‘Leaping-in’ and ‘leaping-ahead’: A hermeneutic phenomenology study of teachers’ lived experiences with physical computing in secondary schools

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

While research on physical computing has often focused on curricula and student outcomes, the lived experiences of teachers remain underexplored. This study addresses that gap by conceptualising physical computing as a practice shaped by both care and technical demand. Drawing on a hermeneutic-phenomenological approach informed by Heidegger's notions of care (Sorge) and Being-with (Mitsein), Gadamer's fusion of horizons, and Moustakas's practice of indwelling, the study engaged five heads of computing departments in semi-structured interviews conducted over a period of thirteen months, producing forty-two crafted stories for interpretive analysis.

Analysis generated four interrelated themes: ***leaping-in*** (troubleshooting as care), ***leaping-ahead*** (anticipatory planning), ***mentoring*** (relational scaffolds for novices), and ***professional identity*** (continually reshaped yet grounded in anchors such as equity and computational thinking as literacy). Together, these themes underpin the Unified Model of Care-Driven Physical Computing Pedagogy.

The thesis makes three contributions to knowledge: (1) it reframes physical computing pedagogy as relational and embodied by placing care at its centre; (2) it demonstrates the methodological value of crafted stories as a vehicle for hermeneutic interpretation, forming the foundation for the Unified Model of Care-Driven Physical Computing Pedagogy; and (3) it offers new insight into how teacher identity and affect shape curriculum development. The study shows that embedding physical computing sustainably requires more than equipment or training; it depends on organisational cultures that recognise care as pedagogical expertise and safeguard teachers' capacity for professional judgement. When such recognition is present, physical computing can move from a peripheral initiative to a sustained, human-centred practice within the curriculum.

Keywords: physical computing; hermeneutic phenomenology; teacher identity; care; crafted stories; pedagogy; computing education.

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List of Abbreviations

BBC	British Broadcasting Corporation
BETT	British Educational Training and Technology Show
CAS	Computing at School
CER	Computing Education Research
CPD	Continuing Professional Development
CQF	Computing Quality Framework
DfE	Department for Education
EAL	English as an Additional Language
ICT	Information and Communication Technologies
IT	Information Technology
K-12	K means Kindergarten
KS	Key Stage (e.g., Key Stage 4)
Ofsted	Office for Standards in Education, Children's Services and Skills
MIT	Massachusetts Institute of Technology
NCCE	National Centre for Computing Education
NYU	New York University
QTS	Qualified Teacher Status
STEM	Science, Technology, Engineering and Maths

Glossary of Phenomenological Terms

Aletheia	Associated with meaningfulness
'Being-in'	Means those things which are familiar to me
Chronos	‘Clock time’
Dasein	Literally ‘existence’, being there
Hermeneutics	Interpretation
Horizontverschmelzung	Gadamer's ‘fusion of horizons’ metaphor
Kairos	An ‘opportune moment’
Leaping-ahead	A supportive intervention that helps another person move forward by strengthening their agency and understanding.
Leaping-in	An intervention where one person steps in and takes over another’s task or problem, potentially reducing the other’s agency.
Mineness	Existence in terms of our own existence
Mitsein	Literally ‘Being-with’
Miteinandersein	Being-with-one-another
Movement	The purposeful shifting of attention between parts and whole (and between experience, interpretation, and context) through which meaning is formed and re-formed.
Present-at-Hand	Something that exists
Ready-to-hand	Practical relationship with tools
Sorge	Heidegger’s notion of ‘care’
Veritas	Heidegger used to describe a distinguishable truth

Chapter 1 Introduction

1.1 The Context

This section introduces hermeneutic phenomenology as the interpretive framework for exploring how secondary computing teachers in England experience and make sense of physical computing. Rather than presenting the methodology in isolation, the study situates it within the broader context of embedding physical computing in schools. The inquiry traces the progression from initial assumptions through methodological choices to an interpretive analysis of teachers' lived experiences, thereby strengthening the study's credibility (Standing, 2009). Building on Creswell and Poth's (2016) emphasis on the researcher's interpretive role, this chapter explains why hermeneutic phenomenology is particularly suited to capturing the lived meanings underpinning physical computing pedagogy. This framing signals the study's contribution: to show how teachers' everyday acts of teaching are simultaneously technical, relational, and identity-shaping.

At the centre of this inquiry are lived experiences: how teachers understood their classrooms before and after the 2014 computing curriculum reforms; how they integrate tangible hardware and teach programming into everyday lessons; and how past educational encounters inform present practice. As Todres and Holloway (2004) remind us, only those who have lived through a phenomenon can convey its essence. Accordingly, this study foregrounds teachers' own words and actions, aiming to uncover and critically examine taken-for-granted assumptions and habitual practices surrounding 'physical computing' embedded within routine pedagogical contexts (Giles, 2008; Willis, 2012; Van Manen, 2016). This focus enables a deeper understanding of the complexities and nuances that shape classroom enactments of physical computing.

Drawing on Heidegger's notion of Sorge (care) and Gadamer's concept of the fusion of horizons, the study explores how teachers' spontaneous troubleshooting, characterised as *leaping-in*, and their forward-looking orchestration, termed *leaping-ahead*, both reveal and continuously reshape their professional commitments and identities. My professional background, supporting computing teachers through subject knowledge enhancement and pedagogical development since the inception of the National Centre for Computing Education in 2019, has sensitised me to the practical opportunities and constraints inherent in teaching and learning with physical computing. This positioning both enhances my connection with participants and requires deliberate reflexivity to avoid over-identification, a balance maintained through critical self-questioning and systematic memoing.

Through an in-depth qualitative design involving three interviews with each of five experienced teachers, this study identifies thematic insights that contribute to expanding the literature on computing pedagogy. By closely attending to teachers' reflections, the research advances both ontological and practical insights: ontologically, by reframing care as a central, foundational dimension of physical computing pedagogy and practically, by offering evidence-based recommendations for teacher preparation, professional development, and school leadership teams to support the evolving demands of contemporary computing classrooms.

This opening chapter situates the study, outlines the problem it addresses, explains its significance and methodological stance, and closes with an overview of the thesis structure.

1.2 Problem Statement

Since the introduction of England's national computing curriculum in 2014, secondary school teachers have had to adapt their practice to accommodate new content, technologies, and pedagogical demands. Despite significant growth in international research on computing education, a persistent gap remains between the questions that researchers prioritise and the issues teachers themselves find most pressing (Denny *et a*l., 2019). Consequently, much of this work struggles to engage with the everyday realities of classroom practice.

A particularly pronounced gap exists in the domain of physical computing. In this thesis, physical computing is defined as the design and programming of interactive systems that connect code to the physical world through tangible hardware, most commonly microcontrollers paired with sensors and actuators (e.g., micro:bit, Arduino, Raspberry Pi Pico). In educational practice, this process involves students writing programs that read physical inputs, such as light, movement, or temperature, and trigger observable outputs, such as LEDs, sounds, or motor movement. This approach enables the learning of computational concepts through making, testing, and debugging. This definition aligns with Romeike and Przybylla's characterisation of physical computing as the design and realisation of interactive objects and installations, through which learners develop tangible products that manifest their ideas in the real world within constructionist and creative learning environments (Przybylla and Romeike, 2014). Existing literature has paid limited attention to the affective dimensions of teaching with physical computing, particularly how moments of breakthrough or breakdown are accompanied by affective responses such as enthusiasm, frustration, or anxiety.

Although physical computing has increasingly moved from extracurricular clubs into the formal curriculum, its affordances and challenges in classroom settings have been examined only partially (Przybylla and Romeike, 2017; Papamitsiou et al., 2020). Overlooking teachers' affective journeys risks misaligning interventions with lived realities, thereby undermining confidence or even provoking resistance. Crucially, sustaining physical computing in everyday schooling is not only a matter of resources or technical training: it also depends on relational support, including mentoring and peer scaffolding, which can make complex hardware–software work feasible for novices and more sustainable within departments. For this reason, mentoring is treated as a substantive element of the study's wider context and is examined explicitly in the literature review (Section 2.5).

The central problem addressed in this study arises from a dual gap: first, between researcher-driven agendas and teacher-centred concerns; and second, between technical accounts of the adoption of physical computing and the affective and identity dimensions of professional practice. By foregrounding the lived experiences of secondary computing teachers in England, the study interprets both their teaching strategies and the emotional and identity-related stakes embedded in them. It aims to generate findings that matter to practitioners, inform policy debates, and provide grounded guidance for sustaining a professional identity in computing education.

1.3 Research Question

Building on the theoretical and practical contributions outlined above, this study is guided by the following central research question:

What is the meaning of teachers' lived experiences with physical computing in English secondary schools?

To explore this question in depth, two sub-questions are posed:

(1) How do teachers describe their experiences with physical computing?

(2) What themes can be uncovered through the study of teachers' lived experiences?

1.4 Contributions of the Study

1.4.1 Introduction

Annells (1999) argues that the hallmark of phenomenological inquiry is its capacity to generate insights that reach beyond the immediate research setting. Consequently, the contribution of this thesis is articulated through three linked contributions to knowledge and practice:

1. It reframes physical computing pedagogy as relational and embodied by placing care at its centre, shifting attention beyond technical or cognitive outcomes to teachers' lived experiences.
2. It demonstrates the methodological value of crafted stories as a vehicle for hermeneutic interpretation, providing the interpretive foundation for the Unified Model of Care-Driven Physical Computing Pedagogy.
3. It offers new insight into how teacher identity and affect shape curriculum development in physical computing, including the emotional and identity-related stakes that existing research has tended to marginalise.

In addition, these contributions have practical relevance by foregrounding teachers' own accounts of working with physical computing. The perspectives presented here are not intended as universal prescriptions but rather as situated insights grounded in classroom realities. Such accounts can inform the design and adaptation of pedagogy, contribute to discussions about how teachers' professional identities are shaped and sustained, and encourage the development of policy frameworks that are more responsive to the everyday realities of classroom practice.

1.4.2 Theoretical Significance

Adopting hermeneutic phenomenology enables the transformation of lived classroom encounters into 'textual expressions of their essence,' inviting readers to engage with their own experiences as they grapple with new insights (Van Manen, 1999, p. 56). In a field still largely shaped by technical framings, phenomenology matters because it repositions computing pedagogy as relational and interpretive, rather than reducing it to the transmission of skills or knowledge. Although seldom employed in computing education, this methodology has already demonstrated its power to surface otherwise hidden dimensions of practice (Sentance and Waite, 2021). Drawing on Heidegger's metaphor of the cabinet-maker whose dialogue with wood discloses its potential form, this study positions the reader as a co-craftsman, moving back and forth between prior understandings and the rich 'crafted stories' drawn from teacher interviews.

Similarly, like Jenner's (2000) 'freezer of waterfalls' analogy, hermeneutic phenomenology interrupts the flow of classroom routine, making visible the nuance and complexity that familiarity tends to conceal. For computing education, this means slowing down practices often framed as technical routines so that their emotional and identity-forming dimensions can be recognised. This research extends existing scholarship by incorporating ontological care, emotional valence, and identity anchors into a field that has thus far focused primarily on curricular outcomes or cognitive benefits.

