focus on engaging teachers in designing from multiple orientations. In Ireland, for example, the Digital Learning Framework focuses on effective and highly effective practice, which are constructivist in nature. In comparison, the UNESCO, outlines three orientations: knowledge acquisition, knowledge deepening, and knowledge creation (UNESCO, 2018b). Whereas there has been much

investment in ICT in Ireland and there is evidence of ICTs in primary schools, there has been much less evidence of actual change in teachers' practice. Proposition three influenced the design of the practical activity model to include opportunities for teachers to experience designing from multiple rather than single orientations. Proposition three and its influence on the design of the 4D model is presented in Table 6.

Table 6: Proposition Three

Proposition	Influence on Design
Teachers' beliefs are multi-dimensional, so CPD design can seek to interconnect beliefs from different pedagogy orientations by engaging teachers in lesson design from multiple rather than single orientations.	• Teachers co-create, implement, and evaluate the use of ICT from multiple orientations – knowledge acquisition, knowledge deepening, knowledge creation.

Proposition 4: *The relationship between teachers' pedagogy beliefs and ICT is bi-directional, so teachers can benefit from guiding and being guided by pedagogy first, ICT-enhanced teaching and learning*.

Proposition four related to evidence that the relationship between teachers' pedagogy beliefs and their use of ICT is bi-directional, meaning that teachers can use ICT achieve existing beliefs about practice, and using ICT can enable teachers to grow pedagogy beliefs. Moreover, working with teachers with prior experiences of using ICT for constructivist teaching and learning can provide further support for teachers to change their beliefs. Proposition four and its influence on the design of the 4D model is presented in Table 7.

Table 7: Proposition Four

Proposition	Influence on Design
The relationship between teachers' pedagogy beliefs and ICT is bi-directional, so teachers can benefit from guiding and being guided by pedagogy first, ICT enhanced teaching and learning.	• Teachers guide and are guided by pedagogy first ICT enhanced teaching and learning working as part of a team.

Proposition 5: *Team support can enable teachers to persist with new practices at school*.

Proposition five related to teamwork as a mechanism for encouraging teachers to persist with novel practice with ICT at school and overcome external barriers to its enactment. Previous studies have reported that teachers working as part of teacher design teams can develop shared beliefs about the effectiveness of ICT-enhanced practice, and the belief that other teachers are implementing the practice at school can act as a motivation for teachers' persistence. Proposition five and its influence on the design of the 4D model is presented in Table 8.

Table 8: Proposition Five

Proposition	Influence on Design
Team support can enable teachers to persist with new practices at school.	• Teachers work as part of a teacher design team.

Subsection 3.3 outlined the theoretical principles underpinning the 4D model and their influence on its design. Section 3.4 presents the actualisation of the theoretical principles into the design of the practical 4D activity model.

3.4 The Practical 4D Activity Model

To help move the 4D model from a theoretical model for teacher continuous professional development to a practical approach that could be implemented in schools, a bespoke activity model is presented in Figure 5.

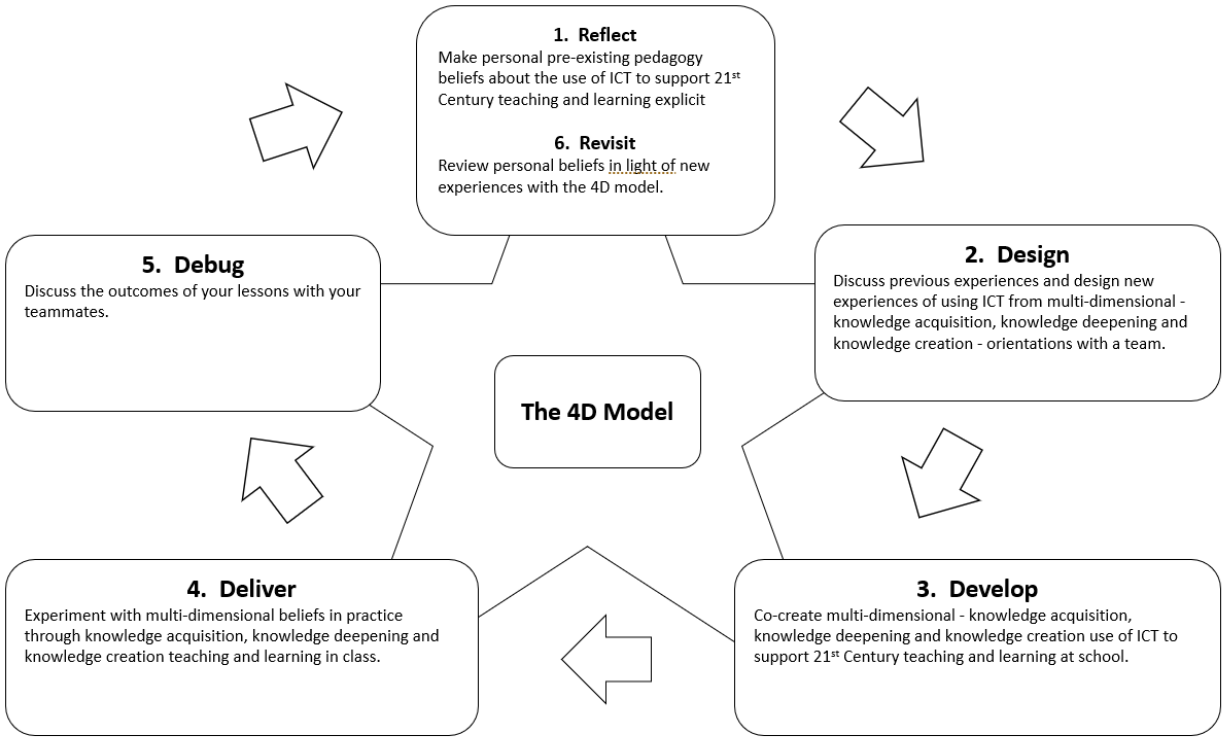

Figure 5: The Practical 4D Model

The activity model involves the following phases repeated across two iterations:

1. **Pre-cycle reflection:** Participants reflect on their beliefs and practice by constructing metaphors about learning theory, design principles, student progression, assessment and feedback, the learning environment, and learning activities.
2. **Design:** The participants form a team, adopt team roles, choose an area from the curriculum, research its constituent parts, research resources, and research appropriate tools.
3. **Develop:** The participants develop a lesson plan that follows a learning trajectory moving from Knowledge Acquisition to Knowledge Deepening to Knowledge Creation. The participants outline learning theory, design principles, student progression, assessment and feedback, the learning environment, and example activities for each of the three lessons.
4. **Deliver:** The participants deliver the lessons in class and collect evidence of student learning outcomes.
5. **Debug:** The participants reflect on the lessons, considering the differences in teaching and learning at each of the three stages: Knowledge Acquisition, Knowledge Deepening, and Knowledge Creation.

6. **Post-cycle reflection:** Participants revisit their pre-cycle reflection and make changes where appropriate, in light of their experiences.

It is understood that within this model, there are multiple iterations. The participants engage in at least two iterations of the model across one school year.

3.4.1 Materials

The following sub-section describes the materials that the participants were presented with to scaffold their CPD experiences. These included an introduction email and master page, information videos, example lessons, and a lesson(s) plan template. Each team had a shared Google Drive folder with copies of the resources, and there was a website the participants could access.

3.4.1.1 Introduction Email and Master Page

The introduction email was sent to the participants who had completed the consent forms and the initial metaphor construction activity. After the participants had confirmed their intention to engage in the study, the participants were assigned to teams by the researcher. Teachers were assigned to teams where they shared similar roles. The purpose of the introductory email was to introduce the team members to one another and to encourage the teams to set up a group messaging communication. Also, the participants were encouraged to organise the time of their next meeting. They were also provided with links to an information video outlining the next task. Finally, they were presented with a master page that included links to the consent forms and reflection one, and information videos about constructing the team, design stage, develop stage, deliver stage, debug stage, and the post-iteration reflection. These are presented in Figures 6 and 7.

Dear Participants,

I'd just like to introduce you all to your teammates. Provisionally your team will be called 'Team 2'. All of the participants on this team are primary school teachers.

To get the ball rolling, the 'Team leader' has been nominated to carry out the following tasks:

Email the other team members and say 'hello'.
Collect your teammates phone numbers and set up an instant messaging group where you can communicate with one another more conveniently. In the past, teams have used applications such as WhatsApp or Viber.

Once you have your instant messaging group setup, it would be of value to provide one another with a short introduction about yourself and the class groups that you are teaching. All teams have been aligned in so far as is possible with teachers teaching the same class groups.

Finally, please organise a time and date for your team to meet with one another online. In the past, teams have used applications such as Zoom or Google Meet. During the next stage of the model you will begin the 'Design stage'. Where you will discuss challenges with the teaching and learning of a particular topic and suggest solutions to overcome those challenges.

A link to a video explaining the team's task is provided here: https://youtu.be/jyorT1pixLU

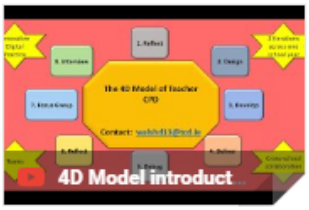

Figure 6: Introduction Email

Important: Attached to this email is the Master Page for the participants. It contains all of the links to the Microsoft Forms and the video introductions you will access during your journey through the 4D model. It may be of value to paste this pdf into your instant messaging group. A copy will also be placed into your team's shared Google Drive folder. The table containing the links to the Microsoft Forms and the videos has also been pasted at the bottom of this email for your convenience. It is recommended that you view the videos prior to each and every activity.

Again, if you have any questions or queries, please contact me at [redacted]
If you are in need of my phone number please email me and I will share it with you directly.

The 4D Model Iteration 1			
1	Consent forms and reflection one	Video	Form
2	Constructing your team	Video	
3	Design Stage	Video	
4	Develop Stage	Video	
5	Deliver Stage	Video	
6	Debug Stage	Video	
7	Post-iteration reflection	Video	Form

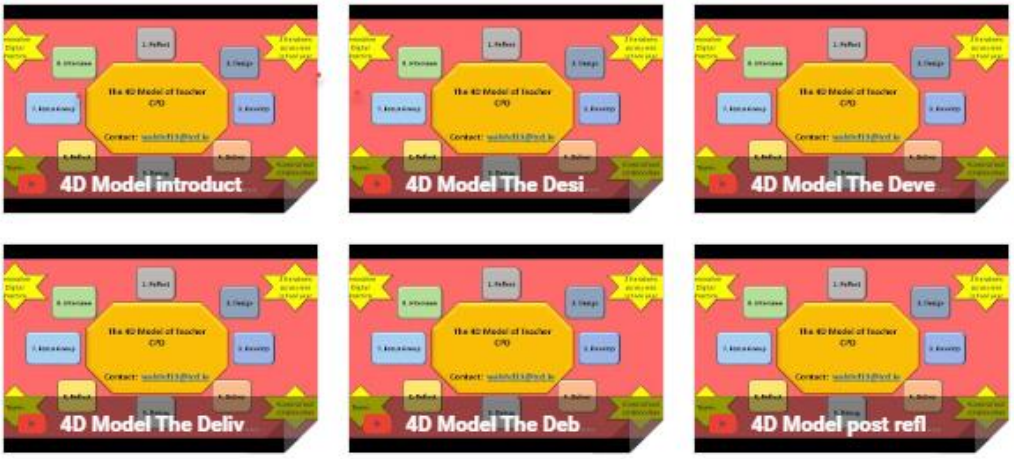

Figure 7: Master Page

3.4.1.2 Information Videos

Information videos that provided information guiding the participants through each stage of the 4D model were also provided to the participants. A concise description of each is provided in Table 9 below.

Table 9: Informational Videos

Video Title	Concise Description
4D Model Consent and Reflection	Describing the process for completing the consent form and the initial reflection which involved metaphor construction.
4D Model introduction to teams	Describing how the teams are setup, suggesting some icebreakers for their first interactions, and information about setting up their first online meeting to begin the design stage.
4D Model The Design Stage	Information about the design stage of the 4D model, including suggested topics to guide their initial discussion.
4D Model The Develop Stage	Information about the develop stage of the 4D model, including suggested activities they could engage in to extend the creativity of the lessons under design.
4D Model The Deliver Stage	Information about the deliver stage of the 4D model, which involved delivering lessons in class.
4D Model The Debug Stage	Information about the debug stage of the 4D model, which involved reflecting on the outcomes of the lesson with teammates.
4D Model post reflection stage	Information about how to access the post-reflection stage form, and its objectives.
The 4D Model December	A short motivational video congratulating the participants on completing the first iteration, thanking them for their efforts, and information about starting the second iteration.

3.4.1.3 Example Lessons

The participants were also provided with a list of example lessons created by the researcher. This list included example objectives, relevant tools, potential activities, and descriptions about how these could be adapted for knowledge acquisition, knowledge deepening, and knowledge creation teaching and learning using ICT. The example lessons were made available to the participants in the Google Drive folder. An image of the example lessons is presented in Figure 8.

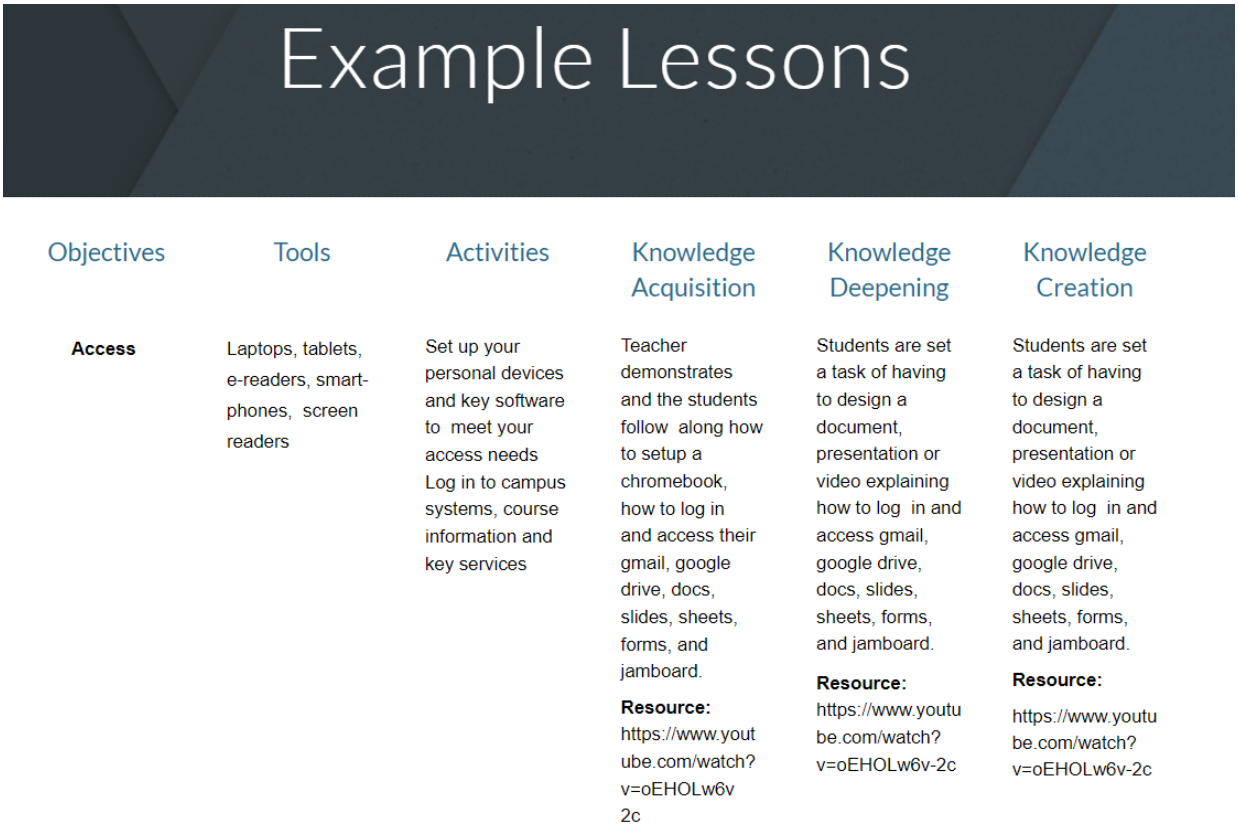

Figure 8: Example Lessons

3.4.1.4 Lesson(s) Plan Template

The lesson(s) plan template was also stored in each team's shared Google Drive folder. The template provided a space for the participants to co-create, design, and develop their knowledge acquisition, knowledge deepening, and knowledge creation learning activities during their online meetings. The participants were tasked with doing so under the sub-headings of subject, strand / strand unit, skills, methodologies, digital skills, design of the learning environment, and assessment. These align with the sub-categories of beliefs under which the participants constructed their metaphors. The lesson(s) plan template is presented in Figure 9.

Learning Plan	**Knowledge Acquisition**	**Knowledge Deepening**	**Knowledge Creation**
Subject			
Strand / Strand Unit			
Skills			
Methodologies			
Digital Skills			
Design of the Learning Environment			
Assessment			

Figure 9: Lesson(s) Plan Template

3.4.1.5 The Website

The participants were also provided with a website as a scaffold for the 4D model. The website included information about the 4D model and its activities, the initial reflection, design, develop, deliver, debug, and post-cycle reflection. It also included information about the individual and group interviews. Finally, example lessons from the teams and the researcher were included. Figure 10 shows the website homepage.

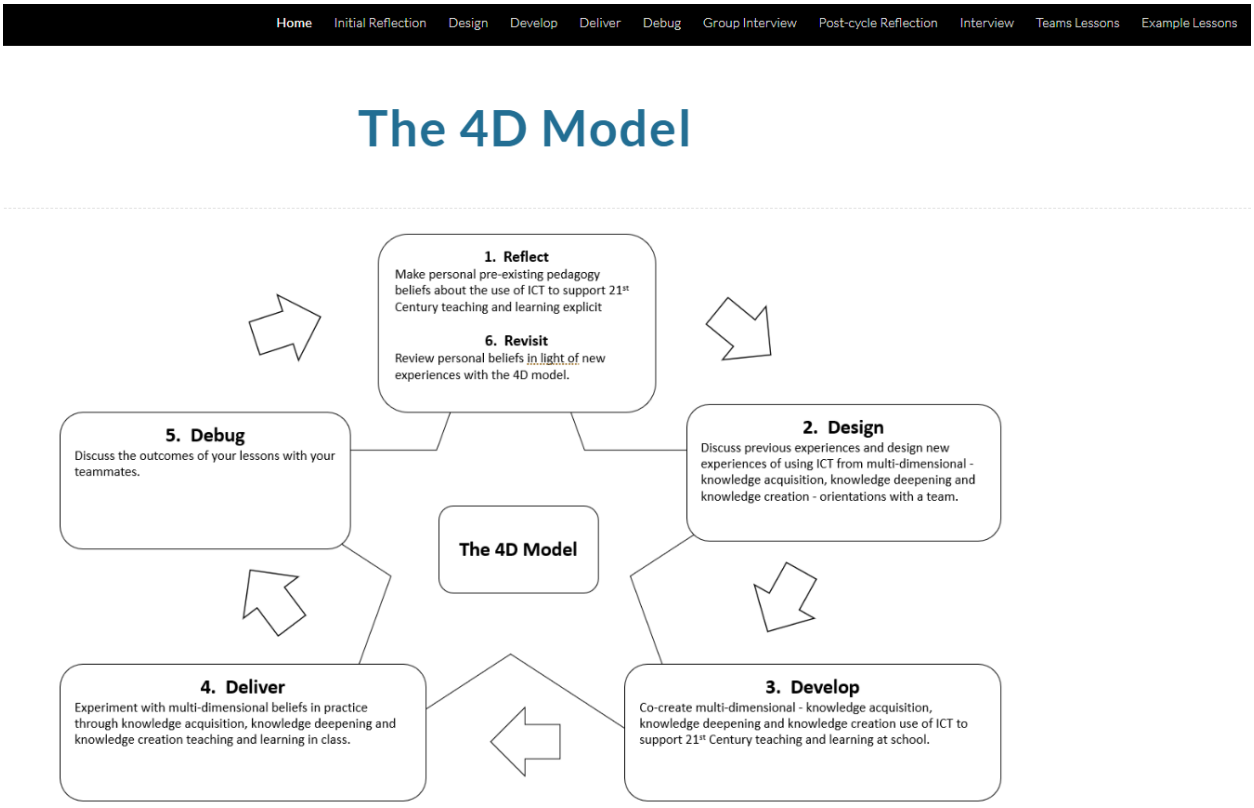

Figure 10: The 4D Model Website

3.4.2 Activities

This subsection describes a typical 4D Model activity. A typical 4D Model iteration involved teachers created a lesson plan in history from the Irish Primary curriculum that followed a learning trajectory moving from knowledge acquisition to knowledge deepening to knowledge creation. Walking through the steps of the model, 4–5 teachers from different schools agreed to participate in a 4D model experience. Each teacher submitted a reflection on their beliefs about teaching and learning with technology at school. The teachers met face-to-face or online and formed a team. The team discussed their prior teaching and learning experiences with technology and then choose a subject and strand from the primary curriculum for research. The team researched the topic, methodologies, and digital tools used to teach the subject. The team outlined their plan.

During the Develop stage, the teachers planned each of the three distinct steps of the lesson: knowledge acquisition, knowledge deepening, and knowledge creation. For example, during the knowledge acquisition step, the teachers chose a direct instruction approach to teaching and learning the topic. During the knowledge deepening step, the teachers visited a physical site relevant to the strand they were

teaching, where the students gathered and collected evidence relevant to the lesson's goals. During the knowledge creation phase, the students took control of the learning experience, analysed, and synthesised the data collected, and communicated, presented, and disseminated their learning to their peers. At the end of the first iteration, the teachers revisited their pre-cycle reflection and made any changes to their texts considering their experiences. The teachers then repeated the steps of the 4D model for the second iteration.

3.4.3 Facilitation

This subsection describes the facilitation of the 4D model. Facilitation of the 4D model was guided by the researcher remotely through email, and through a WhatsApp group with the team leaders. During the two iterations of the 4D model, emails were frequently sent to the participants. These included instructional emails outlining the tasks and activities the participants were to undertake, along with check-in emails reminding the participants of upcoming tasks, and sending motivational messages thanking them for their participation with the project during what was a challenging year-their first full year back at school following the Covid-19 related school lockdowns.

Secondly, a WhatsApp group was set up between the team leaders and the researcher. WhatsApp was chosen as the preferred means of communication as all the participants had experience using the application. This enabled direct contact with the participants, where it was possible to check in with the progress of the teams throughout the study, and to communicate reminders of looming deadlines and tasks that needed to be completed.

The participants were also provided with the researcher's email and phone number. During the group and individual interviews, the participants were provided with further opportunities to discuss the model and to clarify any of its steps and requirements.

3.5 Chapter Summary

This chapter has presented the 4D model of teacher CPD for changing teachers' pedagogy beliefs and practices about using ICT to support students' development of 21st century skills at school. Firstly, it described the context the study takes place within. Next, the theoretical principles informed by the literature review and their influence on the model's design were discussed. Then, the actualisation of those principles into the practical 4D Activity model were presented. Following on, the materials

scaffolding the participants experiences were described. Then, a summary of a typical 4D model activity was outlined. Finally, the model's facilitation was described. The next section discusses the research methodology employed in this study.

4. Research Methodology

4.1 Introduction

The purpose of this chapter is to provide the explanation and rationale for the methodological approach to answer the research questions – How and Why teachers' pedagogy beliefs change during their experiences with the 4D Model. The chapter begins by clarifying the overall research purpose, 4.2, the underlying ontology and epistemology shaping the research paradigm, and the methodology requirements. Next, 4.3 summarises research methodologies aligning with the study's requirements, followed by a rationale for selecting Case Study as the overarching methodological approach 4.4. Then, Case Study is discussed in more depth. The study's design is presented in section 4.5. Sections 4.6 and 4.7 describe the methods used in collecting, analysing, and presenting the qualitative data, offering a rationale for each step. Finally, 4.8 and 4.9 explain participant selection, and how the study's ethical considerations were addressed, and it expresses the limitations of the chosen methodological approach.

4.2 Methodological Rationale

Research methodologies encompass the plans and procedures for research that involve decisions about worldviews, epistemologies and ontologies, and paradigms (Bryman, 2016; Creswell, 2019; Crotty, 1998; Denzin & Lincoln, 2017). The decisions made by the researcher inform the research designs, methods, data collection strategies, and their analysis and interpretation (Bryman, 2016; Creswell, 2019; Crotty, 1998; Denzin & Lincoln, 2017). Firstly, researchers should make decisions about the philosophical assumptions underpinning their work. This requires making decisions about research paradigms, epistemological assumptions, and ontological worldviews. These decisions inform the methodologies utilised in the research design and are discussed in the following subsections.

4.2.1 Research Purpose

The research explored the 4D Model of teacher CPD for changing teachers' pedagogy beliefs about 21st-century teaching and learning. The researcher determined to understand the participants' experiences and to identify and elaborate on elements of the CPD design that contributed to belief change emerging from the data. The researcher also sought to determine whether the 4D Model process is worthy of further study in the area of teachers' pedagogy beliefs and 21st Century teaching and learning.

4.3 Ontology and Epistemology

There is a requirement for researchers to make explicit the ontology, epistemology, and methodology underpinning their study (Creswell, 2019; Crotty, 1998; Denzin & Lincoln, 2017). Collectively, these concepts form paradigms, '*the basic belief system or worldview that guides the investigator, not only in choice of method but in ontologically and epistemologically fundamental ways'* - (Guba & Lincoln, 1994, p. 105). Ontological questions consider the nature of reality and what can there be known about it. Epistemological questions consider the nature of the relationship between the knower and what can be known. Methodology questions consider how the inquirer can go about finding out what can be known (Guba, 1990; Guba & Lincoln, 1994). Answers to these questions guide the researcher's methodological choices, data analysis, and claims of truth (Denzin & Lincoln, 2017).

From a social sciences perspective, researchers must consider two prevailing ontological paradigms: objectivism and constructivism (Bryman, 2016). Objectivism implies that social phenomena confront us as external facts beyond our reach or influence (Bryman, 2016). In contrast, constructivism challenges the objectivist assumption that culture and organisation are pre-given and instead argues that reality is a socially constructed enterprise where the individual gives objects meaning. In the case of this study, the researcher determined that the study of beliefs is more suitably considered from a constructivist rather than an objectivist perspective. Although no one definition of beliefs exists across the belief's literature, they are accepted as being propositions that are inferred from what a person says or does (Ertmer, 2005; Nespor, 1987; Rokeach, 1968; Tondeur et al., 2017). Because constructivists believe learning is an internally mediated process and objectivists believe it is an externally mediated process, the need to infer from what a person says or does suggests this research is more appropriately undertaken from constructivist rather than objectivist ontology.

Following on, from the perspective of the social sciences, there are two prevailing paradigms of epistemology: positivism and interpretivism (Bryman, 2016). Positivism argues for value-free approaches to study where the goal is to construct and test hypotheses the senses can confirm. In contrast, interpretivism, as an anti-positivist stance, argues that studying humans in the social sciences necessitates understanding the subjective meaning of social action (Bryman, 2016). It is argued that its true essence cannot be described by the positivist methods of the natural sciences, which reduce human experience to facts and general laws (Crotty, 1998). Because this study is concerned with investigating growing teachers' pedagogy beliefs that are considered subjective value-laden propositions rather than objective

value-free propositions, the researcher considers it more appropriate to adopt an interpretivist rather than a positivist epistemology.

Having argued the ontological and epistemological perspectives underpinning this study, the next step is to clarify its methodology. Key to this step will be identifying and aligning methodologies which nest within an interpretive-constructivist paradigm. The next section discusses methodologies aligned with this investigation's paradigm and evaluates their suitability for the study's objectives.

4.3.1 Strategy Requirements

The choices of ontology and epistemology inform the methodology chosen by the researcher (Bryman, 2016; Denzin & Lincoln, 2013, 2017; Guba, 1990; Guba & Lincoln, 1994). Bryman argues that deciding upon a research strategy requires deciding whether the research follows a deductive or an inductive approach. Although all approaches involve some elements of both deduction and induction, and the distinction is not entirely straightforward, it may be said that a deductive approach is primarily to test or revise theory. In contrast, an inductive approach aims to generate theory (Bryman, 2016). While it is not the goal of this study to generate theory, the study aims to generate a deeper theoretical and conceptual understanding of teacher pedagogy belief change. Such an approach aligns with what Bryman terms an inductive approach (Bryman, 2016). The researcher determined that a primarily inductive approach was more suitable, although elements of deduction, such as the use of theory as a background to the investigation and the design of the CPD model, inform the theoretical and conceptual framework.

The research aims to develop a deeper theoretical and conceptual understanding of *how* and *why* teachers' beliefs change through their participation in a CPD experience. The focus is on exploring participants' experiences and the choices they made that contribute to belief change, rather than adopting a positivist approach to measuring beliefs. Therefore, the chosen methodology should aim to generate a theoretical understanding of the participants' lived experiences, allowing for in-depth exploration of their meaning-making processes and the factors influencing belief change. Given the entangled nature between the participants' experiences with the 4D model and their day-to-day teaching and learning, the chosen methodology should also enable the investigation of relevant variables while excluding irrelevant ones. Furthermore, the chosen data analysis tools should assist the researcher in making sense of the context the data is gathered within.

For this study, the following requirements for the methodology have been identified:

- Has an interpretivist ontology
- Is in alignment with a constructivist epistemology.
- Enables the exploration of a CPD model in a real-world setting.
- Enables bounding variables relevant to the 4D Model research even when the participants are continuing with their day-to-day practice at school.
- Utilises a primarily inductive approach.
- Places data gathering and analysis within the context of the study.
- Enables the investigation of a deeper theoretical and conceptual understanding of sub-units of analysis.

Having outlined the strategy requirements, the next section outlines the analysis of methodologies appropriate to the aims of this study.

4.3.2 Methodology Analysis

There are many competing research designs for analysis (Cresswell, 2014; Denzin & Lincoln, 2013, 2017; Merriam & Tisdell, 2015). Critical to determining an appropriate research design is its ability to address the research problem. The research problem is restated as follows:

> (PS) Traditional CPD designs are inadequate for changing teachers' pedagogy beliefs about 21st Century learning at school.

As this research is interested in developing a theoretical understanding of growing teachers' pedagogy beliefs using a new model of teacher CPD with small groups of teachers, the author has concluded that it is more appropriate to seek to understand pedagogy belief change from the perspective of the participants' experiences rather than employing quantitative methods. Although quantitative measures exist for categorising teachers' pedagogy beliefs, many are outdated in the context of 21st Century teaching and learning (Fives & Gill, 2014). Having determined that a qualitative study is more appropriate, several methods nest within interpretivist, constructivist qualitative paradigms. These include Design, Case Study, Ethnography, Grounded Theory, Action, and applied research (Cresswell, 2014; Denzin & Lincoln, 2013, 2017; Merriam & Tisdell, 2015). What follows is a summary of the methods listed above.

Design-based research is a methodology that seeks to bridge the gap between laboratory studies of learning and educational practice in situated settings (T. Anderson & Shattuck, 2012; A. L. Brown, 1992; T. Brown, 2008). It pursues the goal of developing effective learning environments using real-world

settings to test complex interventions. The design's ability to do work in the real world and the iterative nature of its development align with a pragmatist epistemology. There are five common characteristics of DBR: (a) pragmatic; (b) grounded in theory and research; (c) interactive, iterative, and flexible; (d) integrative; and (e) contextual (Wang & Hannafin, 2005). According to Anderson and Shattuck, the key elements of DBR include research taking place in an authentic context in a real-world setting, design and testing in collaboration between researchers and practitioners, mixed methods research techniques, it is iterative and involves designing, testing, and refining interventions through repeated cycles of implementation and review, it should lead to the development of design principles, and it should generate practical ideas and guidelines (T. Anderson & Shattuck, 2012).

Ethnography has its roots in anthropology and is concerned with the study of culture (Given, 2008). It is concerned with describing a group or culture, and it is both a process and a product. Its primary methodological tool involves fieldwork, where ethnographers immerse themselves in the culture of the group under study to identify behaviour patterns over time. The product of an ethnographic inquiry is a cultural description that emerges over a period of time and residence in the culture's setting (Merriam & Tisdell, 2015). Fieldwork includes immersion in the site as a participant observer. This method records data, including formal and informal interviews, analysis of documents, records and the fieldworker's diary of events, personal feelings, ideas, impressions, or insights. Thick description coupled with some interpretation of the meanings participants make of their lives forms the write-up part of ethnography (Merriam & Tisdell, 2015). Data is organised into themes and patterns through either an 'emic' perspective – that of the insider to the culture, or an 'etic' perspective – that of the outsider of culture. An ethnographic study is distinguished from a phenomenological study through the lens of culture used to understand the phenomenon (Merriam & Tisdell, 2015).

Grounded theory is concerned with generating a theory grounded in the data (Given, 2008). It consists of systematic, inductive methods for conducting qualitative research to generate theory. Its methodological strategies aim to construct middle-level theories from data analysis. It includes a flexible yet systematic mode of inquiry, directed but open-ended analysis and theorising from empirical data. Its focus on building theory differentiates it from other forms of qualitative research (Corbin & Strauss, 2014). The resulting theory is 'substantive' instead of 'grand,' meaning it has a specificity and usefulness to practice that theories covering more global concerns are limited in addressing (Corbin & Strauss, 2014). Data is collected from a range of interviews, observations, and documentary materials, and it is guided by 'theoretical sampling – where the analyst collects codes and analyses simultaneously before deciding

what data to collect next and where to find them. This process enables the researcher to develop a theory as it emerges. Data analysis consists of the 'constant comparative method' – where one data segment may be compared with another to determine similarities and differences. Similar data are grouped on a dimension which becomes a category, and the analyst's job is to identify patterns and themes. The constant comparative method is not unique to grounded theory. It is used across many kinds of qualitative studies as the inductive comparative nature of this data analysis provides the researcher with a systematic strategy for analysing a qualitative data set (Charmaz & Henwood, 2017).

Action research has evolved out of a critical theory perspective of reality. It is concerned with identifying and overcoming tension and power dynamics between individuals or between individuals and institutions (McNiff, 2013). It is grounded in practice, and it is about taking action for social and political action and then communicating what you have undertaken (McNiff, 2015). Its key aims include improving practice by asking questions such as 'Why are things the way they are?' and seeking to change them if they are unsatisfactory, improving learning by problem posing and then generating solutions to those practices. Unlike positivist research, it is values-based and emphasises the values embedded in life experiences. It is collaborative because the researcher does AR with people, not on them. It is situated, acknowledging that everything we do is part of the wider social, historical, and political context. It demands critical questioning, which can lead to social and cultural transformation, and it is a 'creative process' (McNiff, 2013). Action research is predicated on the desire for improvement to practice, and its claims to validity are based on a rigorous evidential trail of data and research (Cohen, Manion, & Morrison, 2018; McNiff, 2013). Through an action research approach, teachers are empowered to work on problems they have identified themselves, and it is argued that they become more effective teachers as they examine and assess their work and consider ways of working differently. Moreover, teachers in an action research approach support one another in their professional development by working collaboratively (Cohen et al., 2018). There are several different perspectives on AR, including organisational and development learning (Argyris & Schön, 1978), participatory Action Research (Stringer, 2007), participatory evaluation (Kushner, 2000), as a method of enquiry aligning with Dewey's Theory of Enquiry and Schon's 'reflecting in action' (Dewey, 2018; Schon, 1984), as a teacher-as-researcher movement (Carr & Kemmis, 2003), as cooperative inquiry (Bradbury & Koballa Jr, 2008) and as a self-study and auto-ethnography (Bullough & Pinnegar, 2004).

Case study involves the study of a particular case bounded in time and space (Bassey, 1999; Merriam, 1998; Yin, 2018). It enables researchers to focus on specified variables relevant to the study even where

other variables that may influence the study's outcomes are at play. Its strengths are that it enables the researcher to analyse cases in depth, to provide detailed descriptions of naturally occurring events in real-world settings, and it can be relatively unobtrusive, meaning events unfold closely to the way they naturally would when the research lens is not placed upon them. Case study is a contested domain, and there are different ontological and epistemological views. Different case study approaches exist, including single, multiple, embedded, and holistic (Yin, 2018). Because of its contextual focus, there are often issues surrounding its validity and the generalisability of its findings to other settings. Case Study will be discussed in more detail in section 4.4.1.