> *'A man who lives by a waterfall does not 'hear' the fall; it is such a familiar sound that it goes unnoticed. Yet, he notices the cry of the wild geese in the sky above when they fly through the autumn night. But let's say that the waterfall should freeze to ice overnight – then he notices the difference in an instant' - Jenner (2000, p.38)*

The study presents a computing teacher identity model that integrates self-identification, community belonging, agency, self-efficacy, task perception, and emotional landscape. It also develops a specialised mentoring discourse, showing how 'debugging grammars' and anticipatory routines serve as vital pedagogical tools. Finally, by modelling hermeneutic phenomenological story-craft, it offers a replicable analytic approach capable of preserving the integrity of each teacher's voice and illuminating the fusion of emotion, context, and meaning-making in a way that more mechanistic coding schemes cannot (Van Manen, 2016; Crowther et al., 2017).

Taken together, the contributions reframe physical computing pedagogy as a practice lived through relationships, care, and identity. The study offers a step towards strengthening the theoretical base of computing education, while also modelling a methodology that retains its complexity without losing sight of the human dimensions.

These contributions, in turn, provide the conceptual grounding for the research questions that follow.

1.5 The Rationale for Methodology

This study is interpretivist in its orientation. Epistemologically, it aligns with an interpretivist–constructivist view that educational realities are multiple, socially situated, and known through interpretation rather than 'discovered' as objective facts (Lincoln and Guba, 1985; Guba, 1990). It begins with the assumption that teaching cannot be reduced to a set of universal laws or technical procedures but must be understood through the meanings that teachers ascribe to their work. In this framing, my role is not to stand outside the phenomenon, but to work reflexively with my pre-understandings as part of the interpretive process, making visible how understanding is formed and revised through dialogue with participants and texts (Gadamer, 2013; Geertz, 1973).

Interpretivist research values depth over breadth, recognising complexity, variation, and context as essential to understanding how practice unfolds (Denzin and Lincoln, 2011; Hammersley, 2012, p. 29; Creswell and Poth, 2016, p. 24). For this reason, the study places teachers' lived experiences with physical computing at the centre of analysis. Classroom practice is treated as an interpretive activity shaped by values, relationships, and institutional conditions. The aim is not to generate broad generalisations but to build a textured account of how physical computing is integrated into teachers' professional lives and identities.

Hermeneutic phenomenology provides the methodological expression of this stance. Rather than stopping at description, the analysis engages with teachers' accounts to explore how meanings take shape and how these meanings continually reshape their teaching practice. The use of crafted stories, developed iteratively and returned to participants for comment, helped to preserve their perspectives while also creating room for dialogue between us. This process ensures that meaning is not imposed from outside but co-constructed, enhancing both authenticity and rigour.

This interpretivist–phenomenological approach is particularly well-suited to the study's aims. Physical computing is examined here not simply as a technical exercise but as a practice lived through bodies, relationships, and values. By taking this orientation, the study can foreground elements of teaching such as care, identity, and emotion that are often pushed to the margins in technocratic accounts of computing education. In doing so, it ties the research questions directly to a methodological stance that can do justice to the complexity of teachers' lived experiences.

1.6 What Brings Me to This Study?

1.6.1 Context of Personal Experiences with Physical Computing

My awareness of physical computing in the curriculum dates to Michael Gove's 2012 BETT keynote, which replaced ICT and introduced computing to the National Curriculum. That announcement, often recalled by participants as a disruptive turning point, also marked the moment I recognised how policy could reconfigure subject-knowledge expectations. At the time, as an ICT teacher, I saw the gap between the new demands and the patchy professional development available. Williamson (2017) later described this as a hurried and uneven reform process, which matched what many colleagues and I felt. To make sense of this, I turned to grassroots networks, local Computing at School branches and the early Raspberry Jam meet-ups. These modest gatherings, often just a handful of teachers, academics, and hobbyists in a classroom after school, created rare spaces to share ideas, test hardware, and admit when something did not work as planned. In retrospect, I recognise those evenings as early forms of situated, dialogical sense-making that hermeneutic phenomenology would later allow me to examine more systematically.

1.6.2 Pre-understandings

The years that followed deepened these impressions. Much of my professional work involved supporting secondary teachers as they experimented with physical computing, including micro:bits, sensors, and robotics. Sometimes I was delivering enrichment workshops, and at other times I drew on the emerging research literature to design CPD. What struck me most was the variety. In one school, physical computing was integrated into a robotics club; in another, it was briefly introduced in Year 9; in many, it was barely featured at all.

I did not frame this as phenomenological at the time, but I was already trying to make sense of differences by holding them against my own experiences. This process now feels akin to Gadamer's (2013) concept of horizons expanding through dialogue. These experiences also shape the epistemological stance of the study: I treat teachers’ accounts as situated meanings produced in context, and I approach research interviews as dialogic encounters through which understanding is co-formed rather than extracted (Lincoln and Guba, 1985; Guba, 1990). Each visit and each conversation shifted what I thought 'computing' meant in practice.

In the years before the creation of the National Centre for Computing Education, I considered returning to the classroom full-time. I still held QTS and was supporting staff, but I no longer felt 'current.' That realisation hit hardest when I volunteered at a local 'outstanding' school. After I taught a lesson on pair programming, the Head of Department told me:

> *'I can see what you're trying to do, but we don't teach like that here. When we give students an activity to complete, they do it on their own and in silence'.*

That exchange revealed how unspoken cultural assumptions about what counts as 'good teaching' can close down opportunities for collaboration or hands-on approaches.

These moments crystallised the focus of my research. They led me to ask: **What is the meaning of teachers' lived experiences with physical computing in English secondary schools?** Making my own assumptions visible became an essential first step in approaching that question phenomenologically.

1.6.3 Encountering the Phenomenological Research Approach

During this study, I experienced a series of moments where phenomenology 'clicked' and helped me see physical computing in a new light; what Gadamer (2013) describes as horizon-broadening became, for me, a gradual realisation that phenomenology was not only a philosophy but also a way of working that could frame this inquiry. It provided both a theoretical foundation and a set of practices that encouraged me to revisit the phenomenon with fresh eyes.

Reading, reflection, and rereading within the hermeneutic circle proved to be the most authentic means of staying close to the material. Working back and forth between transcripts, crafted stories, and theory required me to set aside assumptions and develop the unexpected in teachers' accounts.

Ultimately, it was this openness to uncertainty that proved most valuable, making hermeneutic phenomenology the approach best suited to capturing teachers' lived experiences with physical computing. Later chapters will demonstrate how this stance influenced my decision to work with crafted stories, which became the methodological foundation for analysis and the basis of the Unified Model of Care-Driven Physical Computing Pedagogy.

1.7 Introducing Hermeneutic Phenomenology as the Interpretive Stance for this Thesis

Hermeneutic phenomenology (HP) is the philosophical and methodological stance that underpins this thesis. HP does not treat analysis as a linear procedure. Instead, it assumes that understanding develops through an iterative ‘back-and-forth’ movement between parts and whole (the hermeneutic circle). Interpretation is refined through repeated engagement with texts (Gadamer, 2013; Heidegger, 1962; van Manen, 2016). In this study, that iterative movement operates across three sites. First, the literature review (Chapter 2) engages with concepts dialogically rather than treating the literature as a source of definitional fragments to be extracted and applied. Second, the analysis process (Chapters 3–5) develops meaning through successive readings of transcripts and crafted stories. Third, the writing itself acts as a mode of phenomenological inquiry rather than a neutral reporting stage (van Manen, 1999).

Table 1 provides a brief overview of the key HP terms used throughout the thesis. A fuller glossary of hermeneutic terms is provided in the preliminary pages. The intention is to make the interpretive logic explicit early, so later chapters can build on this framing without repeatedly re-explaining core terms.

Table 1: Key Hermeneutic Phenomenology Terms

Term	Working meaning in this thesis	Where it is applied
Hermeneutic circle	Understanding develops by moving between parts (extracts, episodes, claims) and the whole (teacher's account; across-case themes).	Ch.2 (reading literature dialogically); Ch.3–5 (iterative reading of transcripts/crafted stories).
Fusion of horizons	Interpretation emerges through the encounter between my pre-understandings and participants' accounts/literature, producing revised understanding.	Ch.1 positioning; Ch.2 conceptual framing; Ch.5 discussion.
Movement	A shift in understanding produced by iterative reading/writing (not a 'step' in a procedure).	Ch.3 analysis cycle; Ch.4–5 theme development and interpretive refinement.
Leaping-in	Forms of immediate, hands-on support that resolve breakdowns (used here as an analytic concept for teacher action).	Ch.4–5 theme(s) and crafted story interpretation.
Leaping-ahead	Support that enables capacity/independence over time (used here as an analytic concept for teacher action and departmental planning).	Ch.4–5 theme(s) and crafted story interpretation.
Indwelling	Sustained attentiveness to the phenomenon through dwelling with texts and episodes until meanings clarify.	Ch.3 interpretive process; Ch.4 crafted story reading.
Aletheia (unconcealment)	'Truth' as disclosure that becomes visible through interpretation, rather than correspondence to a single objective account.	Ch.5 discussion of claims/insights and their limits.

1.8 Thesis Outline

This outline provides an overview of the EdD structure, following the sequence recommended by Peoples (2020) for phenomenological research theses. This thesis comprises six chapters, each building towards a deeper understanding of teachers' lived experiences with physical computing.

Chapter One sets the scene. It introduces the research problem, establishes the study's significance, and explains the methodological approach. It also positions me as the researcher, illustrating how my professional background and prior understandings influence the inquiry. In this way, the opening chapter provides both orientation and rationale.

Chapter Two turns to the literature. Rather than offering a simple survey, it contextualises physical computing within the English curriculum and situates the study against international research. It also examines how phenomenology has been applied in education, laying the groundwork for why a hermeneutic approach is both relevant and necessary in this context. Importantly, it also introduces mentoring as part of the institutional and relational infrastructure that supports computing teachers, through a dedicated section (Section 2.5), to frame why mentoring is relevant to sustaining physical computing practice in schools.

Chapter Three outlines the methodology and design. It explains how participants were selected and how data were generated and analysed. Importantly, it also outlines the philosophical underpinnings of hermeneutic phenomenology, demonstrating how this orientation informed every stage of the research.

Chapter Four presents the findings through a series of crafted stories. These stories are the primary means by which teachers' lived experiences are interpreted. Organised around five themes, they demonstrate how meaning emerges from the ordinary and the everyday, while hermeneutic appropriation allows new insights to surface.

Chapter Five develops the interpretive discussion. Here, the crafted stories are brought into dialogue with the research questions and the existing literature. The aim is to show how the study extends current understandings of computing education while also contributing to methodological debates in phenomenological research.

Chapter Six concludes the thesis by drawing together the study's main contributions and acknowledging its limitations.

Together, the six chapters build a cumulative account of teachers' lived experiences with physical computing, showing how a hermeneutic-phenomenological lens addresses the central research question: ***What is the meaning of teachers' lived experiences with physical computing in English secondary schools?*** And its sub-questions on description and thematic interpretation.

Chapter 2 Literature Review

2.1 Introduction

Through a hermeneutic-phenomenological lens, this literature review examines the emergence, evolution, enactment, and institutional support of physical computing in English secondary schools. It treats seminal tangible bits (Ishii and Ullmer, 1997), policy texts, hardware artefacts, and teachers' accounts as equal participants in an interpretive dialogue (Boell and Cecez-Kecmanovic, 2010; Alsaigh and Coyne, 2021). To maintain analytical depth and align with the study's interpretive methodology, this review concentrates on physical computing within formal secondary education. The decision to exclude primary-level and informal learning contexts reflects both the distinct institutional and pedagogical contexts of those stages, as well as the practical constraints imposed by the EdD word limit.

Section 2.2 outlines existing debates about the philosophical and methodological foundations of hermeneutic phenomenology, including Gadamer's fusion of horizons, the hermeneutic circle of reading and re-reading, and continual reflexive engagement, demonstrating how these commitments help maintain interpretive rigour throughout this review. Section 2.3 examines the 2014 National Curriculum reforms alongside the roll-out of large-scale computing initiatives, such as micro:bits in schools for Year 7 students, showing how statutory changes reshaped classroom practice and norms for physical computing. Section 2.4 examines the multi-academy trust (MAT) environment, encompassing governance structures, resource allocation, and professional networks, and assesses its influence on teachers' professional contexts. Section 2.5 reviews national mentoring frameworks and computing-specific support models for trainees and early-career teachers. Section 2.6 examines how computing teachers construct, negotiate, and sustain their professional identities in the face of technical, curricular, and accountability pressures. Finally, Section 2.7 presents exemplary hermeneutic-phenomenological studies that illustrate how this methodology can uncover the lived meanings underlying teachers' everyday decisions in physical computing classrooms.

Collectively, these sections frame the study through a hermeneutic-phenomenological lens and prioritise depth over breadth. The review identifies areas where existing studies are partial or fragmented and shows how a phenomenological orientation can illuminate teachers' lived experiences of physical computing. Conceived as an interpretive dialogue rather than a catalogue, the review engages critically with the most relevant strands of literature and lays the foundation for the study's contribution.

2.2 Hermeneutic Phenomenology

Hermeneutic phenomenology combines two complementary commitments (Finlay, 2009). The phenomenological tradition draws rigorous attention to the structures of lived experience and how phenomena appear and are understood in the flow of daily life (Langdridge, 2007, p. 4). From hermeneutics, it inherits the conviction that every act of interpretation is shaped by one's history, culture, and prior understanding (Heidegger, 1962; Gadamer, 2013). Under this approach, texts, participants' accounts, and even physical artefacts are never treated as raw 'data' but as conversation partners in an ever-evolving dialogue.

Central to this review is the hermeneutic circle, in which a researcher moves between parts and whole, allowing each reading to reshape the interpretive frame and refocus attention on previously examined passages (Boell and Cecez-Kecmanovic, 2010; Peoples, 2020). This dialogical engagement (shown in Figure 1) aligns with Gadamer's notion of a fusion of horizons, where a researcher's preconceptions and the literature co-shape new insights (Barrett et al., 2011, p. 189). Although hermeneutic phenomenology has been applied in educational research (Dangal and Joshi, 2020a) and more recently in computing education (Sentance and Waite, 2021), its extension to physical computing in secondary schools has been tentative. At present, only a small number of studies explicitly adopt hermeneutic phenomenology in computing education, and even fewer engage with physical computing as an empirical site in its own right. This rarity highlights opportunities for both philosophical and empirical development

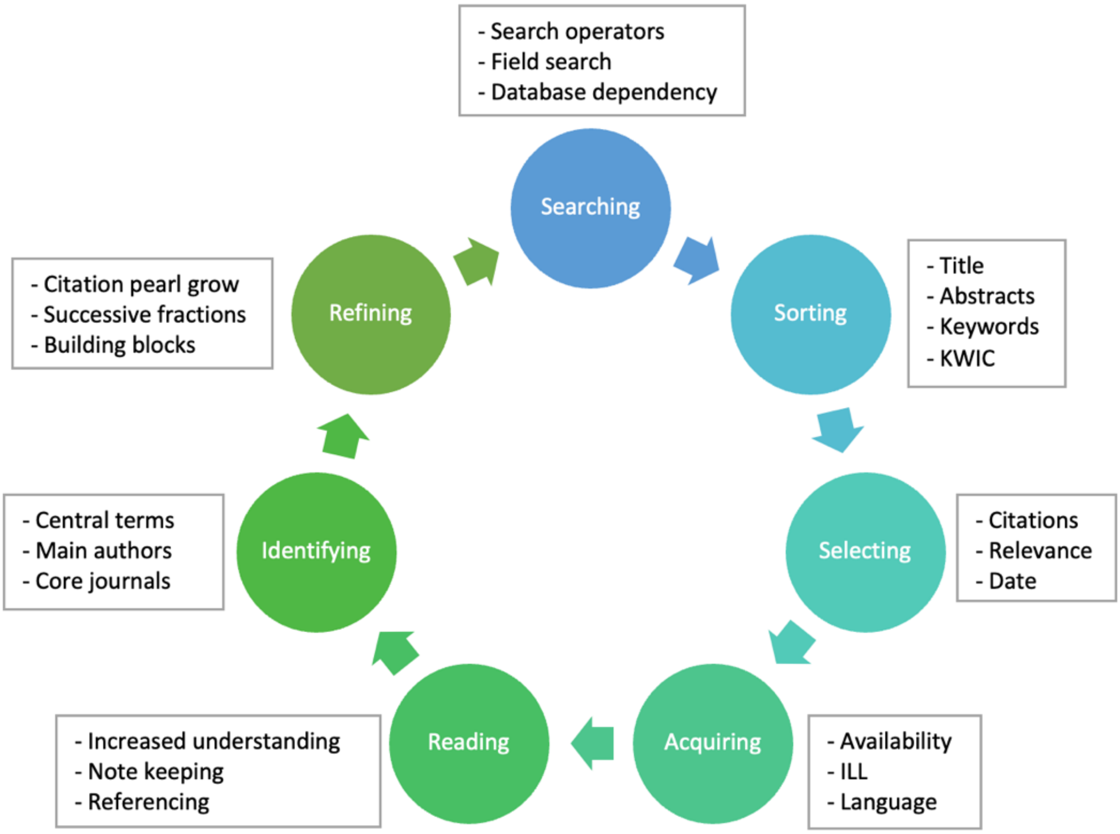

Figure 1: Hermeneutic circle of reviewing literature and techniques (Boell and Cecez-Kecmanovic, 2010)

Rather than accumulating discrete facts, the review is an iterative process in which the literature and emerging interpretations continually inform one another. Furthermore, guided by Heidegger's notion of thought-provoking texts (Heidegger, 1968), a researcher seeks out literature that both resonates with and unsettles emerging interpretive frames, ensuring that the process remains dialogical rather than confirmatory. In this way, the review creates space for themes of *Being* in physical computing practice to emerge, highlighting how teachers' experiences with artefacts and contexts reveal meanings that are continually negotiated rather than fixed.

While systematic literature reviews offer reproducibility, they can constrain the depth of critical reflection essential to qualitative inquiry (Boell and Cecez-Kecmanovic, 2010). Consequently, this chapter integrates selected elements of systematic searching, pattern identification, and critical engagement with limitations in existing studies within a hermeneutic-phenomenological framework that preserves rigour and reflexivity. Pre-understandings are acknowledged not as biases to be eliminated but as productive starting points that shape the interpretive encounter (Kvale, 1996; Annells, 1999). Understanding is treated as provisional rather than final (Sloan and Bowe, 2015), allowing for a framework that is attuned to how physical computing is situated within teachers' professional contexts.

A meta-reflective stance, often referred to as ‘thinking about thinking’ (Crowther *et al*., 2017), follows naturally from this orientation. When literature and lived experiences with physical computing are encountered as partners in a dialogue of Being, a researcher must continually surface and examine their own pre-understandings, recognising how these shape what is attended to and how interpretations unfold. Here, reflexivity is understood as central to the hermeneutic process, grounding interpretive 'leaps' in an acknowledgement of a researcher's positionality. Making this reflexivity visible invites readers to consider the horizons from which claims are made and to view insights as situated, provisional, and open to re-examination.

Physical computing artefacts, including microcontroller boards and sensor add-ons, are read as “objects to think with” (Papert, 1980, p.12). Moreover, instead of viewing a soldered circuit or blinking LED as a mere illustration, hermeneutic phenomenology positions all these material encounters as mediators of meaning (Polkinghorne, 2005). Consequently, engaging with an Arduino or micro:bit in the classroom thus becomes not simply a technical exercise but an interpretive act that brings teaching practice and conceptual reflection into dialogue (Van Manen, 2016).

Finally, hermeneutic phenomenology aspires to Heidegger’s ‘leap’ of genuine thought (Robbins, 2014). Beyond identifying descriptive themes, a researcher seeks moments when sustained engagement with texts, artefacts, and philosophical sources uncovers meanings that resist reductive coding. These interpretive leaps demonstrate the potential of phenomenological inquiry: to bring into view what remains hidden when experience is treated merely as information to be catalogued rather than as a living nexus of possibility. However, in secondary computing education research, there has been scant discussion of how such ‘leaps’ of interpretive insight emerge when engaging with physical computing, an oversight this study seeks to address (Dangal and Joshi, 2020a; Sentance and Waite, 2021). This review, therefore, positions itself as opening the conditions for such insights, while recognising them as provisional, situated, and always subject to further dialogue.

2.3 Contextualising Being a Teacher of Physical Computing

2.3.1 Introduction

Over the past decade, secondary computing education in England has undergone a significant transformation driven by curriculum reform. Before 2014, the curriculum primarily emphasised Information and Communication Technology (ICT) skills, including word processing, spreadsheets, and multimedia creation, framed around digital literacy and the use of digital tools, as well as an understanding of 'control technology,' that is, how technology can be used to operate and regulate systems (Webb and Cox, 2004; Berry, 2018). During this period, the use of resources such as Logo turtle graphics as a vehicle for teaching 'control' in pre-2014 ICT curricula was well-documented, focusing learners on sequencing and system behaviour to support their progress in learning problem-solving, logical thinking, modelling, communicating ideas and information, information handling, or measurement and control (Haq, 2006). However, Ofsted (2011) reported that teachers lacked confidence in certain aspects of the ICT curriculum, and teaching control was challenging, reflecting gaps in their subject knowledge. Moreover, Whalley (1992) found that although microcomputer-based control tasks aim to develop systems thinking and problem-solving skills, teachers frequently become preoccupied with technical troubleshooting, shifting the focus away from higher-order conceptual learning. This misalignment between curriculum intent and classroom practice further exacerbates the confidence gap and limits the educational potential of control-technology activities.