Based on the methodologies described above – Design-based research, Ethnography, Grounded Theory, Action Research, and Case Study – Table 10 presents the analysis of this study's requirements. The requirements include, an interpretivist ontology, a constructivist epistemology, bounding the variables relevant to the study even though other variables are at play, an inductive approach, and data gathering within the study context. Having considered the five methodologies listed above, this researcher determines that case study is most appropriate for the aims of this study.

Table 10: Results of Analysis

Method	Description	Comments
Design Based Research	Multiple iterations of in partnership with participants.	While DBR could potentially form part of a longer-term plan, this study focuses on one specific case, there is a lack of partnership between the researcher and the participants, and site visits are not possible.
Ethnography	Immersive research with flexible and responsive data collection	Although the lived experiences of the participants are being investigated, and this is an investigation into practice in a real-world setting, this study involves the investigation of a model and its efficacy in the real-world rather than established social practice.
Grounded Theory	Aim is to generate theory through a structured approach to data analysis	The aim of this study is to develop theoretical understanding of the 4D model rather than developing a theory of teacher pedagogy belief change.
Action Research	Involves identifying a problem with practice and making significant changes with the researcher heavily involved in the project.	Although the emphasis is on change, the problems have already been identified by the researcher and there is a lack of partnership between the researcher and the participants. Less emphasis on empowerment and critical theory in this study.
Case Study	Enables research to take place in the real world and the bounding of events relevant to the study's goals through an in-depth exploration of a specified case.	Aligns with the aims and requirements of this study by aligning with an interpretivist constructivist paradigm. The study can be bounded to enable the participants to continue with their day-to-day practice, and it places data gather within the context of the study.

Whereas methodologies such as ethnography and phenomenology align with an interpretivist ontology, this study aims to explore a new model of teacher CPD that will enable the participants to change some elements of their beliefs and practice at school. While the study's goals are broadly in alignment with an action research perspective, the problem has already been identified by the researcher during the literature search. The study aims to explore the model's efficacy in enabling teachers to form new beliefs and practices and to develop a deeper theoretical understanding of how and why changes occurred during the participants' experiences with the 4D model at school. There is also some synergy between the study's

goals and a grounded theory approach, as GT approaches aim to generate theory. While many of the techniques used in grounded theory approaches are appropriate for the analysis of qualitative data collected in this study, it is not the goal of this study to generate theory; rather, its stated goals are to develop a deeper theoretical understanding of teacher belief change with the 4D model.

Case Study approach meets the above requirements by:

- Having a flexible ontology and epistemology, allowing for the in-depth analysis of belief change through a constructivist epistemology and a relativist ontology.
- Enabling the erection of temporal and spatial boundaries for a case in naturalistic settings.
- Enabling the explanation of an experience from the multiple perspectives of those individuals who have taken part in the experience.
- Enabling a context-sensitive perspective where each of the multiple actors can share their perspective of the reality of the shared experience.
- Enabling the generation of theoretical understanding from the in-depth analysis of a small number of participants.
- Enabling the identification and analysis of belief change grounded in the data.

4.4 Selected Methodology: Case Study

Having concluded that Case Study is an appropriate overarching methodology for this study, this section discusses Case Study approaches in more depth.

4.4.1 Case Study

Case Study is often employed by researchers seeking to understand phenomena taking place in real-world settings (Cohen et al., 2018; Creswell, 2019; Punch & Oancea, 2014). Case Study is a contested domain, and it may be an overarching methodology, a set of methods, or a case report (Merriam, 1998; Stake, 1995; Yin, 2018). Its defining features involve specifying the case under study and bounding the phenomena in time and space. This involves placing starting and finishing points around data collection and specifying the variables under study. This is useful and necessary when other variables influence the subject under investigation. Case Study is often employed when trying to answer '*how*' and *'why'* questions and is a flexible tool for researchers' approaches to answering its questions. It enables exploration, description, and explanation (Yin, 2018). It enables interpretation, description, and

evaluation (Merriam, 1998). Alternatively, it enables hypothesis generation and theory development, hypothesis and theory testing, and normative theory (Denzin & Lincoln, 2017). Such flexibility can be applied during case studies to understand a complex functioning system better.

Case study's ontological and epistemological alignment are also contested. Yin (2018), for example, argues case study involves a set of methods seeking to develop a post-positivist or critical realist perspective of the case (Yin, 2018). Stake (1995), however, aligns case study more with a constructivist relativist perspective (Stake, 1995). Merriam (1998) also places case study within a constructivist perspective but from more of an interpretivist orientation (Merriam, 1998). Other authors like Bassey are non-committal (Bassey, 1999). All the authors above acknowledge that case study involves different degrees of interpretive work by the author. Moreover, while Yin's stance opposes Merriam and Stake, Yin acknowledges that the author's orientation rather than the case study methods defines its ontology and epistemology (Yin, 2018). Even though a researcher may employ Yin's methods, their orientation may differ from his case study paradigm.

Case study involves identifying a case and applying a suitable design. A case is a unit under study. According to Yin, the case should be more concrete than abstract (Yin, 2018). According to Merriam, it should be a noun rather than a verb (Merriam, 1998). For example, whereas teachers' experiences are not a case, a teacher design team may be considered a case. There are various case study designs and different interpretations of a case. For Yin, these include holistic or embedded, single or multiple (Yin, 2018). For Stake, these include intrinsic, instrumental, multiple, or collective case study design (Stake, 1995). Whereas for Merriam, these include interpretive or evaluative design (Merriam, 1998).

Quantitative and qualitative data can be collected during case studies, and various data-analytic strategies are employed in case study research. Qualitative data collection commonly involves documentation, archival records, interviews, observation, and physical artefacts (Merriam & Tisdell, 2015; Stake, 1995; Yin, 2018). Analysing these data may be approached from a variety of data-analytic strategies. According to Yin, data-analytic strategies may seek to identify generalisable causal relationships through pattern-matching, explanation-building, and cross-case synthesis (Yin, 2018). On the other hand, Merriam argues that there are three distinct levels of analysis. Merriam's levels move from descriptive analysis to category construction to identifying overall themes (Merriam, 1998). Bassey believes that case study data analysis strategies can also explicate assumptions and ideologies by examining power dynamics and social constructions (Bassey, 1999).

Because case study focuses in-depth on specified phenomena in a real-world setting context, the generalisability of its findings is contested (Cohen et al., 2018; Creswell, 2019; Punch & Oancea, 2014). Authors have attempted to overcome this concern in diverse ways. These include: Arguing that recurring similar problems lead to refined generalisation (Stake, 1995); Conceptualising case study data can inform theory (Yin, 2018); and findings should be considered fuzzy generalisations (Bassey, 1999). Alternatively, that particularisation rather than generalisation is the primary goal of the case study. Yin suggests that issues with generalisability may be addressed through data source triangulation, investigator triangulation, theory triangulation, and methodological triangulation (Yin, 2013, 2018).

The validity of the findings of a case study are also contested. Some authors argue that case study is more concerned with trustworthiness than reliability and validity. However, others argue that validity and reliability are key concerns for case study research as they persuade readers of their trustworthiness. Addressing concerns surrounding validity and trustworthiness, Yin suggests construct validity, internal validity, external validity, and reliability, whereas Stake suggests naturalistic generalisations. Despite these differences, there is consensus that a researcher should collect multiple sources of evidence, provide a detailed description of the case, demonstrate that the findings come from the data itself, and leave behind a trail that others can follow to see how the researcher came about their conclusions (Merriam & Tisdell, 2015; Stake, 1995; Yin, 2018).

This study investigated teacher pedagogy belief change during teachers' experiences with the 4D model at school. It was acknowledged that many other variables were at play in the teachers' day-to-day school life. Addressing the overlap between teacher belief change resulting from teachers' day-to-day experiences at school and teacher belief change resulting from the 4D model required bounding the phenomena in time and space. Case study is an appropriate methodology for bounding this study and distinguishing between the conditions that fall outside and within the case under study.

This study concerned a single case of the 4D model between September 2021–June 2022. Even though there was more than one team involved in the study, and it could be argued there was scope for what Yin terms a 'multiple case' case study, the small numbers in each team and the small number of teams that took part in the study, made it more appropriate to consider the complete data set as a single case. This study aimed to explore the 4D model's efficacy, describe the participants' experiences, and explain how and why teachers' beliefs changed. Therefore, it aligns with Yin's exploratory–explanatory case study design. The exploratory element involved identifying the research questions and the procedures for the

study. In contrast, the explanatory element explained how or why teacher pedagogy belief change occurred.

It has been previously discussed that this study was more concerned with qualitative than quantitative data. Whereas quantitative measurement tools (e.g., the Teachers' Beliefs Scale [TBS] and The Behaviour and Instructional Management Scale [BIMS]) exist for measuring teacher belief change, many are outdated in the context of 21st century teaching and learning. Moreover, this study investigates participants' experiences with the 4D model as a starting point for data analysis. In Case Study literature, qualitative data collection commonly involves documentation, archival records, interviews, observation, and physical artefacts (Yin, 2013, 2018). Because the study occurred during the COVID-19 pandemic, when all schools limited visitors' access to their premises, observation had to be ruled out. Instead, this study utilises reflection, interviews, physical artefacts, and documentation to gain insights into the participants' experiences.

4.4.1.1 Case Study Elements

To address the data analysis, this study employs several qualitative analysis strategies. These include rubric analysis and coding. Rubric analysis is employed to the participants' reflections and their lesson plans. Meanwhile, coding is employed to interpret the participants' interviews. While coding is typically associated with Grounded Theory, it is commonly used in qualitative Case Study (Merriam, 1998; Merriam & Tisdell, 2015). The approach involves reading through the data and labelling phrases, sentences, and paragraphs with codes of referential meaning, aggregating codes around similar concepts, comparing codes against one another, asking questions of the data, and building up larger, more abstract categories that are grounded in the data, developing categories in terms of their properties and dimensions and investigating the relationships between them. The approach used in this study does not seek to identify the conditions, context, action/interaction, and consequences or use the conditional consequential matrix used in pure grounded theory approaches, as it is not the goal of this study to develop theory (Bryman, 2016; Corbin & Strauss, 2014). Through this approach, the study aims to highlight the factors of the 4D Model impacting upon changes in teachers' beliefs.

Having outlined the case, the case study design, the data collection, and the data-analytic procedures, it is necessary to address concerns about generalisability. Bassey argues that case study involves value-laden critical inquiry to inform '*educational judgements and decisions in order to improve educational action*' (Bassey, 1999, p. 39). Bassey argues that a case 0study is designed to study a singularity that can be

generalised through what the author terms 'fuzzy generalisations' – propositions that show how the research may apply more widely (Bassey, 1999). Data source and theory triangulation are the main types employed in this case. This involves triangulating the multiple perspectives of the participants as captured in the data collection tools coherently. Moreover, it involves triangulating within an appropriate theoretical framework. These two types of triangulation are intended to achieve convergence from the multiple sources of data collected and boost the case study's validity. Meanwhile, the generalisability of the study's findings aligns with Bassey's fuzzy generalisations. This means that a qualitative estimate can only be made that it is likely that the findings from this study are generalisable to primary teachers working in similar contexts (Bassey, 1999).

Along with addressing issues about generalisability, it is also incumbent on a case study researcher to address issues surrounding validity. The researcher should seek two types of validity. Internal validity involves the extent to which the case study accurately represents the case under study. Achieving internal validity involves minimising biases and addressing alternative explanations of the findings. External validity involves carefully selecting cases that are representative of the wider population, creating a detailed description of the case context and its methodology, and leaving behind a trail so that others can assess the transferability of the case's findings to other settings (Merriam, 1998; Yin, 2018). In this study, addressing validity involves the researcher constructing a trail that includes multiple data sources about teachers' pedagogy belief change, a detailed description of the case, and data-analysis strategies that build the findings from the case study data. This will be achieved through coding, constant comparison of codes, and category construction. Evidence will be presented in coding tables, enabling the case study audience to consider the accuracy of this researcher's conclusions.

Rigor is also another essential element of case study. Whereas one of case study's affordances involves its ability to be flexible and adaptable to the setting under study, case study research is often criticised for being sloppy and not following systematic procedures (Yin, 2018). Addressing concerns about whether case study is rigorous enough, it is argued that the case study researcher should demonstrate rigorous data collection methods involving the collection of multiple data sources that triangulate and enhance the reliability and credibility of the findings. Rigorous data analysis involves systematic and transparent procedures, often involving coding and categorisation techniques and a clear auditing trail documenting the process. To address the potential for personal biases and preconceptions impacting the case study, it is recommended that the researcher engages in reflexive thinking. This involves the researcher critically

reflecting upon their preconceptions and experiences and addressing their potential impact on their interpretation of the participants' data (Merriam, 1998; Yin, 2018).

The following section outlines how the research design follows a Case Study approach.

4.5 Study Design

This study employed Yin's case study approach as the overarching design and Merriam's case study data analysis techniques to the data (Merriam, 1998; Yin, 2018). Figure 11 presents the research design. In turn, the steps undertaken by the researcher in determining an appropriate design are discussed.

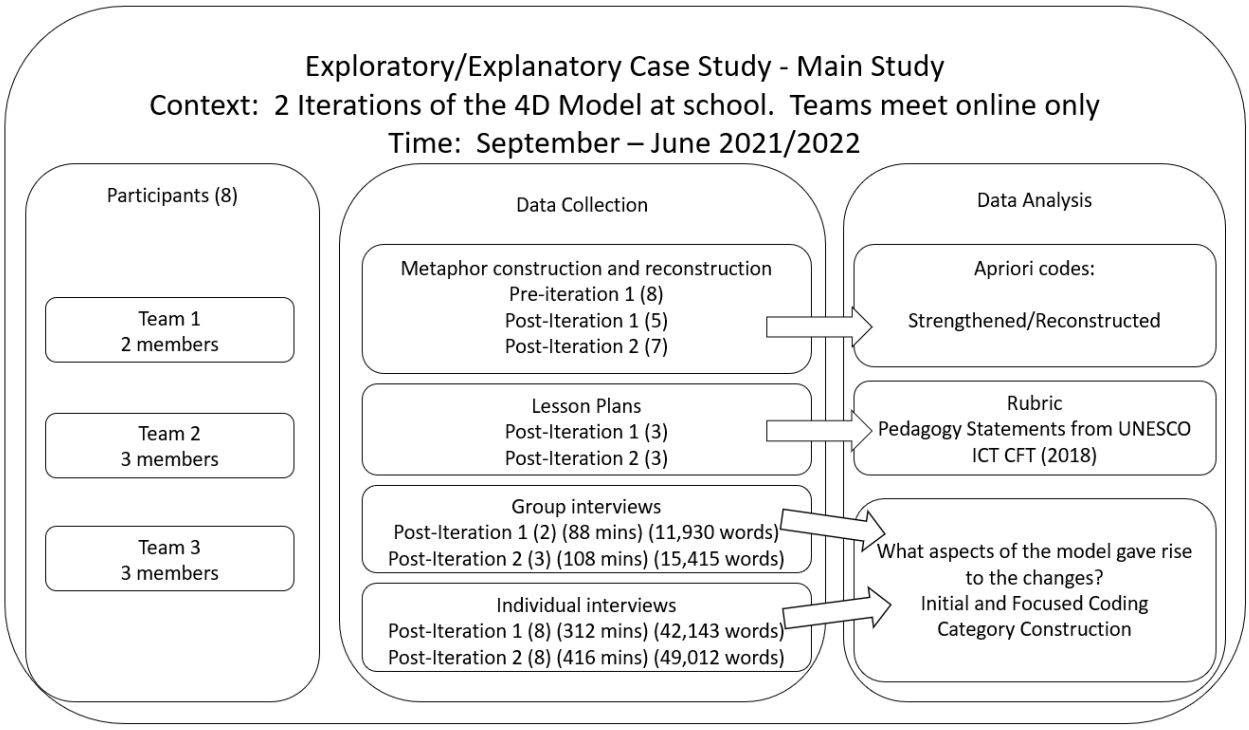

Figure 11: Research Design

The following section outlines the steps undertaken by the researcher in developing the research design. Yin (2018) recommends that the following components be embedded in any case study design:

1. The Case Study's questions
2. Its propositions

3. Its case(s)
4. The logic linking the data to the propositions
5. The criteria for interpreting its findings

4.5.1 The Case Study's Questions

For this component, Yin (2018) recommends using the literature to narrow interest, dissecting a few key studies in the area of interest, and examining other studies on the same topic (Yin, 2018). This component was reported earlier in Chapter 2, The Literature Review. Chapter 2 identified a gap in the literature for a model of CPD aiming to change primary school teachers' pedagogy beliefs about the use of ICT to support 21st century teaching and learning at school. Because of these issues, it was decided that it was more appropriate to design a bespoke model of teacher CPD rather than using existing interventions. This led to the identification of the study's questions:

- Do teachers' pedagogy beliefs change following their experiences with the 4D model? If so, then
- How do teachers' beliefs change?
- Why do teachers' beliefs change?

4.5.2 The Study's Propositions

This component involves developing theory, propositions, and related issues to guide the anticipated case study's design and consider how to generalise its findings (Yin, 2018). Chapter 3, 'The Design of the 4D Model,' provides a detailed account of the inception and design of the 4D model used in this study. In that chapter, theoretical and practical propositions guided the model's design. These propositions, which are detailed in Chapter 3, are summarised here:

- Because beliefs are functionally connected to and in communication with one another, raising and changing deeply held beliefs has more ramifications across the belief system.
- The belief change process involves raising, experimenting, reflecting, and refining beliefs that align with an experiential learning cycle of abstract conceptualisation, active experimentation, concrete experience, and reflective observation.

- Teachers' beliefs are multi-dimensional, so CPD design can seek to interconnect beliefs from different pedagogy orientations by engaging teachers in lesson design from multiple rather than single orientations.
- The relationship between teachers' beliefs and ICT is bi-directional, so teachers can benefit from guiding and being guided by pedagogy-first, ICT-enhanced teaching and learning.
- Team support can enable teachers to persist with new practices at school.

4.5.3 The Case

The next component of case study design involves defining the case to be studied (Yin, 2018). In this study, the 4D model is the case. The 4D model is bounded in time and space. In this study, it ran from September 2021–June 2022. Moreover, it defined the teachers' pedagogy beliefs as the units of analysis. It acknowledged that the participants in this study are practising teachers at school who are likely to be involved in the design and implementation of lessons weekly. However, this study was only concerned with the participants' experiences co-creating, implementing, and evaluating the knowledge acquisition, knowledge deepening, and knowledge creation lessons they designed with their team. This fulfils the bounding criteria, which concerns distinguishing between the conditions that fall within instead of outside the case (Yin, 2018).

Having defined the case, deciding what form the case study research design will follow is necessary. This involves deciding whether the case study design is single, multiple, holistic, or embedded (Yin, 2018). A single holistic case study is an appropriate design where the rationale for the case is critical, unusual, common, revelatory, or longitudinal. It is similar to a single experiment, but it is potentially vulnerable because 'the case may later turn out not to be the case it was thought to be at the outset' (Yin, 2018). An extension of the single holistic case is the single embedded case. A single embedded case involves subunits of analysis, creating more complex case designs. The subunits can enhance the opportunity for extensive analysis and extend the reach of the single holistic case. However, they run the risk of losing the original case's essence (Yin, 2018). Multiple holistic cases extend the single holistic case and are often considered more compelling and robust. They can require extensive resources and time and may be beyond the means of a single student or an independent research investigator (Yin, 2018).

In this study, it was decided that taking a single holistic case study better suited the research conditions. Even though there are multiple teams involved in the study, and it could be argued that each of the three

teacher design teams that took part in the study could be considered as a case, the small sizes of the teams and the small number of teams directs the author's choice towards single rather than multiple cases. Moreover, a multiple case study approach is beyond the scope of this study.

Case study experts also recommend employing a pilot study. In case study research, a pilot study may involve testing research propositions, questions, and procedures that later inform the design and implementation of the formal Case Study (Yin, 2013, 2018). Yin argues that the data from the pilot case study should not be reused in the formal case study (Yin, 2018). The pilot study should be formative, focusing on the researcher's learnings about the appropriateness of the research questions, data collection tools, and data analysis procedures. This study employed a pilot study, as reported in Chapter 5. The main study built on learnings from the pilot study and used a refined 4D model, data collection instruments, and data analysis techniques.

4.5.4 The Logic Linking the Data to the Propositions

The logic linking the data to the propositions foreshadows the data analysis steps in the case study (Yin, 2018). It involves deciding between pattern matching, explanation building, time-series analysis, logic models, or cross-case synthesis. As previously discussed, the study focuses on changing teachers' pedagogy beliefs. Thus, it is important to capture some evidence of teachers' pedagogy beliefs prior to their engagement in the 4D model. Moreover, it is of interest to the research to analyse teacher belief change after each of the two iterations of the 4D model. Therefore, a time-series analysis aligns with the study's goals. Time-Series analysis involves tracking a relevant measure over time. Because it can be difficult to track variables over time, it is important to outline the data's starting and ending points intending to be tracked. The ability to track changes over time is a major strength of case study. In the case of this study, the goal is to track teacher belief change. This involves collecting evidence of teachers' pedagogy beliefs before beginning the 4D model study, evidence of any belief change after the first iteration, and evidence after the model's second and final iteration. This approach will enable the researcher to analyse belief change over time.

This study's logic linking the data to the propositions involves explanation building. Explanation building is often narrative and relevant to explanatory case studies (Yin, 2018). However, explanation building through narrative form is often imprecise compared to cases whose explanations reflect theoretically significant propositions (Yin, 2018). It is an iterative process involving making initial tentative theoretical

statements, comparing the data from the case against the propositions, revising earlier statements, comparing details against revisions, and repeating the process as many times as needed (Yin, 2018). In the case of this study, whereas the time-series analysis tracks belief change over time, the explanation-building analysis aims to explain how and why belief change occurred.

4.5.5 The Criteria for Interpreting its Findings

Finally, it is incumbent upon the case study research design to outline the criteria for interpreting its findings (Yin, 2018). According to Merriam, findings from case study can be presented in three layers: a descriptive account, category construction, or themes (Merriam, 1998). Whereas all case study research provides levels of descriptive analysis, category construction and the development of themes are used when the research aims to make theoretical contributions. Category construction involves capturing recurring patterns that cut across the data, sorting bits of information into groupings with something in common and making plausible conclusions that other investigators would agree with (Bryman, 2016; Corbin & Strauss, 2014; Merriam, 1998). Categories should reflect the purpose of the research and answer the research questions; they should be exhaustive, whereby units of data should fit into only one category, they should be sensitive to the data itself, and they should be conceptually congruent with the same level of abstraction being applied across all categories (Bryman, 2016; Strauss & Corbin, 1998).

The following steps can be employed when coding qualitative data to construct categories: Firstly, the researcher reads through a transcript and takes notes; then, reviews the notes and comments, and tries to group them. Next, they move to the next data set, repeat the previous step, and check to see if the codes from the first transcript are also present. They should make a separate list of comments, terms, and notes and begin to compare the emerging lists. Then, merge the lists into one master list, constituting a primitive outline or classification system reflecting the regularities of the codes. Finally, develop the patterns and regularities into categories and analyse for relationships within and across categories (Bryman, 2016; Strauss & Corbin, 1998).

4.6 Methods: Data Collection

This section describes the data collection methods and instruments used in this study: 4.6.1 qualitative data; 4.6.2 documentation; and 4.6.3 interviews. Data analysis techniques are discussed in the following section, 4.7. The purpose of these three was to collect the qualitative data from the participants during the exploratory and explanatory case study as part of their experiences with the 4D model. In case study

research, qualitative data methods commonly involve documentation, archival records, interviews, observation, and physical artefacts (Bassey, 1999; Merriam & Tisdell, 2015; Yin, 2018). The following subsections outline how metaphor construction and reconstruction, lesson plans, and group and individual interviews were collected.

4.6.1 Metaphor Construction and Reconstruction

In the literature on teachers' beliefs, metaphor construction and reconstruction have been used as a data collection tool for enabling teachers to construct concrete artefacts of their abstract thoughts during reflection (Leavy et al., 2007; Martínez et al., 2001). Metaphors are implicit comparisons where individuals reveal their implicit theories or preconceptions about our world. Metaphors have been employed in several studies into teachers' beliefs, as they are argued to represent and reveal teachers' deep thinking about a subject (Fives & Gill, 2014). For example, metaphors have been used to reveal links between teachers' beliefs and the enactment of teacher roles (Bullough Jr, 1992), teachers' teaching (Saban, Kocbeker, & Saban, 2007), and teachers' experience of school (Massengill, Mahlios, & Barry, 2005). Metaphors also enable individuals to project an image of themselves to which they aspire. Individuals can use these metaphors to call themselves back to their espoused beliefs, which become difficult to adhere to when the individual comes into conflict with the traditions and cultures of the school (Fives & Gill, 2014).

Changes in metaphors enable the temporal comparison of intentions (Fives & Gill, 2014; Leavy et al., 2007). Temporal comparisons are features of time-series analysis (Yin, 2018). The author, Leavy (2007), used metaphors to enable teachers to make their internal beliefs about pedagogy explicit (Leavy et al., 2007). During this research project, pre-service teachers constructed metaphors about their beliefs about teaching and learning before engaging in a pre-service course module focused on teaching methodologies. Upon completing the course module, the participants reflected on their initial metaphors and made changes considering their new experiences. The researcher argued that a change between the preservice teachers' initial and final metaphors was evidence of changes in teachers' pedagogical beliefs. The researcher analysed the pre-service teachers' metaphors for their alignment with orientations of pedagogy and categorised their beliefs as either traditional, constructivist, or socio-cultural (Leavy et al., 2007).

In this study, the participants were tasked with reflecting on their beliefs about teaching and learning using ICT, pre-iteration one. The participants constructed metaphors about their prior teaching and

learning experiences with ICT. The activity aimed to enable the teachers to explicitly articulate their deeply held internal beliefs about teaching and learning. In an adaptation of the tool utilised in the Leavy (2007) study above, the teachers were tasked with reflecting on their beliefs about teaching and learning in the following areas:

- Learning theory
- Design principles
- Student progression
- Student assessment and feedback
- The design of the learning environment
- Example activities.

After each model iteration, the participants reviewed the initial metaphors they constructed. The participants were tasked with indicating whether there have been changes in their initially stated beliefs following their experiences with the 4D model. The participants were also asked to provide reasons for the outcomes. Where changes had been made, the participants constructed or adapted new metaphors. Screenshots of the pre- and post-iteration metaphor construction and reconstruction activities, and some example metaphors that were presented to the participants to complete the task using an online form, are included in the appendices.

4.6.2 Documentation

In case study research, documents can contain rich data. One of the advantages of collecting documents is that they are unobtrusive. Moreover, participants often naturally create them during a research project. Documentary evidence is also a valuable data collection tool in case studies, as it may be combined with other data sources for triangulating the multiple perspectives of the participants (Merriam, 1998; Miles & Huberman, 2020; Yin, 2013). While documents are not objective accounts of the participants' experiences, they can be used to highlight individual and group perspectives (Miles & Huberman, 2020). One advantage of collecting documents, such as schemes of work and lesson plans, is that they provide the researcher with tangible evidence of teachers' practice at a point in time and space. Differences between lesson plans over time can provide evidence of teachers' progress, or lack thereof, with implementing new initiatives (Fletcher & Luft, 2011).

This study collected documentation of teachers' lesson plans and schemes of work after iteration 1 and iteration 2. In this case, the participants were tasked with co-creating, implementing, and evaluating teaching and learning from knowledge acquisition, knowledge deepening, and knowledge creation orientations. According to the relevant research literature, teachers prevailingly design lessons using ICT that lack innovation and creation experiences with ICT (DES, 2020, 2022). By documenting teachers' capacity for designing from the multiple orientations listed above, the researcher gained insights into teachers design of innovative and creative lessons with ICT. Moreover, documentation provided evidence of progress in their capacity for innovative and creative design using ICT between iteration 1 and iteration 2. The lesson plan template provided for the participants was presented in Figure 9.

4.6.3 Interview

Interviewing is a flexible research tool often used as part of a case study and enables the researcher to examine critical aspects of their research focus (Miles & Huberman, 2020; Seidman, 2006). Interviews can fall within an interpretivist or a positivist paradigm. Interviews that seek an understanding 'in the lived experience of other people, and the meaning they make of that experience' fall within an interpretivist paradigm. However, interviews may also be a written questionnaire to establish a hypothesis's 'truth or falseness' (Miles & Huberman, 2020). Of the three types of interviews-structured, semi-structured, and unstructured-semi-structured interviews are often used within a qualitative approach. Semi-structured interviews involve the researcher asking participants pre-determined but open-ended questions. Using a semi-structured interview approach enables the researcher to ask major questions, with sub-questions and follow-up questions, reducing the danger of non-response (Miles & Huberman, 2020). Moreover, the researcher can ensure consistency between the questions they ask each participant, even though the question prompts may differ. While there may also be differences in the amount of time each interview takes, the same issues are raised across each interview, and the interviewees have the same opportunity to generate an equal volume of data. Group interviewing is another strategy commonly used in case studies. The advantage of the group interview approach is that the researcher can observe the group dynamics of the research group. It also enables the researcher to obtain data unlikely to emerge in one-to-one interview settings (Miles & Huberman, 2020).

Both individual and group interviews with each participant and each team were employed in this study, and the same set of questions were used in both. Group interviews were employed to investigate the team's experiences; individual interviews were employed to investigate each participant's personal

experience. This study employed the interview to gather data about how and why teachers' pedagogy beliefs changed during their experiences with the 4D model at school. To address this aim, open-ended questions were constructed. Because the teachers were experiencing the 4D model at school while also engaging in their day-to-day teaching and learning activities, the researcher determined to collect data relating to their experiences with the 4D model and its impact on teachers' personal beliefs, classroom factors, school-wide factors, and team factors. The questions used to guide the interview are included in the appendices.

This study's data collection instruments are summarised in Table 11.

Table 11: Data Collection Instruments

Data Collection Instrument	Rationale
Reflection – metaphor construction and reconstruction	Teachers raise deeply held beliefs about teaching and learning using ICT through metaphor construction and reconstruction.
Documentation	Teachers co-create, implement, and evaluate digital educational practice from knowledge acquisition, knowledge deepening and knowledge creation orientations.
Group semi-structured Interview	Each team discusses their lived experience with the 4D Model.
Individual semi-structured interview	Each teacher discusses their lived experience with the 4D Model.

Section 4.6 has outlined the rationale for the data collection methods chosen to support the investigation into the 4D model. It has described how reflection through metaphor construction and reconstruction, documentation, and interviews were employed to collect data pertaining to changes in teachers' pedagogy beliefs.

4.7 Qualitative Data Analysis

This section describes the data analytic strategies used and for what purpose. According to Miles and Huberman (2020), some common components and features of data analytic methods in qualitative research exist (Miles & Huberman, 2020). Common components include data collection, condensation, display, and drawing and verifying conclusions. Common features include assigning codes or themes to data; identifying relationships between variables, patterns and categories; isolating patterns and processes and their commonalities and differences; noting reflections in jottings and memos; elaborating assertions, propositions, categories, themes and concepts; and comparing those generalisations with formalised concepts or theories (Miles & Huberman, 2020). The components and features are also commonly employed in qualitative case study research (Bassey, 1999; Merriam & Tisdell, 2015; Yin, 2018).

Even though this chapter is presented sequentially and in a linear framework, the process involved multiple iterations of coding, analysis, and feedback before an appropriate framework emerged. The next subsections aim to remain true to the actual experiences of the researcher while also keeping in mind the case study goal of leaving behind a trail that others can follow to evaluate its conclusions (Bassey, 1999; Merriam, 1998; Yin, 2018).

4.7.1 Metaphor Construction and Reconstruction Analysis

The coding strategy for the metaphor construction and reconstruction analysis involved coding teachers' metaphors for their alignment with different orientations of pedagogy, similar to the process used in the Leavy study (Leavy et al., 2007). In that study, the author read 200–300 words of metaphors submitted by the participants. The author interpreted the participants' metaphors for their alignment with pedagogy descriptions, utilising a seminal paper, 'Cognition and Learning' by Greeno, Collins and Resnick, as a guide (Greeno et al., 1996). Leavy's approach is consistent with another study using metaphors as a blueprint for teaching and learning by Martinez, Sauleda, and Huber (Martínez et al., 2001).

Table 12 outlines the metaphor construction and reconstruction analysis strategy.

Table 12: Metaphor Analysis Strategies

Strategy	Type	Labels
Rubric Analysis	Pedagogy Codes	Traditional, individually constructivist, socially constructivist, and socio-cultural (Using rubrics from Greeno et al., 1996 & Beetham & Sharpe, 2019(Beetham & Sharpe, 2013).

4.7.2 Lesson Plan Analysis

Document analysis enables a researcher to move from descriptive observation to focused observation – "*narrowing one's field of observation to focus on those problems and processes that are most germane to the research purpose and questions*" (Cohen et al., 2018, p. 551). During the 4D model, the participants were tasked with designing lesson plans that follow a learning trajectory progressing from knowledge acquisition, to knowledge deepening, to knowledge creation. These documents allowed the researcher to analyse the group's understanding of these different lessons during each of the participants' two iterations. They also provided the researcher with evidence of the participants' developing a deeper conceptual understanding of knowledge acquisition, knowledge deepening, and Knowledge Creation between iteration one and iteration two of the 4D model. These documents were analysed to align with the three stages of knowledge acquisition, knowledge deepening, and knowledge creation as outlined in the pedagogy sub-category of the UNESCO ICT Competence Framework for Teachers (UNESCO, 2018b).

4.7.3 Interview Analysis

Several strategies were also available for analysing the group and individual interviews. Coding is commonly employed to interpret group and individual interviews (Bryman, 2016; Merriam & Tisdell, 2015). Both open and focused coding strategies were employed before an appropriate orientation emerged. Examples of both are presented in the appendices. Open coding involves reading through the data and coding segments without a pre-decided coding framework, and is commonly employed during Grounded Theory analysis. On the other hand, focused coding involves applying pre-decided codes to the data. Open coding risks seeing too many different perspectives in the data; focused coding risks missing out on other perspectives on the data (Miles & Huberman, 2020). The data analysis process is explained

in more detail in Chapter 6. A summary of the data analysis approaches employed in this study is presented in Table 13.

Table 13: Data Analysis

Data Collection Instrument	Data Analysis Method	Example
Metaphors	A priori codes	Pedagogy orientations
Team and individual semi-structured interviews	Open/initial coding, constant comparative method	Emergent codes, themes, and concepts
Documentation	Rubric Analysis	Alignment of teachers' lessons with knowledge acquisition, knowledge deepening and knowledge creation statements from UNESCO ICT CFT.

4.8 Participant Selection

Having identified the problem, the research design, the data collection tools, and the data analysis strategies, the researcher needs to consider where, when, who, and what to observe (Merriam, 1998). Because the study took place against the backdrop of the COVID-19 pandemic and public health guidelines restricted school visitors, convenience sampling methods were used, and the participants were self-selected to participate. An email was sent out to all the primary schools across Ireland and the Computers in Education Society of Ireland mailing list. The email included an invitation to study and details about the 4D model of CPD. It also included a consent form for participants and the board of management of their respective schools. The consent form detailed the study's aims and the 4D model experience. Ten primary school teachers submitted their consent forms and were all inducted into the study. During the study, two participants pulled out due to Covid-related issues. A temporal boundary was placed around the study, and the data collection was halted after each of the three teams had completed two iterations of the 4D model at school; saturation could not be achieved with such a small sample. However, the case study provided a boundary.

Inclusion criteria involved teachers being primary school teachers. Exclusion criteria involved teachers at post-primary level and those who were EFL teachers not teaching in primary schools. The main study occurred online, and the participants did not meet face-to-face. Data were collected at the following

points in time and the following ways: After submitting their intention to participate in the study, the participants were sent a hyperlink to an online form, which tasked them with constructing metaphors about their beliefs about teaching and learning using ICT at school. The participants filled in the online form, and the data were accessible by the lead researcher. During the two iterations, the three teams co-created lesson plans for knowledge acquisition, knowledge deepening, and knowledge creation orientations. The lesson plans were stored in a Google Drive folder the lead researcher had access to. After each team had completed an iteration of the 4D model, they conducted a semi-structured interview with the lead researcher to explore their experiences. Next, using an online form, they revisited their initial metaphors and indicated whether there had been any changes to their beliefs following their experience. Finally, each participant engaged in an individual interview with the lead researcher, exploring their experiences with the 4D model.

The researcher is a practising primary school principal and a PhD candidate. All the participants are colleagues from the primary teaching profession, but they are all teaching in different schools and are mostly unknown to the lead researcher. One participant is a principal in a local school; one participant acted as a substitute teacher in my school for three days; one participant is married to a friend. These issues were addressed in the invitation to study, and participants were asked to act in good faith and without bias. Participants were anonymised in the data.

4.9 Ethical Considerations

Several ethical considerations were adhered to in this investigation. Because the study involved primary school teachers and the researcher is also a primary school teacher, several considerations had to be considered, such as protecting the anonymity of the participants, how the data was collected, and how the final report was communicated. A research approach that adheres to the ethical standards required by the School of Computer Science and Statistics, Trinity College Dublin, was devised and applied at both stages of the study, prior to the Pilot study and again before the main study. Approval for the pilot study was granted in September 2019; approval for the main study was granted in August 2021.

Both the pilot and main study required informed consent from the teachers. Furthermore, consent was also obtained from the teachers' relevant Boards of Management and the school principals from each school involved in the study. The participants were given the right to refuse to take part or withdraw from the study at any time, without penalty, up to and including the time the final report was published. The

participants' confidentiality was strictly respected, and they were attributed anonymous codes in the data. In addition to the consent forms, the researcher reminded the participants of their rights and sought consent before recording the semi-structured interviews and the focus group sessions. All information collected was anonymised and stored per the Data Protection Act guidelines on an online, safely secured site.

4.10 Limitations

To draw on Yin (2018), it is important for case study researchers to openly acknowledge the strengths and limitations of a case study and to take steps to address them (Yin, 2018). Considerations relating to the study's limitations are discussed in the next sub-sections: 4.10.1 Research Design and 4.10.2 Research Methods.

4.10.1 Research Design

To investigate the efficacy of the 4D model approach to growing or changing teachers' beliefs about the use of ICT to support 21st century teaching and learning at school, this research utilised case study methodology. Here, the researcher opportunistically selected a particular case and carried out the study with the aim of answering the research questions and generalising the findings to the wider population (Yin, 2013).

Although case studies are a powerful tool for illuminating rich insights into the lived experiences of the participants, they are also limited in their generalisability. Because a case study illuminates insights from participants during their experiences in a particular context, the findings are also limited to the events that occurred in that context. This limits the extent to which it is valid to argue that the outcomes of the study are likely to occur in another context. Despite this limitation, case study findings can help researchers to make predictions about the likelihood of the findings being replicated in similar contexts with similar participants. In this study, the participants are primary school teachers who work together as part of a team. Because the participants on the team are from different schools, reducing the contextual limitations, the researcher determined that a case study was an appropriate approach.

The exploratory and explanatory case studies in real world settings helped the researcher to identify units of analysis and sub-units of analysis relevant to the research aims – to grow or change teachers' beliefs about the use of ICT at school – and to examine how the 4D model influences teachers' educational

practice. The role of the researcher in the research design is critical, as the changes they make to the design of the experience impact upon the outcomes of the study. The researcher had a significant role in the design of the 4D model prior to the pilot study and its subsequent redesign prior to the main study – creating the phases of the study, the stages of the model, and the tasks and activities the participants engaged in – and then implementing them with the participants. Though this was a necessary process, given this research was an investigation into the researcher's creation of a new model of teacher CPD for changing or growing teachers' beliefs, my biases in terms of the authenticity of activities and their relevance to both the co-creation, implementation. and evaluation of teaching and learning activities and changing teachers' beliefs were reflected upon in the redesign of the model.

Another issue with the research design is a need for the researcher to have been '*explicit and as self-aware as possible about personal assumptions, values and biases, and affective states – and how they may have come into play during the study*' (Miles & Huberman, 2020). The researcher is a practicing schoolteacher and a principal of a school, who has been involved in attempts to embed the educational use of technology in formal settings for several years. As such, the researcher is both part of the research and shares the participants' experience (Berger, 2015). While this issue has been addressed by the researcher maintaining a reflexive approach throughout the study, it means that the researcher needs to '*increasingly focus on self-knowledge and sensitivity; better understand the role of the self in the creation of knowledge; carefully self-monitor the impact of their biases, beliefs and personal experiences on their research; and maintain the balance between the personal and the universal*' (Berger, 2015, p. 2).

Reflexivity is commonly viewed as the process of a continual active acknowledgement and explicit recognition that this position may affect the research process and outcome (Berger, 2015). According to Berger (2015), the researcher's positioning, including personal characteristics, such as gender, race, affiliation, age, sexual orientation, immigration status personal experiences, linguistic tradition, beliefs, biases, preferences, theoretical, political and ideological stances, and emotional responses to participants may impact the research in three major ways. First, they can affect access to the 'field' because respondents may be more willing to share their experiences with a researcher whom they perceive as sympathetic to their situation, and the researcher may be more knowledgeable about potentially helpful and informative resources. Second, they may shape the nature of researcher-participant relationship, which, in turn, affects the information that participants are willing to share. Finally, the worldview and background of the researcher affects the way in which he or she constructs the world, uses language, poses questions, and chooses the lens for filtering the information gathered from participants and making

meaning of it, and thus may shape the findings and conclusions of the study (Berger, 2015). While such effects exist in all types of research, qualitative researchers, particularly practitioner researchers, tend to recognize and address them as an inherent part of the research, and to use reflexivity to monitor the tensions between involvement and detachment of the researcher and the researched to enhance the rigor of the study and its ethics (Berger, 2015).

4.10.2 Research Methods

The position of practitioner-researcher during this investigation also impacts upon the research methods, the development of the research tools, the data collection, analysing, and reporting of the findings (Berger, 2015; Miles & Huberman, 2020). Accordingly, the researcher used reflexivity throughout the research process to recognize and address how their worldview and background, and their '*lens for filtering the information from participants and making meaning of it may shape the findings and conclusions of the study*' (Berger, 2015, p. 2).

The researcher tasked the participants with constructing metaphors as a method for making their internal beliefs about teaching and learning using technology explicit. Though this method was modelled on other studies, e.g., Leavy (2007), the interpretation of metaphors is open to bias on behalf of the researcher. To address this issue, the researcher used the same pedagogy rubric as has been used in previous studies, such as Leavy (2007) and Martinez (2001). The rubric is aligned with the pedagogy descriptions from the authors, Greeno et al. (Greeno et al., 1996), and most recently updated to include digital practice by the authors (Beetham & Sharpe, 2019). This enabled the researcher to ensure uniformity in their decision-making.

The analysis of the documentation collected during the study, i.e., the lesson plans and learning plans, were also open to potential researcher-practitioner bias. To address this issue, the standards from the UNESCO ICT CFT (UNESCO, 2018b) were utilised to analyse the lessons for their alignment with either a knowledge acquisition, knowledge deepening, or knowledge creation stage. The use of these standards limited the potential for research bias and aimed to ensure uniformity with other researchers.

The questions asked during the group and individual semi-structured interviews were also at risk of practitioner-researcher bias. To address this issue, the questions were formulated to explore elements of the teachers' personal practice, their school context, and the team they were working with. Questions focused on factors that afforded or construed changes in practice and beliefs such as designing,

implementing, and evaluating from multiple dimensions; the tools used; feedback from peers, school leaders, and parents; and the team and the team's process for working together successfully. This approach ensured that the key elements from the teachers' classrooms and the wider socio-cultural environment they were working within were included in the study.

Through the process outlined above, the researcher determined the likelihood that another researcher would be enabled to arrive at the same conclusions, regardless of the researcher's researcher-practitioner potential bias.

4.11 Chapter Summary

This chapter began by clarifying the methodological rationale and the research purpose underpinning this investigation into a new model of teacher CPD – the 4D model. The ontological and epistemological rationale were clarified, and the research paradigm was presented. Next, the overarching research methods – Case Study – were argued to be most appropriate for the aims of this study, regarding other methodologies nesting within the chosen research paradigm. This chapter provided an overview of the qualitative methods used in the study. Reflective metaphor construction, documentation, and group and individual interviews were presented as data collection tools supporting this study. Next, the chapter discussed how the reflective metaphors, the documentation, and the group and individual interviews would be analysed using rubrics and qualitative data analysis techniques involving coding, constant comparison, and category construction. The ethical considerations of this study were addressed before the researcher outlined the methodological considerations and limitations by engaging in reflexivity. The next chapter will describe the pilot study and the main study that occurred as part of this investigation.

5. Pilot and Main Study

5.1 Introduction

This chapter describes the pilot study and the main research carried out in this thesis. Firstly, it describes the background context of the pilot study, the pilot study team, and their context. This is followed by a description of the artefacts they co-created. Following on, the chapter describes how the learnings from the pilot study informed the redesign of the 4D model for the main study, which took place in 2021–2022. Then, the background and context for the main study are described before each of the three teams who took part in the main study are described in depth in terms of their background context and the artefacts they designed.

5.2 The Pilot Study Iteration One and Two

The 4D model was piloted in the 2018–2019 academic year with a convenience sample of four female primary school teachers from three different primary schools located within a 30-kilometre radius of one another in the west of Ireland. The researcher purposively approached local schools to participate in a digital schools' excellence project to embed ICT in teaching and learning at the primary school level in Ireland. As part of the project, the four participants received invitations to a study piloting the 4D model at school, to which they consented. For their participation in the digital schools' excellence project, the participating schools received funding from the Irish Department of Education (DoE) to enhance their school's digital infrastructure. Table 14 presents the demographic background of the teachers who participated in the pilot study.

Table 14: Pilot Study Participants' Attributes

Participant ID	**Position**	**Current Class**	**Accumulated years teaching**	**Years at current School**	**Number of teachers**
1	Deputy Principal	4th Class (9–10 years)	18+	13–17	18+
2	ICT Coordinator	2nd Class (7–8 years)	13–17	13–17	18+
3	Mainstream Class Teacher	Junior Infants and Senior Infants (5–7 years)	13–17	0–2	6
4	Mainstream Class teacher	5th & 6th Class (11–12 years)	8–12	3–7	3

The participants included a deputy principal from a large school, a mainstream class teacher from the same school who was the school's ICT coordinator, a teacher in their first year at a new school, and a teacher who was the youngest member of a three-teacher school. Whereas two schools had significantly emphasised developing their digital educational practice, one of the three schools had little to no experience. The largest school, an all-boys urban school, was serviced by quality, robust ICT infrastructure and an internet speed of 100 mb/s. The second largest of the three schools, a mixed-gender rural school, was serviced by an internet speed of 30mb/s and is also fitted with quality, robust ICT infrastructure. The third school was also a mixed-gender rural school; however, its internet was 10 mb/s, and the school lacked quality digital infrastructure.

Participants 1 & 2, who had both been employed by their school for over 13 years, reported how there had been an emphasis on developing digital educational practice at their school. They were experienced in using both Microsoft and Google apps, including word processors, presentation software, and spreadsheets for teaching and learning. Participant 2 was also a member of the Irish Professional Development Services for Teachers Technology in Education (PDST-TIE) – an Irish government-funded teacher professional development body whose role it is to promote and support the integration of technology in teaching and learning – and had experience delivering digital educational professional development to colleagues at their school and other schools nationwide. Participant 3 had recently joined

a school that emphasised digital educational practice. However, participant 3 had come from a smaller school with little to no interest in using ICT for teaching and learning. Participant 3's new school used laptops and iPads daily, focusing on numeracy and literacy development, and created a film each year. Participant 4 came from a school with little to no ICT infrastructure, with colleagues who, although interested in listening to how the project developed, had no interest in utilising ICT for learning at school beyond the daily use of interactive whiteboards for presenting content.

As a first step in the pilot study, the participants submitted initial reflections. The initial reflections tasked the participants with constructing metaphors about their pedagogy beliefs about digital educational practice at school, which they emailed to the lead researcher. Following on, they met twice face-to-face, where they engaged in the design and development of teaching and learning activities from knowledge acquisition, knowledge deepening, and knowledge creation orientations. Then, the participants implemented the lessons in their classes. After this, they again met face-to-face for the debug stage of the 4D model to reflect on and evaluate the lessons.

Having completed the debug stage, the participants revisited their initial reflections and made any changes to their metaphors they deemed necessary. This was followed by a group interview with the researcher, where the team and the researcher discussed the participants' experiences. Lastly, each participant engaged in a one-to-one semi-structured interview with the researcher, where the participants' experiences were discussed in more depth. The steps above were repeated during iteration two. Throughout the two iterations, the participants met both face-to-face and online. Face-to-face meetings took place in the largest of the three participating schools, while the team maintained online contact through a WhatsApp group. The participants also used a shared Google Drive folder set up by the researcher to collaborate on lesson design and to document their progress. The teaching and learning activities the participants designed are discussed next and presented in Table 15.

Table 15: Pilot Study Co-Created Learning Activities.

	Iteration 1	Iteration 2
Subject & Strand	History – My Local Area	History – Change and continuity, people's lives in the past.
Knowledge Acquisition	Teacher-led presentation followed by a discussion of the local town.	Teacher-led exploration of Dúchas website. Children engage in a Webquest using Dúchas to find information about their locality in the past.
Knowledge Deepening	Walking tour of a local town with an outside expert. Students gather evidence through photos, videos and observations using IPADS	Using Google Docs, students collaboratively prepare an interview for a grandparent/local historian. Students record the interviewee through audio and video.
Knowledge Creation	In groups of three, students create photo stories of their local area using the evidence collected during the Knowledge Deepening stage. Students present evidence to their classmates and upload it to the school's website.	Using Google Slides, students create and then deliver a presentation which compares and contrasts their findings from their Webquest with the perspective of their interviewee. Students upload artefacts to the website. Students reflect on their learning using Padlet.

During iteration one, the participants created a suite of history lessons focused on objectives from the Irish primary curriculum. The lesson trajectory moved from knowledge acquisition, to knowledge deepening, to knowledge creation. The trajectory began with a knowledge acquisition approach, which involved a teacher-led presentation about the students' local area. This was followed by the knowledge deepening lesson that included a guided tour of a local historical site with an external expert, where the students used tablets to take images and record videos of their learning. Finally, the students collated their evidence and presented it to their peers for the knowledge creation lesson. During the second iteration, the teachers designed a suite of lessons that also followed a lesson trajectory moving from knowledge acquisition, to knowledge deepening, to knowledge creation. The lessons took the following

trajectory, again focusing on strands and strand units from the history subject area: During the knowledge acquisition stage, the students researched online resources for information about schooling in the past. During the knowledge deepening stage, the students interviewed a local community member about their school experiences. During the knowledge creation stage, the students presented their findings to their peers and the individuals they interviewed.

5.2.1 Qualitative Data Collection and Analysis

The next sub-section describes the qualitative data collection and analysis procedures. The data set included teachers' metaphors, lessons, and group and individual interviews. A summary of this is presented in Table 16.

Table 16: Pilot Study Data Collection

Data Collection	Pre-Iteration 1	Post-Iteration 1	Post-Iteration 2	Total
Metaphors	4	2	4	10
Lessons		1	1	2
Group Interviews		1	1	2
Individual Interviews		4	4	8

5.2.1.1 Metaphor Construction and Reconstruction

To explore the relationship between teachers' pedagogy beliefs and their use of ICT to support 21st-century teaching and learning, the participants constructed metaphors about their beliefs about teaching and learning with ICT. The participants submitted their metaphors before beginning iteration one, and they revisited those metaphors post-iteration two. For the post-iteration two reflection, they were asked to reflect on their experiences and to make any changes to their metaphors they deemed necessary in light of their experiences, or to indicate if there had been no changes in their beliefs. All four participants submitted their post-iteration two reflections and suggested some changes had occurred. The pilot study participants' self-reported changes in beliefs are presented in Table 17.

Table 17: Pilot Study Participants' Self-Reported Changes in Beliefs

Participant	Post-Iteration 2 Self-reported change
1	Upon review, I now believe in the importance of keeping abreast with the most up-to-date teachings and technologies. The skills of baking and teaching date back centuries. Over the years, there have been many changes, and both sets of practitioners have learned new ways of doing things. Technology has played a role in enhancing both teaching and baking and we, as practitioners, for the most part, have embraced these changes. We must not forget, however, the importance of the support we can give to each other in each of our professions. Working collaboratively with each other cannot only lessen the load, but it can also provide us with a fantastic support system and lots of new ideas.
2	I would add the following to my Reflective Writing Activity: Using the boat journey metaphor, it is important that when teaching and learning with technology: Preparation is key - preparation of the technology and, indeed, all resources that are needed for the teaching & learning journey must be prepared/tried & tested before embarking on the journey. Collaboration with the learners was mentioned above (both the captain/teacher and the passengers/learners will learn from one another on the journey). However, collaboration with other learners and experts in the field plays an important part of T & Learning using Technology. E.g., The captain/teacher should consult with other colleagues / fellow captains/teachers before beginning the journey. The Teaching & Learning journey may produce tangible outcomes/deliverables - these are important, too, as well as the enrichment of the learners.
3	Technology within teaching, I believe, allows for the pupils' creative side to flourish. It promotes collaboration amongst pupils of different educational abilities and encourages the inclusion of SEN pupils who may struggle with traditional project work. It teaches pupils to create, edit and finally publish a student-led piece of work. It opens up a world of information and new opportunities to pupils. It would be remiss of us as educators to not do everything we can to enhance our pupils' education, and technology is now a fundamental element to meet this requirement. Just like the easel, paper and paint are traditionally the materials used by artists to create masterpieces; in today's world, some masterpieces are created using digital technologies!
4	As we come to the end of year one of our project, it is a good time to reflect and take stock of things to date. We began the year as total novices-our only experience of IT being 3 PCs in the room that were shared between 24 pupils. Nine months later and we all have our own personal laptop, which is used on a daily basis, both for individual use as well as group/project work. We have explored, researched, produced, presented, and debugged.

The teachers' post-iteration two reflections indicated some change in their beliefs.

5.2.1.2 Interview Collection

Post iterations one and two, the participants participated in group and individual interviews with the researcher. The interviews were conducted online using the Zoom video conferencing app and were audio-recorded only with the participants' consent. The interviews focused on gaining a deeper understanding of the participants' experiences with the model. Questions focused on the participants' self-reported changes in beliefs, their experiences of co-creating, implementing, and evaluating the use of ICT to support 21st-century teaching and learning from knowledge acquisition, knowledge deepening, and knowledge creation orientations, and working as part of a team.

Each of the four participants took part in two interviews. Each interview lasted 30–35 minutes and was recorded using an audio device after gaining the participant's consent. An interview protocol was followed, and the participants were informed that they did not have to answer any question they did not wish to. A summary of the pilot study participants' interview length in minutes and words is presented in Table 18.

Table 18: Pilot Group Interviews

Participant	Iteration 1	Iteration 2
1	26 mins 3011 words	25 mins 2891 words
2	35 mins 4470 words	28 mins 3584 words
3	27 mins 2965 words	24 mins 2516 words
4	27 mins 3444 words	24 mins 2897 words

5.2.1.3 Interview Analysis

The analysis of the interview data aimed to explain if elements of the 4D model caused the participants' changes in beliefs. The process involved open coding, aggregating codes at nodes, reflecting, reviewing, and category construction. NVIVO, a qualitative data analysis software, was used to create a database

that included the interviews as sources. Codes that were applied to the data were recorded as references. A snapshot of an initial coding cycle is presented in Figure 12. It includes the name of the code or emerging category, the number of sources it was identified in, and the number of references to it across the data.

Name	Sources	References
Multi-dimensional approaches	9	36
Process	8	26
Locating	8	45
New learning	8	42
Authentic situated experiences contribute to growing or changing beliefs	8	141
Teamwork contributes to persistence with novel digital educational practice	8	81
Action interaction between team and authentic situated practice	8	48
Team work	7	58
Familiarity	7	23
Motivation	7	22
Reinforcment from peers	5	7
Habit	1	2
Extending the reach	1	1
Outcome of having researched	1	1
Life is a bit easier for me	1	1
Self-directed learning strategy	1	1
Student autonomy	1	1
Organisation	1	1

Figure 12: Initial Coding Cycles Pilot Study

Building the categories involved sorting and categorising interrelated codes. The researcher used several questioning strategies to open insights into the data. This involved flip-flopping and asking 'what-if' questions. The codes were constantly compared with one another to reduce overlap. From these approaches, the following categories emerged: Figure 13.

A : Co-creating, implementing and evaluating ...	B : Multiple iterations	C : Observing student learning outcomes	D : Situated experiences	E : Team
13	0	3	9	16
9	0	2	7	11
2	11	1	5	10
8	4	2	7	9
1	3	3	11	8
2	1	3	3	9
5	1	6	11	10
3	2	4	3	9

Figure 13: Pilot Study Emergent Categories

While the pilot study data was not included in the main study findings, the categories that emerged from the analysis initially influenced the focused codes for the main study data analysis; however, they were

later discarded, this is discussed in more depth in Chapter 6. The categories that emerged from the analysis of the pilot data included co-creating, implementing, and evaluating knowledge acquisition, knowledge deepening, and knowledge creation orientations; multiple iterations; observing student learning outcomes; situated experiences; and the team.

5.2.1.4 Category overviews

Co-creating, implementing, and evaluating from knowledge acquisition, knowledge deepening, and knowledge creation approaches: All the participants referred to this element of the 4D model. It involved discussing using ICT to support 21st century teaching and learning from knowledge acquisition, knowledge deepening, and knowledge creation approaches. The participants discussed how the lesson trajectory felt familiar; they also reported that they aimed for this type of lesson sequence in their established practice. However, they discussed how they had been doing each of the three stages as part of one whole lesson instead of each of the three orientations separately.

Multiple iterations: All but one of the participants discussed how multiple iterations of the 4D model at school were of significance to their self-reported changes in beliefs. The participants discussed how they and their students developed a deeper understanding of the model and the knowledge acquisition, knowledge deepening, and knowledge creation orientations of using ICT to support 21st century skills development at school. They reported that multiple iterations gave them opportunities to develop a better understanding of the model. Moreover, they reported there was less pressure on them during term 2 than there had been during term 1, which meant they felt they had more time to experiment in class.

Observing student learning outcomes: All the participants referenced how observing student outcomes influenced changes in their beliefs. They discussed observing students overcoming traditional difficulties with traditional learning through their experiences of using ICT from knowledge deepening and knowledge creation approaches.

Situated experiences: Situated classroom experiences were also an essential element in teachers' self-reported changes in their beliefs. They reported how they encountered access issues with technology, which they had to overcome to enable the lessons to progress smoothly, and how they identified solutions to those problems, which were factors enabling the lessons to progress smoothly as planned.

The team: The team was the final major category that emerged from the exploratory phase of the case study. The participants discussed how they learned innovative ideas from one another, how they used the

team as a point of reference for gaining assistance when problems emerged, and how it was positive to be able to check in with one another to see how they were progressing, which motivated them to persist with their delivery of the lessons at school.

5.2.2 Learning from the Pilot

Even though the data had indicated some efficacy of the 4D model for changing teachers' pedagogy beliefs, several design considerations were raised. These resulted in changes to the model's structure and modifications to the metaphor construction and reconstruction activity.

5.2.2.1 Changes to the Structure of the 4D Model

The participants' progress through the two iterations of the model differed from the researcher's initially designed learning sequence. Figure 14 presents differences between the researchers' intended learning sequence and the participants' actual learning sequence during the pilot study.

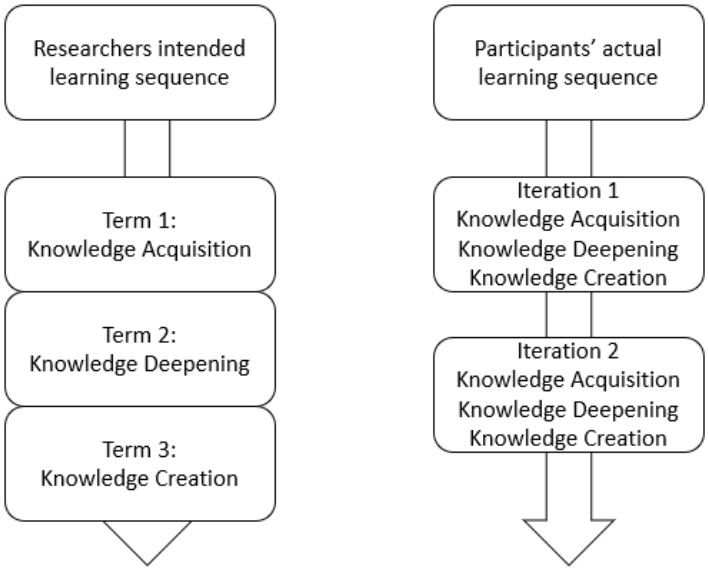

Figure 14: Intended vs Actual Learning Sequence

Whereas the researcher initially planned for the teachers to complete one iteration of each pedagogical orientation each term for two years, the participants completed two iterations of all three orientations across one school year. When discussed, the teachers reported that although they felt they were familiar with the three orientations of pedagogy, they did not know them by name. The participants discussed

how they felt familiarity between the prescribed learning trajectory and their existing classroom practice. They felt that many of their lessons involved an initial stage where the teacher directed the learning, followed by opportunities for students to deepen their knowledge through hands-on activities, and the aim was that by the final stage of the lesson, all things proceeding as planned, the students would be in control of the learning.

The teachers conceded that while they envisaged the trajectory as a flow from one stage to the next, they lacked understanding and experience in utilising the orientations separately. Although many of their lessons included all three orientations, the lessons always began with knowledge acquisition. Little to none of these lessons began from knowledge deepening or knowledge creation orientations. The insights gained from the participants' feedback informed the redesign of the structure of the 4D model. Figure 15 presents the redesigned learning trajectory.

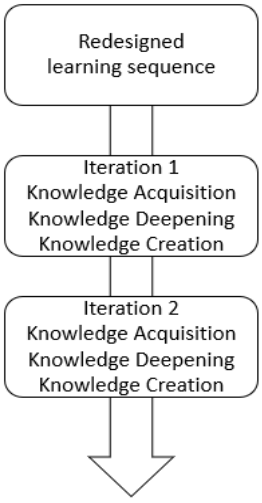

Figure 15: Redesigned Learning Trajectory

5.2.2.2 Changes to the Metaphor Construction and Reconstruction Activity

The second main change to the 4D model involved redesigning the metaphor construction and reconstruction activity. During the pilot, the participants were tasked with constructing metaphors about their pedagogy beliefs regarding digital educational practice at school. The data were analysed and compared for its alignment with traditional, constructivist, or socio-cultural pedagogy. The analysis was guided by a rubric of pedagogy definitions from Greeno et al. (1996), a strategy previously utilised by Martinez et al. (2001) and Leavy et al. (2007) in studies of teacher pedagogy belief change (Leavy et al., 2007; Martínez et al., 2001). The activity involves participants submitting approximately 200–300 words

containing metaphors about their beliefs about digital educational practice at school. An example of Participant 4's metaphor is provided in Table 19.

Table 19: Example Metaphor

Participant	Metaphor
4	Teaching is like a juggler in a circus act. The Juggler has often grown up in a family steeped in the craft of juggling. His career begins with the simplest of acts-juggling 1-2 balls in front of a small group. He doesn't just fling 3-5 balls in the air and make it all look simple. It takes years of practice to make his act look effortless while, at the same time, keeping the attention of his audience. The Juggler often has to overcome various distractions that may arise during his act- an audience with little or no interest in his act. The balls that the juggler uses also represent the life of a teacher. A young juggler (teacher) starts out with one to two balls – teaching and a new school, perhaps. As the teacher refines her act and more balls are introduced (extra school duties, parents, other staff, budgets, planning), the teacher must learn to continue in perpetual motion. Not only does the teacher have to increase the items juggled, the whole situation in which she juggles in constantly changing-personal life, a growing family at home, staff relations etc. An experienced Juggler will use whatever materials are available to him to create an entertaining, interesting act that, from the outside, looks effortless.

The researcher analysed the resulting data for its alignment with the pedagogical orientations using the pedagogy rubric from Greeno et al. (1996). The researcher categorised the participant's metaphor as traditional, constructivist, or socio-cultural. Post-intervention, the participants revisited their initial metaphors. They could leave the metaphor as it was, make changes to their metaphors, submit new metaphors, or provide responses justifying any changes in their beliefs in light of their experiences. The resultant changes, if any, were coded for their alignment with the different pedagogical orientations and presented as evidence of changes in teachers' beliefs.

While following the process, several challenges arose. Even though the essence of the metaphor could be coded to indicate an alignment with an orientation of pedagogy, looking under the hood of the metaphor implied that different elements could be interpreted as aligning with varying orientations of pedagogy. Some were consistent, and others were inconsistent with the overall essence of the metaphor. Figure 16 has two parts. On the top with the green background is the metaphor. In the rows and columns below is

the metaphor broken up into different lines of code. Whereas the metaphor was coded as aligning with constructivist pedagogy, when it was broken up into segments, it was coded differently. Moreover, the segments revealed that the teachers were talking about different elements of teaching and learning. In the example in Figure 16, the segments in the rows indicate teachers have beliefs about assessment, how students learn, and methodologies, amongst others. While the essence of the metaphor was indicating one orientation, when it was segmented, it was revealing multi-dimensional orientations.

Teaching is like baking. Given a few basic ingredients, flour, eggs, sugar and milk, you can bake just about anything, however with some extra skills and an imagination you can become an truly amazing baker. Likewise, a teacher is given the ingredients of students, a curriculum and resources, however only with the proper skill set & imagination will the teacher make an impact and become a truly great teacher. Bakers need to be creative and teachers also need to be creative. Bakers are often judged by their end product, and in the same way teachers are often judged by the results of their students. Bakers use different utensils to acquire different results. For example they might use a sive to sift the flour. In the same way teachers use varying resources to teach the children. for example concrete objects for maths. Bakers and teachers use varying techniques to achieve varying results. Bakers follow a plan(recipe). Likewise teachers follow a plan (lesson plan/fortnightly scheme) when teaching. Bakers often tweak their recipes, in the same way that teachers tweak their teaching/plan/techniques. Finally some of the best baked treats come from experimentation and in a similar way some of the beat teachers are those who are able to think outside the box.

Participant	Team 1 Participant 1 Iteration 1	Traditional	Constructivist	Socio-Cultural
Metaphor	Teaching is like baking.		1	
	With extra skills and creativity you can become an amazing teacher.		1	
	Teachers need a proper skills set and imagination to make an impact.	1		
	Teachers need to be creative.			
	Teachers are judged by the results of their students.	1		
	Different teachers use different methodologies.			
	Teachers use a variety of resources to teach children.	1		
	Different methodologies lead to different results.	1		
	Teachers follow a plan when teaching.	1		
	Teachers tweak their plans.		1	
	Professional experimentation is important.		1	
	Thinking outside of the box is important.			

Figure 16: Challenges Coding Metaphors

The researcher found it challenging and inconsistent to categorise the essence of the metaphors as either traditional, constructivist, or socio-cultural. This was because the segmented text of the participants' metaphors aligned with a range of pedagogy orientations. As such, it was deemed insufficient to categorise a participant's metaphor specifically as one orientation or another, even where there was a majority of one pedagogy orientation over the other two underpinning the participants' metaphors. Furthermore, the data set indicated that teachers reported beliefs about different sub-categories of teaching and learning within their metaphors. For example, teachers' metaphors included constructivist

beliefs about how students learn but traditional beliefs about student assessment. Rereading the relevant literature in this area provided opportunities for developing a more consistent procedure for this data collection and analysis strategy.

Building on research literature reporting that teachers hold multi-dimensional beliefs (Tondeur et al., 2017) and updated definitions of pedagogical orientation by Beetham and Sharpe (2019), the researcher refined this data collection and analysis procedure in the following ways. Instead of asking the participants to submit 200–300 words of text which were then categorised, the participants were tasked with submitting 2–3 metaphors about the following pedagogy sub-categories: learning theory, lesson design, student assessment and feedback, student progression, design of the learning environment, and example activities. This refined strategy aimed to open a window into the sub-categories of teachers' pedagogy beliefs, which could provide insights into the relationships between teachers' beliefs about the pedagogy sub-categories. A summary of the changes is presented in Figure 17.

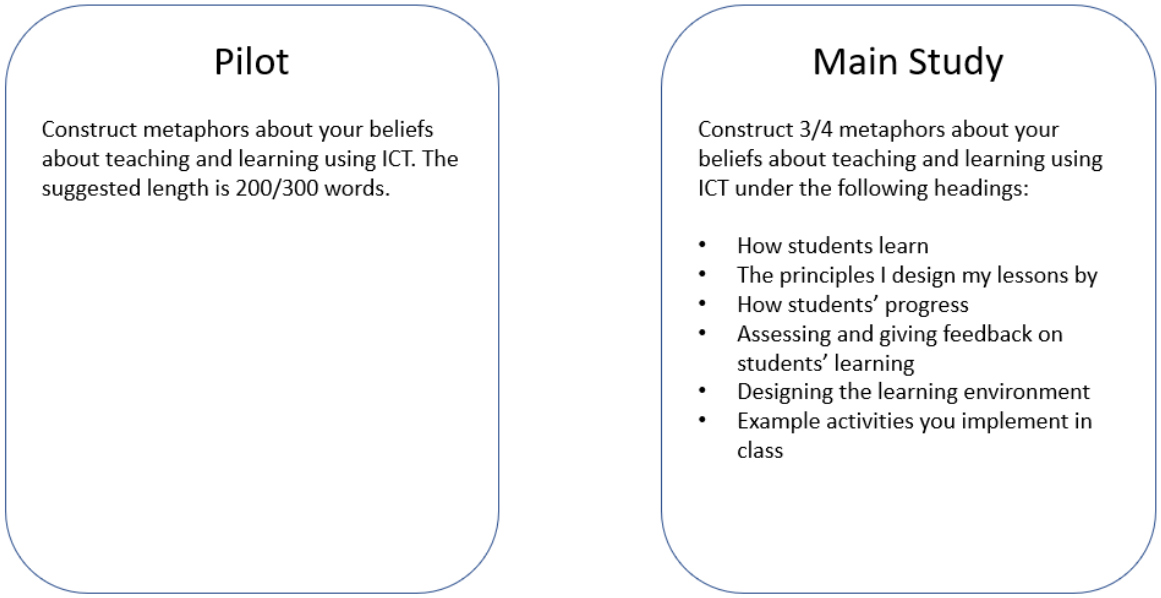

Figure 17: Changes in the Metaphor Construction and Reconstruction Process

5.3 The Main Study Iteration One and Two

Having described the pilot study, the changes to the model, and the metaphor construction and reconstruction process, the next section describes the main study of the 4D model. First, the study's context is described, followed by a description of the three team's experiences with the 4D model.

5.3.1 Context

The main study of the 4D model took place between September 2021 and May 2022. Since the pilot had taken place in 2018–2019, the country-wide focus on teachers' digital educational practice had significantly amplified because of school closures during the COVID-19 pandemic. In Ireland, schools closed from March 2020 to the end of that school year – June 2020. A second school closure occurred the following year, from January 2021 until April 2021. During these school closure periods, teachers were tasked with the continuation of schooling through the provision of emergency remote teaching and learning. Emergency remote teaching and learning required teachers to provide students with learning activities, assessments, and feedback. In practice, teachers across the country adopted many approaches to this challenge, including sending books and worksheets home for the students to complete, synchronously teaching students through online classes using Google Meet and Zoom, and asynchronously interacting with parents and students using applications such as Seesaw – to post videos, images, docs, hyperlinks, and feedback (DES, 2020).

Schools fully reopened for the academic year September 2021–June 2022, but they were still in a state of disruption because of the continuing presence of COVID-19. To cope with mandatory social distancing, classes were split into pods of students of 6 or fewer, and bubbles of no more than 30. Students were not allowed to mix pods indoors or bubbles outdoors, meaning student-to-student interaction during yard and class times was limited. Teachers were also missing interactions with their colleagues at school. Yard times were staggered to limit pods and bubbles from mixing, meaning teacher staff rooms were emptier than normal because their break times were at separate times. Because of social distancing, staff and parent-teacher meetings were also disrupted, with many schools choosing to go online for staff meetings and parent-teacher meetings (Dempsey & Burke, 2020).