By contrast, the 2014 National Curriculum for Computing upended this mode of ICT. It marked a shift from ICT to a computer science focus, mandating computational thinking, programming, and systems understanding alongside digital literacy for all students in Key Stages 3 and 4 (Berry, 2018; Sentance and Waite, 2018). However, educators faced a steep learning curve adopting this new subject area, with many lacking prior experience in computer science pedagogy (Royal Society, 2017). Moreover, the development process itself was far from straightforward. Williamson (2017) describes it as the outcome of an 'anarchic mix' of governmental urgency, industry lobbying, and competing educational priorities. In his account, what emerged was less a coherent design than a compromise assembled under external pressures. This policy backdrop helps explain why many teachers experienced the reforms as abrupt and unevenly supported, even as the new framework elevated computational thinking and programming to a statutory focus.

Furthermore, Wing (2006) positions computational thinking as a form of problem-solving reasoning that makes solutions explicit and executable by humans and/or machines, and it became central to this new mandate. Although the statutory framework did not explicitly prescribe physical computing, it nevertheless legitimised the incorporation of hardware-based projects into the classroom. In response, teachers have been tasked with the new challenge of linking together abstract algorithmic reasoning and hands-on construction of tangible artefacts, navigating both pedagogical and technical demands to deliver a curriculum that is at once conceptual, practical, and embodied. While the post-2014 curriculum broadened the scope of computing education, there is relatively little research exploring teachers' lived experiences of implementing physical computing. This study addresses this gap by foregrounding secondary school teachers' perspectives on how physical computing is enacted and how they make sense of it within their professional contexts.

2.3.2 The Origins of Physical Computing in Education

Physical computing traces its roots to the late 1990s, when Ishii and Ullmer (1997, p.234) proposed that the "tangible bits" vision, which involves interfaces that seamlessly integrate digital information into physical objects. From an educational perspective, Blikstein (2013) traces a complementary constructionist lineage from Logo to early educational robotics such as LEGO Mindstorms and the Cricket, which helped establish microcontrollers, sensors, and iterative prototyping as classroom materials for learning through making. Stager (2013) adds a further historical anchor through his account of Papert's Constructionist Learning Laboratory (1999–2002), highlighting how constructionism, tinkering, and the making of shareable artefacts anticipated later 'maker' and school fab lab approaches that now shape how physical computing is framed in education. O'Sullivan and Igoe (2004) operationalised these ideas through the Wiring prototyping platform, enabling artists and educators to embed sensors and actuators within creative installations. The subsequent release of Arduino (Banzi and Shiloh, 2022) democratised access to microcontrollers, offering novices an open-source ecosystem with accessible C-like programming and community-driven libraries. As Shultz et al. (2015) demonstrated, these boards serve as an ideal platform for K–12 students to explore core principles of circuitry and programming through hands-on projects that bridge theory and practice. Next, the Raspberry Pi's launch in 2012 extended these affordances by providing low-cost, fully fledged Linux computers capable of interfacing with hardware and networks (Wang and Yu, 2022).

The micro:bit initiative (2015–present) marked a watershed in UK computing education (Knowles *et al.*, 2018). Developed by the BBC in partnership with Microsoft and the Micro:bit Educational Foundation, the micro:bit combined a simple block-based coding environment with durable, sensor-laden hardware designed specifically for classroom use. Over 750,000 devices were distributed to Year 7 students, catalysing grassroots user groups and a proliferation of curriculum resources (Kumar, 2016; Sentance *et al.*, 2017).

2.3.3 Theoretical Framings

Physical computing pedagogy aligns with multiple theoretical traditions. From a constructivist perspective, learners actively build mental models through hands-on exploration, experimentation, and reflective practice (Piaget, 1952). Furthermore, when students formulate hypotheses about sensor behaviour or iteratively refine a circuit's design, they test ideas against tangible feedback, adapting their strategies and continuously updating their cognitive schemas in light of real-world evidence (Piaget, 1952). Building on this foundation, constructionism emphasises that knowledge is most meaningfully acquired when learners create external artefacts that embody their understanding (Papert, 1980). Project-based tasks, such as designing robotic vehicles, environmental monitoring devices, or wearable technologies, enable students to bring abstract code to life in a physical form and receive immediate, actionable feedback, thereby building a cyclical process of artefact creation and conceptual refinement (Papert, 1980). However, Holbert *et al.* (2020) contend that cognition is not confined to internal mental processes but instead arises through the interplay of tools, social interaction, environment, and the body, conceptualising constructionist learning as a distributed, socio-material activity system. Although these framings offer important insights, their translation into secondary computing education remains sparsely examined in secondary contexts, raising questions about how teachers interpret and reconcile these perspectives in practice.

Complementing these perspectives, theories of embodied cognition argue that cognitive processes are rooted in sensorimotor interactions with the environment. In physical computing contexts, observing an LED blink in response to code or feeling a motor's vibration when parameters change can ground abstract programming constructs in concrete experience (Cápay and Klimová, 2019; Juškevičienė *et al.*, 2021). Yet, a recent systematic survey of forty-three child–computer interaction studies found that much of the empirical support for embodiment derives from behavioural observations and self-reports among narrow age cohorts (predominantly children aged seven to eleven) and limited sensory modalities (vision and touch), without the benefit of neurophysiological measures or longitudinal tracking (Ale *et al.*, 2022). Moreover, by filtering exclusively on the term 'embodied,' this literature often overlooks adjacent frameworks, such as enactivism and tangible interaction, and underrepresents developmental stages ranging from the sensorimotor to the formal operational phase (Ale *et al.*, 2022). Enactivism conceives cognition as emerging through dynamic, sensorimotor 'sense-making' loops between an agent and its environment (Tscholl *et al*., 2013), implying that in physical computing, learners construct understanding by actively manipulating hardware, such as sensors and actuators, and perceiving the real-time effects of their actions. Tangible interaction, by contrast, utilises physical objects as the interface, where moving, touching, or arranging tangible artefacts directly controls and reflects digital processes, allowing learners to ground abstract computational concepts in concrete, multisensory experiences (Falcão and Price, 2010). Consequently, these perspectives highlight the potential of physical computing to connect abstract reasoning with embodied practice. At the same time, they also expose limitations in the evidence base: much of the research has centred on younger learners and short-term interventions, leaving secondary classrooms and longer-term trajectories comparatively overlooked.

Physical computing also thrives within a socio-cultural framework, wherein knowledge emerges through collaborative activities and shared social practices (Vygotsky, 1978; Kafai and Burke, 2014). In many classrooms, students work in pairs or small groups, exchanging debugging heuristics and co-designing solutions, engaging in a collective cognitive apprenticeship that mirrors authentic engineering practice (Blikstein, 2013; Hodges *et al.*, 2020). Finally, tangible interaction paradigms, articulated by Ishii and Ullmer (1997), provide the design principles for interfaces that blend digital and physical environments. Contemporary adaptations of these principles have yielded child-friendly, tangible devices and curricula in K–12 settings, reinforcing that intuitive, hands-on manipulation of physical inputs and outputs can make computational ideas more accessible and engaging for young learners (Przybylla and Romeike, 2014). Despite this, little research has examined how socio-cultural or tangible-interaction frameworks are negotiated by teachers themselves, particularly in secondary contexts where accountability and resource pressures shape pedagogical choices. This study addresses the neglected intersection.

Consequently, while constructivist, embodied, socio-cultural and tangible-interaction theories each reveal facets of physical computing, there is little longitudinal work exploring how these dimensions unfold in teachers' lived experience across multiple years. This study begins to address that need by examining how secondary-school computing teachers encounter, negotiate, and embed physical computing as an evolving practice rather than a static pedagogy.

2.3.4 Operational Practices in Physical Computing

Przybylla and Romeike (2014) characterise the operationalisation of physical computing through three interrelated dimensions. Embodiment emphasises the importance of tactile engagement with hardware, encouraging learners to manipulate sensors, wires, and microcontrollers to gain a deeper understanding of computational phenomena. Interactivity emphasises the bidirectional flow between the system and the environment, in which coded programs sense stimuli, such as light, motion, and temperature, and deliver immediate feedback, thereby reinforcing the reciprocity inherent in computational processes. Creation positions students as designers and makers, conceiving and fabricating novel artefacts that instantiate their evolving understanding.

While these operational dimensions provide a practical framework, there is a risk of presenting physical computing as a linear sequence of steps rather than as an iterative and situated learning process embedded within social and material contexts. Building on these operational insights, Cápay and Klimová (2019) frame iterative prototyping as a cyclical process of coding, wiring, and testing in which each cycle enhances the prototype's performance and brings its underlying principles into sharper relief. This iterative emphasis aligns physical computing more closely with authentic engineering practice, contrasting with fragmented skill drills that risk divorcing technical fluency from conceptual growth.

Complementing these hands-on practices, Genota (2019) identifies reflective logging as a metacognitive scaffold: by maintaining structured journals of wiring diagrams, annotated code snippets, empirical test results, and conceptual reflections, students externalise their thought processes and engage in deliberate self-assessment. Such practices highlight the importance of making thinking visible and of supporting learners in developing habits of reflection that transcend the immediate project.

However, while embodiment, interactivity, creation, prototyping, and logging collectively foreground the individual's technical and conceptual journey, they often underplay the social, collaborative, and institutional dimensions of practice. Few studies examine how peer interaction, classroom culture, and teacher facilitation intersect with these operational elements to shape learning. Moreover, existing work is primarily short-term, leaving unanswered questions about how these practices evolve over multiple years or under different policy and accountability regimes.

This study contributes by situating classroom practices within the lived realities of secondary computing teachers. In doing so, it extends beyond a focus on individual learners to consider the entanglement of pedagogy, institutional context, and teacher identity in shaping physical computing practices.

2.3.5 Physical Computing in UK Schools

When the BBC distributed more than 750,000 micro:bit devices to Year 7 pupils in late 2015, it marked a significant milestone in efforts to scale physical computing in schools *(Knowles et al.*, 2018). The BBC's first-year impact report revealed high levels of perceived benefit: 90% of participating 11–12-year-olds stated that the device demonstrated to them that ‘anyone can code,’ and 88% found coding to be less difficult than they had expected. Teachers also responded favourably, with 85% reporting that the micro:bit made ICT/Computer Science more enjoyable for students and roughly half noting a boost to their own confidence (BBC, 2017). While encouraging, these findings were based on a short-term, self-selected survey and offer little evidence on whether confidence or skills were sustained over time. This limitation highlights the importance of conducting longer-term, systematic evaluations. While the early findings helped to launch regional communities of practice and informal support networks, it is uncertain how far these initiatives can be sustained or whether they reach schools with fewer resources on an equitable basis. More broadly, the Royal Society (2017) highlighted the need for longitudinal studies of at least five years to capture pupil progression in computing education. While this call applied to computing as a whole rather than physical computing specifically, it is especially pertinent to this subfield.