On top of this, National Public Health Emergency Team (NPHET) guidelines were issued to schools concerning mandatory isolation in the event of either contracting COVID-19 or being near another person with COVID-19, meant that school attendance was significantly disrupted. Because guidelines recommended individuals isolate for 14 days, higher-than-average student and teacher absences were

recorded throughout the year. This led to a substitute crisis because there were not enough substitute teachers to cover teacher absences, leading to some schools having to send classes home or, in extreme cases, having to close the whole school. Against this backdrop, the main study occurred during the academic year 2021–2022, the first school year without school closures since the pandemic began in March 2020.

For the main study, participants were convenience sampled. Between June and September of 2021, invitations to study were emailed to all the primary and post-primary schools in Ireland, the Computers in Ireland Society of Ireland (CESI) mailing list (approximately 2000 primary and post-primary teachers), and shared on social media platforms, including Facebook and Twitter. A copy of the invitation to study is included in Appendix 1. From this approach, 23 participants expressed interest; of whom, 10 primary school teachers completed the online consent forms, the pre-iteration one reflection, and self-selected themselves onto the study.

Using a Microsoft Form, teachers submitted background information about themselves, including their school's location, their role at school, classes being taught, accumulated years of teaching, and years at their current school. This form also enabled teachers to access the pre-iteration one reflection task, where they constructed metaphors about their beliefs about digital educational practice at school under six headings. Between the submission of the initial reflection and the end of iteration 1, two participants dropped out, citing COVID-19-related issues, and their data is not included. Table 20 Participants Attributes' is a summary of the cohort's information.

Table 20: Main Study Participants' Attributes

Participant ID	County	Role	Classes being taught	Years teaching	Years at current school	School size (teachers)	Gender
1	Dublin	Mainstream AP 2 acting post holder;	6th Class (11–12-year-olds);	13-17	13-17	14	F
2	Kildare	S.E.T.	Senior Infants (5–7-year-olds);	13-17	0-2	18+	F
3	Mayo	Teaching principal;	4th, 5th & 6th (9–12-year-olds)	13-17	3-7	3	F
4	Offaly	Deputy principal;	S.E.T. (5–12-year-olds);	18+	13-17	18+	F
5	Mayo	S.E.T. Teacher;	1st Class (7–8-year-olds);	8-12	0-2	16	M
6	Mayo	Teaching principal;	5th & 6th (10–12-year-olds)	13-17	8-12	5	F
7	Waterford	Teaching principal;	3rd, 4th, 5th & 6th, (8–12-year-olds)	8-12	3-7	3	F
8	Mayo	Teaching principal;	4th, 5th & 6th (9–12-year-olds)	13-17	3-7	3	M

Using the background data in Table 20, the participants were organised into teams by school and class levels. This led to the creation of three different teams: Team 1 consisted of three teachers in their schools' Special Education Teacher (S.E.T.) role; Team 2 consisted of teachers teaching 5th and 6th classes; Team 3 consisted of teachers teaching 4th, 5th, and 6th classes. This gave the teams a good geographical spread, with teachers from the east, west, and south of the country working together. The teachers had various roles at their respective schools, including teaching principal, deputy principal, and ICT coordinator. All the teachers had been teaching for at least 8 years. Some were new to their respective schools, whereas others had been at their schools for much longer.

All the schools, except one, reported having robust and reliable technology infrastructure. Whereas all schools had access to a range of computers, including laptops, Chromebooks, and tablets, one school's internet access was limited to 10m Mbp/s. All teachers reported having experience using online learning

environments such as Google Classroom and Seesaw, and they said that they were comfortable with video conferencing in Zoom and Google Meet. One teacher was using Virtual Reality headsets at school.

Within these three teams, the researcher appointed team leaders. Team leaders were chosen based on their school position and years of experience teaching and learning. The team leader became the first point of contact with the researcher. A team leader's WhatsApp group was set up between the team leaders and the researcher to keep up to date with the project's development and to be on hand to answer any team queries or questions. Regular emails were also sent to the participants, reminding them of the resources available and the sequence of tasks to be undertaken during each iteration. Figure 18 is a screenshot of the master page outlining the 4D model process that was emailed to the participants. It includes links to videos about each activity and the online data collection forms. This is followed by Figure 19, a screenshot of the Google Drive folder and its resources that each team used throughout the study.

Important: Attached to this email is the Master Page for the participants. It contains all of the links to the Microsoft Forms and the video introductions you will access during your journey through the 4D model. It may be of value to paste this pdf into your instant messaging group. A copy will also be placed into your team's shared Google Drive folder. The table containing the links to the Microsoft Forms and the videos has also been pasted at the bottom of this email for your convenience. It is recommended that you view the videos prior to each and every activity.

Again, if you have any questions or queries, please contact me at [redacted]
If you are in need of my phone number please email me and I will share it with you directly.

The 4D Model Iteration 1			
1	Consent forms and reflection one	Video	Form
2	Constructing your team	Video	
3	Design Stage	Video	
4	Develop Stage	Video	
5	Deliver Stage	Video	
6	Debug Stage	Video	
7	Post-iteration reflection	Video	Form

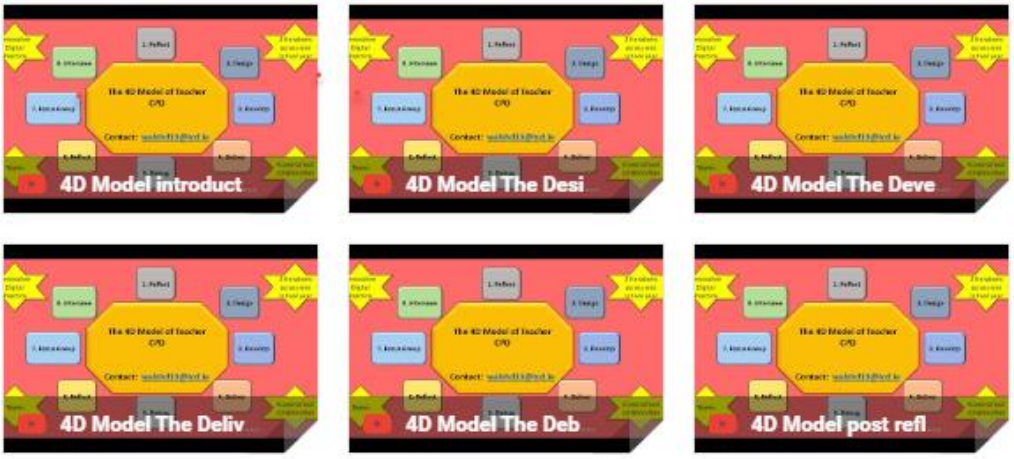

Figure 18: Master Page

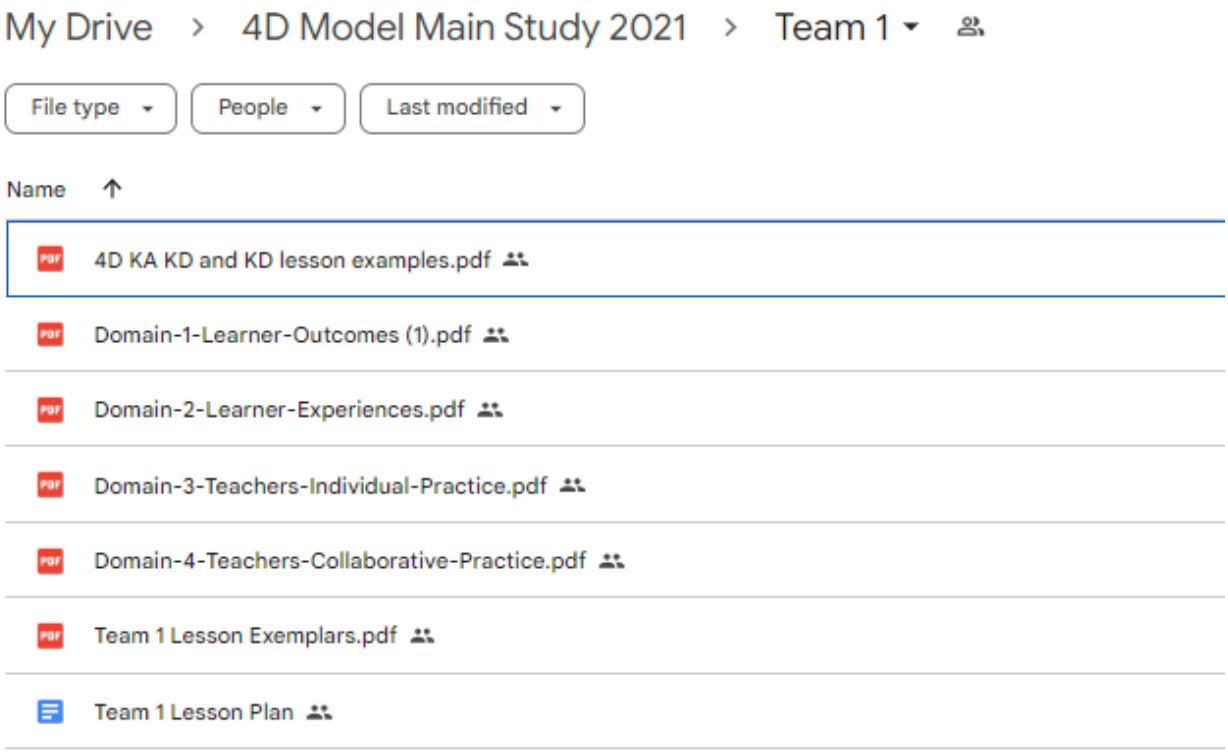

Figure 19: Google Drive Folder

Participants used Zoom and Google Hangouts to meet online, with no face-to-face meetings taking place. They set up WhatsApp groups to keep in regular communication. Each team was provided with a Google Drive folder containing resources, lesson templates, links to video explainers, and sample lessons (Figure 19). The teams were set with a flexible schedule to have iteration one completed by the end of the first term and iteration two completed by the end of the second term of the school year. Because the 2021–2022 school year occurred within the context of the COVID-19 pandemic, and even though it was the first unbroken school year, many teachers' initial plans were interrupted. Many participants had to restrict their movements during the year, meaning absences from school impacted the teams' intended schedule. Despite these interruptions, eight participants persisted with the study. This involved two iterations of co-creating, implementing, and evaluating digital educational practice from knowledge acquisition, knowledge deepening, and knowledge creation orientations; pre- and post-iteration reflections; and group and individual semi-structured interviews. What follows is a description of each team's experience interwoven with quotes from the participants' group and individual interviews.

5.3.2 Main Study: Team 1

Table 21: Team 1 Participants' Attributes

Participant ID	County	Role	Classes being taught	Years teaching	Years at current school	School size (teachers)	Gender
Participant 2	Kildare	S.E.T.	Senior Infants	13-17	0-2	18+	F
Participant 5	Mayo	S.E.T.	1st Class	8-12	0-2	16	M

Table 21 lists the attributes of the two participants from Team 1 who completed the study. Team 1 initially consisted of four teachers. However, two teachers pulled out during the first iteration because of issues external to the study. The two remaining teachers – one male and one female – were both Special Educational Teachers (S.E.T.), new to their respective schools, who had been teaching abroad in the preceding years and were unbeknownst to one another before the study's beginning. Participant 2 was in their first year teaching at the school and moved from a temporary contract to a permanent one during the school year. Participant 5 was continuously working as a substitute at their respective school, and it was only after January that they were guaranteed work in that school until the end of the school year. Both had recently moved back from abroad, where they had spent more than three years teaching in countries in Asia. Both teachers also had experience teaching and learning different national curricula. Both reported that the digital resources available abroad were more plentiful and reliable than those in Ireland. Both teachers had trained as primary school teachers in Ireland and had previous experience designing teaching and learning in the Irish setting.

Despite one school being situated in the east and one in the west of the country, both participants' schools were of comparable size, with more than 18 teachers in each. This meant that both teachers – working in the S.E.T. position – were part of a school S.E.T. team with more established teachers. Both teachers reported that their colleagues supported them in participating in the project. However, one teacher said that the emphasis on using ICT was against their SET team's traditional teaching and learning culture. Because the two teachers were working in S.E.T., they were required to communicate with the mainstream class teacher regarding the teaching and learning activities they planned. The knowledge

acquisition, knowledge deepening, and knowledge creation teaching and learning activities from Team 1 are presented in Table 22.

Table 22: Team 1 Co-Created Learning Activities

	Iteration 1	**Iteration 2**
Subject / Strand	Maths: Number, Operations, Fractions	Maths: Number - Decimals Measures - Time
Knowledge Acquisition	Teacher demonstrates to the children how to design, record, edit, and publish a video of their partner sharing the story they have read. Their partner explains the story in their own words.	The teacher demonstrates to the students who follow along how to find a pathway through a virtual environment and how to investigate a problem, e.g., Kahoot.
Knowledge Deepening	Students are set a maths-related problem of having to design, record, edit, and publish a video of a teaching and learning topic from the curriculum.	The students are set a challenge of finding their own pathway through a virtual environment to investigate a topic, e.g., Kahoot.
Knowledge Creation	Working in teams, the children design, create, use, present, share and reflect on a video of a teaching and learning topic of their choice from the curriculum.	The students design, create, use, present, share and reflect on a virtual environment to investigate a problem.

Team 1's learning activities focused on Mathematics teaching and learning for both iterations one and two. During iteration one, the knowledge acquisition orientation started with the teacher demonstrating to the students how to use an iPad to record a video discussing their learning. The knowledge deepening orientation extended the learning. Here, students worked in pairs and recorded their video about their understanding of multiplication and how to multiply a one-digit or two-digit number by 0–10. During the knowledge creation orientation, the students were given more autonomy and recorded their video about their learning of fractions.

During iteration two, team 1 introduced the quizzing app 'Kahoot' for the knowledge acquisition phase to the students, who investigated a problem. During the knowledge deepening phase, the students were presented with a Kahoot, which they had to find their pathway through. During the knowledge creation phase, students had to design and share their own personally made Kahoot with their peers.

5.3.3 Main Study: Team 1 Experience

Participant 5 reported that designing digital educational practice from multiple orientations "*highlighted to me using technology in a different way,*" where "*the children are showing their learning, where they're using it as a teaching tool,*" which resulted in Participant 5 "*broadening my methodologies and my assessment tools using I.T. differently."* Participant 2 agreed and reported that they had observed the "*students using IT to co-create their own understanding, getting a deeper understanding of the target of the lesson,*" and that the approach to designing digital educational practice enabled Participant 2 to reflect on "*how I had been using IT until now and look at ways I could use it in a more effective manner, a more inclusive manner.*"

The participants also reported that during the second iteration, they had pushed the boundaries of the lessons more toward knowledge creation. Whereas Participant 5 felt that '*in the first iteration, the same goal could have been achieved without using the iPad*. *In the second one, where the students were coming up with their own content again, I felt they had to have a deeper understanding in order to be able to create the quiz,*" and Participant 2 reported, "*in the second iteration, my students wouldn't have been able to make a quiz or write questions to ask their peers without using Kahoot*." During the second iteration, Participant 5 reported, *"I think we had more of an idea of what we wanted to do,"* and Participant 2 expanded, saying "*I think we have had a better idea of what would sort of work for our groups, so we are more able to honestly feedback to one another,*" because we "*used our shared experience to have a better idea of what would be applicable in the small group setting.*"

Team 1 also discussed how their new practice enabled them to observe student learning outcomes during class. Participant 5 reported, "*Whereas I felt that they had grasped the concept of the decimals and fractions, and it was tenths and converting tenths to decimals and vice versa, and putting it on a number line, but when they went to create their video, they weren't as confident, and they didn't demonstrate the understanding that I thought they had,*" meaning that a feedback loop was created which wasn't previously there: *"they weren't where I thought they were at."* Participant 2 observed how his students became more engaged: "*Like one student, if I gave him a busy at maths page, he would just look at me*

*lost, but if I put a game or a task on his iPad that is the same, he will read it, so he is more engage*d." Participant 2 also reported observing that students were more willing: "*When you've explained it, and you give them the iPad, they just go, and it's almost like they'll give it a go first, and then they'll say, 'I'm not sure what I have to do,' whereas when you tell them the game first, they'll automatically say 'I don't know what I have to do,' but with the I.T., they're willing to give it a go first*." Participant 5 reported, *"Sometimes when you start and you're explaining the game, or you give them a task to do, automatically some of them say 'I don't know what to do,' whereas when you've explained it to them, and you give them the iPad*, *they don't feel like they're doing work when they're playing with the iPad.*"

As a team, Participant 5 felt, "*we were equals, nobody was dictating to anybody else, and we were trying to come up with a way that works best in our classrooms*," and even if one person forgot about their meetings, "*one of us would remind the other*." Participant 2 felt they could "*talk openly and honestly about your role and how you were going to incorporate technology in what you wanted to achieve*." The team also reported that even though one of their teammates had dropped out of the study, they had persisted because there were tacit rules such as "*we knew what we were signing up to, we knew what was going to be involved, so we knew what was expected,"* which also meant coming to the team meetings "*with the work done,*" according to Participant 2.

5.3.4 Main Study: Team 2

Table 23: Team 2 Participants' Attributes

Participant ID	County	Role	Classes being taught	Years teaching	Years at current school	School size (teachers)	Level
Participant 3	Mayo	Teaching principal	4th, 5th & 6th	13-17	3-7	3	F
Participant 7	Waterford	Teaching principal	3rd, 4th, 5th & 6th,	8-12	3-7	3	F
Participant 8	Mayo	Teaching principal	4th, 5th & 6th	13-17	3-7	3	M

Team 2 consisted of three teaching principals, and their attributes are listed in Table 23. A teaching principal has the duties of both a mainstream class teacher and a school principal's responsibilities. The three teaching principals in this team, two female and one male, were all teaching 3rd, 4th, 5th, and 6th classes in a mixed classroom – one where the class groups are mixed, unlike a single stream class in a larger school. All three participants came from small schools and were in their schools for the same length of time. Whereas two participants had over 13 years of experience, one had between 8–12 years of teaching and learning experience. Participant 3 had previously worked in industry, whereas Participants 7 and 8 had spent their professional lives as teachers.

Two of the participants' schools were in the country's west, whereas the third was in the south. The schools shared similar ICT infrastructure, and each reported emphasising digital educational practice at school using computers, laptops, tablets, and applications. One teacher said that since their school closure because of the lockdown, they had completely changed their views on the place of ICT at school. One of the participants had poor broadband at school and was also hampered by IP address conflicts at their school, meaning sometimes students would get knocked off the internet. The knowledge acquisition, knowledge deepening, and knowledge creation teaching and learning activities from Team 2 are presented in Table 24.

Table 24: Team 2 Co-Created Learning Activities

	Iteration 1	**Iteration 2**
Subject / Strand	English	English
Knowledge Acquisition	Design a toy for the Toy Show and write up a presentation	Write and present a news item using Greenscreen.
Knowledge Deepening	Create a prototype of the toy	Create a School News Station.
Knowledge Creation	Present the project using greenscreen	Present the news using greenscreen

Team 2's learning activities focused on English from the new primary language curriculum. During the knowledge acquisition stage, the students had to design a toy for the Toy show – the toy show is an annual event held before Christmas on Irish TV – and they had to write about what they were designing. For the knowledge deepening stage, the students had to write about how their toy works, and for the knowledge

creation stage, the students had to present the project using a greenscreen to their peers. During iteration 2, Team 3's knowledge acquisition stage involved the students writing and presenting a novel item using greenscreen. For the knowledge deepening orientation, the students had to create a school news station and research, recount, and write a piece of news. The students presented their original news stories using greenscreen for the knowledge creation phase.

The key difference between iteration 1 and iteration 2, as the team's participants reported, was that during the second iteration, the participants handed over more control to the students. Whereas much of the learning had been initially teacher-led during the first iteration, they were more comfortable handing over the entire project to the students, who were given agency and autonomy to develop their news stories and presentations during the second iteration. This meant that teachers were enabled to hop from group to group, and they were enabled to stand back and observe the learning as it unfolded.

5.3.5 Main Study: Team 2 Experience

Participant 8 noted how designing from multiple orientations enabled him to "*step back, let them go and do it,*" which also helped them to "*observe and see how things are going*." Participant 8 noted how the different approaches were "*better because you allow them more scope to do it themselves*."

Participant 3 noted how students could overcome challenges more readily with ICT, observing that "*when we bring in technology, they actually exce*l." Similarly, Participant 3 said the students "*looked all engaged and really excited*" during ICT projects.

Participant 7 reported that "*there was a huge amount of peer review going on and peer assessment,*" where "*the boys and girls were telling each other, 'Pronounce your ts and stop waving around when you're standing,' while they were preparing their presentations*."

Participant 8 stated how the approach had enabled him to "*open a door to allow the creativity to happen*" and helped him to see "*creativity that I couldn't really see*" using traditional approaches. The approach opens much more "*sharing between the kids,"* and there is great "*peer-to-peer learning going on*." Participant 8 stated, "*If I don't know the content of what I'm teaching, then they won't know it, whereas I saw learning happening here that I didn't know anything about. You know, it wasn't my knowledge. It was their knowledge*."

Participant 7 said, "*I really enjoyed actually doing the second one, I think a lot more than I did the first one,*" and that "i*t's kind of the debug from the last, the first stage that allowed us to do the second stage better.*" The debugging phase was important "*when we reflected on what we had done, you know, where people had fallen into different difficulties, and people were able to debug them for other people*." The debugging phase also meant the participants extended their ideas for the second iteration: "*I learned a lot the second time around because I would have approached it the way I knew how to approach using green screen,"* but after looking at how teammates had approached it, "*it just looked so effective, and I suppose I started to change the way we approached our second one based on that as well*." Participant 7 continued, "*I feel I was a little bit lost at the beginning, and I think I didn't give enough concentrated time into reading what I signed up for, and I actually feel round two, I'll be a lot better, I think I'll get more out of it*."

Participant 8 also felt they saw students having fun and enjoying their learning: "*It just showed me how enjoyable and engaged they are,"* and "*the amount of learning that happens by just trying something out*." Participant 3 observed that the digital educational practice brings perceived weaker children "*on a par with the rest of the class,"* and that they "*are the ones that are able to show you if you do this, you can get this done, and they kind of find the shortcuts and the extra settings*." Moreover, the participants reported observing how students enhanced the amount of time spent doing work in class, with one student being observed to have "*clearly spent hours at home doing it*" independently of the project.

It was also reported that students' behaviour changed. Participant 3 had "*some really strong personalities"* in the class, but they observed how those personalities changed "*when it's something that they feel confident in doing,"* which meant that it was "*really interesting to watch, actually, how it manifested as a group dynamic*."

Team 2 took ideas from one another: "*I took your idea, participant 7, and got a screen for the second one. It just worked out really well, a lot better than using the interactive whiteboard*,' "Y*eah, so did I. It made a massive difference*."

Team 2 organised and mobilised by "*nailing down dates*." The team leader *"initiated a lot of contact*." Team 2 shared ideas, made plans, and elicited their intention to persist with novel practice at school. "*I learned about Canva from Participant 3, and hopefully, we could include it in the next part*."

5.3.6 Main Study: Team 3

Table 25: Team 3 Participants' Attributes

Participant ID	County	Role	Classes being taught	Years teaching	Years at current school	School size (teachers)	Gender
Participant 1	Dublin	Mainstream AP 2 acting post holder	6th Class;	13–17	13–17	14	F
Participant 4	Offaly	Deputy principal	S.E.T.;	18+	13–17	18+	F
Participant 6	Mayo	Teaching principal	5th & 6th	13–17	8–12	5	F

Team 4 consisted of three teachers, two of whom were situated in the east of the country and one in the west. Their attributes are listed in Table 25. Each teacher had a managerial role in their school: one principal, one deputy principal, and one I.C.T. coordinator. Team 3's members were at their school for over 8 years and had been teaching for more than 13 years cumulatively. Two teachers were mainstream teachers teaching 5th and 6th classes, whereas the third member was in the S.E.T. position, working with 5th and 6th class students. All teachers reported having robust and reliable ICT infrastructure in their school and regular use of laptops and tablets for teaching and learning. One teacher reported being part of a separate project that had led to significant funding for their school and now had experience using Virtual Reality headsets at school. The knowledge acquisition, knowledge deepening, and knowledge creation teaching and learning activities from Team 3 are presented in Table 26.

Table 26: Team 4 Co-Created Learning Activities

	Iteration 1	**Iteration 2**
Subject / Strand	History	Maths
Knowledge Acquisition	Use Google search engine to elicit information about the famine in Ireland.	Create grids and investigate making shapes in the area.
Knowledge Deepening	Create a slideshow of the information and present it to the class.	Reflect on learning and use Flipgrid to record and explain learning to date.
Knowledge Creation	Present and talk and discuss your learning in small groups with others.	Listen to and critique and leave feedback on peers' Flipgrid to consolidate learning.

For the first iteration, Team 3 focused on developing a sequence of history lessons. For the knowledge acquisition stage, this involved acquiring knowledge about the Irish famine using Google Search that was guided by the teacher. For the knowledge deepening stage, the students had to create a slideshow of the information they had collected. For the knowledge creation stage, the students presented their slideshow and engaged in talk and discussion with their peers in small groups. For the second iteration, Team 3 focused on Maths. Their lessons involved the following: For the knowledge acquisition stage, the students investigated making shapes using a grid. For the knowledge deepening stage, the participants used Flipgrid to record a reflection on their learning. For the knowledge creation stage, the participants listened to and critiqued their peers' recordings to consolidate their learning.

5.3.7 Main Study: Team 3 Experience

Team 3's participants discussed having limited awareness of designing from multiple orientations: "*I wouldn't have been hugely aware of them prior to this,*" Participant 1. Whereas previously, Participant 4 would have used ICT with students at school for looking up information online, she was now *"beginning to explore how to use it from a more creative angle,"* and that was now encouraging the children to *"show your learning rather than just writing it down or putting it into a PowerPoint instead*." Participant 1 said they were now encouraging the students to "use *evidence to back up your thinking in maths, explaining*

how you got your answer." The novel approach was opening new windows into students learning. "*The way we were using it, it's kind of given a different view on assessment really and giving feedback*."

Overall, the team reported they were now "*trying to look into the more creative side of IT more,*" Participant 1. Still, they stated there was an element of risk: "*Other teachers might not have the comfort level to go into the knowledge creation, to the take risks, or feel that they can kind of let go of the control,*" and that even though "*I would aspire to knowledge creation, I'd say realistically I'm probably at knowledge deepening*." Many external factors were limiting the teachers' ability to achieve this goal: "*They're always throwing things at you, you know there are always things to do, and then you have confirmation, sacramental prep, you have the Cumann na mBunscoil Gaelic football tournaments, you know it's never-ending, but then you also have a curriculum to cover,*" Participant 6. Participant 1 agreed, "*You feel under pressure, especially coming up to like the assessments and all that, to make sure you've covered everything*."

Team 2 recognised the need for a second iteration. Participant 6 stated, **"***I suppose the whole design and then debug thing I liked because the first attempt at it, you know, there were challenges, and so it was necessary to debug it and go back and do a better job the next time,***"** and that **"***Using that methodology of debugging, there's something positive and something necessary***."**

The second iteration enabled them to delve deeper into the methodologies. Participant 1 stated, "*Now I'm trying to use it in a broader sense and even just in terms of using Flipgrid and to get more thought processing, so it's more about challenging them to think rather than just looking up facts,*" and they also reported that they were beginning to give more ownership of the learning over to the students: "*Initially, we would have started out with the fact-finding, and now it's more that the kids have ownership*."

Through the use of Flipgrid, the teachers observed changes in their students' behaviour: **"***It gave a voice to your quiet children, you know, they don't speak up when we work in groups,***"** Participant 6, and that they were satisfied with this outcome because "*The whole ideas of student voice is so topical currently; the inspectors are on the hunt for that in schools,*" Participant 4.

Whereas teachers observed that students were becoming self-directed, "*It makes sense that the students lead their own development,*" Participant 6, there was also an element of fear: "*The kids are becoming better at computers than I am,*" and "*That's a nerve-wracking step for a teacher,*" Participant 6. They also observed how "*the kids were involved in their own self-reflection. Yeah, they're able to look back and self-assess or peer assess as well*." And that the approach "*enhanced their oral language and their speaking*

skills and their presentation skills, *like you said, learning presentation skills and making eye contact and then playing it back to themselves and watching it over and then editing it*." Moreover, they observed a deeper window into the students' achievements: "*It provided insights into the children, you know, on, what their thought process was,*" Participant 1.

Working as part of a team was enjoyable: "*I enjoyed just kind of bouncing ideas off each other,*" and "*We kind of talked about what we were doing and tried to delve into what was happening in different schools,*" meaning "*We kind of bandied around some ideas,*" and it was both beneficial: "*It was interesting to see what other schools were up to,*" and surprising the differences in resources in each school: "*I was surprised that participant 6 had a Chromebook for every student in her room,*" because "*We have one between two, and when I talk to people they are jealous,*" Participant 1.

Their team "*was fairly democratic; like we tried to organise meetings on different days and things came up, and you know that's just life, so we just had to be flexible and make a different date and hope it suits everybody,*" even though "*We had no constitution, no, we just got on with the task at hand,*" Participant 6.

The team shared ideas: "*It's great to talk to other people and get ideas of what worked for them, the same way if we're teaching RSE, it's great to hear if participant 4 used something that worked well with her class, I might use it with my class,*" and the team acted as a motivator for participants to persist with enhancing their digital educational practice: "*Even after talking to the others, I'm already kind of thinking, oh yeah I must get back to that*," because "*Each time you meet you might get a renewed sense of enthusiasm that I must go and try this, or I'm looking forward to trying that out,*" Participant 4.

Comment

While the three teams' lessons demonstrated distinctions between knowledge acquisition, knowledge deepening, and knowledge creation orientations, their alignment with the UNESCO framework's objectives was not exact. Although the overall lessons did not fully align with the framework, there were elements that corresponded to the various stages, and discernible efforts to transition the control of the learning from the teacher to the students. The discrepancies highlight the complexity primary school teachers face when designing sophisticated learning activities using ICT, and shed light on elements that need refining in future iterations of the 4D model.

5.4 Chapter Summary

This chapter has described both the pilot case study and the main study for investigating the efficacy of the 4D model for growing or changing teachers' beliefs about digital educational practice at school. Firstly, the chapter described the pilot study with four female participants and the resulting changes to the model, the data collection, and the data analysis. Then, it described the main study with eight teachers who worked as three teams to co-create, implement, and reflect on digital educational practice at school. In turn, each team was described, as were the lessons they collaborated on, along with some evidence of data from their team and individual interviews about their experiences with the 4D model. The following chapter will describe the analysis of the participants' metaphors, lesson designs and their group and individual interviews.

6. Data Analysis

6.1 Introduction

This chapter presents the data analysis conducted in the main study. It begins by restating the research aims and the research questions. Next, is a summary of the data collection instruments that were employed, and the total data collected. The data collection and analysis process of the participants' metaphor construction and reconstruction activities is described. Following on, is a description of the collection and analysis of the participants' lesson designs. Subsequently, it presents the collection and analysis of the participants' group and individual interviews. The final subsections discuss the five main categories that emerged from the analysis of the interviews.

6.2 Research Aims and Research Questions

The literature review revealed that recent findings about the relationship between teachers' pedagogy beliefs and ICT challenge the effectiveness of traditional continuous professional development (CPD) models in changing teachers' pedagogy beliefs about 21st century teaching and learning. Additionally, the literature review highlighted the absence of research on CPD models specifically designed to change teachers' pedagogy beliefs about 21st century teaching and learning in primary schools in Ireland. As a result, the research aim was established:

- Research Aim: Create a new model of teacher CPD that is effective at growing primary school teachers' beliefs about the use of ICT for 21st-century teaching and learning at school.

Through a case study approach, the research explored the 4D Model of teacher CPD for changing teachers' pedagogy beliefs about 21st century teaching and learning. The researcher determined to understand the participants' experiences and to identify and elaborate on elements of the CPD design that contributed to belief change emerging from the data. The researcher also sought to determine whether the 4D model process is worthy of further study in the area of teachers' pedagogy beliefs and 21st century teaching and learning. The following research questions guided the study and its subsequent analysis:

- Q1. Do teachers grow beliefs about 21st Century teaching and learning because of their experiences with the 4D model? If so, then
- Q2. How do teachers grow beliefs about 21st Century teaching and learning because of their experiences with the 4D model?

- Q3. Why do teachers grow beliefs about 21st Century teaching and learning because of their experiences with the 4D model?

6.3 Data Collection and Analysis Summary

The qualitative data collected for analysis during this case study included the teacher's pre- and post-cycle metaphor constructions and reconstructions, the teams' iteration one and two lesson plans, and the post-iteration one and two group and individual interviews. A summary of the total data collected is presented in Table 27, followed by an overview of the data analysis procedures in Table 28.

Table 27: Collected Data Summary

Collected Data	Pre-Iteration 1	Post-Iteration 1	Post-Iteration 2	Total
Metaphor Forms	8	5	7	20
Lesson plans		3	3	6
Group Interviews		2	3	5
Individual interviews		8	8	16

Table 28: Data Analysis Procedures

Data Collection Instrument	Data Analysis Method	Example
Metaphors	*A priori* codes	Pedagogy codes-Traditional, Individually Constructivist, Socially Constructivist, Socio-Cultural
Lesson Plans	Rubric Analysis	Alignment of teachers' lessons with knowledge acquisition, knowledge deepening and knowledge creation statements from UNESCO ICT CFT (2018).
Group and individual semi-structured interviews	Open and Axial Coding Constant comparative method, Questioning, Memos	Emergent codes, categories, and concepts
	Initial and Focused coding	Elements of the 4D Model, e.g., Co-creating from different orientations, the team, authentic situated experiences, multiple iterations, and observing student learning outcomes.

6.4 Metaphor Construction and Reconstruction

This section outlines the analysis of the metaphor construction and reconstruction process. As discussed in section 4.6.1 of the research methodology chapter, participants constructed and reconstructed metaphors about their beliefs about teaching and learning using ICT. This involved constructing metaphors pre-iteration one and revisiting those metaphors post-iterations one and two. Pre-Iteration one, the participants were requested to submit metaphors using an online form under the following headings:

- Learning theory
- Design principles
- Student progression
- Student assessment and feedback
- The design of the learning environment
- Example activities

The metaphors were read, and a rubric was consulted to locate the metaphors for their pedagogical orientation accordingly. The process is presented in Figure 20.

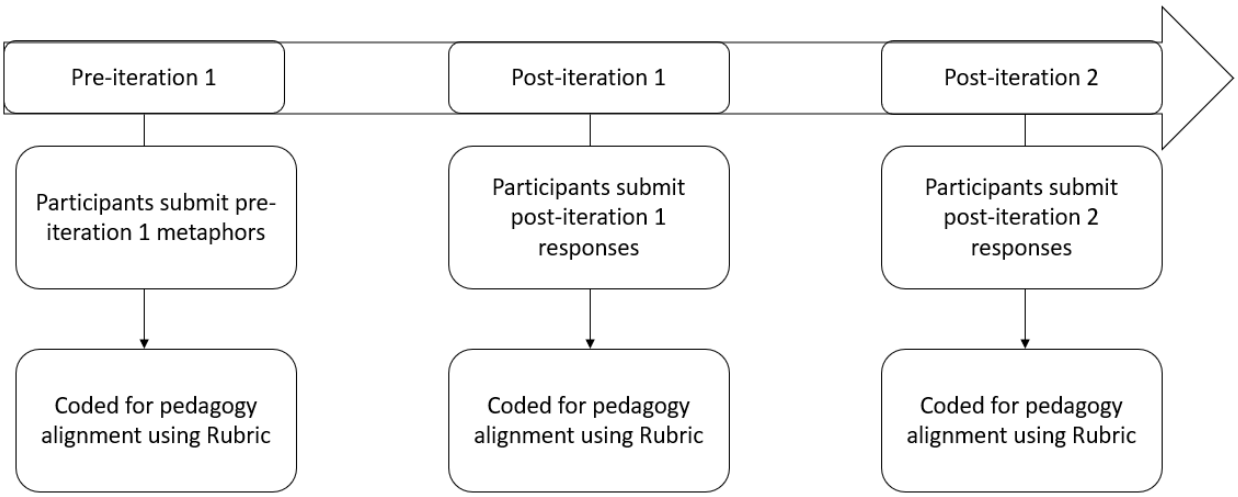

Figure 20: Metaphor Coding

The rubric used in this study is adapted from Beetham and Sharpe (2019). It includes statements of traditional, individually constructivist, socially constructivist, and socio-cultural pedagogy under the headings: learning theory, lesson design principles, student progression, assessment and feedback, designing the learning environment, and example activities. A sample of the rubric is presented in Table 29.

Table 29: Metaphor Analysis Rubric

Sub-Category	Associative / Traditional	Constructive (Individual)	Constructive (Social)	Situative / Socio-Cultural
Learning Theory	Learning is successful when instruction leads to accurate or smooth performance.	New learning must be integrated into the individual's existing conceptual or competency structures.	Individual exploration is scaffolded by social interactions.	People learn by participating in communities of practice, progressing from novice to expert.
Design principles	Analyse concepts/skills into component units.	Design tasks to support active sense-making and analysis of problems.	Design collaborative tasks.	Enable participation/immersion in authentic situations and practices.
Student progression	Progress from component to composite or simple to complex.	Progress from simple, intensive problems to complex, extensive problems.	Move from closed to more open groups for learning.	Progress from novice to expert tasks and roles.
Assessment and Feedback	Test for accurate reproduction.	Test for conceptual understanding.	Develop peer evaluation and shared responsibility.	Focus on extended performance or practice.
Designing the learning environment	One-to-one tutoring or one-to-many instruction.	Active learning environments e.g., exploratory simulations, games, virtual worlds.	Collaborative learning environments	Authentic collaborative environments
Example Activities	Follow a method or a route through materials.	Present an outcome, result, or solution.	Present a shared outcome, result, or solution.	Produce artefacts suitable to role and setting.

The analysis involved reading the metaphors the participants submitted and then locating them for pedagogy alignment using the rubric. Table 30 presents some examples of the participants' metaphors, the relevant sub-category, the codes attributed to them and the rationale – a statement from the rubric.

Table 30: Metaphor Codes

Participant	Sub-category	Metaphor	Code and Rationale
1	Learning Theory	Students learn like trees, each one branching out in different directions with their own thoughts and questions and answers.	Individually Constructivist: Individual takes control over how the task is approached.
2	Student Progression	I design for student progression, like knitting a jumper; at first, you start with wool and needles, creating a small part of the design to putting all the different parts together to complete the jumper pattern.	Traditional: Progress from component to composite or simple to complex
3	Learning Theory	Students stand on the shoulders of giants; their world is greatly expanded by the knowledge they can acquire with the right help.	Socially constructivist: Emerging concepts or skills are supported by others.
6	Assessment and Feedback	I design for assessment and feedback like Hawkeye- careful monitoring, and exact criteria ensure that no fouls are made.	Traditional: Test for accurate reproduction
8	Lesson Design	My lessons are like keys on a keyring. You have to choose the correct key to open the right door.	Individually Constructivist: Design tasks to support active sense-making.

When the participants revisited their initial metaphors, they were asked to consider if there had been any changes to their beliefs following their experiences with the 4D model. When responding, the participants were asked to make changes to their initial metaphors, construct new metaphors, or make comments justifying changes or no changes. Then, the analysis process was repeated, and the participants' responses were compared for their alignment with the statements from the rubric. All 8 participants submitted metaphors pre-iteration one; 5 participants responded post-iteration one, and 7 participants responded post-iteration two.

Not all the metaphors or the participants' responses were easily coded. When doubt emerged, two other rubrics were consulted. The first involved Beetham and Sharpe (2013). The second involved Greeno et al. (1996). Moreover, member checking was employed with the participants during the group and individual interviews. This is highlighted in the question-and-answer exchange below.

Q: *"Post iteration one, I've noted from what you said there's been very little change in your beliefs, except maybe in this sub-category where you said that these beliefs, relating to the design of the learning environment, changed slightly. You responded to your initial metaphor that 'My beliefs have changed slightly in that not all questions have to be answered.' Could you explain the meaning behind that?"*

A: *"Yeah, I suppose so what I was kind of thinking is that we didn't necessarily have to come to an answer for all the questions or topics, you know, sometimes it might just be discussion and using your own evidence to back up your own thoughts. If you get me."*

Before the first iteration, the participants submitted a total of 143 metaphors. The breakdown of their analysis when coded against the rubric is presented in Table 31.

Table 31: Pre-Iteration 1 Metaphors

Sub-category	Traditional	Individually constructivist	Socially constructivist	Socio-cultural	Total
Learning Theory	6	10	10	0	26
Lesson Design	7	11	7	0	25
Student Progression	14	7	2	0	23
Assessment and Feedback	10	8	3	2	23
Learning Environment	3	16	4	0	23
Example Activities	10	3	8	2	23
Total	50	55	34	4	143

Post iterations one and two, the participants revisited their initial metaphors and were asked to consider whether there had been any changes in light of their new experiences. The participants submitted a total of 85 responses. A summary of the responses and their codes, when analysed against the rubric, is presented in Table 32.

Table 32: Post-Iteration 1 & 2 Metaphors

Sub-category	Traditional	Individually constructivist	Socially constructivist	Socio-cultural	Total
Learning Theory	0	11	5	3	19
Lesson Design	0	7	6	0	13
Student Progression	1	4	6	0	11
Assessment and Feedback	3	7	3	3	16
Learning Environment	0	2	10	1	13
Example Activities	2	1	5	5	13
Total	6	32	35	12	85

Overall, the eight participants from the main study submitted a total of 228 metaphors and responses. A summary of the total amount of metaphors and responses that were submitted by the participants and coded for their alignment with either traditional, individually constructivist, socially constructivist, or socio-cultural pedagogy when aligned with the rubric is presented in a stacked column chart in Figures 21 and 22. The charts include the pre- and post-iterations one and two responses.

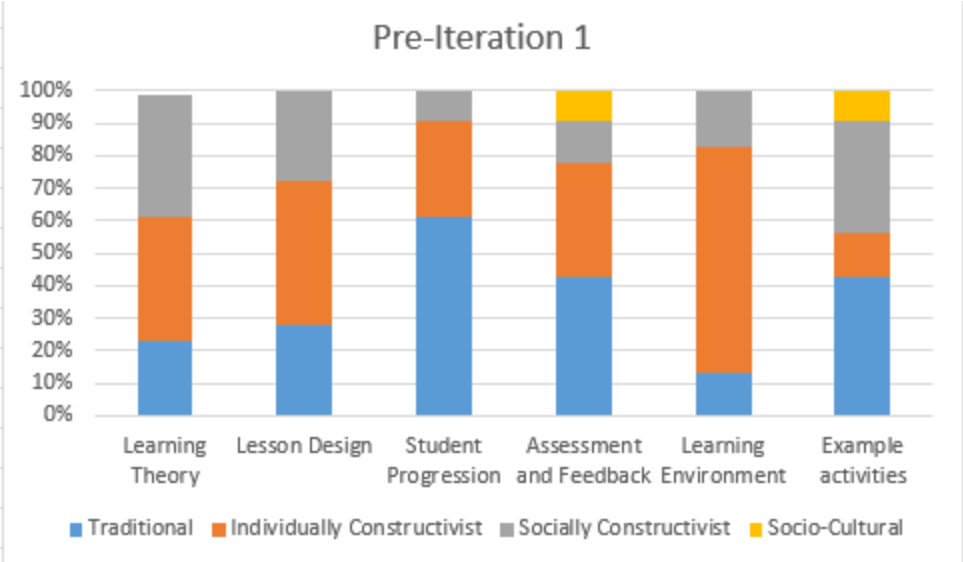

Figure 21: Pre-Iteration 1 Metaphors

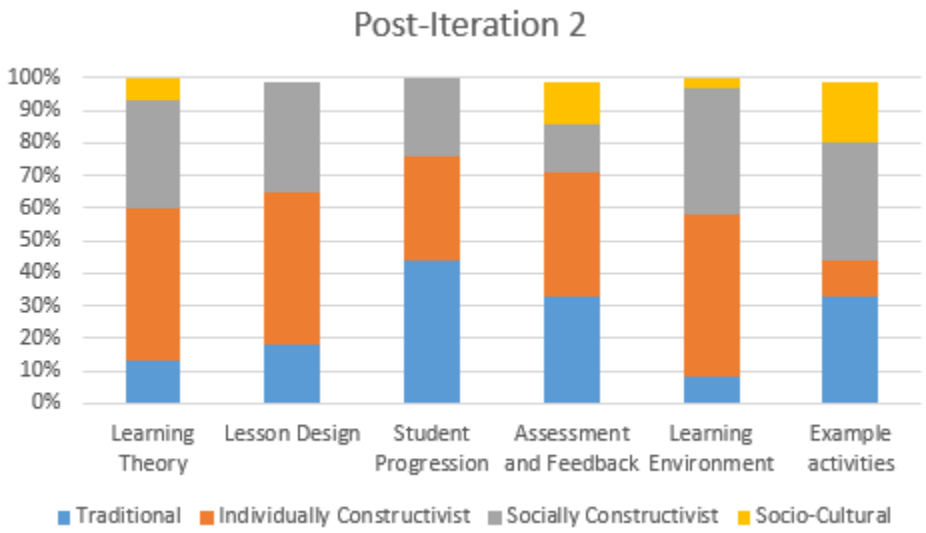

Figure 22: Post-Iteration 2 Metaphors

The analysis revealed that there had been changes in the participants' beliefs. Changes occurred across all six of the sub-categories colour-coded above – learning theory, lesson design principles, student progression, assessment and feedback, design of the learning environment, and example activities. The

analysis indicated that following their experiences with the 4D model, the participants had responded that they had grown individual and social constructivist beliefs as well as a smaller number of socio-cultural beliefs. There was also a reduction in the percentage of traditional beliefs submitted post-iterations one and two, indicating the participants' experiences with the 4D model enabled them to construct new beliefs about innovative and creative use of ICT at school – in line with the study's aims. Six of the eight participants were recorded as having submitted new beliefs aligning with constructivist pedagogy.

Conclusions were further supported by triangulating data from other sources. This involved presenting other information that supports or confirms hypotheses and conclusions converging in a triangulating fashion. In case study research, confirmatory evidence can involve evidence from two or more sources (Yin, 2018). In this study, it involved data from the participants' group and individual interviews converging to support the conclusion that changes in teachers' pedagogy beliefs self-reported in their metaphors were in evidence elsewhere in the data set. This involved re-reading the participants' interviews to investigate whether the changes the participants had indicated in their metaphors were supported by their discussion of their experiences of the 4D model. While not all the metaphors the participants' submitted had supporting quotes in the interviews, several quotes had close alignment. Moreover, the overall essence of the interviews supported the finding that participants' experiences with the 4D model enabled them to construct new beliefs about innovative and creative use of ICT at school. Samples of quotes from the participants' interviews that are in alignment with the changes reported in their metaphors are provided in Table 33. Phrases in bold emphasise alignment between the participants' post-iteration response to their pre-iteration metaphors and supporting evidence from the group and individual interviews.

Table 33: Alignment Between Metaphors and Interviews

Participant	Post-Iteration Response to Pre-Iteration Metaphor	Aligned Interview Quote
1	Lessons delivered **allowed me to assess the thought process** and the children's progress to assess their strengths and weaknesses.	*"**We are giving more of our own thoughts** and our own kind of evidence without having to come to a factual answer."*
3	I design for assessment and feedback like Michael Davitt and the Land League- children are given the information equally, **but what they do with it** is assessed, and their outcomes are at different levels.	*"Really a lot of the time its **giving children the ownership themselves**, and children having to take accountability."*
4	I believe that until NQTs have had teachers themselves who operated outside the normal geographical constraints of a classroom, **who took risks and let go**; that the traditional geography of the classroom will pervade.	*"Again, **it comes back to the risk-taking,** will a teacher kind of break the mould and decide I'm going to create my own learning environment."*
5	I think that **student progress is not linear**. I think it can happen all at once and not in the way you thought. I think that a stimulating class environment fosters progress.	*"I saw that things could be much more open, or much broader, and sweeping, that **you can design lessons from any point**."*
8	The learning environment is open-ended **to allow students to work independently or in a group**. It also allows them to show their creativity during the task. Mistakes are shared, and peers can help to solve problems.	*"Whereas now I feel **I can allow them a bit more scope to investigate on their own**, I can create parameters for them, and they can investigate themselves more now."*

6.5 Documents

This subsection presents the analysis of the participants' lesson(s) plans. As discussed in section 4.6.2 of the research methodology chapter, the participants were tasked with designing and implementing lessons from knowledge acquisition, knowledge deepening, and knowledge creation orientations during iterations one and two. The aim of the analysis was to investigate the teams' lessons for their alignment

with knowledge acquisition, knowledge deepening, and knowledge creation teaching and learning, and it also provided evidence of teachers designing from different orientations under the sub-categories of subject, strand, strand unit, skills, methodologies, digital skills, design of the learning environment, and assessment, which were in alignment with the sub-categories under which they had submitted their metaphors. The analysis involved reading through the teams' lesson plans and comparing them for their alignment with knowledge acquisition, knowledge deepening, and knowledge creation criteria using the UNESCO ICT Competence Framework for Teachers as a rubric (UNESCO, 2018b). The process is summarised in Figure 23.

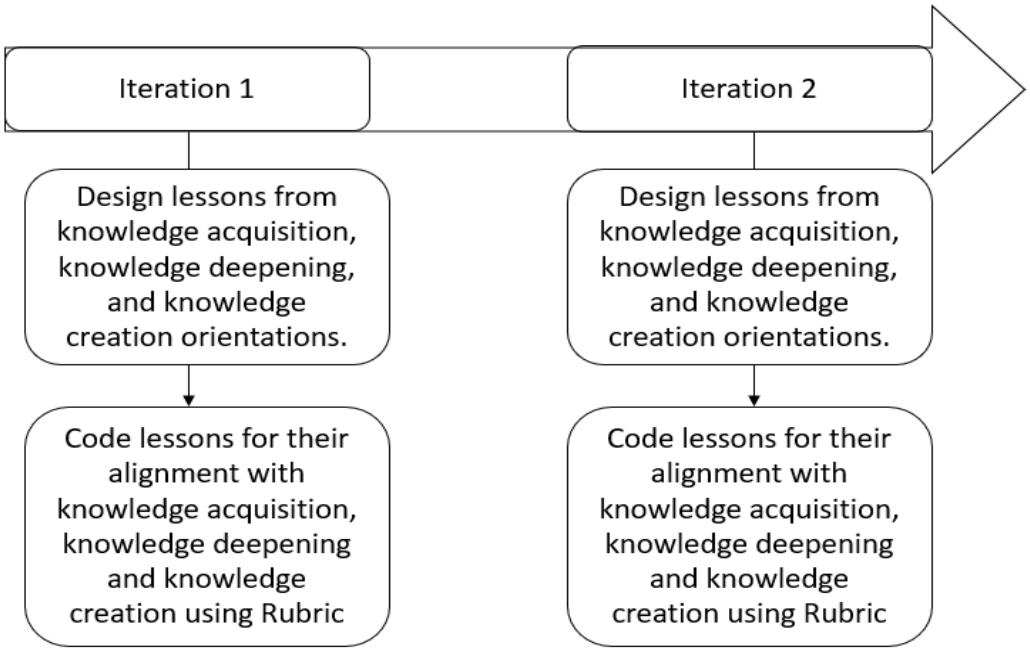

Figure 23: Lesson Plan Analysis

An example of Team 2's lesson plan is presented in Table 34. It includes the topic, subject, strand, strand unit, skills, methodologies, digital skills, design of the learning environment, and assessment under each of the three orientations: knowledge acquisition, knowledge deepening, and knowledge creation. Although the lessons were populated into one lesson plan, each of the three lessons was implemented separately. All the teams followed the same trajectory. This involved implementing the knowledge acquisition lesson first, followed by the knowledge deepening lesson on a different day, ending with the implementation of the knowledge creation lesson on a different day.

Table 34: Team 2 Lesson(s) Plan Iteration 1

Learning Plan Topic: Toy Show	Session 1: Knowledge Acquisition	Session 2: Knowledge Deepening	Session 3: Knowledge Creation
Subject English	Design a toy for the Toy Show and write up a presentation	Create a prototype of a toy	Present the project using Greenscreen
Strand / Strand Unit Writing	Report writing -what is being designed	Procedure writing -how does the toy work	Presentation -discussion and presentation using Greenscreen
Skills	Modelled genre writing Shared writing	Oral familiarisation Language experience	Presentation to the audience with a toy model using Greenscreen
Methodologies	Enquiry Talk and discussion Free exploration of materials to create a toy	Active Learning Guided discovery/Problem-solving Collaborative/ Cooperative learning	Using the environment Skills through content Use of ICT
Digital Skills	Typing- use google docs.	Designing- using cameo /taking photos to record their toy design	Using green screen -Present their project using Greenscreen
Design of the Learning Environment	Group writing and designing	Group STEAM - designing a prototype of their toy	Group presentation using Greenscreen
Assessment	Self-assessment -Rubrics, thumbs up, thumbs down	Teacher observation Did the children achieve the content objective at a differentiated level?	Conferencing Questioning

The lesson plans were coded to align with aspect 3: pedagogy from the UNESCO ICT CFT. Table 35 provides an example of Team 1's lesson plan, its codes, and its rationale, referencing the relevant statement from UNESCO (UNESCO, 2018b, pp. 27 - 47).

Table 35: Team 1 Lesson(s) Plan

Team	Lesson Summary	Coded as and Rationale
1	The teacher demonstrates to the children how to design, record, edit, and publish a video of their partner sharing the story they have read. Their partner explains the story in their own words.	Aligns with Knowledge Acquisition **Rationale:** K.A.3.b Devise lesson plans that incorporate ICT-supported activities to support students' acquisition of subject knowledge.
1	Students are set with the problem of having to design, record, edit, and publish a video of a teaching and learning topic from the curriculum.	Aligns with Knowledge Deepening **Rationale:** KD.3.d Design learning activities to engage students in reasoning with, collaborating on, and solving real-world problems.
1	Working in teams, the children design, create, use, present, share and reflect on a video of a teaching and learning topic of their choice from the curriculum.	Aligns with Knowledge Creation **Rationale:** KC.3.e. Help students reflect on their learning.
2	Design a toy for the Toy Show and write up the presentation. Typing- use google docs.	Aligns with Knowledge Acquisition **Rationale:** KA.4.b Create simple text documents using word processor software.
2	Create a prototype of a toy for the Toy Show. Designing- using cameo / taking photos to record their toy design	Aligns with Knowledge Deepening **Rationale:** KD.3.d Design learning activities to engage students in reasoning with, collaborating on, and solving real-world problems.

Having completed the analysis, with one exception, elements of the teams' lesson plans aligned with the analysis of the rubric in terms of their pedagogy orientation. Only team 3's lessons did not contain any elements align with the knowledge creation stage during iteration one.

The analysis indicated that the three teams had experienced co-creating, implementing, and evaluating lessons from knowledge acquisition, knowledge deepening, and knowledge creation orientations. Moreover, the participants had experienced designing, implementing, and reflecting on lessons that

aligned and misaligned with the sub-categories of beliefs they raised during their metaphor construction and reconstruction tasks.

6.6 Group and Individual Interviews

After iterations one and two, participants conducted group and individual semi-structured interviews with the researcher. The interviews were conducted online via the Zoom video conferencing application and audio recorded with participants' consent. During the interviews, participants discussed their experiences with the 4D model, addressing questions on the relationship between their pedagogy beliefs and their use of ICT, including topics such as co-creation, implementation, evaluation, team setup, objectives, student learning outcomes, impact on the school community, and types of ICT tools used. Table 36 presents the total number of individual interviews, transcribed words, and accumulated minutes.

Table 36: Interviews: Total Words and Minutes

Iteration 1			**Iteration 2**		
Interviews	Words	Minutes	Interviews	Words	Minutes
8	40268	277	8	53271	375

Table 37 presents the total group interviews, transcribed words, and accumulated minutes.

Table 37: Group Interviews: Total Words and Minutes

Iteration 1			**Iteration 2**		
Group Interviews	Words	Minutes	Group Interviews	Words	Minutes
2	11930	88	3	15415	108

In total, there were 21 group and individual interviews, comprising 120884 words and 848 minutes.

6.6.1 Data Preparation

The 8 post-iteration one interviews, 8 post-iteration two interviews, and five group interviews were transcribed using the 'dictate' function in Microsoft Word, this involves uploading an audio file into the

program which then transcribes the interview and timestamps the interactions. The interviews were then cleaned, where repeated words, mistaken words, and breaks in the interactions were structured to more appropriately represent the dialogue that had occurred. This involved listening back to the interviews and editing the text in the Microsoft Word document.

Once the interviews had been cleaned, the documents were imported in NVIVO, a Computer Assisted Qualitative Data Analysis Software (CAQDAS). NVIVO facilitates the analysis of several types of data, including text, audio, video, pictures, and web pages. Its tools support coding, aggregation, model building, queries, and data visualisation (Edhlund & McDougall, 2019). The interviews were separated into folders. The participants' attributes were inputted, and both the participants and their data were classified under the umbrella of a single case.

6.6.2 Data Analysis Process

This subsection outlines the data analysis process applied to the group and individual interviews. The first step in the process involved 'micro-analysis'. In summary, this involves, a detailed line-by-line analysis of the data, during which objects, concepts, and events, from words, sentences, or paragraphs are coded with labels of referential meaning (Corbin & Strauss, 2014; Strauss & Corbin, 1998). The aim of this stage of analysis is to generate initial categories, along with their properties and dimensions, and to suggest relationships among categories. The process can involve a combination of 'open' and 'axial' coding. Open coding involves fracturing and labelling the data, then building it back up into conceptual categories and sub-categories, whereas axial coding involves identifying relationships within categories and between categories (UEA & DUB, 2015). The process is guided by a number of techniques-such as asking who, why, where, when, and how questions; making theoretical comparisons; writing memos; theoretical sampling; the flip-flop technique; and making systematic comparisons of two or more phenomena-all the while waving the red flag at the researchers own personal beliefs that can limit the objectivity of the qualitative data analysis process (Corbin & Strauss, 2014; Strauss & Corbin, 1998).

The process is summarised in Figure 24. Even though the steps are presented sequentially, in reality, it involved multiple iterations of data analysis, coding and recoding, and constructing and deconstructing categories and sub-categories (Corbin & Strauss, 2014; Strauss & Corbin, 1998).

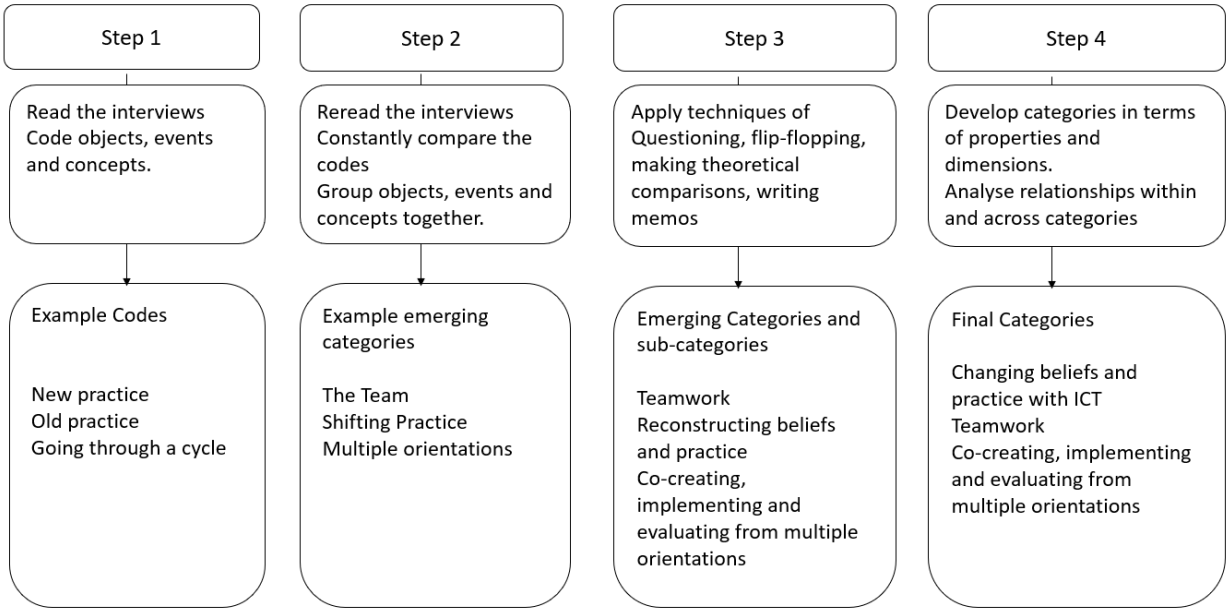

Figure 24: Interview Analysis Process

First, the group and individual interviews were read, and segments of the data were attributed codes. This involved analysing the participants' text for events, objects, and concepts and coding words, sentences, and whole paragraphs with labels of referential meaning. Table 38 presents some examples of the participants' quotes and the codes they were labelled with. The words in bold are for emphasis.

Table 38: Initial Codes

Participant	Quote	Code(s)
1	*"I suppose in terms of using IT, **I would have been** always looking for an answer and using it more research based, always looking to find an answer to something that we were looking for on a certain topic."*	Old Practice
5	*"Because of the success of using the iPads with the learning support group I'm trying to bring in iPads to them **at least once a week."***	Developing new habits
3	*"Just to **give them the freedom**, that it's not solely knowledge based from questions and answers."*	Giving students more ownership
2	*"I had to **set up the deadlines**."*	Setting dates and times
6	*"You know how students learn is obviously **what drives** how you design all your lessons."*	Interconnected

These steps were then repeated across a sample of interviews chosen from the data set. While analysing these interviews, some new codes emerged, and some of the codes were repeated. Then ,these interviews and their codes were compared with one another. Some codes were aggregated together under new names; some codes were deleted; some codes began to aggregate together under nodes and hierarchies. Next, the rest of the interviews were treated in a similar manner. The overall process was iterative, involving multiple cycles of coding and recoding. This involved breaking codes down into smaller bits of information and classifying and reclassifying them while using the constant comparative method to compare the data against one another.

Table 39 presents quotes from each participant that were labelled under the code '*Comparing old practice with new practice*'.

Table 39: Aggregated Codes: Comparing Old Practice with New Practice

Participant	Quote	Code
1	*"Obviously we still use technology to look up facts for working on a project or whatever, but now I am trying to use it in a broader sense."*	Comparing old practice with new practice
4	*"So, you give them the tool and then they can create without putting the narrow parameters that we often put on more paper-based work or more traditional teaching and learning."*	Comparing old practice with new practice
6	*"Obviously, there are certain things that still need old school rote learning, but you know it can only enhance it. There's so much you can do."*	Comparing old practice with new practice
3	*"Everybody knows that ICT is important, but we're still very book heavy in school and there's still you know content that has to be covered and we've been doing it the same way for so long."*	Comparing old practice with new practice
8	*"I was thinking if I could create more opportunities like this in my class, it would lead to more creativity, which is probably lacking in my teaching because I like to be telling them I'm an expert in what I'm doing here, and sit down, and learn this."*	Comparing old practice with new practice

The process was repeated several times, and similar text was aggregated under appropriate nodes. This led to the creation of a code list that included over 100 codes at the end of the open coding cycle. Over time, the number of codes was reduced. This involved renaming some codes and discarding others. A sample of the coding table is presented in Table 40. The table includes the name attributed to the code, the description of the code, the number of files in which the code was present, and the number of references made to the code.

Table 40: Code List

Code	Description	Files	References
Changing ICT Use	References to changes in ICT use in class	21	258
Changing Practice	References to teaching and learning events	21	216
Changes in Students learning	References to enhanced student learning using ICT	20	136
External factors influencing change	References to External factors impacting upon changes in beliefs and practice	20	111
Stages of ICT use	Referring to the use of ICT and developmental stages	18	110
Interactions	Interactions between the team members	21	99
Mediating processes	Mediating processes that helped the team to succeed	19	89
Roles	References to teachers' roles at school	17	89
Team Outcomes	The outcomes of working in the team	20	78
Teammates learning from one another	Teammates discussing learning from one another during their interactions	18	77
Beliefs	References to beliefs about practice	19	65
Team activities	The activities the team had with one another	19	65
Students more engaged	References to students being more engaged in the learning process	16	52
Barriers to the use of ICT at school	References to barriers to the use of ICT at school	16	50
Enablers for the use of ICT at school	Enablers to the use of ICT	17	49
New Practice	Descriptions of new teaching and learning practice	15	48
Knowledge Creation	References to Knowledge Creation	19	44
Comparing old practice with new practice	Participants comparing old practice with new practice	18	44
Feedback from colleagues	Feedback from participants colleagues about using ICT at school	18	44
Using ICT for Enhancing teaching and learning	References to teachers' use of ICT for enhancing teaching and learning	16	43
Policy initiatives	References to policy initiatives that influence change, such as the curriculum, the digital learning framework, ICT funding	16	41

Team persistence	Being part of a team motivates the individual to persist with the project.	16	40
Transitioning Phase	References to transitioning from ineffective to effective	12	40
New Habits	References to new habits	17	39
Established practice	References to established practice that is not going to change	15	39
Positive experience working with the team	References to working with the team that were positives	18	38
Giving Students more ownership	References to giving students more choice in their learning	12	37
Going through a cycle	Participants outline the steps they went through to complete a cycle	17	34
SET Role	SET role in implementing ICT at school	8	33
Knowledge Acquisition	References to Knowledge Acquisition	21	32
Team Strategies	Strategies the team employed	17	32
School culture	References to the school culture towards teaching and learning using ICT	12	31
Satisfactory environment	References to a stable ICT teaching and learning environment	13	30
Interconnected	References to beliefs being interconnected	9	30
Changing Beliefs	References to belief change	16	29
Feedback from parents	References to feedback from parents	12	26
Students taking ownership	References to students taking ownership of the teaching and learning	11	26
Time	References to time as a factor influencing change	11	25
Metaphors	References to the metaphor construction and reconstruction activity and participants use of metaphors during the interviews	11	25
Team environment	Relating to the feelings the team had	14	23
Integrating	Integrating the three orientations into existing practice	11	23
Knowledge Deepening	References to Knowledge Deepening	19	22
Levelling the playing field	Students overcoming established difficulties engaging with classroom teaching and learning	12	21
Unsatisfactory environment	References to an unstable ICT teaching and learning environment	9	21

New Assessment	Experience of ICT use enabling new forms of assessment	12	20
Setting dates and times	Discussing setting dates and times of meetings	13	19
Strengthening Beliefs	Participants reporting experiences strengthening existing beliefs	11	19
Role of the Teacher	References to the role of the teacher	8	19
Principal's Role	References to the role of the principal impacting on ICT use at school	11	18
Old Practice	References to old practices	12	17
Feeling equal	Feeling like equal partners in a team	11	17
Student centred belief	Reference to students as a motivating factor for exploring ICT use	9	17
Conflicts	Conflicts between codes	10	16
Feedback from the Inspector	References to feedback from the school inspector	5	16
Students' capacity	References to students' capacity with ICT enabling its use at school	9	15
Differentiating	Breaking apart knowledge acquisition, knowledge deepening and knowledge creation	8	15
Feedback from students	References to the impact of feedback from students	10	14
Colleagues unwilling to let go of established practice	References to colleagues being unwilling to let go of control of the established classroom	9	14
Teacher CPD	References to teacher professional development	8	14
Negative access to ICT	References to negative access to ICT	7	14

6.6.3 Category Construction

This section describes the process undertaken to develop the categories that emerged from the analysis. Categories are concepts that stand for phenomena relevant to the participants' experiences (Strauss & Corbin, 1998). Categories differ from containers that aggregate codes arising from the open and axial coding process. Although initial categories are developed during the microanalysis stage through the aggregation of codes, the final categories should be well-developed in terms of their properties and dimensions. Developing categories in terms of their properties and dimensions involves comparative

analysis, comparing participant against participant and looking for similarities in properties and dimensions (Corbin & Strauss, 2014).

The categories that emerged in this study took time to develop and involved multiple iterations of coding, recoding, constant comparison, asking questions, writing memos, structuring, and restructuring. During this time, the category set varied. There were several reasons for this variation. Firstly, it was challenging to remain objective to the participants' experiences. At times, there was an inclination by the researcher to apply focused codes rather than open codes when building up the categories. Because the study was concerned with the 4D model, there was an inclination to name the categories using elements of the model as a reference. While these categories spoke directly to the 4D model, they did not speak directly to the participants' experiences. On the other hand, there was also a tendency to get lost in the dataset. This happened when interesting comments by the participants about events outside of the study were followed up on and became pathways that were explored. Examples of categories that were too focused and too open are presented in Figure 25.

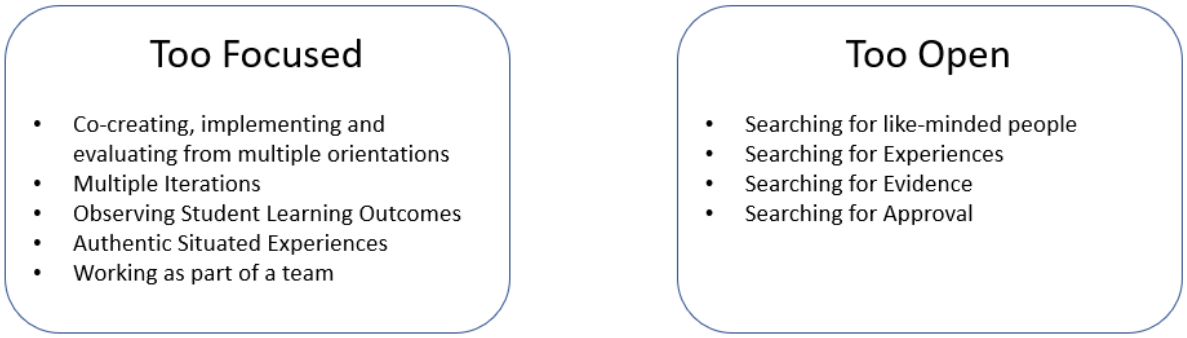

Figure 25: Initial Categories

In constructing the final categories, the researcher aimed to strike a better balance between elements relevant to the 4D model and day-to-day factors that impacted upon teachers' change. To achieve this, the initial categories were broken apart, recoded, and aggregated around nodes, resulting in the code set in Table 40. Following on, codes of likeness were grouped together and built up into categories over time. From this framework, categories were constructed, and the final category set is presented in Table 41.

Table 41: Final Categories

Category Name	Description	Files	References
Changing beliefs and practice with ICT	Relating to the participants experiences of changing beliefs and practice with ICT	21	786
Teamwork	Experiences working as a teacher Design Team	21	321
Co-creating, Implementing, and evaluating from multiple orientations	Teaching and learning from knowledge acquisition, knowledge deepening and knowledge creation orientations	21	190
Evaluating Feedback	Receiving and managing feedback from referents on ICT enhanced teaching and learning	21	116
Managing Roles	The relationship between the participants role at school and trying to implement ICT use	17	89

The researcher identified five main categories describing elements of the 4D model and their interaction with teachers' day-to-day experiences impacting upon changes in teachers' beliefs. The categories were labelled as Changing beliefs and practice with ICT, Teamwork, Co-creating, implementing, and evaluating from multiple orientations, Managing feedback, and Managing roles. Further developing the categories in terms of their properties and dimensions involved examining relationships between and within the categories. This was an iterative process and involved the use of questioning, making, and revising hypotheses, as delineating between properties, dimensions, and ranges was challenging. Over time, the categories were developed, and this dilemma was more appropriately resolved. The resolution is discussed in more depth in the findings chapter. The following subsections provide a more detailed explanation of each category.