Next, the Department for Education invested £84 million in the National Centre for Computing Education (NCCE) in 2019, supporting the Teach Computing Curriculum, embedding micro:bit and Raspberry Pi Pico units in Key Stages 3 and 4, including sequenced lesson plans, loan kits, and formative rubrics (Sentance, 2024). These measures were intended to reduce technical barriers to classroom adoption. Supplementary professional development, including face-to-face workshops, school support, troubleshooting drop-ins, and online modules, aims to enhance teacher capacity. Yet questions remain about whether such structured pathways empower teachers or inadvertently constrain their professional agency by limiting scope for local adaptation (Cochran-Smith *et al.*, 2022).

Collectively, these initiatives demonstrate that physical computing has been established as a tangible approach for teaching programming in English secondary schools, facilitated by national implementation of hardware, curriculum resources, and professional development. The factors influencing the sustained adoption of physical computing, such as infrastructural limitations, accountability demands, and methods for evidencing progress, are addressed later in this review following the discussion of barriers (Sections 2.3.9–2.3.10).

2.3.6 Pedagogical Implementations and Student Learning

Physical computing inherently risks hardware and circuit failures that can quickly derail student motivation if unmitigated. Hennessy Elliott *et al.* (2023) analysed 120 hours of classroom video to develop a 'Debugging Interactional Grammar' comprising three interlocking strategies: diagnostic scaffolding, guiding systematic circuit and code checks; affective encouragement, reframing failure as a valuable learning opportunity, and modelled vulnerability with teachers openly sharing troubleshooting struggles, humanising technical setbacks and reducing anxiety. Although this scaffold improved persistence, self-efficacy, and attitudes in a single novice-teacher case, there is a notable lack of research assessing its effectiveness across diverse classroom contexts and teacher expertise levels, leaving generalisability uncertain. This narrow evidence base raises the question of whether debugging pedagogies can be sustained in the realities of high-accountability secondary classrooms, or whether they remain fragile innovations dependent on particular conditions.

Extending the emotional dimension of debugging, Law's (2023) ‘Thoughtful Computing’ framework emphasises three affective pathways: emotional engagement, creative agency, and communal problem-solving as critical levers for sustained motivation. By interweaving diagnostic rigour with emotional support and collaborative inquiry, Law argues that breakdowns in hardware and software become fertile ground for the development of technical skills and learners’ confidence in innovation. Yet here too, most evidence stems from small-scale case studies, often in supportive extracurricular settings. We know far less about how such affective scaffolds fare when teachers are balancing curriculum coverage, assessment demands, and accountability pressures.

Gender dynamics compound these pedagogical challenges. Cheryan et al. (2009) and Yadav et al. (2014) highlight persistent confidence gaps in computing contexts. Furthermore, a randomised study of middle-school students by Love and Asempapa (2022) found that physical computing units drive higher engagement overall, but that male students experience disproportionately larger gains in career-relevance confidence. Conversely, Love and Hughes (2023) observed that female teachers who were initially less comfortable with electronics exhibited the most significant increases in both technical confidence and pedagogical intent following targeted professional development. These mixed outcomes underscore the need for gender-responsive scaffolds: without intentional design, physical computing risks perpetuating existing inequities rather than addressing them. Longitudinal gender studies in computing remain scarce, a gap Holmegaard et al.'s (2025) twelve-year qualitative investigation begins to fill by revealing persistent, gendered divergences in engagement and career trajectories among CS learners.

Culturally responsive e-textile initiatives suggest a promising model for inclusive engagement, leveraging familiar craft traditions and personal storytelling to bridge technical and cultural divides (Buchholz et al., 2014; Searle and Kafai, 2015). However, scaling such projects requires significant material resources, bespoke scaffolding, and sustained support from school leadership, factors often in short supply in under-resourced settings. This underscores a wider sustainability challenge: physical computing can generate strong engagement in the short term, but its continuation depends on structural support at the departmental and institutional levels.

Although individual studies have highlighted technical scaffolds, affective frameworks, and culturally responsive approaches, few have examined how these elements function together in real-world classrooms with varying levels of teacher confidence and resources. By exploring the lived experiences of secondary school teachers in embedding physical computing, this study addresses the paucity of research on how debugging strategies, emotional scaffolding, and culturally responsive design are integrated into cohesive classroom curricula. By attending to teachers' lived experiences of embedding physical computing, this study begins to explore how these diverse pedagogical threads may intersect or diverge in the day-to-day realities of secondary education.

2.3.7 Social Dynamics and Skill Development in Physical Computing

Building on the pedagogical challenges discussed above, it is also essential to examine how collaborative dynamics within classrooms affect students' and teachers' experiences of physical computing. Collaborative work in physical computing can accelerate learning, yet simultaneously expose coordination challenges (Papavlasopoulou et al., 2019; Lui *et al*., 2020). Lui *et al.* (2020) found that high school learning partners designing e-textiles often shift from joint ideation, where they co-plan overarching project goals, to siloed execution, with one student handling hardware and the other handling coding. While this division of labour can deepen individual expertise, it risks producing lopsided skill sets and hinders cross-domain fluency unless deliberately countered. This suggests that collaboration in physical computing is not inherently equitable or productive; instead, it requires careful orchestration to avoid reinforcing technical silos and gendered patterns of participation.

Hodges *et al.* (2020) and Parsons and MacCallum (2022) both demonstrate that pair programming and collaborative prototyping with physical computing can facilitate active learning, distribute cognitive load, and promote critical thinking. However, these studies focus on short-term interventions within well-resourced settings. The absence of longitudinal evidence means we know little about whether the benefits of collaboration persist or whether inequities and role imbalances resurface once scaffolds are removed.

Recent work in computing education highlights both technical and pedagogical challenges that shape the design of physical computing activities. Ofsted (2022) reports that ambitious curricula relying on block- or text-based environments, microcontrollers, robotics kits, or networked devices often exceed the capacity of many schools' network security policies and hardware budgets. Within these infrastructural constraints, Hodges *et al.* (2020) demonstrate that tight integration of hardware and software environments underpins a smooth, end-to-end learning experience. Building on this technical foundation, Parsons and MacCallum (2022) argue for a phased scaffolding approach in pair work, beginning with instructor-led sensor introductions, progressing through guided pair tasks to address measurement inconsistencies, and ultimately supporting more independent exploratory projects. Yet equity considerations complicate this picture. Lewis and Shah (2015) demonstrate that even well-intentioned structures, such as scheduled role-switching driver and navigator approaches, can become token gestures under time pressure, allowing dominant students to marginalise their peers.

Collectively, these findings suggest that an effective pair-programming pedagogy must reconcile school infrastructural realities (Lui *et al.*, 2020), layered scaffolding strategies (Hodges *et al.*, 2020; Parsons and MacCallum, 2022), and equity monitoring, providing an integrated perspective that remains underexamined in the existing literature. While Papavlasopoulou *et al.*'s (2019) two-year design-based study offers valuable longitudinal insights into collaborative coding activities, no research to date has applied a similar approach to pair programming longitudinally in physical computing across diverse secondary contexts. This study begins to address that gap by exploring structured collaboration strategies and their impact on sustained engagement in physical computing.

2.3.8 Assessment Practices

Removing non-exam coursework from GCSE Computer Science (Dallaway, 2016) has compelled teachers to develop formative assessment frameworks that more authentically capture students’ physical computing competencies. In particular, the National Centre for Computing Education’s Teach Computing Curriculum articulates rubric descriptors across four interdependent dimensions: programming proficiency, judged by code correctness and structural clarity; system design, evaluated in terms of hardware selection, wiring accuracy, and circuit resilience; debugging processes, evidenced through structured reflection logs and teacher–student feedback; and collaboration and communication, assessed via the quality of peer feedback, documentation, and presentations.

Although this multidimensional rubric provides a scaffold for classroom practice, Kalelioglu and Sentance's (2020) survey of 215 UK computing teachers revealed significant time constraints that limit the use of live coding demonstrations and e-portfolios. In response, many teachers have expressed interest in video reflection assignments, where students verbally articulate their design rationale and troubleshooting decisions. This approach promises richer qualitative insights into procedural fluency and metacognitive growth. Pilot data on video reflection assignments exist in upper-elementary settings (Nguyen *et al.*, 2020), but their effectiveness in secondary physical computing contexts and at scale remains untested. This highlights a methodological gap: while teachers recognise the value of multimodal assessments, the tools and time to embed them sustainably remain elusive.

Next, Pearson Edexcel introduced an on-screen GCSE assessment in 2020 that enables students to write and run Python code within a locked-down browser, closely mirroring industry practice (Baker and Denes, 2022). While this shift lends greater authenticity to algorithmic evaluation, it also risks downplaying the hands-on circuit-building skills at the heart of physical computing. Seeking to restore balance, Neutens (2022) devised an eight-category code-assessment schema that spans functionality, readability, algorithmic thinking, testing and debugging, mathematical integration, creativity, iteration, and personal reflection, explicitly integrating design reasoning alongside syntax proficiency. Similarly, Przybylla and Grillenberger (2021) adapted an embedded-systems taxonomy from higher-education contexts. Still, they cautioned that its abstraction must be tailored and simplified to suit the developmental stages of K–12 learners. Taken together, these frameworks illustrate creative attempts to capture the richness of teaching with physical computing but also emphasise the difficulty of balancing standardisation with the contextual nuances of classroom practice.

Extending these theoretical frameworks into practice, Kalovrektis *et al.* (2023) piloted a formative Arduino rubric that brings together computational thinking dimensions and circuit design criteria. Teachers participating in the pilot reported that this rubric enhanced the specificity of their feedback. However, its effectiveness was enhanced through reflective professional development and by implementing its descriptors across diverse classrooms. This suggests that assessment tools do not stand alone: their value depends on teacher interpretation, professional learning, and institutional support.

Despite these innovations, assessment in physical computing is still developing in three areas. First, there is little evidence on co-developing age-appropriate concept maps or learner-centred descriptors that can translate higher-education taxonomies into secondary practice. Second, scalable peer-assessment frameworks remain under-examined, despite their potential to reduce workload and build metacognitive reflection. Third, while machine-learning approaches that analyse student solution traces are emerging in broader computing education, they have yet to be adapted to the challenges of assessing physical computing.

2.3.9 Barriers that Exist to Physical Computing

Drawing on Heidegger's (1968) concepts of Geworfenheit ('thrownness') and Zuneigung ('inclination'), teaching physical computing presents educators with novel pedagogical challenges, alongside substantial logistical and cognitive burdens, that actively shape their professional identities (Dreyer, 2024). Geworfenheit captures the sense of being thrust into complex hardware setups, breadboarding components, configuring software libraries, and troubleshooting faults, often without dedicated technical support (El Moussaoui, 2023). This 'thrownness' is also evident in empirical accounts: teachers report that barriers cluster around time pressures, organisational complexity, technical difficulty, and financial constraints, alongside concerns about excessive crafting and pupils' limited prior experience with hardware (Przybylla et al., 2017). They also emphasise the need for better-organised teaching resources and clearer support structures (e.g., guidance, examples, and opportunities to exchange practice) to make physical computing manageable in day-to-day schooling (Przybylla et al., 2017). In contrast, Zuneigung, described by Britt (2014) as an attentive 'inclining-towards,' captures teachers' proactive and committed engagement as they iteratively refine pedagogical strategies and respond thoughtfully to emergent classroom challenges. These existential dimensions frame teaching physical computing not as a neutral act of skill transmission but as an ongoing negotiation of vulnerability, agency, and professional meaning.

Before lessons even begin, teachers must assemble breadboard components, install and configure software libraries, and verify device functionality, all to forestall disruptive technical failures. Once the lesson is underway, they are expected to diagnose and repair a range of glitches in real-time (open circuits, miswired pins, library mismatches), often without dedicated technical support (DesPortes and DiSalvo, 2019). This becomes a pedagogical challenge as well as a technical one: teachers must support pupils to get ‘unstuck’ while debugging hardware–software systems, frequently drawing on embodied, material, and social resources and (especially for novices) modelling vulnerability and systematic troubleshooting (Hennessy Elliott et al., 2023). These practical demands position teachers as both instructors and technicians, a dual role that intensifies workload and leaves little room for reflective or exploratory pedagogy.

These practical pressures mirror the cognitive challenges students face, as they must learn hardware concepts, programming syntax, and debugging techniques simultaneously. Sweller's (1988) Cognitive Load Theory suggests that worked examples of annotated schematics and partial code templates can reduce split-attention effects. Muldner *et al.* (2023) provide empirical support, showing that students given progressively faded scaffolding outperform unguided peers. Yet, designing and sustaining those scaffolds requires domain expertise and extensive planning time for teachers, which are precious commodities in tightly scheduled school settings (Kaivo, 2019). When the national curriculum changed in 2014, a significant shortage of specialist computing teachers emerged, with many computing classes being taught by teachers holding ‘ICT’ qualifications rather than computer science qualifications (Boulton and Csizmadia, 2018). Furthermore, the recruitment of computing teachers has consistently fallen below target, and high dropout rates in computing training, coupled with persistent salary differentials relative to industry, continue to undermine specialist retention and the provision of meaningful physical computing (Ofsted, 2022).

Platform choice also complicates matters. DesPortes and DiSalvo (2019) found that modular blocks, such as BitBlox, reduce wiring errors compared to breadboard–Arduino setups; however, friction often re-emerges once students transition to text-based coding. In addition, Pennisi (2022) warns of supply-chain delays; cloud-based editor outages can also upend lesson plans. In response, teachers sometimes project live schematics alongside code, establish troubleshooting stations with spare parts, and appoint rotating peer ‘experts’ to share emerging debugging strategies. These real time scaffolds can mitigate immediate crises, but they require departmental backing, a robust

IT infrastructure, onsite technical staff, and a budgetary commitment, without which, even the best classroom innovations falter (Ofsted, 2022).

Long-term success may depend on a continuum of professional development that brings together technical, pedagogical, and socio-emotional competencies. Workshops on electronics and platform-specific troubleshooting, pedagogical seminars on scaffolding inquiry and debugging, and training in normalising failure and building growth mindsets are vital (Hennessy Elliott et al., 2023; Law, 2023). Yet, other studies lament the scarcity of peer-reviewed, classroom-focused professional development (PD) resources, prompting many educators to turn to informal online communities for support (Fincher and Robins, 2019; Guzdial and du Boulay, 2019). This reliance on ad hoc networks highlights a systemic gap: without sustained and formalised PD pathways, teachers must cobble together support in ways that can reproduce inequities between well-connected and isolated schools. Consequently, mentored communities of practice pairing novices with experienced mentors for co-teaching, co-planning, and joint reflection could offer a promising model for accelerating skill and confidence.

To widen access, induction programmes may need to target teachers with lower self-efficacy, particularly women, who report larger confidence gains when supported (Love and Hughes, 2023). Although there is growing advocacy for systemic solutions, such as cost-effective scaffolding toolkits, ongoing technical support at the school level, and rigorous evaluations of professional development programmes (Menekse, 2015), there remain few empirical studies demonstrating their long-term effectiveness, particularly in the context of physical computing. This suggests that while promising initiatives exist, much remains provisional: teachers’ challenges are not yet matched by a sufficient evidence base or infrastructure to sustain their work over time.

2.3.10 Regulatory and Inspection Constraints

External inspection by Ofsted (the Office for Standards in Education, Children's Services and Skills) remains a pivotal mechanism for evaluating computing provision in England, employing lesson observations, work scrutiny, and stakeholder interviews (Ofsted, 2023). Although national initiatives exist, physical computing often remains marginal or excluded in some schools due to ongoing practical challenges, such as insufficient on-site technical support and inconsistent infrastructure (Royal Society, 2012; Ofsted, 2022).

At the departmental level, the Computing Quality Framework (CQF) gives limited explicit attention to physical computing, referring to it within a Level 4 descriptor that foregrounds well-scaffolded practical work supported by dependable software and hardware, including physical computing kits; more broadly, it frames technology outcomes in terms of students using technology independently and effectively, including making appropriate choices about tools and applying them purposefully. (National Centre for Computing Education, n.d.). As a result of this limited mention, departments may face evidencing pressure, with staff prioritising activities that are easier to document over those that are most educationally generative. In this context, iterative physical computing projects may be deprioritised because they are harder to stabilise, resource, and evidence consistently (e.g., network security, maintenance, and setup dependencies).

When computing is subject to a ‘deep dive’ inspection, inspectors assess the coherence of curriculum design, teaching quality, pupil outcomes, and leadership effectiveness. However, there is minimal research on how deep dive inspections specifically evaluate physical computing; Ofsted (2023) hints at this but stops short of providing detailed guidance. Moreover, the iterative, process-oriented nature of physical computing involves multiple design–test cycles, transient wiring configurations, and ephemeral peer debugging interactions that are difficult to represent in static work samples and written records. This disconnect illustrates a structural misalignment: inspection frameworks privilege durable artefacts and quantifiable outcomes, whereas physical computing frequently produces transient, dialogical moments of learning that such measures may overlook.

In its 2022 Research Review for Computing, Ofsted (2022) notes that physical computing hardware can conflict with school network security and performance requirements. This cautionary stance is compounded by Ofqual’s January 2018 decision that the GCSE Computer Science non-exam assessment would not count towards the final grade for 2018 and 2019, leaving summative assessment based on examination performance for those cohorts (Ofqual, 2018; Dallaway, 2016). Consequently, these developments have created what might be termed a compliance–innovation dilemma: schools must demonstrate measurable attainment within frameworks that structurally marginalise the embodied, hands-on elements of physical computing.

This compliance-innovation dilemma constrains school leaders, forcing them to choose between advocating for physical computing at the risk of misalignment with inspection criteria and adhering to evaluative frameworks that tend to undervalue hands-on pedagogical approaches. Teachers, in turn, experience this tension in everyday practice. While they recognise the value of open-ended design cycles and collaborative debugging, these practices often carry little weight in inspection reports or accountability measures.

The challenge, then, is to develop evaluation tools that acknowledge both the process and the outcome. Debugging logs, short video accounts of design cycles, or group reflections could all serve as valid forms of evidence, helping to move physical computing from the periphery to the centre of computing education. Yet research into how schools actually implement such multimodal forms of evidence and whether inspectors accept them as legitimate indicators of quality remains extremely limited. Without this validation, even innovative assessment practices risk being sidelined.

2.4 Contextualising Being a Computing Teacher in a Multi-Academy Trust

Being a computing teacher within a multi-academy trust (MAT) entails navigating a landscape of shifting governance, evolving accountability regimes, and complex professional networks. Since the early 2010s, successive governments in England have encouraged schools to withdraw from local authority oversight and form Multi-Academy Trusts (MATs), a process framed as creating a self-improving school system in which high-performing schools support those deemed underperforming (Simon *et al.*, 2021). While the impact of MAT structures on science and mathematics has been explored (Bevins *et al.*, 2024), there remains a limited body of research specifically addressing computing or physical computing within this governance context. This lack of subject-specific attention matters because the technical and pedagogical demands of computing, particularly physical computing, differ markedly from those of other subjects.

Firstly, the rapid expansion of MATs has been accompanied by a significant rescaling of local governance. Wilkins (2017) argues that large MATs replicate many bureaucratic features they purportedly replace, consolidating control in a private monopoly rather than truly decentralising decision-making. Computing teachers in these contexts often find that strategic and budgetary decisions such as hardware procurement, platform choices, or timetabling are determined at the trust level. While some teachers welcome economies of scale and shared resources, others feel constrained by trust-wide policies that standardise practice across schools, thus reducing the capacity to tailor computing provision to the specific needs of their local student populations. For physical computing, these tensions are especially acute: standardised approaches may prioritise software-based or unplugged activities that are more cost-effective and easier to evidence, while hands-on pedagogies that depend on specialist hardware can be deprioritised because they demand greater investment, technical expertise, and tolerance for uncertainty.

Such centralisation sits uneasily with the professional narrative of autonomy. Thompson et al.'s (2021, p. 230) study of headteachers in Northern England highlights what they term ‘indentured autonomy’: leaders gain formal freedom but become bound by new layers of oversight and performance measures. A similar tension may exist for computing teachers, who are simultaneously encouraged to innovate with new pedagogies and curricula while being constrained by uniform performance indicators often aligned with high-stakes examinations rather than engaged, project-based learning. This autonomy paradox has been observed in the literature on curriculum innovation (Tan and Leong, 2014), and reflects a wider paradox for computing teachers: while innovation is often encouraged in principle, the surrounding managerial structures tend to reward compliance, which can limit opportunities for experimentation with resource-heavy or less predictable practices such as physical computing.

Professional networks offer one potential remedy, yet their emergence within a MAT context is far from straightforward. Greany *et al.*'s (2024) ego-centric analysis reveals that historical informal partnerships seldom predict MAT configurations. In other words, where computing teachers once relied on geographically proximate clusters of collaborators and specialist technologists from neighbouring schools or university outreach programs, these ties are often disrupted by MAT boundaries. Joining a MAT can sever longstanding lateral links, replacing them with vertical relationships with trust-appointed leaders. While the MAT may establish new cross-school computing networks or centralised professional learning communities, these are typically bounded by trust membership rather than geographical proximity or subject affinity. For computing teachers, this shift risks professional isolation: a loss of informal, lateral networks that once provided mutual support in tackling challenges such as integrating physical computing into classroom practice. This narrowing may make the already resource-intensive nature of physical computing even more challenging to sustain.