6.6.4 Category One - Changing Beliefs and Practice with ICT

Table 42: Category One - Changing Beliefs and Practice with ICT

Property	Dimension	Range
Changing Practice	Comparing old practice with new practice	Old to New Established to aspirational practice
	Developing new habits	Infrequently to Frequently implementing
	Developing new assessments	Closed to open-ended
Changing Students learning	Levelling the playing field	On a par to passing out
	Enhancing Student engagement	Giving students more ownership to students taking more ownership
External factors influencing change	Policy initiatives	Enabling to Construing
	School culture	Enabling to Construing
	Time	Enabling to Construing
	Teacher CPD	Implemented immediately to never implemented
Changing Pedagogy Beliefs	Pedagogy beliefs	Strengthening existing to Constructing new
	Value Beliefs	Student-centred to teacher-centred
Changing ICT use	Stages of ICT use	Closed to open ended
	Purpose of ICT Use	Enhancing established practice to enhancing novel teaching and learning

	Classroom environment with ICT	Uncomfortable to comfortable

From Table 42, it can be seen that under the category **Changing Beliefs and Practice with ICT,** four properties emerged. The first, **Changing Practice,** related to instances where the participants discussed changes in their practice. Three dimensions were identified. The first, *'comparing old practice with new practice,'* related to the participants comparing old practice with new practice. This dimension ranged from *old practice* they used to implement and they were trying to get move away from, to *new practice* they were implementing in their class. It also included the range of *established practice* they would always continue to implement, such as handwriting, and *aspirational practice* that they aspired to achieve at school. The second dimension, '*developing new habits,'* refers to instances in the participants' interviews where they discussed new habits they were forming as part of their goal to change their practice with ICT. This dimension ranged from *infrequently* to *frequently*, where participants discussed their attempts to embed new practice with ICT into their classroom timetable, from weekly to daily basis. The third dimension, *'developing new assessments,'* involves participants discussing new types of assessments made possible by ICT. The assessments ranged from using ICT for *closed* to *open-ended* assessments. These include traditional graded assessments and assessments aiming to evaluate students' thought processes and creativity.

The second property, **Changing students' learning,** had two dimensions. The first, *'Levelling the playing field,'* referred to the participants' discussion about how ICT had changed the learning experience of students who traditionally had challenges accessing and succeeding against curriculum learning outcomes during class time. The introduction of ICT enabled those students to achieve learning outcomes that were *on a par* with their peers, and in some cases, *exceeded* their peers' capabilities to the extent some of the children became the expert who was the one who was assisting the other students in their learning. *'Enhancing student engagement'* was the second dimension identified. Throughout the interviews, the participants reported enhanced student engagement when ICT was introduced to their learning and they specifically referenced the tools – Canva, Flipgrid, Kahoot-used by the teams in their lesson designs. As regards the pedagogy underpinning those lesson designs, an interesting conflict emerged. This conflict ranged from *giving the students ownership* to the *students taking ownership* of the learning. The issue of control was often referred to and the participants discussed how they felt nervous at times giving over

control to the students. However, they also discussed how giving ownership to the students enabled them to stand back and observe the learning from a perspective they were unable to when their practice was more teacher directed.

The third property referred to **External factors that impacted upon change**. The '*policy initiatives'* dimension of this property included participants' references to the Digital Learning Framework (DLF), Digital Funding, The Primary Curriculum, and Teaching Council directives. In all cases, these could act as either *enablers* or *construers*. For example, digital funding initiatives and the DLF enabled the schools to enhance their access to digital devices and to justify experimenting with ICT at school. However, they also brought pressure to spend money and to make changes to teaching and learning in the classroom they felt there was unclear guidance about. The new primary curriculum enabled teachers to integrate objectives from different subjects into their lessons and gave them a sense of freedom, but it also restricted the amount of time the participants could give over to the project as they felt the core subjects of Irish, English, and Maths had to be covered on a daily basis. Teaching Council directives were referred to when the participants were discussing implicit team rules, and these acted as guides for behaviour such as respecting one another and being professional. *'School culture'* was another external factor impacting upon change. In some cases, teachers felt restricted by a school culture that emphasised traditional teaching and learning, whereas in other cases, teachers felt motivated by their school culture as it encouraged them to give ICT a go in class and to experiment with new practice, so long as it was good for the kids. *'Time*' was another dimension that *afforded* or *construed* the teachers. Time was used as a guideline for getting things done. One team purposely chose a seasonal activity that required them to get the first iteration completed before the Christmas holidays. On the other hand, time was a restrictor, with participants being unable to give as much time as they liked to the first iteration due to the demands of the school year. Time was also cited as a factor in determining the orientation of their practice at various times of the school year. At the beginning of the school year, the participants reported using established practices to get their classroom routines set up and in motion. At the end of each term, there was pressure to have an appropriate number of textbook chapters covered and teachers adjusted their practice towards more teacher-directed learning. At the end of the school year, the students' standardised assessments meant the participants felt they had to have their students adequately prepared. This involved revising the content covered throughout the school year and provided little opportunity for open-ended learning. The last dimension in this property was *'Teacher CPD.'* Teachers reported that in some cases, it was *implemented immediately,* while in other cases, it got left on the shelf and was *never implemented.*

The fourth property is **Changing pedagogy beliefs**. This is a dynamic process that is always changing. For example, teachers change their beliefs about what types of pedagogy is most appropriate based on the students they have in front of them, or they change these beliefs about appropriate pedagogy at various times of the year. The ranges these beliefs were identified as having include *strengthening existing* to re*constructing*. All of the participants, including Participant 6 who reported no changes in their beliefs during the metaphor construction and reconstruction process, reported having had their pre-existing beliefs about ICT having a role to play in enhancing students' learning at primary school level strengthened. They also reported having reconstructed beliefs about how students learn effectively in their class. Another dimension identified was '*orientation.'* This referred to instances where teachers discussed decision making that was guided by either *teacher-centred* or *student-centred beliefs*. Student centred beliefs were often employed as motivation for embracing ICT use at school and as a rationale for moving themselves outside of their comfort zone. Participants reported that teacher centred beliefs were often the cause of their colleagues being unwilling to experiment with ICT purposively at school, beyond using it to play games.

The fifth property is **Changing ICT use**. The participants stated that there are *'stages of ICT use'* they have progressed through before reaching their current perspective and practice with ICT. Initially, there was a tendency to use ICT for *closed* learning outcomes, such as fact-finding and researching information. However, as the participants grew in confidence, knowledge, skills, and student trust, they reported their practice began to become more *open-ended,* where students could be more creative, and lessons became more open-ended, and new outlooks on assessment and student learning outcomes emerged. The participants also reported using ICT for several *'purposes,'* ranging from *enhancing established practice,* such as file sharing, collaborating with peers, and playing maths games in class, to *enhancing novel practice,* where there is more of an emphasis on how ICT can be used to enable the students to dig deeper, or to be more creative, or to achieve new learning outcomes. Finally, the '*Classroom environment with ICT*' was another dimension identified in teachers changing ICT use. Participants referred to old settings where there were large desktops in the classroom, or they had to access a computer room to use ICT. Often, their practice was disrupted by poor internet connectivity or unreliable ICT, making it an *uncomfortable experience* for teachers and students. In comparison, teachers reported that they now had *comfortable* settings, with a positive ratio of students to devices, such as Chromebooks or tablets, there was reliable internet connectivity, and sharing resources and documents with peers and students had become more straightforward.

6.6.5 Category Two: Teamwork

Table 43: Category Two - Teamwork

Property	Dimension	Range
Team Interactions	Team Activities	Infrequent to Frequent
	Going through a cycle	Going through most of a cycle to Going through a full cycle
Mediating processes	Teammates learning from one another	Sharing to receiving
Outcomes	Team persistence	Persisting to not persisting
	Experience working with the team	Positive Experience
Strategies	Setting dates and times	Flexible to Too Flexible
	Team Rules	Spoken to unspoken
Team Environment	Feeling equal	Being led to leading
	On the same sheet	Unsure to Sure

From Table 43 under the category '**Teamwork,**' five properties emerged. '**Team interactions'** referred to the interactions between the team members during each iteration. The dimension *'Team Activities'* refers to the participants' interactions through WhatsApp and Zoom which they used to stay in contact with one another and to problem solve, or brainstorm, or to keep up to date with one another's progress. These interactions ranged from *infrequently* to *frequently,* becoming more frequent as deadlines came into sight. The second dimension is '*Going through a cycle.'* This refers to the participants' references to completing the full cycle of the 4D model, including reflecting, designing, developing, delivering, debugging, and revisiting. This ranged from *going through most of a cycle*, where one team missed out on the debug stage at the end of iteration one, to *going through a full cycle*.

The second property is **'Mediating processes,'** which refers to the participants' references to factors that enabled the team to function well. The dimension identified in the data is '*Teammates learning from one*

another,' which refers to the participants' discussions about new learnings from one another. The participants referred to learning about ICTs and how to use them, how to overcome challenges they had encountered in class, and they reported learning about one another's schools, their ICT infrastructure, and how they had been going about implementing ICT. This property had a range of teachers *sharing* their own learning experiences and expertise to *receiving* information and expertise from their teammates.

The third property is '**Outcomes**,' and this refers to the outcomes of working as a team as reported by the participants. The first dimension is **'***team persistence.'* The participants reported how being part of a team motivated them to continue with the project even when other demands limited their time or made them feel under pressure. They reported that they did not want to let one another down and that being part of a team acted as an enabler for them to experiment with ICTs, which they felt they would not have done working alone. The dimension ranged from *persisting* to *not persisting*. While eight of the participants persisted with the project, two others dropped out during the first cycle citing COVID-19 related issues and school demands. The second dimension is the outcome of '*participants' experience working with the team.'* All of the participants reported it as a *positive* experience. The participants reported how it was nice to be able to reach out to other teachers in similar roles in other schools who were also motivated to enhance ICT practice at school.

'Team strategies' is the next property in this category. It refers to the strategies the team used to start off, to function, and to maintain its momentum. The first dimension, *'setting times and dates,'* referred to the teams outlining the times and dates of their meetings and the times and dates they intended to have their lessons completed by. This dimension included the range of *being flexible* to being *too flexible* and refers to the need to be flexible when other life events prevent teammates from attending meetings or having lessons completed; however, the participants were conscious of being too flexible, and there were times when they had to reinvigorate the team to complete the tasks. The second dimension is '*Team Rules,'* and it refers to the tacit and explicit rules the team adopted. These ranged from *spoken* to *unspoken*. Whereas spoken rules referred to being respectful and professional, unspoken rules referred to ensuring the participants came to meetings with the work done.

'Team Environment' is the final property in this category. It refers to the shared beliefs the participants had about their team. The dimension *'feeling equal'* refers to the participants' enjoyment of feeling as though they were all equal in the team. Interestingly, the principals in the cohort all discussed their enjoyment of being part of a team where they weren't the principal. This dimension had a range of *leading* and *being led*. The participants referred to times when they were led by other teammates' experiences

and times when they led the group using their prior experiences as guides. The second dimension is labelled '*on the same sheet.'* The participants referred to their co-development of a shared understanding of the project and what it entails; this ranged from *being unsure* to *being sure* that they were on the same page as their teammates about the project's goals and what they were trying to achieve. All of the participants reported becoming surer of both the 4D model and the different orientations of knowledge acquisition, knowledge deepening, and knowledge creation during the second iteration.

6.6.6 Category Three: Co-creating, Implementing, and Evaluating from Multiple Orientations

Table 44: Category Three: Co-creating, Implementing and Evaluating from Multiple Orientations

Property	Dimension	Range
Orientation	Knowledge Acquisition	From the teacher to Self-Discovered
	Knowledge Deepening	Acquired to Self-Discovered
	Knowledge Creation	Open ended to Unscaffolded
Stages of Lesson Progression	Implementing	Separately to Collectively
Observing	Student Learning	Anticipated to Unanticipated
Interconnecting	Students learning	Integrating to Differentiating
	Lesson Design	Integrating to Differentiating
	Student progression	Integrating to Differentiating
	Assessment and Feedback	Integrating to Differentiating
	Design of the Learning environment	Integrating to Differentiating
	Example Activities	Integrating to Differentiating
	Classroom Management	Integrating to Differentiating

From Table 44, under category three – **Co-creating, implementing, and evaluating from Multiple Orientations** – four properties emerged. The first property, **'Orientation,'** refers to the orientation of the

lesson the team co-created. It had three dimensions. The first dimension, *'Knowledge Acquisition,'* refers to teaching and learning prioritising students' acquisition of knowledge. This was a familiar strategy for the teachers, who all reported it as a necessary component of any lesson. It ranged from knowledge acquisition that was *directly taught by the teacher* to knowledge that was acquired through the *students' self-discovery*. The participants reported that all of their lessons involved some teacher-directed phase where they tried to enable the students to acquire knowledge from the teacher, but also reported that students have knowledge they have acquired from sources other than the teacher. The *'Knowledge Deepening'* dimension refers to teaching and learning prioritising students' deepening of their learning experiences. It ranged from the knowledge that had been *acquired from the teacher* to students deepening of knowledge they had *acquired through self-discovery*. Whereas lessons were designed to enable the students to deepen the knowledge they had acquired from the teacher, students also deepened knowledge they had acquired through self-discovery or from sources other than the teacher. The participants reported that knowledge deepening was an aim of every lesson. *'Knowledge Creation'* refers to teaching and learning prioritising students creating their own knowledge, and it ranged from designing lessons that were *open-ended* to *unscaffolded*. Whereas open-ended lessons involved planning lessons with criteria and appropriate levels of scaffolding, the participants also discussed how they might approach a knowledge creation lesson by leaving art resources on tables and saying to the children, "off you go." The participants reported that knowledge creation was also a goal of every lesson, but not all children had the capability to reach that stage of the lesson. The participants reported that they were often satisfied if students with access challenges reached the knowledge acquisition stage of a lesson.

The second property, **'Stages of Lesson Progression,'** refers to the participants' discussion about the three orientations as being familiar to their established practice, which involves stages of lesson progression. They reported that in their day-to-day practice, prior to their engagement in the 4D model, their lessons follow a progression sequence. This involves a beginning stage where teachers teach relevant content knowledge to the students, a middle stage where students attempt to deepen their understanding of the knowledge acquired, and then a final stage where the students are given opportunities to manipulate that knowledge and create something with it. Despite this being the overall aim of their lesson, they reported they didn't always reach the knowledge creation phase and that some students don't always progress beyond the initial acquisition stage. The range identified here is *teaching stages separately* to *teaching stages collectively*. In their day-to-day practice, teachers reported teaching the stages collectively as part of one lesson, whereas during the project they experienced teaching them separately, breaking them up into separate knowledge acquisition, knowledge deepening, and knowledge creation lessons. Moreover,

the teachers reported that while the orientations were familiar to them and there was alignment between them and their established practice, they were not familiar with the terminology, nor had they much experience of beginning a lesson from a knowledge deepening or a knowledge creation orientation.

The third property of this category is **'Observing.'** This refers to the different observations the teachers experience when teaching from different orientations. The dimension '*student learning'* refers to the teachers' ability to observe student learning from different orientations. The teachers reported that when teaching through knowledge acquisition and knowledge deepening, they were more restricted in their ability to observe student learning due to their being directly involved in either teacher-led instruction or working with students in small groups. In comparison, during knowledge creation lessons, the teacher stepped back and allowed the learning to occur, and this enabled them to observe diverse types of student learning as it unfolded. For example, the participants referred to observing students moving from group to group, sharing expertise and problem-solving with one another, which wasn't possible when the students relied upon the teacher as the expert.

'Interconnecting' was the final property that emerged in this category. This referred to the interconnectedness of the sub-categories of beliefs and included the dimensions of *how students learn, design principles, student progression, assessment and feedback, design of the learning environment*, and *example activities*. The participants had submitted metaphors under these headings during their initial reflection, and the participants had experienced designing and implementing lessons guided by the sub-categories from three different orientations. A range of *integrating* and *differentiation* was identified. This referred to instances where the participants integrated their understanding of the sub-categories with their pre-existing day-to-day practice and aligned it with their perspective that the sub-categories were three stages of one lesson, to instances where they differentiated them into separate lessons under the headings knowledge acquisition, knowledge deepening, or knowledge creation.

6.6.7 Category Four: Feedback

Table 45: Category Four: Feedback

Property	Dimension	Range
Feedback on ICT use at school	Colleagues	Not keen to Keen
	Parents	Deflating to Motivating
	Inspector	Fear to No fear
	Students	Non-influential to Influential
	Board of Management	Ambivalent to Supportive
	Principal	Not interested to interested

Table 45 outlines category four, **Feedback,** and its property '**Feedback on ICT use at school'**. This property refers to the participants' use of ICT at school and the feedback they receive about it. The first dimension is *'colleagues'* feedback. It ranged from colleagues who were *not keen* about enhancing their use of ICT at school to colleagues who were *keen* on enhancing their use of ICT at school. The next dimension is *'parents,'* referring to parental feedback on the use of ICT at school. This ranged from *deflating* to *motivating*. Whereas on some occasions, parents' feedback is motivating, in other cases, it can be deflating and can cause teachers to re-evaluate their use of ICT or to revert to more traditional practice. Feedback from the *'inspector'* was another dimension that emerged. It ranged from *fear* that the inspector might not agree with the use of ICT, particularly for open-ended lessons that involved more student ownership of the learning, to *no fear* about the inspector's feedback. Experienced participants were more likely to report having no fear.

'Students' feedback is another dimension that emerged. Students' feedback can play a role in teachers' use of ICT, especially where the students are engaged and having fun; however, in some cases, when teachers take out textbooks and the students start groaning, the teachers reported they will persist with the lesson regardless. Feedback from the *'board of management'* was another property and ranged from

ambivalent to *supportive*. In school management, participants such as the principal, deputy principal, and ICT Coordinator were more likely to have the support of the board as they were in direct contact with them, whereas teachers without in school management positions reported the board were ambivalent to their practice. Lastly, feedback from the *'principal'* emerged. It ranged from *not interested* to *interested*. Where the principal took an interest in an ICT initiative, the participants reported being more likely to implement it; however, the participants also reported that they would implement ICT in class without the principal's interest in what they were doing.

6.6.8 Category Five: Roles

Table 46: Category Five: Roles

Property	Dimension	Range
Role in implementing ICT use at school	S.E.T.	Constricted to Agentic
	Teacher	Old to New
	Principal	Implementee to Implementer
	ICT Co-ordinator	Expected practice to Desired practice
	Temporary Teacher	Non-experimental to Experimental
	Deputy Principal	Being in the background to Being front and centre

Category Five – **Roles** is presented in Table 46, and it refers to the impact that the participants' roles have on their use of ICT at school. Five dimensions emerged. The *'Special Education Teacher'* (S.E.T.) works with small groups of students with challenges accessing the curriculum in conjunction with the mainstream class teacher. They reported being *constricted* because they must follow the same outline as the mainstream class teacher and they must focus on foundational skills such as reading, writing, and numeracy. They also reported being *agentic* because they were often called in to cover other teachers'

classes for a short period of time, and they would use this as an opportunity to experiment with new ICTs. The *'teacher'* referred to the role the participants reported on, on account of being a teacher. This ranged from *old* to *new*. Whereas the old role was referred to as being in control, and teaching in traditional ways, the new role involves stepping back, encouraging students to find out things for themselves, and not being the expert, particularly when it comes to ICTs. The *'principal'* was another dimension in this category and referred to the role of the principal. This ranged from being someone who feels the need to implement policy initiatives and novel learning to having the freedom to be the person who produces innovative ideas and implements them as whole school initiatives.

The *'ICT Coordinator,'* who is responsible for the school's ICT planning and infrastructure, was another dimension that emerged. This ranged from work that was *expected* of them, including fixing computers and infrastructural maintenance, to *desired* practice involving getting everyone singing off the same hymn sheet and getting teachers to use ICT purposively rather than as a treat or for a break from the daily grind of classroom teaching. The role of the '*temporary teacher*' is another dimension to this category and it referred to teachers who are new to the school environment and who are employed on a temporary rather than a permanent basis. Interestingly, they range from being *non-experimental* with ICT, so they can play it safe and fit in with their peers' practice, to being *experimental* because they recognise that they might not be in the school once their temporary contract ends, so their endeavours might not matter in the long run. The last dimension was *'deputy principal,'* who works in conjunction with the principal to run the school. Their input into using ICT at school ranges from *being in the background* and working on their own initiatives to being *front and centre,* which can bring them into conflict with the role of the principal.

6.6.9 Orphan Codes

There were several codes that did not fit in with the coding categories discussed above but are of relevance to the study. Examples are presented in Table 47 and discussed thereafter.

Table 47: Orphan Codes

Name	Description	Files	References
Metaphors	References to the metaphor construction and reconstruction activity	11	25
Multiple Iterations	Completing multiple cycles	11	31
Conflicts	Tension points causing participants to weigh up actions	10	16

'Metaphors' was an interesting code that emerged from the data. It referred to the participants' discussion about the metaphor construction and reconstruction activity and their use of metaphorical language during the interviews. Those who reported on it discussed how it differed from other forms of reflection they had experienced during CPD, how it made them stop and think about what they were trying to write, and how they were looking forward to revisiting their initial metaphors to see if their beliefs had changed. Where changes were discussed, participants discussed 'refining' their metaphors to make them more in tune with the reality of classroom practice or trying to 'knit them together' to make them more precise. The participants also used metaphorical language during the interviews. Quotes including, 'chalk and talk' and 'sage on the stage' were used to describe old and new teaching approaches, whereas one phrase captured the dilemma of trying to transition from traditional to ICT-embedded practice. 'Fine words don't butter the parsnips' was used to sum up the dilemma of changing from textbook learning towards more ICT embedded learning. It referred to the dilemma of the teacher being able to observe creativity, higher levels of student engagement, and deep learning during knowledge creation lessons; they were unsure whether it was going to outweigh the results they can achieve through traditional practice, which are ultimately reported to the parents from the students' end of year standardised tests.

'Multiple iterations' was of importance but it did not fit conveniently into any one category. Many of the references were to the two cycles of implementing the 4D model, and the participants referred to this element as being both positive and necessary. By the second cycle, the participants were more familiar with the model, the multiple orientations, and the ICTs they had used in their lessons. There were also references to being able to put their new thoughts into practice during the second iteration, indicating that during the first cycle, new beliefs and ideas about practice were emerging, and the second cycle enabled them to strengthen or reconstruct them.

A final code that was of interest is '**conflicts**'. This code covered several areas, including conflicts between traditional and new practice, parents' expectations and teachers' desires, sticking to the curriculum times and continuing with positive learning experiences, taking risks and playing it safe, and getting back to the normal day-to-day activities or persisting with novel activities.

The relevance of the orphan codes to explaining the phenomenon under study became more apparent during the translation of the data analysis into the findings.

6.7 Chapter Summary

This chapter has outlined how the participants' metaphors, lessons, and group and individual interviews were analysed to gain insights into the impact of the 4D model for changing teachers' pedagogy beliefs. The chapter concluded with a discussion of the five main categories that emerged from the researcher's analysis and addressed some alternative explanations through the discussion of orphan codes and disbanded categories. The next chapter presents the findings from this study.

7. Findings

7.1 Introduction

This chapter presents the findings from the analysis in relation to this study's goals. Firstly, the study's aims and its research questions are stated. These are followed by the findings from each of the three research questions that guided the study's investigation. The first finding presents evidence of teacher belief change. The second finding describes how the participants' beliefs changed following their experiences with the 4D model at school. The third finding addresses why teachers' beliefs changed by discussing the five propositions that guided the design of the 4D model. The research aims and the research questions are stated below.

- Research Aim: Create a new model of teacher CPD that is effective at growing primary school teachers' beliefs about the use of ICT for 21st-century teaching and learning at school.

Through a case study approach, the research explored the 4D model of teacher CPD for changing teachers' pedagogy beliefs about 21st-century teaching and learning. The researcher determined to understand the participants' experiences and to identify and elaborate on elements of the CPD design that contributed to belief change emerging from the data. The researcher also sought to determine whether the 4D Model process is worthy of further study in the area of teachers' pedagogy beliefs and 21st century teaching and learning. The following research questions guided the study and its subsequent analysis:

- Q1. Do teachers grow beliefs about 21st Century teaching and learning because of their experiences with the 4D model? If so, then
- Q2. How do teachers grow beliefs about 21st Century teaching and learning because of their experiences with the 4D model?
- Q3. Why do teachers grow beliefs about 21st Century teaching and learning because of their experiences with the 4D model?

The findings from this case study build upon the data analysis techniques reported in Chapter 6. Through the analysis of multiple sets of data, including participants' metaphors, lessons, and individual and group interviews, the following subsections demonstrate that the findings originate directly from the data itself, leaving behind a trail that others can follow to understand how the conclusions were reached. The case study approach employed in this study, such as its use of iterations to establish spatial and temporal

boundaries, enabled the researcher to analyse belief change over time and to explain how and why belief change occurred following the participants' experiences with the 4D model.

7.2 RQ1: Do Teachers Change Beliefs?

RQ 1: Do teachers change their beliefs and practices following their experiences with the 4D Model?

This research question investigated whether changes in teachers' pedagogy beliefs occurred following their experiences with the 4D model. This finding was built on the analysis of the participants' pre- and post-cycle metaphors and the group and individual interviews. From the analysis, a clear finding emerged indicating that the majority of teachers in this study reconstructed beliefs about practice with ICT. Moreover, all the participants strengthened existing beliefs about the role ICT can play in enhancing primary education.

Finding 1: All teachers strengthened existing beliefs about the role of ICT in primary education, and the majority of teachers self-reported reconstructing beliefs and practices. Five out of the eight teachers reconstructed metaphors post-iteration 1, while six did so post-iteration 2. Overall, of the seven teachers who responded, six reconstructed their beliefs at least once of the two cycles. This is summarised in Table 48.

Table 48: Teachers' Strengthening and Reconstructing Beliefs

Participant	Post-Iteration 1	Post-Iteration 2
1	Reconstructed	Reconstructed
2	Reconstructed	Reconstructed
3	Did not Respond	Reconstructed
4	Reconstructed	Reconstructed
5	Reconstructed	Reconstructed
6	Did not Respond	Strengthened
7	Did not Respond	Did not Respond
8	Reconstructed	Reconstructed
Total	5	6

Representative samples from the participants' pre- and post-cycle metaphors, coded as either reconstructed or strengthened, are presented in Table 49.

Table 49: Strengthening and Reconstructing Beliefs

Participant	Metaphor – Pre	Metaphor - Post	Code
2	Students' learning is like a field of grass growing. Knowledge and information aid growth in a stimulating learning environment, where the teacher then sprinkles the water to nourish and enhance this learning.	Students' learning is like a field of grass growing. Teachers create a stimulating environment (the field) where children's learning is nourished, encouraged, and supported (water, sunlight, soil). I felt the metaphor needed to be more specific and in alignment with daily school life.	Reconstructing
3	I design for assessment and feedback like Michael Davitt and the Land League- equality of opportunity and give ownership to the children.	I design for assessment and feedback like Michael Davitt and the Land League- children are given the information equality, but what they do with it is assessed, and the outcome is at different levels.	
6	Students learn as much from their peers and group work as they do directly from the teacher. The teacher is a facilitator.	No, I agree with my initial reflections.	Strengthening
5	My design for student progression is like building a ship. The parts of the ship are created individually and then come together to form a whole that is much bigger than an individual part.	I agree with my initial metaphors, I think that tech is another enabler in encouraging student progress. It can be a boost for students who are less able and an extension for students who are more able.	

All eight of the participants discussed changes in their beliefs following their experiences with the 4D model during the group and individual interviews. Participant 6, who had responded as having had no change during their metaphor reconstruction activity, discussed slight changes in their beliefs and referred

to their existing beliefs about ICT having an effective role to play in primary level teaching and learning having been strengthened. Participant 7, who did not respond to the post-iteration 1 or 2 metaphor tasks, also discussed changes in their beliefs. Representative samples from two codes that emerged from the analysis of the participants' interviews, '*Reconstructing beliefs*' and '*Strengthening beliefs*,' are presented in Table 50.

Table 50: Strengthening and Reconstructing Beliefs

Participant	Quote	Code
1	*"I've definitely changed some beliefs, just in terms of how I would plan an activity, to see the bigger picture that you're not just doing it for the sake of a closed question"*	Reconstructing Beliefs
8	*"I can step back a bit and just observe and see how things are going. This is where the learning happens. Where you don't have to be the centre of the learning at all times. They're actually learning themselves. It's really engaging for them."*	
2	*"I don't think it changed my beliefs and I think you know it just probably embedded my beliefs all the more."*	Strengthening Beliefs
6	*"I don't know if my beliefs have changed because they're very strong as it is and very motivated towards using technology"*	

This finding, that the majority of participants self-reported changes in their beliefs, indicates some efficacy in the 4D Model for changing teachers' pedagogy beliefs. Following their experiences of two iterations of the 4D model, the teachers have revisited their initial beliefs and indicated there have been some changes. Even though the teachers were continuing with their day-to-day teaching and learning at school, the participants attest to their experiences with the 4D model as having influenced changes in their beliefs. This finding supports the efficacy of the 4D model as a constructivist learning experience where *"learning is best facilitated by a process that draws out the students' beliefs and ideas about a topic so that they can be examined, tested, and integrated with new, more refined ideas"* (Kolb, 2014, p. 26).

7.3 RQ 2: How do Teachers Reconstruct their Pedagogy Beliefs?

This research question investigated *how* teachers reconstructed their pedagogy beliefs following their experiences with the 4D model. This finding was built on the analysis of the participants' post-cycle group and individual interviews. From the analysis, a clear finding emerged indicating interplay between elements of the 4D model and the teachers' day-to-day practice leading to changes in pedagogy beliefs about the use of ICT.

Finding 2 – In this instance, teachers' reports indicated that their belief change involved a continuous process of resolving conflicts between new and pre-existing practice.

Two pre-existing factors are acknowledged to have an influence on this finding. Firstly, the participants' beliefs and practice are constantly changing. As the category '**Changing beliefs and practice**' indicated, teachers' practice changes at various times of the year, and it can change during single lessons as teachers differentiate strategies and learning outcomes to enable students to achieve aims relative to their perceived abilities. Secondly, the participants who took part in this study already had strong beliefs about ICT use at school. However, many of the participants' beliefs were about ICT having a role to play in enhancing students' learning at primary level. Moreover, there was a lack of reference to specific pedagogy principles guiding the design of their day-to-day practice. Instead, the code '*stages of lesson progression*' explained how the participants viewed the knowledge acquisition, knowledge deepening, and knowledge creation orientations as collective rather than separate. The participants reported that the three orientations aligned with the aims of their pre-existing practice. This involved starting with knowledge acquisition of content knowledge, moving towards knowledge deepening of the content knowledge the students had acquired, and a final stage where the students were given opportunities to experiment or create something with the acquired knowledge. In contrast to their existing practice, the 4D model approach tasked them with designing, implementing, and evaluating lessons separately from distinct orientations.

From Figure 26, it can be seen that the categories that emerged from the analysis of the data indicated there are day-to-day practices and elements of the 4D model relevant to changing teachers' beliefs. The elements specific to the 4D Model are emboldened and discussed thereafter.

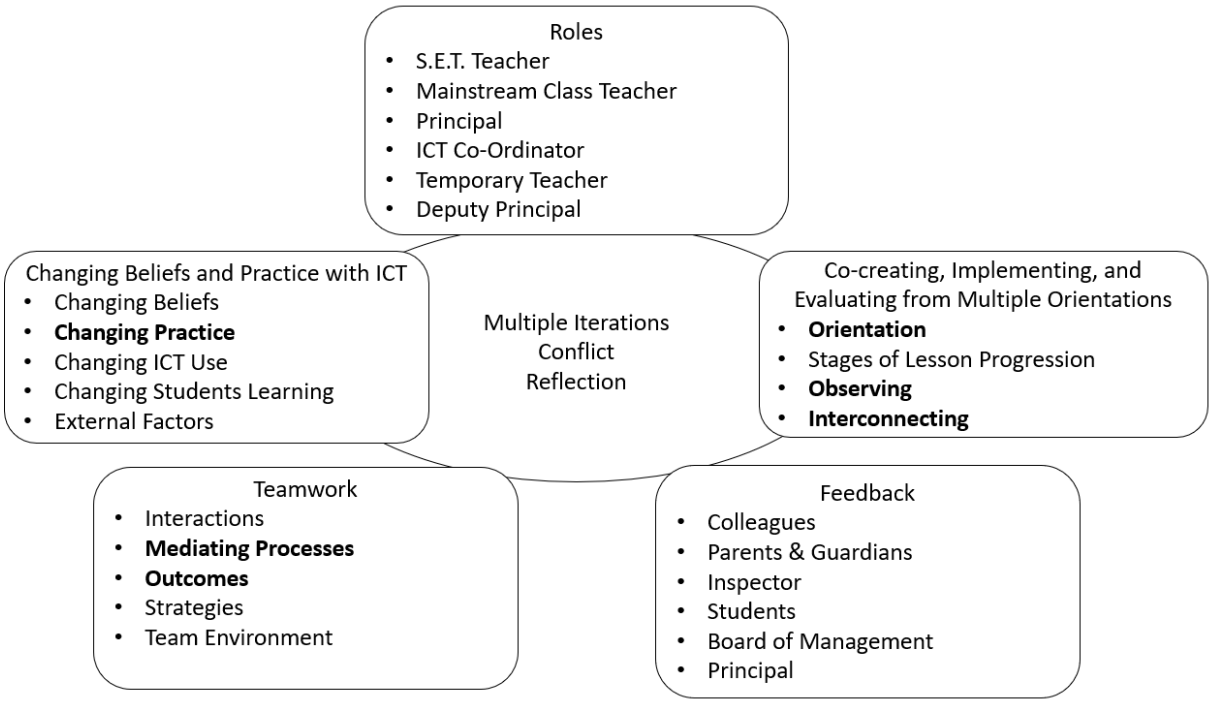

Figure 26: Factors Impacting Changing Teachers' Beliefs

The category **Co-creating, implementing, and evaluating from multiple orientations** and its property *'orientation'* refers to the new practice that was introduced to the participants' classrooms through the knowledge acquisition, knowledge deepening, and knowledge creation lessons. Although the participants were familiar with the orientations and they reported that they were the aims of their established day-to-day practice, the 4D model provided them with new experiences where they designed and implemented them separately as part of three distinct lessons rather than collectively as part of one lesson. Using the lesson plan, the participants also experienced planning the lessons from different orientations under headings that aligned with the sub-categories under which they had submitted their pedagogy beliefs.

This enabled an experience where the participants engaged in '*interconnecting,'* which involved *'integrating'* the design tasks with existing and familiar practice and '*differentiating*' them into new practice by separating them into distinct lessons. The approach also enabled the teachers to experience new forms of '*observing students' learning'* when the teachers stepped back and allowed the students to take more ownership of the learning. These events were recalled and used as reference points when the teachers were *'comparing old practice with new practice'* during the group and individual interviews.

Although the participants are part of a wider team in their respective schools, the 4D model introduced them to teammates who were '*on the same sheet*' when it came to their perspectives on ICT at school. During their team interactions, they *'learned'* about new ICTs, how to implement them in class, and how to problem-solve challenges they encountered. The experiences were supported by *'multiple iterations*,' which involved two cycles of the 4D model across one school year. Multiple iterations were important because they enabled the participants to develop a deeper understanding of the model and to tweak the lessons, so they ran more smoothly during the second iteration. Lesson tweaking was informed by new insights from their individual *'reflections*' and from their interactions while debugging the lessons with their teammates.

This finding highlights the value of situated CPD, where teachers enact new practices in their classrooms and then reflect on its outcomes and compare it with previous experiences as a precursor to changing beliefs (Guskey, 2002b, 2014). It also provides further support to the 4D model as an effective CPD experience that utilises content focus, active learning, collaboration, models and modelling, feedback and reflection, and sustained duration (Darling-Hammond et al., 2017).

7.4 RQ 3: Why do Teachers Reconstruct beliefs?

This research question investigated *why* teachers reconstructed their pedagogy beliefs following their experiences with the 4D model. This finding is presented in the form of five subsections. Each subsection refers to one of the five propositions that were discussed in the literature review and informed the design of the 4D model. In each subsection, the relevant proposition is stated first, and then followed by evidence providing insight into its effectiveness in changing teachers' beliefs. Before that RQ 3 is stated below.

RQ 3. Why do teachers reconstruct beliefs and practices following their experiences with the 4D Model?