Local authorities (LAs) have likewise been repositioned. Crawford *et al.* (2022) demonstrate that LAs retain strategic responsibilities in the 'school-led' system, including ensuring equitable access and supporting vulnerable learners. Still, their role in supporting subject-specific developments has diminished. For computing teachers, this means relying less on local authority advisers for continuing professional development and more on MAT-provided offerings, which vary widely in quality. Where a MAT invests in specialist computing leaders or collaborates with external university partners, teachers report enhanced pedagogical confidence; elsewhere, they struggle to access up-to-date training and must self-organise networks via social media or grassroots meetups. This unevenness creates a postcode lottery for computing teachers' access to expertise, with direct implications for whether physical computing can be meaningfully embedded or remains a marginal enrichment.

This fragmentation through formal trust boundaries highlights the importance of local middle tiers. Simon *et al.,* (2021) characterise MAT growth as emergent and complex, driven partly by the sponsorship of underperforming schools. In such sponsored MATs, computing provision may be uneven: well-resourced schools within the trust can pilot robotics clubs or advanced electronics modules, while newly acquired schools contend with legacy infrastructure deficits and low staff confidence. Furthermore, Ehren and Godfrey (2017) demonstrate that external accountability through Ofsted and Regional Schools Commissioners often prioritises rapid improvements in examination results for statutory inspections over the sustained development of subject expertise.

Consequently, computing teachers face pressure to meet baseline targets, such as the percentage of students achieving grade 4 or above in GCSE Computer Science, rather than pursuing exploratory, project-based curricula by adopting physical computing to build deeper computational thinking. In this climate, physical computing can be perceived as risky, as it demands time, resources, and tolerance for failure; qualities not easily reconciled with the performance metrics that drive trust-level accountability.

MAT boards play a critical governance role in this landscape. Baxter and Cornforth (2021) reported that while boards strive to engage with school communities, their focus tends toward financial oversight and compliance, with less attention to curriculum nuance. This frequently results in decisions about technology budgets being made without meaningful input on computing pedagogy or integration across subjects. Boards often focus on finance and compliance and may give less attention to curriculum nuance. In physical computing, this gap may lead to investment in screen-based or unplugged provision, which is easier to evidence, at the expense of hands-on artefact work that, while harder to measure, can impact on learning in ways that are easily overlooked in compliance-driven systems.

Furthermore, Leat *et al.*'s (2015) exploration of teachers' engagement with educational research provides insights into professional isolation within MATs. While MATs promise collaborative research partnerships, in practice, computing teachers often find themselves isolated from the broader field, with limited opportunities to contribute to or draw upon the evidence base in computing education, leaving them dependent on trust-curated resources that may not be subject-specific. Consequently, professional marginalisation can diminish teacher efficacy and weaken the trust's capacity for evidence-informed curriculum development. Here, the autonomy–standardisation paradox reemerges, computing teachers are expected to deliver innovative curricula while working within tightly bounded frameworks that restrict their access to broader professional communities.

Several strategies have shown promise in mitigating these challenges. First, building subject-specialist networks that transcend trust borders can re-establish coalitions of computing teachers. Regional Computing Hubs funded through the National Centre for Computing Education offer one such mechanism, but their uptake remains uneven across MATs. Second, embedding classroom research within computing departments can generate local evidence to inform pedagogical and governance decisions, aligning with Leat *et al.*'s (2015) call for teacher-led inquiry. Third, trust boards should include subject representatives, either serving officers or co-opted trustees, with curriculum expertise in computing to ensure that resource allocations and accountability frameworks reflect disciplinary requirements.

Competing forces can shape a computing teacher's position within a MAT, with the potential benefits of shared expertise and economies of scale set against reduced autonomy, disrupted networks, and accountability demands**.** For physical computing in particular, these tensions are magnified, as its resource-intensive and exploratory character sits uneasily with trust-level imperatives of efficiency, standardisation, and rapid results. This study does not resolve these contradictions; rather, it begins to explore how they are lived and negotiated by teachers in practice, providing a starting point for rethinking how governance structures might better accommodate hands-on, materially grounded forms of computing education.

Moreover, computer science evolves so rapidly that curricular and governance structures can struggle to keep pace. Primary-teacher accounts within a MAT reveal this misalignment starkly: "Technology moves so much quicker than the changes in the curriculum" (Chikomba, 2024, p. 148). At the same time, studies of MAT governance, e.g. Ryan-Atkin (2023), suggest that trust-level accountability and autonomy influence professional practice; however, they seldom examine how MAT decision-making processes can facilitate timely curriculum development in response to emerging tools, languages, or computing pedagogies. Consequently, these investigations highlight a neglected nexus and a gap in the literature: the tension between the rate of innovation in computer science and the comparatively static processes of curriculum design and trust governance. This study addresses that gap by examining the lived experiences of secondary computing teachers in assessing and iterating computing curricula when embedding physical computing under MAT governance.

2.5 Contextualising Being a Mentor

2.5.1 Conceptualising Mentoring: Roles, Relationships and Definitions

Mentoring in teacher education is widely understood as a collaborative partnership in which a more experienced educator (the mentor) supports the professional growth of a less experienced colleague (the mentee) through ongoing guidance, feedback and shared reflection. Yet, its aims, enactments, and outcomes remain defined and unevenly implemented (Ambrosetti *et al.*, 2014). Unlike unidirectional coaching or supervision, effective mentoring is characterised by reciprocal exchanges: mentors and mentees co-construct knowledge, engage in critical dialogue and reflect jointly on practice (Hobson *et al.*, 2009). Within this broad definition, mentors may assume various roles, including instructional coaches, pedagogical role models, sounding boards for concerns, or assessors of progress, depending on the needs of the mentee and the context (Hawkey, 1997). Traditional apprenticeship models position the mentor as an expert whose methods the novice is expected to emulate, whereas more contemporary educative approaches emphasise shared inquiry and mutual professional learning (Feiman-Nemser, 2001). Despite the recognition of the value of mentoring, studies on computing-specific mentoring remain rare. However, MacArthur *et al.*, (1995) posit that mentoring models provide valuable, sustained, and context-sensitive support, which is essential for teachers navigating new computing instructional technologies. For computing teachers, this distinction is crucial: mentoring is not merely about replicating techniques, but about developing the confidence to work with rapidly changing tools, including hardware and software that often fall outside the original training of mentors.

Furthermore, mentoring is not a monolithic practice but an inherently complex and context-sensitive endeavour. Hall *et al.* (2008, p. 330) demonstrated, for example, that even within a single programme, mentors held widely divergent understandings of their responsibilities, ranging from providing emotional support and materials to facilitating reflective critique. This highlights how personal experience and context influence the enactment of mentoring. The field has long suffered from conceptual ambiguity: Colley (2003, p.13) argues that mentoring was “ill-defined, poorly conceptualised and weakly theorised,” a concern echoed by Kemmis *et al.* (2014), who posit competing frameworks operating in parallel. This ambiguity is evident in computing, where mentors are expected to guide novices through both curriculum reform and technical troubleshooting, yet may lack formal preparation for either.

Consequently, the quality of mentoring is particularly significant in this study of computing education, where rapid technical and curricular reform has compounded classroom teaching challenges over recent decades. Computing mentors face unique technical demands; however, existing mentor-training frameworks typically overlook hardware troubleshooting, a critical issue identified early in computing education mentoring research and still relevant today (MacArthur *et al.*, 1995). While this early work highlighted the value of mentoring for long-term teacher development, subsequent studies have consistently affirmed its importance. For example, (Yadav *et al.*, 2016) report that structured mentoring relationships, particularly when supported by context-aware resources, enhance both teacher self-efficacy and the pedagogical integration of computing. Yet, most of this evidence is general to computing, leaving open questions about how mentoring can specifically support teachers as they integrate physical computing into their everyday practice.

2.5.2 Mentoring Models and Effectiveness

Beyond definitions, outcome studies examine what works in mentoring. Early research into mentor perceptions revealed a striking divergence between normative models and actual practice. Hall *et al.* (2008) surveyed 264 mentor teachers of pre-service educators and conducted follow-up interviews with 34 to explore mentors' perceptions of their roles. They found that most mentors saw themselves primarily as providers of emotional and professional support, such as modelling lessons, offering resources, and reassuring novices of their efforts. In contrast, only around 8% of responses related to ‘critical evaluation and reflection’ and a mere 2% to ‘team teaching or collaboration’ (Hall *et al.*, 2008, p. 336-337). These data suggest that mentors often conflate basic cooperating-teacher duties with explicit role definition and training, thereby reducing the classroom to completing assessment forms and providing a classroom and, in the process, obscuring the deeper, dialogic work of reflective feedback. For computing teachers, this creates a risk that mentoring defaults to logistical support rather than helping novices build strategies for teaching complex concepts, scaffolding projects, or managing the unpredictability of hardware-rich classrooms.

Ingersoll and Strong's (2011) meta-analysis of induction and mentoring programmes found broadly positive effects on teacher retention, classroom practice, and student achievement. Across multiple studies, novice teachers who participated in structured induction schemes were more likely to remain in the profession over their first three years and were observed to demonstrate stronger classroom management, more effective questioning, and more engaging learning environments (pp. 207, 212–214). Their students also achieved higher scores on standardised assessments (p. 215). However, the review also reports a large, randomised trial in under-resourced urban schools that showed mixed outcomes (pp. 218–223). This single trial highlighted that programme success depends on factors such as careful mentor selection, protected meeting time, and systematic mentor training. For computing teachers, these findings carry an added complication: subject-specialist shortages mean mentors may come from ICT or other disciplines, so guidance on physical computing or coding can vary widely depending on who is available rather than who is best qualified.

While outcome studies answer the question of what works, Pountney (2019) investigates what mentors need to know to support novices effectively. Drawing on his work delivering the Enhance Your Mentoring Skills programme in South Yorkshire and for the Chartered College of Teaching, he applies Maton's (2013) concepts of semantic gravity (context dependence) and semantic density (conceptual complexity) to distinguish between concrete descriptions of practice and abstract pedagogical principles. Pountney (2019) observed that mentors often remain at the level of contextualised anecdotes (strong semantic gravity) and struggle to articulate underlying pedagogical rationales, such as scaffolding strategies or iterative hardware refinement, in an accessible, shareable form. He argues for developing a specialised mentoring discourse, a shared glossary of routines, frameworks and metaphors that makes expert judgement explicit and supports peer learning among mentors. For physical computing, such a discourse might codify practices for debugging, iterative prototyping, or assessing open-ended projects, enabling mentors to make visible the tacit expertise that often remains unspoken.

2.5.3 Mentoring Policy and Frameworks

At a national level, England's National Standards for School-based Initial Teacher Training (ITT) (Department for Education, 2025) formalises mentoring as a professional skill set. These standards articulate requirements across personal qualities, teaching support, professional knowledge and mentors' development. Yet Jerome and Brook (2020) inter-professional critique, comparing the ITT mentor standards with nursing and social work guidance, found the DfE framework to be overly technocratic, emphasising procedural tasks and generic support while under-specifying assessment processes, power dynamics, and the mentor's role in cultivating a school-wide learning culture. Unlike nursing standards, which detail structured evaluation cycles or social-work frameworks that foreground ethical power-sharing, the ITT standards remain dyadic and compliance-focused. Therefore, Jerome and Brook (2020) call for a revised framework that integrates relational, organisational, and moral dimensions, empowering mentors to verify competencies and lead communities of practice within their schools. For computing, this compliance-driven framing risks reinforcing surface-level mentoring interactions, leaving little space for grappling with the complexity of guiding novices through physical computing pedagogy.