7.4.1 Finding 3.1

Proposition 1: Because beliefs are functionally connected and in communication with one another, raising and changing deeply held beliefs has more ramifications across the belief system.

This proposition influenced the design of the 4D model leading to the inclusion of an individual reflection activity where teachers had the opportunity to raise, revisit, and refine, deeply held beliefs about teaching and learning using ICT, through metaphor construction and reconstruction. Moreover, it was hypothesised that the sub-categories of beliefs the participants submitted their metaphors under – how students learn, lesson design principles, student progression, assessment and feedback, design of the learning environment, and example activities – were interconnected, or functionally connected and in communication with one another. Furthermore, changes in beliefs in one sub-category would have implications for beliefs in the other sub-categories.

This finding built upon the analysis of the participants' metaphors and their group and individual interviews. The analysis indicated that metaphor construction and reconstruction enables teachers to raise deeply held beliefs. Moreover, some evidence of the sub-categories' interconnectedness was identified.

The participants' metaphors provided some evidence of beliefs being functionally connected and in communication with one another. In Table 51, the words in bold in the participants' post-iteration two self-reported changes in beliefs are connected across the sub-categories of pedagogy beliefs.

Table 51: Interconnected Subcategories

Participant	Sub-Category	Post-Iteration 2	Code
1	Learning Theory	It was great to be able to see the **process of thinking** rather than only the product or end result.	Interconnected
	Student Progression	The children progressed differently and at different rates. Use of IT allowed **children** of different levels to **progress** at their own speed.	
	Assessment and Feedback	The lessons delivered allowed me to assess the **thought process** and the **children's progress**.	
8	Learning Theory	Student learning is like an explorer following a **map.** This metaphor still stands. I believe students require some guidance to initiate their learning **journey**, i.e., the **map**. Several learning experiences are possible along the route. Sometimes students have to return to the start and begin again with a clearer map provided.	Interconnected
	Lesson Design	I design a task to initiate the students' learning. I provide the necessary information **(map)** to allow them to start their **journey**. Students determine where the journey takes them on the map. Learning happens on the route.	
	Student Progression	Students' progress by initiating the **journey** and seeing where they can go by themselves and with the support of a group. Progress is made through trial and error. Making mistakes and asking questions leads to further learning.	

There was also evidence of changes across the sub-categories of beliefs the participants submitted their metaphors under. Figures 27 and 28 present evidence that teachers' self-reported changes were not confined to any single sub-category; instead, there is evidence of change having occurred across all of the six sub-categories between pre-iteration one and post-iteration two.

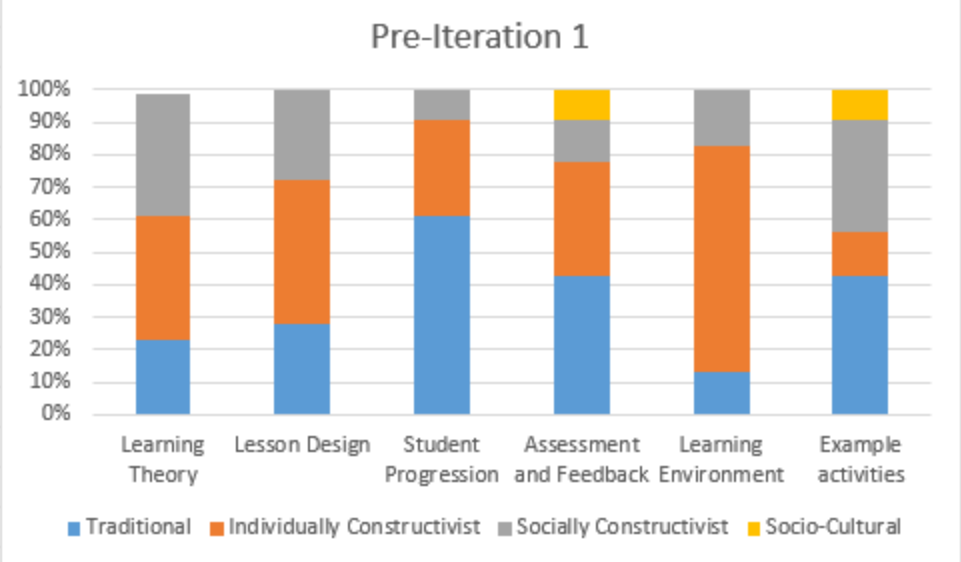

Figure 27: Pre-Iteration 1 Metaphors

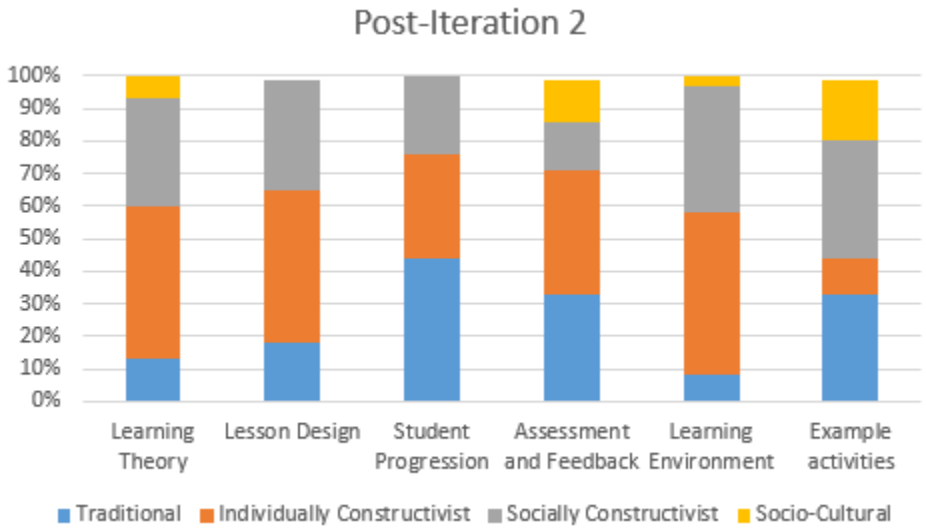

Figure 28: Post-Iteration 2 Metaphors

The participants' interviews provided further evidence of references to beliefs interconnectedness. As well as this, during the interviews, the participants discussed how the metaphor reflection activity enabled them to raise deeply held beliefs. Representative samples from two codes, *'Interconnected'* and *'Metaphors,'* are presented in Table 52.

Table 52: Interconnected Beliefs

Participant	Quote	Code
1	*'they're all very important, students' progression, assessment, the learning environments, they definitely would link into each other"*	Interconnected
2	*'I suppose designing your learning environment will affect how students' progress, how you design your lessons, like they're all interlinked."*	
4	*'I suppose the reflecting piece the metaphors made you kind of look at what your beliefs are as a teacher and it's not something that you think about too often."*	Metaphors
7	*'I loved making the metaphors I found that really just made me take a step back and look at what I do from a global perspective, from my head, from the top"*	

This finding builds upon previous literature in the field, arguing that beliefs are interconnected or functionally connected and in communication with one another (Ertmer, 2005; Pajares, 1992; Rokeach, 1968). Moreover, it adds weight to the use of metaphors as an approach for raising deeply held beliefs (Leavy et al., 2007; Martínez et al., 2001). This finding supports the argument that changing single beliefs has some ramifications for other beliefs that are interconnected with one another. It is argued that this study presents evidence that the six sub-categories – learning theory, lesson design, student progression, assessment and feedback, the learning environment, and example activities – show some interconnectedness.

7.4.2 Finding 3.2

Proposition 2: The belief change process involves raising, experimenting, reflecting, and refining beliefs that align with an experiential learning cycle of abstract conceptualisation, active experimentation, concrete experience, and reflective observation.

This proposition influenced the design of the 4D model, leading to the sequencing of the model's activities in the following order: reflection, design, develop, deliver, debug, and reflection. It was hypothesised that the sequence aligns with both the belief change process and an experiential learning cycle. Scaffolding an experience along those lines can enable teachers to change their beliefs while continuing with their day-to-day practice at school.

This finding built upon the analysis of the participants' group and individual interviews. The analysis indicated that the sequence of the 4D model's activities is effective for facilitating teacher pedagogy belief change at school.

In Figure 29, abstract conceptualisation aligns with the initial metaphor construction activity, active experimentation aligns with the design and develop stages, concrete experience aligns with the deliver stage, and reflective observation aligns with the debug and revisit stages. Following on, Table 53 presents representative quotes from the participants that were coded under the label '*going through a cycle*'.

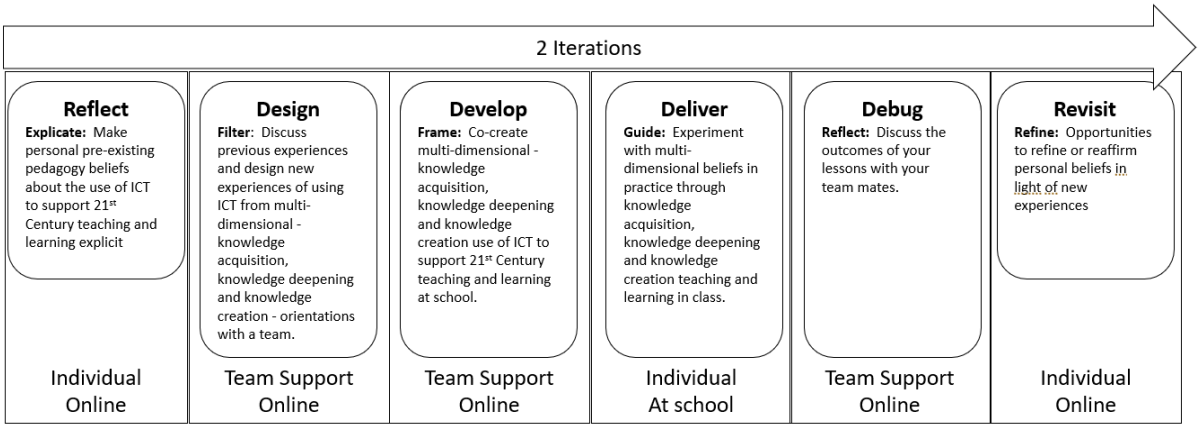

Figure 29: The 4D Model

Table 53: Going Through a Cycle

Participant	Quote	Code
1	*"So, reflecting, designing, developing, delivering, yeah, we definitely did those steps, debug then reflect, we did the same thing second time around, but we probably knew more what we were doing, so we reflected on first time round before we started again"*	Going through a cycle
2	*"When we first met, we reflected on what we had to do, how we were going to achieve it. So, then we designed our lessons. We developed our lessons and then we delivered the lessons. And I suppose we discussed how we were going to do it, what we were going to do as a team and then to debug I suppose we looked at what we need to do now."*	

This finding indicates that the 4D model process is appropriate for engaging teachers in the types of activities where they can change their beliefs. During the metaphor construction step, the participants abstracted their deeply held beliefs and conceptualised them as metaphors. During the design and develop steps, the participants engaged in active experimentation where they co-created lessons from three different orientations. During the debug step and the group and individual interviews, the participants discussed their reflective observations about their experiences with the 4D model. During the last step, where they revisited their initial metaphors, the participants returned to the initial beliefs they had raised and made changes in light of their experiences. This finding builds on previous literature arguing that the process of belief change involves raising, experimenting, reflecting, and refining beliefs (Ertmer, 2005; Rokeach, 1968). It suggests alignment between the belief change process and an experiential learning cycle, and it indicates that the 4D model is an appropriate scaffold for enabling teachers to experience the belief change process at school.

7.4.3 Finding 3.3

Proposition 3: Teachers' beliefs are multi-dimensional, so CPD design can seek to interconnect beliefs from different pedagogy orientations by engaging teachers in lesson design from multiple rather than single orientations.

This proposition influenced the design of the 4D model leading to the inclusion of an activity where teachers experienced co-creating, implementing, and evaluating from multiple rather than single orientations. This involves the teachers designing, developing, delivering, and debugging from knowledge acquisition, knowledge deepening, and knowledge creation orientations. This was a change from the participants' existing practice.

This finding built upon the analysis of the participants' metaphors, the teams' lesson plans, and the group and individual interviews. The analysis indicated that teachers' beliefs are multi-dimensional and that designing lessons from multiple orientations was effective in changing teachers' pedagogy beliefs.

Analysis of the participants' metaphors indicated that teachers' beliefs are multi-dimensional, with evidence of traditional, individually constructivist, socially constructivist, and socio-cultural beliefs present in the sub-categories: learning theory, lesson design, student progression, assessment and feedback, design of the learning environment, and example activities. The metaphors are colour-coded and presented in the chart in Figure 30.

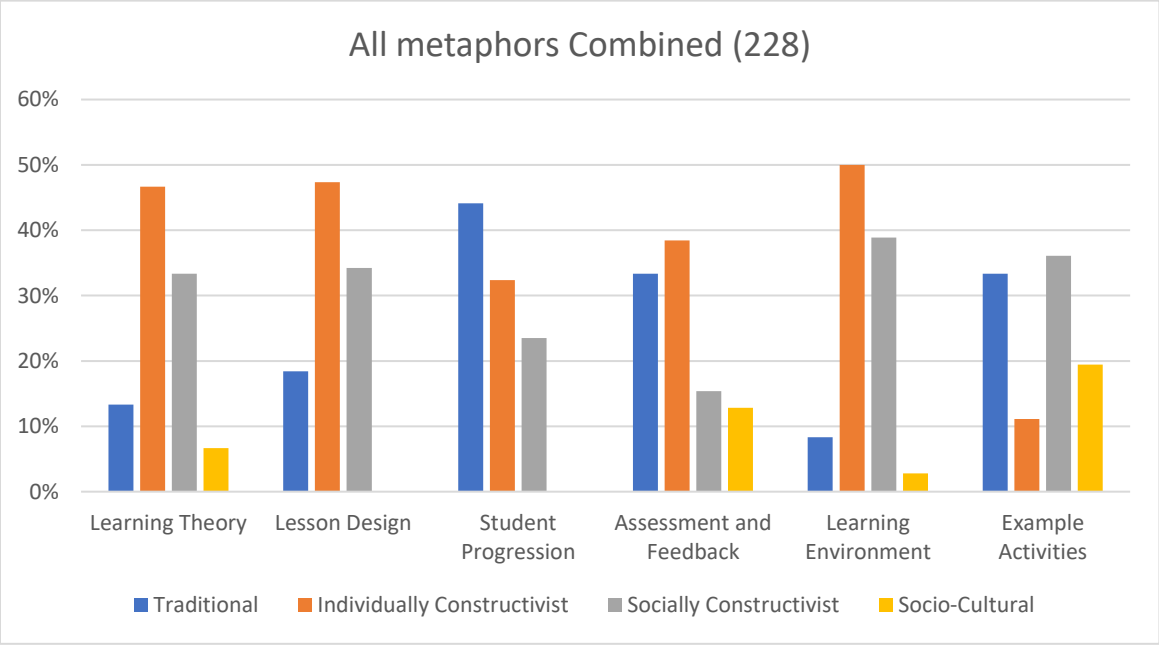

Figure 30: Multi-Dimensional Beliefs

The participants' interviews also indicated that teachers' beliefs are multi-dimensional. The code '*stages of lesson progression'* indicated that teachers' established day-to-day practice involves lessons that are

multi-dimensional, including starting, middle, and end phases that have some alignment with knowledge acquisition, knowledge deepening, and knowledge creation. Moreover, the participants reported that the overall orientation of their classroom practice changes throughout the year in response to external factors such as covering textbook chapters and preparing students for end-of-term and end-of-year assessments.

The teams' lesson plans provided evidence of the teachers having co-created, implemented, and evaluated from different orientations, a change to their pre-existing practice. Team 3's lesson plan from iteration one is presented in Figure 31.

Learning Plan Topic: Toy Show	**Knowledge Acquisition**	**Knowledge Deepening**	**Knowledge Creation**
Subject English	Design a toy for the Toy Show and write up the presentation	Create a prototype of a toy	Present the project using Greenscreen
Strand / Strand Unit Writing	Report writing -what is being designed	Procedure writing -how does the toy work	Presentation -discussion and presentation using Greenscreen
Skills	Modelled genre writing Shared writing	Oral familiarisation Language experience	Presentation to the audience with a toy model using Greenscreen
Methodologies	Enquiry Talk and discussion Free exploration of materials to create a toy	Active Learning Guided discovery/Problem-solving Collaborative/ Cooperative learning	Using the environment Skills through content Use of ICT
Digital Skills	Typing- use google docs	Designing- using cameo /taking photos to record their toy design	Using green screen -Present their project using Greenscreen
Design of the Learning Environment	Group writing and designing	Group STEAM - designing a prototype of their toy	Group presentation using Green Screen
Assessment	Self-assessment -Rubrics, thumbs up, thumbs down	Teacher observation Did the children achieve the content objective at a differentiated level?	Conferencing Questioning

Figure 31: Team 3 Lesson(s) Plan Iteration One

During the group and individual interviews, the participants discussed their new experiences, and the category '**Co-creating, implementing, and evaluating from multiple orientations'** emerged from the data. Two codes, *'integrating'* and *'differentiating,'* provided insights into this experience. 'Integrating' referred to the participants integrating designing from multiple orientations with their existing practice as part of one lesson that followed a linear process. 'Differentiating' referred to the participants breaking the

lessons apart into three separate orientations that could be designed and implemented separately, starting from any point. Representative samples are presented in Table 54.

Table 54: Integrating and Differentiating

Participant	Quote	Code
1	*'I think I'd be fairly balanced in my approach to them you know you're basically talking about your KWL in a way, that's kind of what I would use as a basis for most of my lessons."*	Integrating
6	*'It's almost like it's your starting point and then your middle point, and then your end."*	
1	*'it's quite interesting to think about it, because I've never seen it broken down like that, I don't think I've seen it broken down like that before this."*	Differentiating
6	*'I suppose all three don't have to be together, but yeah, you could have a knowledge creation lesson on its own."*	

This finding aligns with existing literature arguing that teachers hold multi-dimensional pedagogy beliefs within their belief systems (Tondeur et al., 2017). It builds upon that research by indicating that teachers also hold multi-dimensional beliefs about sub-categories of pedagogy, which in this study were identified as learning theory, lesson design, student progression, assessment and feedback, design of the learning environment, and example activities.

The orientations used in this study has implications for the findings. In a change from national policy in Ireland this study used the UNESCO ICT Competence Framework for Teachers, (UNESCO) rather than the Digital Learning Framework, (DLF). Whereas the UNESCO outlines three stages – knowledge acquisition, knowledge deepening, and knowledge creation – the DLF outlines two stages: effective practice and highly effective practice. The main difference being the omission of the knowledge acquisition stage from the

DLF. In this study, however, the participants reported that knowledge acquisition is a key part of every lesson. Moreover, they reported that the process in this study aligned with their existing practice. By focusing the design on three orientations, the participants had to differentiate between their existing practice and the new practice they were aiming to implement.

7.4.4 Finding 3.4

Proposition 4: The relationship between teachers' beliefs and ICT is bi-directional, so teachers can benefit from guiding and being guided by pedagogy-first, ICT-enhanced teaching and learning.

This proposition influenced the design of the 4D model, leading to the inclusion of an activity where teachers could experience guiding and being guided by ICTs to realise new beliefs and practice. It was hypothesised that by working in teams, some teachers would suggest using ICTs that were familiar to them and unfamiliar to others, and the use of ICTs could open up new experiences that would enable teachers to grow new beliefs. Moreover, by co-creating, implementing, and evaluating from multiple orientations, the participants would guide the use of ICT to achieve new forms of practice that could grow beliefs.

This finding built upon the analysis of the teams' lesson plans, and the participants' group and individual interviews. The lesson plans presented evidence of the teachers having guided the learning experience by putting the pedagogy before the technology. The interviews provided further insights into the bi-directional nature of the relationship.

The code '*New Practice'* provided insights into the bi-directional relationship between teachers' pedagogy beliefs and their existing practice. Representative samples of teachers growing new beliefs through the use of ICT and teachers using ICT to realise existing beliefs and practice are presented in Table 55.

Table 55: Bi-Directional Relationship

Participant	Quote	Code
1	*"Assessment and giving feedback is one that's kind of jumped out from using flip grid it's a good tool to give a different way of assessing."*	New Practice
2	*"So, I have to say that it was, I suppose, broadening my methodologies and my assessment tools and using IT in a different way."*	
3	*"it's definitely something that I'm going to continue using in the class and it was a great tool it was just so beneficial for all of the children, there was no barriers for any of the children."*	
4	*"In terms of getting involved and doing lots of research around different programs, platforms, Nearpod, Co spaces. All of these ones that I probably wouldn't have dabbled in because we wouldn't have had the equipment."*	
8	*"No, I wouldn't have used them in this way before no, definitely not. But it did open my eyes up to the possibilities that are there with the iPads."*	

This finding aligns with previous literature arguing that the relationship between teachers' pedagogy beliefs and ICT is bi-directional (Prestridge, 2017; Rowston et al., 2020; Tondeur et al., 2017). This means that teachers can use ICTs to realise pre-existing beliefs, and teachers' use of ICT can enable them to develop new beliefs. It indicates that the bidirectionality of the relationship can be leveraged during CPD to enable teachers to realise pre-existing beliefs in the form of new practice or to grow new beliefs through experience of practice with ICT.

7.4.5 Finding 3.5

Proposition 5: Team support can enable teachers to persist with new practices at school.

This proposition influenced the design of the 4D model leading to the teachers working together in teacher design teams. It was hypothesised that by working in teams, teachers would develop shared

beliefs about the effective use of ICT, and they would develop persistence in its implementation at school even when external factors impacted upon its realisation. This finding built upon the analysis of the teams' group and individual interviews. Clear evidence that being part of a team can enable teachers to develop persistence emerged.

The participants indicated that team support enables them to learn about and persist with new practices at school. The category '*Teamwork'* emerged from the data, and the code *'Team Persistence'* provided insights into the participants' developing persistence with ICT use at school. Representative samples are presented in Table 56.

Table 56: Team Persistence

Participant	Quote	Code
6	*"No constitution, I suppose we just got on with it, got on with the task at hand."*	Team Persistence
2	*"An explicit rule is that we would do what we said we would do so that was a rule, and we did so."*	
7	*"It's like, 'come on guys we need to get this done,' it was like 'let's meet next week and go over what we've done,' because, I was like, 'OK, well, I'd better do it then.' So yeah, I do like that kind of pressure because without that, sometimes things just don't happen."*	
1	*"Definitely, from talking to the others and even say from tonight, I'm already kind of thinking, oh yeah must get back at that, each time you might get a renewed sense of enthusiasm'*	
5	*"I suppose there's an aspect of a lack of self-confidence as well. It's slightly easier to go and present something and say well, I'm doing this as part of a design team that we've talked about rather than saying this is an idea I plucked from my brain."*	

This finding aligns with previous research literature that working as a team can enable teachers to persist with novel practice at school. Whereas Girvan et al. (2016) argue that the team creates their own shared

beliefs that its members are enacting the desired practice at school, Fishbein and Ajzen (2011) argue that teachers build normative beliefs about referent individuals who either prescribe or proscribe the desired behaviour or are carrying out the behaviour themselves that act as motivators for the participants to persist with new practices (Fishbein & Ajzen, 2011; Girvan et al., 2016). This finding indicates that teacher design teams can play a significant role in teachers growing new beliefs about innovative and creative ICT enhanced teaching and learning and that the team can act as a motivation for teachers to persist with new practices during their day-to-day teaching and learning at school.

7.5 Chapter Summary

This chapter has presented the findings from this investigation into the 4D model for changing teachers' beliefs. Firstly, RQ1 presented evidence of teacher belief change. RQ2 presented evidence of how teachers' beliefs changed. RQ3 presented evidence of why teachers' beliefs changed by addressing five propositions raised in the literature review that informed the design of the 4D model. The next chapter presents the conclusions from this investigation.

8. Conclusions

8.1 Introduction

The final chapter presents the conclusions of this study. To start, the findings are briefly reviewed. Subsequently, the study discusses its two primary contributions: the 4D model and the process of constructing and reconstructing metaphors. Then, it presents the study's strengths, limitations, scope, transferability, ethical challenges, and suggestions for future research. Finally, the chapter concludes with a personal reflection.

8.2 Review of Findings

Three questions guided the research:

1. Do teachers' pedagogy beliefs change following their experiences with the 4D model? If so, then
2. How do teachers' beliefs change?
3. Why do teachers' beliefs change?

These questions were addressed in Chapter 7, and a concise summary of the findings follows:

Finding 1: Teachers self-reported strengthening and reconstructing their pedagogy beliefs about the use of ICT at school.

Finding 2: In this instance, teachers' reports indicated that their belief change involved a continuous process of resolving conflicts between new and pre-existing practice.

Finding 3.1: Metaphor construction and reconstruction enables teachers to access deeply held beliefs, and there is some interconnectedness between the six sub-categories of pedagogy beliefs the participants submitted their metaphors under – learning theory, lesson design, student progression, assessment and feedback, design of the learning environment, and example activities. Moreover, there is some evidence of changes in one sub-category impacting upon changes in other sub-categories.

Finding 3.2: There is alignment between the belief change process, which includes raising, experimenting, reflecting, and refining beliefs, and an experiential learning cycle consisting of abstract conceptualisation, active experimentation, concrete experience, and reflective observation. The 4D model process-reflect, design, develop, deliver, debug, and revisit-is an appropriate scaffold for teacher CPD in this area.

Finding 3.3: Teachers' pedagogy beliefs are multi-dimensional, including beliefs from a range of pedagogy orientations – traditional, individually constructivist, socially constructivist, and socio-cultural. There is evidence that teachers hold multi-dimensional beliefs about how students learn, lesson design principles, student progression, assessment and feedback, the design of the learning environment, and example activities. Engaging teachers in co-creating, implementing, and evaluating from multiple orientations is an effective strategy for changing teachers' beliefs as it engages them in activities where they integrate and differentiate between pre-existing and new practice.

Finding 3.4: The bi-directional relationship between teachers' pedagogy beliefs and their use of ICT can be leveraged and used as a strategy to enable teachers to change their pedagogy beliefs when working as part of a team.

Finding 3.5: Working as part of a teacher design team can enable teachers to develop persistence with the implementation of novel ICT use at school.

8.3 Contributions

This subsection presents the two main contributions of this study and relates them to the findings: The 4D model and the metaphor construction and reconstruction process.

8.3.1 The 4D Model

The first contribution is the 4D model. The 4D model aims to change teachers' pedagogy beliefs about the use of ICT at school through a process of raising, experimenting, reflecting, and refining. The 4D model has similarities with an Experiential Learning Cycle (ELC) (Kolb, 2014). Whereas an ELC involves abstract conceptualisation, active experimentation, concrete experiences, and reflective observation, the 4D model used a structure of metaphor construction and reconstruction, designing, developing, delivering, debugging, and revisiting. The 4D model also included co-creating, implementing, and evaluating from multiple orientations, authentic situated experiences at school, multiple iterations across one school year, observing student learning outcomes, and teamwork. The participants' experiences with the 4D model impacted changes in their beliefs about the innovative and creative use of ICT at school as described in Finding 3.2.

The model demonstrates the value of situated CPD, where teachers can observe student learning outcomes as a precursor to changes in beliefs. Furthermore, Finding 3.3 indicates that designing from multiple orientations, which in this case involved knowledge acquisition, knowledge deepening, and knowledge creation, engages teachers in teaching and learning experiences where teachers experience integrating and differentiating between pre-existing and novel practice as a precursor to changing beliefs (Kolb, 2014). Multiple iterations enable the participants to dig deeper into the learning experience. Finally, the contribution supports previous research that working as part of a team can enable teachers to persist with new practices at school (Girvan et al., 2016).

The combination of those theoretical elements into the model's design and their actualisation into a bespoke practical model of teacher CPD for investigating changing primary teachers' pedagogy beliefs about ICT sets the 4D Model apart from an experiential learning cycle as discussed in Finding 2.

8.3.2 Metaphor Construction and Reconstruction

The second contribution is the metaphor construction and reconstruction process used in this study. Metaphors enable individuals to reveal their implicit theories or preconceptions about our world, and they enable individuals to construct artefacts of their abstract thoughts during reflection (Fives & Gill, 2014). In previous studies, metaphor construction and reconstruction has been used to enable teachers to raise their implicit beliefs about teaching and learning, engage in a CPD intervention, and then revisit their initially stated metaphors before recording any changes in their beliefs because of their experiences (Leavy et al., 2007; Martínez et al., 2001).

In this study, metaphor construction and reconstruction were employed in a comparable way. Teachers were tasked with constructing metaphors about their beliefs about teaching and learning with ICT before engaging in two iterations of the 4D model, with the participants revisiting their initial stated metaphors post-iterations one and two. The initial metaphors were coded for their alignment with traditional, individually constructivist, socially constructivist, and socio-cultural orientations of pedagogy, and the participants' final responses were analysed for evidence of change in beliefs. While this process was broadly in line with previous studies using metaphor construction and reconstruction for investigating teachers' pedagogy beliefs, this study extended the process in the following ways.

Building on recent literature, the study used an updated list of pedagogy terms that include ICT practices, making the process more relevant to 21st century teaching and learning (Beetham & Sharpe, 2019).

Furthermore, this study identified sub-categories of pedagogy beliefs that it is argued are interconnected. The sub-categories identified in this study include how students learn, lesson design principles, student progression, assessment and feedback, design of the learning environment, and example activities.

The six interconnected sub-categories are a contribution to investigating teachers' pedagogy beliefs through metaphor construction and reconstruction. The use of an updated rubric makes the process more relevant to the relationship between teachers' pedagogy beliefs and their use of ICT, as described in Finding 3.1.

8.4 Conclusions

The research explored the 4D Model of teacher CPD for changing teachers' pedagogy beliefs about 21st-century teaching and learning. The researcher determined to understand the participants' experiences and to identify and elaborate on elements of the CPD design that contributed to belief change emerging from the data. The researcher also sought to determine whether the 4D model process is worthy of further study in the area of teachers' pedagogy beliefs and 21st century teaching and learning.

In conclusion, the findings of this study strongly suggest that elements of the CPD design contributed to belief change, and that the 4D model is worthy of further study in the area of teachers' pedagogy beliefs and 21st century teaching and learning.

8.5 Limitations

There are several strengths and limitations in this study. As with any case study, the data analysis enables the researcher to dig deeply into the participants' experiences and to provide a rich description of how and why events occurred as they did. In this study, this involved investigating teacher belief change during their experiences with the 4D model while the participants were also engaging with their day-to-day teaching and learning. A strength of this study was its ability to isolate specific variables relating to the participants' experiences with the 4D model even though other factors outside of the influence of the 4D model were also at play and were likely to have been impacting on other beliefs teachers have. The study's strength in being able to isolate sub-categories of beliefs – how students learn, lesson design principles, student progression, assessment and feedback, design of the learning environment, and example activities – and to analyse what happened to those beliefs when the participants engaged with the model provided a valuable lens into how and why teachers' beliefs about the innovative and creative use of ICT

at school can change. Moreover, its use of metaphor construction and reconstruction, lesson plans, and group and individual interviews provided the researcher with valuable data appropriate to the aims of the study.

Research bias was a potential limitation of this study that was managed in the following ways. Because the researcher was the designer and facilitator of the CPD experience, I had developed some beliefs in the efficacy of the 4D model that had to be set aside during data collection and analysis and the presentation of the findings. Care was taken to use or create data collection instruments that were fair and unbiased. A rubric was employed to interpret the participants' metaphors for their alignment with different orientations of pedagogy. In particular, the participants were given options to indicate whether there had been changes in their beliefs. That not all teachers reported changes in beliefs and also that not all metaphors were coded as having changed suggests the process was fair and unbiased. The group and individual interviews were also approached in a fair and unbiased way. All the questions were designed to give the participants the opportunity to discuss whether the relevant factors had afforded or construed changes in beliefs. During the interviews, the participants were given the opportunity to speak freely and openly about their experiences.

The small number of participants in this study is a limitation of its findings. The cohort involved 8 teachers who were assigned to 3 teams. Despite the small number of participants, rich data was collected that enabled the researcher to engage in multiple cycles of coding and recoding from different lenses.

Another limitation was the inability to observe the lessons the participants created being implemented in their classrooms. Observation is a method that is often used in case study but because this study took placing during the COVID-19 pandemic, it was not feasible to access the sites.

In considering the validity of this study, both internal and external validity were sought. Internal validity is used in explanatory case studies where the researcher seeks to establish a causal relationship, whereby certain conditions are believed to lead to other conditions as opposed to spurious relationships (Yin, 2018). The data collection instruments, metaphor construction and reconstruction, lesson(s) plans, and individual and group interviews provided multiple perspectives on the participants' experiences. Each of the sources shed a light on the five propositions underpinning the 4D model's design. In combination, they provided some evidence of the propositions' efficacy. During the data analysis this involved explanation building and rival explanations were also addressed.

External validity refers to whether and how a case study's findings can be generalised (Yin, 2018). This may involve the use of theory in single-case studies or replication logic in multiple case studies. This study relied on the use of theory as a form of external validity. In alignment with Yin's perspective, this study identified an appropriate theory for the design of the 4D model, aligning it with an experiential learning cycle. Moreover, five theoretical propositions were identified, and it is argued that these laid the groundwork for establishing the external validity of this case study (Yin, 2018).

8.6 Scope and Transferability

Generalisability is often cited as a primary limitation of case study research. Because of its focus on investigating a case in a real-world setting, its findings can be faulted for a lack of representativeness (Merriam, 1998). Bassey argues that there are two kinds of outcomes of educational research: predictions of what may happen in particular circumstances and interpretations of what has happened in particular situations (Bassey, 1999, p. 4). This study has not used quantitative analysis, so statistical generalizations cannot be made. However, according to Bassey, it is possible to make a qualitative estimate or a 'fuzzy generalisation' where it is possible to claim, '*It is very likely that….*' (Bassey, 1999, p. 4).

Firstly, it is very likely that the metaphor construction and reconstruction process will yield teachers' deeply held beliefs about the sub-categories of teaching and learning using ICT if used in similar studies. The value of employing metaphors as a medium for teachers to raise their deeply held beliefs results in teachers constructing personal metaphors that are representative of their own beliefs about teaching and learning. Rather than presenting the participants with a list of pre-constructed metaphors and asking them to indicate their agreement using a Likert scale or some other measure, constructing metaphors enables teachers to create abstract conceptualisations of their deeply held beliefs. It is very likely that other researchers using the process would reveal teachers' pedagogy beliefs at a particular time, and the participants could reflect on these in light of experiences with CPD interventions.

Secondly, it is very likely that the 4D model is transferrable to other studies. The aim of the model is to enable teachers to raise, experiment, reflect, and refine their beliefs. This is scaffolded through steps including reflection, design, develop, deliver, debug, and revisit. While elements of the model need refinement in light of its implementation in a real-world setting, the overall process is similar to an experiential learning cycle which involves abstract conceptualisation, active experimentation, concrete experiences, and reflective observation. It is also argued that the 4D model is not confined to research

with Irish primary school teachers. This study employed an international framework, the UNESCO ICT CFT, that has influenced other countries digital learning strategies. It is also very likely that different frameworks could be employed with the model.

8.7 Ethical Challenges

There were several ethical challenges to this research. This study involved participants who were primary school teachers. The researcher is also a primary school teaching principal. One of the cohort had previously worked in the same school for a very short period, one of the cohort is a school leader in a neighbouring school, and one of the cohort is married to a friend. The potential of there being a conflict of interest was addressed in the invitation to the study that acknowledged due to my being a primary school teacher and lead researcher there was a likelihood of some participants either knowing or being known to me previously and so the intention to act in good faith and without bias was agreed upon. Although some of the cohort were previously known to me, they were not sought out or specifically approached; instead, they responded voluntarily to emails that were sent out to national mailing lists.

A second ethical challenge that arose involved whether there was a need for child consent forms. The teachers had to implement the lessons with the students in their own classes, and during the group and individual interviews, they were asked about their experiences of implementing the lessons at school. Although the participants discussed their observations of their students learning, and referred to the types of activities they engaged in, no student names were used in the conversations. Moreover, no data pertaining to the students was collected or formed any part of the study. All the participants were required to gain consent from their schools' boards of management prior to engaging in the study. This consent form included information about the study and the rationale for engaging teachers in activities seeking to enhance their use of ICTs at school for innovative and creative teaching and learning.

A third ethical challenge involved changing teachers' beliefs. It is potentially very harmful to change teachers' beliefs about teaching and learning. While the aims of this study involved changing teachers' beliefs about innovative and creative uses of ICTs, it is incumbent upon both the researcher and the participants to ensure that the students' learning at school is not adversely affected. In fact, there was some mention by the participants of the activities conflicting with the prevailing teaching and learning school culture. To address this, the participants were given a recognised framework as a guide for their lesson design. This included statements of pedagogy and ICT use the participants could follow. Moreover,

the UNESCO framework underpins the Irish Digital Learning Framework. Because the participants are being encouraged to enact the Irish DLF at school, the approach taken in this study was determined to be in synergy with national policy goals. These challenges were also addressed in the Board of Management consent forms.

8.8 Recommendations for Future Research

The 4D model is currently in the early stages of development. It has undergone a pilot study involving 4 participants and a main study with 8 participants. Although the model has shown some effectiveness in altering teachers' beliefs, there is room for improvement. Proposed modifications to enhance the model include organising an introductory event. During this event, all participants will be invited to an online information session to provide a more detailed description of the model's activities. This session will also allow for addressing any questions to ensure participants have a clearer understanding.

The model used in this study can be adapted to different frameworks. While the research used the UNESCO ICT CFT, there is potential to apply other frameworks. For instance, in Ireland, the Digital Learning Framework could be used. Another possibility is to include a fourth pedagogy approach to the model.

In this study, participants designed, developed, and implemented lessons based on three pedagogy orientations: knowledge acquisition, knowledge deepening, and knowledge creation. These align with traditional, constructivist, and socio-cultural pedagogy. However, it is possible to expand the design tasks to involve co-creating, implementing, and evaluating from various pedagogy orientations, including traditional, individually constructivist, socially constructivist, and socio-cultural approaches.

The metaphor construction and reconstruction process could be further developed. Currently, it involves teachers constructing metaphors about their beliefs about teaching and learning using ICT under the following sub-categories: learning theory, lesson design principles, student progression, assessment and feedback, design of the learning environment, and example activities. The sub-categories could be further explored, and it is likely there are other sub-categories that are interconnected. Additionally, the sub-categories themselves could be furtherly differentiated or hierarchically integrated.

8.9 Reflections

Reflecting on the study brings to light many events, personal beliefs, and experiences. The pilot study took place before the COVID-19 pandemic impacted upon national and international education systems. Since that time, teachers have had to enhance their use of ICT to support teaching and learning through the provision of emergency remote teaching and learning to help students to continue their education. Moreover, technology has continued to develop at a rapid pace, access to technology at primary schools has improved, and the sophistication of the tools available to the teachers and students has also enhanced. All of these factors have enhanced the potential of technology enhanced learning for educators.

During this time, my own skills have advanced. For example, during the pilot study my initial analysis of the participants data involved attempts to apply quantitative methods to the qualitative data that had been collected. This involved going as far as counting the frequency of pedagogy terms that could be categorised (as traditional, individually constructivist, socially constructivist, and socio-cultural) in the data and then attempting to apply t-tests to demonstrate changes in beliefs between iteration one and iteration two.

This has been a huge learning curve for me as a researcher and as a practitioner – a teaching principal at primary school level. I believe that I now approach my roles more strategically and with a greater emphasis on planning, implementing, evaluating, and reflecting. I feel that I can get tasks completed to a higher level of quality in a much shorter time space and that my ability to think and communicate is enhanced in clarity. I am also confident that my teaching and learning at school is of a much higher quality and that the students' learning experiences have been enriched when using and not using ICT.

I have also developed a much deeper respect for teachers, a deeper awareness of the pressure they are under day-to-day in their classroom settings, and more patience towards teachers who have not jumped on board the ICT-enhanced learning train as quickly as others have. Looking back to when I first began teaching, ICT infrastructure at school was limited, constantly breaking down, unreliable, and in many cases, unable to support the delivery of the sophisticated pedagogy that is now achievable.

There is much more to uncover about the relationship between teachers' pedagogy beliefs and their use of ICT to support 21st century teaching and learning at school. Although I recognise that this is quite a challenging field of research, I am eager to continue in this field. The study of beliefs is complex. In many ways, beliefs are like the Greek god Proteus who could foretell the future but would always change his

shape to avoid doing so. This is quite similar to the study of beliefs. Making teachers' beliefs explicit is challenging; moreover, there is much evidence that teachers, like all humans, rarely, if ever, make their internal beliefs explicit. Furthermore, the differences between espoused and enacted beliefs means that many of those beliefs teachers do make explicit are value-laden, contextual, and can change shape from one day to the next.

However, there is much to be learned from studying teachers and their beliefs. If, as is held by many authors, beliefs underpin attitudes, knowledge, and skills, then unlocking teachers' beliefs and finding processes for enabling teachers to change, refine, or form new beliefs is of huge benefit to education systems both nationally and internationally. I am hopeful that this study has built upon existing literature in this area and has shed new perspectives on this area of study. Moreover, I am confident that the 4D model and the metaphor construction and reconstruction process are valuable contributions to the field.

8.10 Chapter Summary

This chapter has presented the discussion and conclusions from this investigation. It has also discussed its strengths and limitations, its scope and transferability, and some of the ethical considerations that presented as challenges. It has made some recommendations for future research in this area and ended with a personal reflection.

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Appendices:

Appendix 1: Information Email

Dear colleagues,

You are receiving this email in reply to your expression of interest towards a research project that I am carrying out this academic year.

The research project engages teams of teachers from different schools in the co-creation, implementation and evaluation of innovative digital educational practice from a range of pedagogic orientations at school.

The study process is as follows:

September - November

- 20 minute online reflection on your current beliefs about teaching and learning with technology.
- Meet three times with your teammates - approximately 1.30 hrs each
- Implement three technology enhanced lessons with your own class
- Online focus group with you and your teammates - approximately 30 mins
- Review your reflection - approximately 20 mins
- Online interview - approximately 30 mins

January - March

- Review your reflection - approximately 20 mins
- Meet three times with your teammates - approximately 1.30 hrs each
- Implement three technology enhanced lessons with your own class
- Online focus group with you and your teammates - approximately 30 mins
- Review your reflection - approximately 20 mins
- Online interview - approximately 30 mins

***Your total time commitment is approximately 12 hours across one school year**
***The project aligns with Croke Park hours criteria**
***Your team sets your own dates and times to meet online**
***All meetings will take place online this year**

Appendix 2: Metaphor Form

Creating Reflective Metaphors

Information for participants:

For this reflection you are tasked with creating metaphors about teaching and learning with technology.

Constructing your metaphor of teaching and learning with technology is an important component of the 4D model. By constructing a metaphor, you can make implicit knowledge explicit through reflection on and representation of the concepts related to teaching and learning. What the metaphor construction task will do is help you reflect upon and identify your beliefs about teaching and learning before your experiences with the 4D model. Unexamined, our implicit beliefs and tacit knowledge may remain undeveloped and serve to reinforce and support classroom practices. This is a good thing if our beliefs are sophisticated and informed by current theories and authentic experiences. Thus, it is envisioned that your metaphors will evolve and develop over the course of your experiences with the 4D model.

Examination of alternative metaphors can empower you as a teacher to examine your own assumptions. Thus, you will be responsible over the course of the 4D model for reflecting on your metaphor and making any changes to it that you see fit in light of your new experiences.

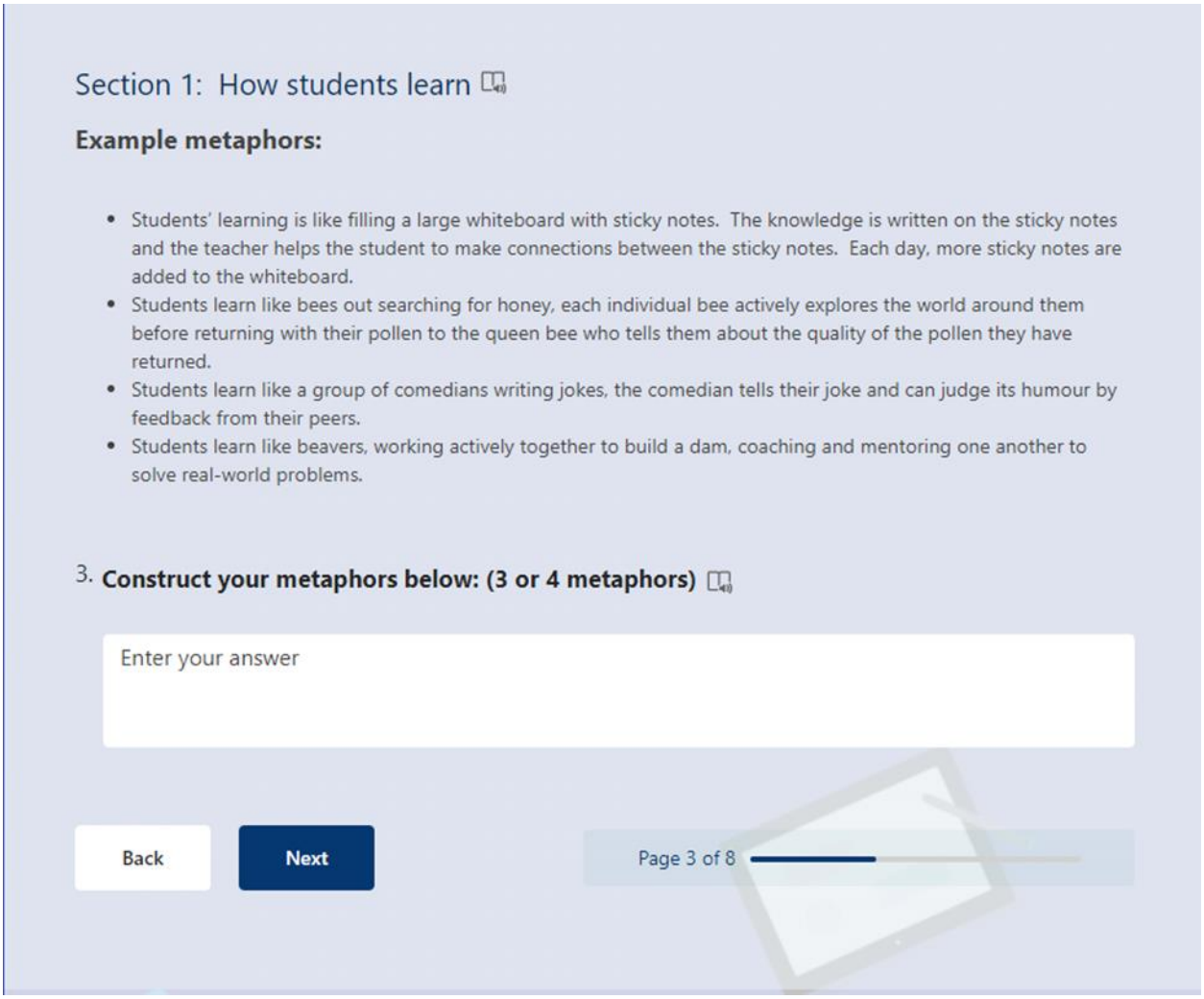
Your metaphor should be detailed enough to incorporate reference to theories of learning, design principles, student progression, assessment and feedback and example activities.

As such, you are tasked with constructing your own personal metaphors about the educational use of technology at school under the following headings:

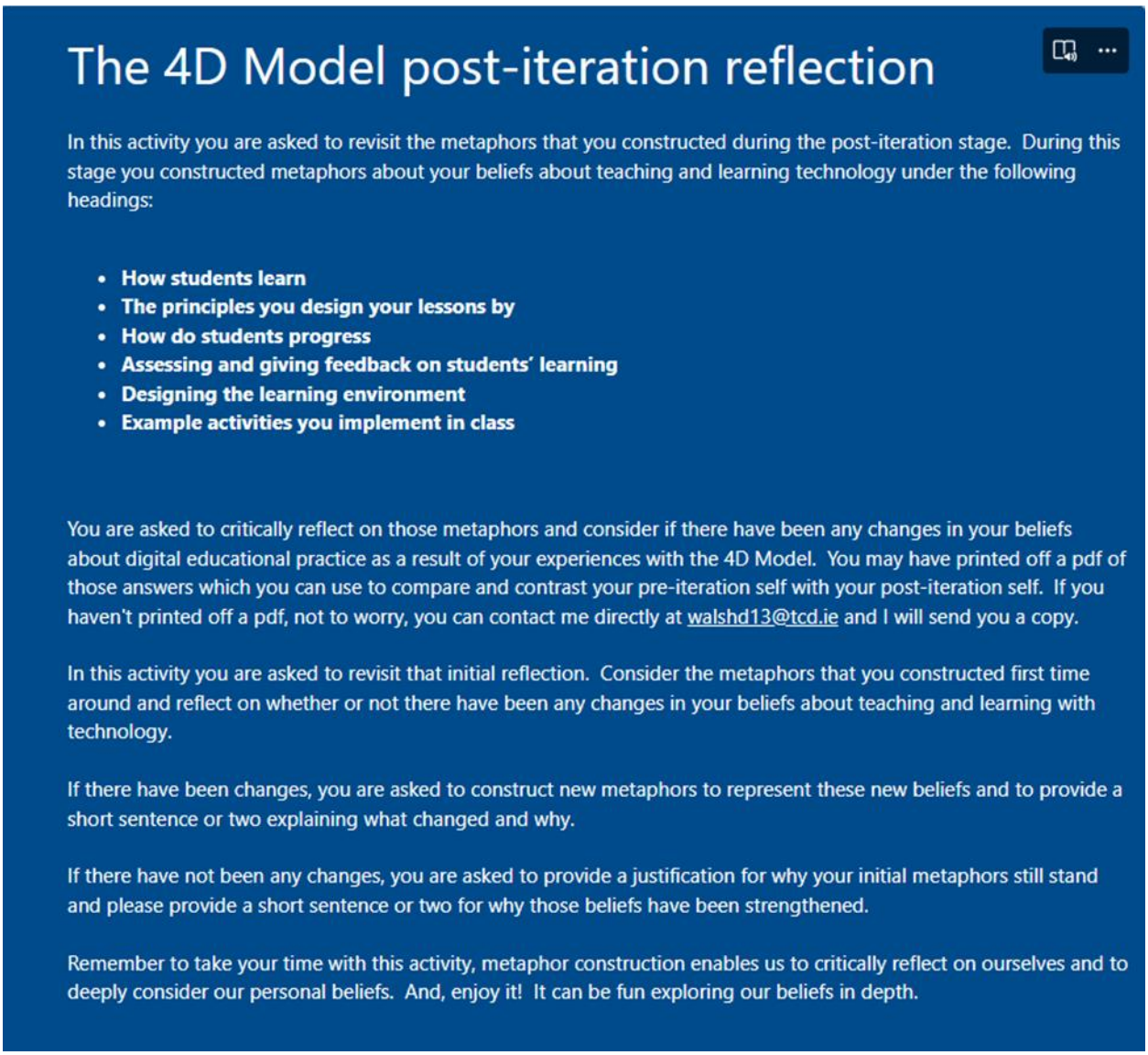
- **How students learn**
- **The principles you design your lesson by**
- **How do students' progress**
- **Assessing and giving feedback on students' learning**
- **Designing the learning environment**
- **Example activities you implement in class**

Each heading should consist of no less than 50 words, approximately 3/4 metaphors. Each question is optional. Feel free to omit a response to any question; however the researcher would be grateful if all questions are responded to. Example metaphors are provided in each of the following sections.

Appendix 3: Example Metaphors for Participants



Appendix 4: Post-Iteration Metaphor Reconstruction Form



The 4D Model post-iteration reflection

In this activity you are asked to revisit the metaphors that you constructed during the post-iteration stage. During this stage you constructed metaphors about your beliefs about teaching and learning technology under the following headings:

- **How students learn**
- **The principles you design your lessons by**
- **How do students progress**
- **Assessing and giving feedback on students' learning**
- **Designing the learning environment**
- **Example activities you implement in class**

You are asked to critically reflect on those metaphors and consider if there have been any changes in your beliefs about digital educational practice as a result of your experiences with the 4D Model. You may have printed off a pdf of those answers which you can use to compare and contrast your pre-iteration self with your post-iteration self. If you haven't printed off a pdf, not to worry, you can contact me directly at walshd13@tcd.ie and I will send you a copy.

In this activity you are asked to revisit that initial reflection. Consider the metaphors that you constructed first time around and reflect on whether or not there have been any changes in your beliefs about teaching and learning with technology.

If there have been changes, you are asked to construct new metaphors to represent these new beliefs and to provide a short sentence or two explaining what changed and why.

If there have not been any changes, you are asked to provide a justification for why your initial metaphors still stand and please provide a short sentence or two for why those beliefs have been strengthened.

Remember to take your time with this activity, metaphor construction enables us to critically reflect on ourselves and to deeply consider our personal beliefs. And, enjoy it! It can be fun exploring our beliefs in depth.

Interview protocol

Introduction:

Thank you for participating in this cycle of the 4D model and thank you for agreeing to the individual/group interview online. It is important to re-inform you that the interview is being recorded for research purposes and I am seeking to gain a deeper understanding of the reasons for changes in your beliefs and practice with technology following your experiences with the 4D Model. You may refuse to answer any question in this interview. If you have no further questions I will begin the recording with your consent.

Could you take me through your experiences with the 4D model and outline the process through which you achieved your goals?

Do you think there have been any changes in your beliefs, your day-to-day practice, and/or your student learning outcomes as a result of your experiences?

Could you highlight any specific experience that afforded or construed these changes?

Was there any positive or negative feedback from peers, parents, principal, or board of management and what impact did this have?

How do you feel the different orientations on teaching and learning aligned with your existing school culture?

Could you discuss your beliefs about Knowledge Acquisition teaching and learning?
Could you discuss your beliefs about Knowledge Deepening teaching and learning?
Could you discuss your beliefs about Knowledge Creation teaching and learning?

How did you as an individual contribute towards achieving the goals?
How did the team afford or construe any changes in your beliefs about teaching and learning?
How did the team roles afford or construe any changes in your beliefs about teaching and learning?
Were there any explicit rules adopted by the team that afforded or construed change?
Were there any tacit or implicit rules adopted by the team that afforded or construed change?

If there anything I haven't asked you, or any other activities or anything else you have reflected on that you would like to talk about that I haven't mentioned?

Appendix 6: Knowledge Acquisition Rubric

Knowledge Acquisition

	CURRICULAR GOALS FOR TEACHER TRAINING	TEACHER COMPETENCY (Teachers can ...)	OBJECTIVES (Teachers should be able to ...)	EXAMPLE ACTIVITIES
ASPECT 3 *Pedagogy*	**ICT-enhanced Teaching.** Teachers integrate technologies, tools and digital content to support teaching.	Make appropriate ICT choices to support specific teaching and learning methodologies.	**KA.3.a.** Choose appropriate ICT solutions in teaching to support students' acquisition of subject knowledge.	Describe how the use of ICT can support and supplement existing classroom teaching. Teachers investigate how ICT can ensure the engagement of students of different abilities, ages, genders, and socio-cultural and linguistic backgrounds, offer higher levels of productivity, and provide greater professionalism to their teaching.
			KA.3.b. Devise lesson plans that incorporate ICT-supported activities to support students' acquisition of subject knowledge.	Author, share and comment on lesson plans that incorporate different roles for ICT. Lesson plans might foresee ICT providing tutorials and drill-and-practice exercises or providing access to a collection of accessible, multilingual digital resources to be manipulated and reinterpreted.
			KA.3.c. Use presentation software and digital resources to support instruction.	Demonstrate the use of presentation software and incorporate additional inclusive and accessible digital media such as audio, video, animations, and virtual and/or augmented reality to supplement subject content in an interesting and engaging way.

Appendix 7: Knowledge Deepening Rubric

Knowledge Deepening

	CURRICULAR GOALS FOR TEACHER TRAINING	TEACHER COMPETENCY (Teachers can ...)	OBJECTIVES (Teachers should be able to ...)	EXAMPLE ACTIVITIES
ASPECT 3 *Pedagogy*	**Complex Problem-solving.** In collaborative, project-based learning, students explore a subject deeply and bring their knowledge to bear on complex, everyday questions, issues and problems.	Design ICT-supported project-based learning activities and use ICT to facilitate students to create, implement and monitor project plans, and solve complex problems.	**KD.3.a.** Describe how ICT can support project-based learning.	Describe how different technologies – appropriate for different grades and subjects – can support project-based learning tasks, such as student research, group communication, and presentation of findings.
			KD.3.b. Identify a real-world problem to support project-based learning.	Discuss characteristics of authentic problems that incorporate key concepts; examine examples of such problems; and have students generate examples, such as the need to improve crop productivity, to market a product, or to ensure gender equality in programmes.
			KD.3.c. Identify and evaluate resources that support project-based learning.	Analyse online materials to identify key features of the materials that support deep understanding. For example, do the resources offer alternative perspectives for the students to debate and research? Might the collection by students and analysis of big data be appropriate to solve their particular problem?
			KD.3.d. Design learning activities to engage students in reasoning with, collaborating on, and solving real-world problems.	Design student activities that allow students to collaborate to identify solutions to a real-world problem. Identify technology that can support these activities, such as the use of mobile technologies and social networking groups to encourage discussion and access to outside expertise. Use public spaces such as libraries and museums. Alternatively, encourage students to work together to write code to provide a solution to a specific community challenge, for example the need for more efficient traffic lights.

			KD.3.e. Structure lesson plans and learning activities that describe project-based learning.	Synthesize project-based learning ideas into a lesson plan. Identify how the lesson will be launched, how students will initially be confronted with the problem, how they will access resources, how they will engage with activities, what the final output will be, and how students will be assessed.
			KD.3.f. Implement collaborative, project-based lesson plans, and provide guidance to students towards the successful completion of their projects.	Implement and facilitate a problem-based learning initiative where the teacher supports and guides student-centred learning, taking into account considerations of different abilities, ages, genders, and socio-cultural and linguistic backgrounds.

Appendix 8: Knowledge Creation Rubric

Knowledge Creation

	CURRICULAR GOALS FOR TEACHER TRAINING	TEACHER COMPETENCY (Teachers can ...)	OBJECTIVES (Teachers should be able to ...)	EXAMPLE ACTIVITIES
ASPECT 3 *Pedagogy*	**Self-management.** Students work in a learning community in which they are continually engaged in creating knowledge products and building upon their own and one another's knowledge and skills.	While determining learning parameters, encourage student self-management in student-centred and collaborative learning.	**KC.3.a.** Explicitly model their own reasoning, problem-solving and knowledge creation while teaching students.	Model – and ask students to emulate thoughtfulness, curiosity, creativity, good interpersonal skills and self-regulation – when coordinating students involved in collaborative group work.
			KC.3.b. Design online materials and activities that engage students in collaborative, problem-solving research.	Devise a set of activities that task students to work together to produce a digital product or artefact or develop a virtual environment. Support teams of student research and curate a web-based, VR or AR exhibition. Alternatively, students can be required to create a series of infographics on curriculum topics.
			KC.3.c. Help students design project plans and activities that engage them in collaborative, problem-solving research or artistic creation.	Plan a lesson, prior to a big project, to provide students with organizational skills. Encourage students to develop project plans with activities, timelines, milestones and allocation of responsibilities for each project team member.
			KC.3.d. Help students create digital media resources that support their learning and interaction with other audiences.	Identify and alert students to media tools that might prove useful for their projects. Consider mobile apps to edit photographs and video, graphics packages that support the design of infographics, website builders, and alternative publishing options to reach a wide audience.
			KC.3.e. Help students reflect on their own learning.	Devise a set of milestone activities within a project that encourage students to reflect on their learning processes. Consider student blogs or video diaries for recording and sharing reflective experiences.

Appendix 9: Example Memo 1

Memo
1. Concept: Organisation 04/06/2020 "*Well, do you know I suppose no more than any part of teaching Dermot you constantly think something might work and it doesn't always work even in terms of some of the technology that we thought we might start out with that we've actually changed it to something that's more accessible and even in terms of just even organizing the lessons you know initially we thought we'd work with each child would work individually you know and it actually works better when they are working collaboratively working in groups so in that sense you know no more than you know working on a lesson I find technology fantastic because it keeps me organised even down to just using a PowerPoint rather than having to say look up this website here I'd have the links ready to go on the website in terms of using technology it certainly makes me more organised as a teacher.*" In this data, the participant is talking about the impact technology has on classroom organisation. The teacher is talking about the impact which technology has on her organisation. The teacher is talking about the impact that technology has on the students' learning organisation. For example, when the teacher says that initially, they had planned to work with each child individually, this would be a traditionally organised classroom environment. Later the participant says that 'actually' it works better when the children are working collaboratively. This is interesting because it suggests that the teachers' original intention, to organise the class in a traditional way has been changed. The change is indicated by the phrase 'we've actually changed it to something that is more accessible'. I don't know what the participant means by 'accessible' - could this mean that they are able to have more students working on a single computer instead of groups of individual students working on one computer each, or does the teacher mean that what they had initially planned to do wasn't 'accessible'? The teacher also makes a comparison between technology use from the student's perspective and technology use from the teachers' perspective. From the teachers' perspective the technology helps them to be more prepared for the lesson, hyperlinks enable them to go straight to a website for example instead of having to search for URL's or type in URLs. This may suggest that technology also can be used to quicken up the pace of the lesson. The teacher is also talking about professionally experimenting when she talks about 'you think something might work, and it doesn't always work', sometimes it is the technology's fault, but we can make a comparison and say that it may not always be the technology's fault, it can also be the teachers' fault or the students fault when things don't work. Maybe fault is not the correct term here.

On reflection of this memo, there appears to be a more meta-level term here which may be more appropriate. If the teacher is talking about and making distinctions about technology assisting with organisation in the classroom it may be possible to abstract the term 'organisation' to the term 'pedagogy'. Using this term, it is possible to begin to identify properties such as 'teaching' and 'learning'. Furthermore, it is possible to identify dimensions, such as 'students working individually' and 'students working collaboratively' and 'students working in groups'. The teacher also makes a comparison after discussing the students working collaboratively, she refers to how technology helps her using the phrases 'you know for me' and 'I find'. This may suggest that the teacher is also making a distinction between her own teacher-centred view of technology and a student-centred view of technology. This may mean that we could add the dimensions 'teacher-centred' and 'student-centred' to the overarching concept of 'pedagogy'.

Memo

2. The Right Tools
04/06/2020

"*I suppose, sometimes, Dermot it's down to not having the right tools like for example, one of the things we had anticipated using was Photostory, but despite the fact that we had ordered headsets and microphones to be able to use Photostory like they haven't arrived. Like you know we ordered them quite a while ago. Sometimes it's down to the technology you have so we just went with Google Slides instead because it was free it was easier to access, and we didn't need to have the voiceover that we would have wanted with the Photostory so I suppose that's one example*."

Here the participant is talking about how their initial plan to use Photostory changed to using Google Slides because the headsets and microphones which they had ordered hadn't arrived. The participants used Google Slides because it was accessible and free, and they didn't need to have voiceover, which they would have wanted if they had purchased Photostory. The participant doesn't specifically mention the impact this decision had on the teaching and learning but she does mention that Google slides is easier to access, and it is free, which suggests that 'easier access' and 'free' justifies the decision not to purchase Photostory.

We could ask a 'what if' question here and wonder what would have happened if the headsets and the microphones had arrived earlier and 'what if' they had used Photostory instead of Google Slides. How would the teacher justify the use of Photostory? Would it have been as accessible? Would they be able to justify the cost of the headsets, microphones and Photostory software? It is interesting to think of the opening line in relation to the 'what if' analysis, the teacher mentions 'sometimes it's down to not having the right tools' indicating that they thought Photostory, headsets and microphones were 'the right tools', making a comparison does this mean that they thought that Google slides were the 'wrong tools'? and what is the outcome? Has the teaching and learning been diminished by using the 'wrong' tools? or have the teachers found new ways of using the 'wrong tools' in order to achieve the learning outcomes? There is a suggestion that having the wrong tools has led to creativity and being able to problem-solve, it would be interesting to find out what impact this had on the classroom organization.

For example, in the previous memo, the participant mentions they had initially planned to have the students working individually, but they made it more 'accessible' to the students having them work collaboratively. Is there a link between 'accessibility' used in both chunks of data? Did having the 'wrong tools' result in the students working collaboratively instead of working individually? I will create a new node titled 'accessibility' and link the relevant text from this node with the relevant text from the previous node.

Appendix 11: Example Memo 3

Memo
3. Accessibility Definition: The quality of being easy to obtain or use This node was created as a result of reflections on Memo 1 and Memo 2 where I noticed the use of variations of the word accessibility. In the first node the teacher talks about changing the technology they were going to use to something that is more 'accessible'. In the second node the teacher talks about using Google slides because it was easier to 'access'. The teacher does not mention whether it is more 'accessible' for the teachers or the students, however in the first instance there may be a link between 'accessible' and organising the lessons as the participant mentions that their initial plan was to have the students work individually, however, the students ended up working in groups and working collaboratively which the participant notes 'actually' works better. In the second instance the participant specifies that the technology 'Google Slides' was easier to access than 'Photostory'. The participant also adds the qualifier 'we didn't need to have the voiceover we would have wanted with the Photostory'. If I 'flip flop' this term and say, 'we needed to have the voiceover, we wanted Photostory' it suggests that a recorded voiceover was only possible with 'Photostory' so, why did the participants decide they didn't need the voiceover? and what effect did this have on the teaching and learning activity? And, as a result of their not needing the voiceover - did this mean the need for headsets and microphones vanished? and did this mean that the teachers didn't have to work with each child individually? For example, if the students had to record a voiceover, would this have necessitated taking the students, individually out of the classroom to a quieter area where they could record the voiceover, would this have meant they would have to have been monitored by a teacher? would this have meant that the students wouldn't have been able to work collaboratively? Would this have meant that when the teacher was taking the student out to record the voiceover, they would have given direct instruction to the child on how to use 'Photostory' which may have reduced the learning which went on when the students were working collaboratively on Google Slides, which, according to the teacher 'actually worked better'?

Appendix 12: Memo Authentic Situated Experiences

Code:	Authentic Situated Experiences

"*To be fair, Dermot as I say, I'm new to fourth this year, as a year group, I had come from second, so the ability of the children in fourth is obviously a bit stronger technology-wise specifically and in general as well but in general you know they are stronger learners*."

"*so has my experience changed as a result of the project itself, so if I literally focus on the history project itself, to be honest I would say that I broaden it that my experience in this first term in fourth class has definitely changed from my experience in the last four years in second class be it using technology the lads in fourth class are more capable and it's not just this project it's the whole term because I have used the same technology not just for this history project I've used it in other curricular areas as well so if anything again the history project the digital schools project has confirmed my general experience from fourth class in the entire term. But that has changed my experience for the previous four years because I can take them further as it were both technology-wise and planning-wise in general*"

Node: Need for authentic situated experiences

28/08/2021

In this text, the participant mentions that she has changed classes and is now teaching new students compared to the previous year. She has learned that these students are more capable. A question arises about teacher CPD during the summer months when the teacher learns new skills and strategies but she does not have the experience of teaching those learners in an authentic setting and so even though the CPD may have been tailored to a class level, it is unlikely that until the teacher actually enacts the new learning with the class, they will be able to master the lesson and appropriately cater for the actual rather than perceived needs of the students.

Appendix 13: Memo Team

Code:	Team

"*Yeah okay well I suppose we set ourselves a target of Christmas time that we'd get through, again I suppose we all need deadlines to work through and then how we'd come back together in January and see if we could repeat the three stages again so I suppose that put a deadline on the lot of us and then we decided we used Google Slides and I would initially turn to PowerPoint because I'm old fashioned I know how it works, it works well I can pick it up this minute but they had said no we will use Google Slides and I said okay and I have to go and work with Google slides so I suppose again you know the lazy option for me would be to say no I'll just use PowerPoint it'll force me now to use google slides and work with it*."

Memo: Teamwork can limit persistence with established habits

28/08/2021

In this quote, the teacher talks about how they moved away from a reliance on Microsoft PowerPoint towards utilising Google Slides because of the team's decision-making. Whereas usually the participant would have used PowerPoint they have now gone on to use Google slides because of the referent power of their teammates.

Appendix 14: Memo Authentic Situated Experiences

Code	Authentic Situated Experiences

"*Do I feel I suppose my feeling is that technology has definitely helped us I had that before in iteration one absolutely, so it continued as part of this iteration so did my feelings change well, they were strengthened as it were they are affirmed."*

"My thoughts in relation to teaching and learning with technology have been affirmed so I see their value I see the value of it to the teacher and to the learners."

"*I think it is suitable it still works it's not like I'm getting to this stage and I'm thinking oh why did I choose that I'm still happy with what I chose. When I wrote it first it was a basic metaphor and when we started off the project it was tough integrating all this technology, from having no technology in the classroom to having all this technology so I did feel that after the first two or three lessons that I was like a student teacher again that I didn't know whether I was coming or going but now if I was to do something tomorrow or I did something I would be very at ease taking out the laptops, getting started on something and I wouldn't feel as nervous as I did back in November and December*."

Memo: Authentic situated settings affirm previously established beliefs

28/08/2021

This is an interesting node as it can intimate a sense of trepidation because in this quote the participant states that her beliefs were affirmed as a result of her authentic situated experiences.
This means that depending on the pedagogical orientation of the experience, e.g., if the experience was only oriented towards traditional pedagogy, then the participants may only reaffirm beliefs about previously established practice.
Whereas with a multi-pedagogical approach, the participants are witnesses and experiencers of digital educational practice from a range of orientations.

Appendix 15: Memo Multiple Iterations

Code:	Multiple Iterations

"*So again the structure the definite structure of the three phases without a doubt it gives again so this new model so the terminology is new to us so this is our second iteration using this model I really like the way it is structured I like the way that there is a definite sequence to the model I was more sure this time round because it is the second iteration I was more sure myself how I'd go about this iteration this programme of work so when we discuss our objectives way back at that planning meeting I was sure about where this was going to go so it was lucky for us for me that it is 2nd iteration and life is a bit easier for me and it was affirmed that obviously, 2nd time round is always better and even looking forward to next year obviously we are moving away to a new subject area next year but we'll go through the same process again so yeah good."*

Memo: Looking for habits to develop

28/08/2021

This memo is linked to a piece of text where the participant discusses the process of the model, i.e., going through the three phases of the model, Knowledge Acquisition, Knowledge Deepening, Knowledge Creation at the end of the quote the participant discusses how they will go through the process again. It appears to me that the participant is discussing how they are trying to develop a habit so that when they return to practice, they will have mastered/coordinated action over the new process, and they will be able to integrate it into their teaching and learning at school.

The participant also talks about not being so nervous if they were to do this again - nerves and apprehension are often a consequence of meeting an ill-structured problem, however the ability to gain confidence is a sign of coordination.

Appendix 16: Memo Co-creating, implementing, and evaluating from multiple orientations

Code:	Co-creating, implementing, and evaluating from multiple orientations

"*Well do you know Dermot, I possibly haven't been using these terms but I would have used all of them in the past now admittedly technology literacy was probably the most common one that I used I would have used the knowledge deepening and adding to the knowledge creation you know I've worked as a PDST tutor and I'd know a lot of those things and I would have used some elements of it but what it did like was using the three together you know, they know there's something at the end of it if they complete it*." (Participant 1)

"*but I'd say is that there are aspects of my teaching that I have done all of them I or I had never categorised them or given them that name if you like so I would have always started off with let's call it you know if you are learning a new language in Irish you know so you're going to start off with the vocab so you are going to take it further and then you are hoping that your knowledge deepening and then your knowledge creation and if you get that far with your teaching of gaeilge and so forth then you have done very well*" (Participant 2)

"*Yes I think it gave a more structured approach and you know it opened my eyes and you know that you have to, checklist, you know that people probably go in to any classroom with certain assumptions with any project so just starting with the basic of everyone say with tech lit, you know now we have a starting point a level playing field, the knowledge deepening is a very good one and people are learning along the way and the knowledge creation is paramount at the end of the day because, that's where the kids get involved that's where the children are involved and as a teaching approach yeah, I like, I think it works, it's a planned structure, you know exactly what stage, you are at and you know where you are going and you know where each step is where you need to develop this.*" (Participant 3)