For early-career teachers (post-QTS), the Government's Early Career Framework (Department for Education, 2024) extends induction to two years and mandates fully trained mentors with protected time for regular coaching. However, this strong policy emphasis on mentoring has exacerbated ongoing difficulties in providing mentors with adequate training and protecting their time for these duties (Hobson *et al.*, 2009). Furthermore, Ofsted's inclusion of mentoring quality in ITT inspections highlights the regulatory weight placed on mentoring yet also risks narrowing mentor roles to inspection checklists rather than providing holistic professional support (Ofsted, 2023). In practice, computing mentors may find themselves accountable for compliance-oriented tasks while lacking the institutional support to guide novices through the hands-on, often unpredictable work of physical computing.

2.5.4 Addressing the Challenges of Computing Teacher Mentorship

Novice teachers adopting physical computing face unique mentoring demands. First, the pace of technological change demands that mentors model real-time technical problem-solving, not merely pedagogical planning (Kalelioglu and Sentance, 2020). For example, mentors can share debugging approaches or computing pedagogies within a specialised discourse (Pountney, 2019). Second, many computing teachers operate in isolation within their schools (Mouza *et al.*, 2022), thereby magnifying the roles of mentors as network brokers, who facilitate connections to inter-school communities and online forums for exchanging resources and classroom strategies. Third, effective computing mentorship should attend to project-based pedagogy mentors who require tools for reflective dialogues on adopting physical computing in classrooms.

Consequently, these elements form a coherent, computing-specific mentoring model: mentors act as disciplinary experts, staying abreast of evolving hardware and software; as pedagogical leaders, they scaffold learning with physical computing; and as community builders, they develop school-wide learning networks rather than merely verifying competencies (Jerome and Brook, 2020). Yet this remains more an aspiration than a reality. Empirical evidence on how mentoring actually supports teachers in embedding physical computing is limited, meaning this study offers only an initial step in exploring how mentors and mentees negotiate these challenges in practice.

2.6 Teachers' Professional Identities

Teachers' professional identity, the continually evolving sense of what it means to be an educator, is widely discussed in the literature as a key influence on how teachers understand and carry out their work (Beijaard *et al*., 2004a). For example, Day *et al*., (2006) characterise identity as a negotiation that draws together personal history, professional values, and the shifting expectations of policy and practice. Such identity work influences teachers' responses to curriculum change, their willingness to explore new pedagogies, and the resilience they bring to adapting to shifting institutional demands. In computing education, where technological advances and new pedagogies (e.g., physical computing) disrupt established practice, attending to identity formation is especially urgent.

2.6.1 Conceptual Foundations of Teacher Identity

Contemporary studies reject essentialist or static notions of identity in favour of dynamic, relational models. Building on Wenger-Trayner and Wenger-Trayner's (2014) Landscapes of Practice, Traini *et al.* (2021) demonstrate that teachers construct their professional selves through participation in multiple, overlapping communities, school departments, online networks, and subject-specific forums where meanings circulate and are renegotiated. This situated view aligns with Beijaard *et al*.'s (2004) tripartite identity model, which comprises subject-matter expertise, pedagogical craft, and didactic knowledge, each refined through social interaction.

Hermeneutic phenomenological studies further expose the lived experience of identity work. Hashemi Moghadam *et al.* (2019) reveal how institutional power relations shape the self-conceptions of English as an Additional Language (EAL) teachers, foregrounding the interplay between personal agency and organisational constraints. Bynum and Varpio (2018) argue that phenomenology unmasks often-overlooked emotional undercurrents of anxiety, exhilaration, and doubt that inform teachers' daily enactments of their roles. Yet, despite this richness, many conceptual frameworks under-attend to affective dimensions; van Veen and Lasky (2005) call for integrated models that explicitly weave emotion into identity theory, noting that pedagogical efficacy and resilience are anchored as much in feelings of belonging and self-worth as in skills or knowledge. For computing teachers, this dimension may be particularly acute, since the emotional weight of navigating unfamiliar hardware, recurring technical breakdowns, or accountability pressures intersects with identity in ways that go beyond technical competence.

2.6.2 Computing Teachers' Identity: Challenges and Domains

Computing educators face identity-specific tensions. The field's evolution, ephemeral curricular standards, and the perennial shortage of subject-specialist teachers all conspire to fragment a coherent sense of self. Ni *et al.* (2021) respond to this by developing the Computer Science Teacher Identity Survey, which offers four core dimensions: CS teaching commitment, pedagogical confidence, student engagement efficacy, and sense of professional community, validated across a national sample of 3,540 teachers. Parker (2018) similarly highlights the legal practices of computing (projects, internships) as crucibles for identity formation, advocating tools that capture teachers' anticipations of future professional roles.

Shafiee *et al.* (2022, p. 2) extend this work to technology-enhanced language teaching, demonstrating how self-images (e.g., I see myself as a "CALL specialist"), role perceptions, and institutional identities interact to support or hinder the integration of technology. Their findings suggest that when teachers internalise identities as innovators or facilitators rather than mere content deliverers, they are more likely to persist with complex technologies. This resonates with computing education, where identity anchors such as innovator, problem-solver, or technologist may make teachers more open to physical computing. At the same time, more traditional self-images can produce resistance or ambivalence.

Drawing on an adopter-centred perspective, Liu and Geertshuis (2016) demonstrate that teachers' adoption of learning technologies is influenced by antecedents related to professional identity. These antecedents are synthesised across three interrelated domains. The first domain, work-related orientations, encompasses personal innovativeness, openness to change, autonomy, and perceptions of control. The second domain, technology-related dispositions, includes attitudes and emotions towards technology, prior experience and habit, knowledge, and technology self-efficacy. The third domain, teaching-related factors, involves pedagogical beliefs, teaching approaches, and commitment to teaching. Liu and Geertshuis argue that these identity-linked orientations influence how teachers interpret and evaluate the characteristics of an innovation. Adoption is more likely when a new tool aligns with teachers' self-concepts and preferred professional practices.

When applied to computing education, this framework elucidates why teachers may perceive new tools as either professionally coherent, supporting agency, ownership, and sense-making, or as misaligned with their role expectations. In the context of physical computing, the consequences are particularly tangible. Successful builds can reinforce professional confidence, whereas hardware failures or unreliable equipment may increase feelings of vulnerability in front of students. These experiences can subsequently influence teachers' evolving sense of competence and professional identity.

2.6.3 Emotion, Agency, and Identity Anchors

Emotions shape and stem from identity, encapsulated in "identity anchors" (Mockler, 2011, p. 123), which are the core beliefs and values that tether teachers to their professional selves. In computing education, anchors might include commitments to digital equity, computational thinking as a literacy, or teaching with physical computing as a pedagogical stance. However, if these anchors clash with mandated, exam-driven curricula or restricted timetables, for example, teachers experience dissonance that can erode their efficacy and enthusiasm (Freedman and Appleman, 2008).

Philipsen *et al.* (2019) locate philosophical outlooks, pragmatism, constructivism, and critical pedagogy as formative influences on teachers' identities. For example, a computing teacher grounded in constructionist theory might welcome physical computing as a means for students to learn through hands-on experience. At the same time, a colleague focused primarily on measurable outcomes may see it simply as another instructional tool. This divergence underscores how teachers' identities, rooted in creativity, equity, or accountability, influence not only their teaching practices but also their self-perception as computing educators.

2.6.4 Institutional Contexts and Identity Negotiation

As noted in Section 2.3, computing teachers in a multi-academy trust must balance centrally imposed programmes with local school realities. Under academisation, headteachers and, by extension, their staff often trade local discretion for trust-wide directives, forcing computing teachers to reconcile standardised curricula with their pedagogical values (Thompson *et al.*, 2021). These trust-level accountability arrangements can marginalise teacher expertise in curriculum design and narrow professional identity to compliance with performance metrics rather than innovation (Ehren and Godfrey, 2017). At the same time, emergent MAT hierarchies can strip individual schools of pedagogical authority, undermining teachers' sense of agency and eroding the collective validation that is central to their professional self-understanding (Wilkins, 2017; Simon *et al.*, 2021). However, when MAT boards deliberately invest in local networks by hosting regional workshops or cross-school teacher forums, they can develop a shared professional identity among computing educators, creating spaces where individuals reaffirm their craft and collaboratively negotiate new teaching roles (Baxter and Cornforth, 2021). For physical computing, such support is crucial, as identity work in this area often depends on opportunities to share practices, build confidence, and collectively navigate the uncertainties of hands-on pedagogy.

2.7 Researching Teachers' Lived Experiences

Having examined the literature on the curricular and pedagogical context of teaching with physical computing, this review now turns to studies that centre on teachers' lived experiences. Such accounts are important because they reveal how teachers understand and enact their work, a perspective that aligns with hermeneutic phenomenology.

2.7.1 Hermeneutic Phenomenology in Educational Inquiry

Hermeneutic phenomenology has steadily gained traction as a means of understanding the complex realities of teaching (Friesen *et al.*, 2012; Van Manen, 2016). By privileging teachers' descriptions of their practice, it transcends technicist accounts that reduce pedagogy to inputs, outputs, or checklists. Instead, it attends to embodied gestures, emotional currents, and situated judgments that remain largely invisible in outcome-driven research (Dangal and Joshi, 2020). Yet the method's philosophical inheritance from Heideggerian ontology has attracted critique.

Kakkori (2009) cautions that invoking hermeneutic-phenomenological without grappling with its ontological underpinnings risks superficiality. Her call for deeper epistemological reflection resonates here, suggesting that Heidegger's *Sorge*-centred vision of care remains central rather than decorative (Smythe *et al.*, 2008). Additionally, Van Manen's translations of phenomenological concepts into pedagogical research offer one path forward, reminding researchers that interpreting lived meaning demands ongoing self-reflexivity and resistance to reifying categories (Van Manen, 2016). For computing education, adopting this stance is particularly valuable, as it allows the teacher's encounter with code, hardware, and students to be treated not simply as instructional events, but as sites of meaning-making where professional identity, technical practice, and affect converge.

2.7.2 Navigating Curricular and Technological Change

Within the field of computing education, hermeneutic phenomenology has shed light on how institutional reforms influence identity and practice. Sloan and Bowe's (2015) study of higher-education lecturers confronting policy-driven curriculum redesign revealed an emotional gap between management’s procedural framing and lecturers’ investment as knowledge-makers. Similarly, McPherson (2021) demonstrated that teachers’ shift toward student-centred computing pedagogy hinges on relational support as much as new hardware or software. Cole Jr's (2017) work with Iowa superintendents further highlights that sustainable technology integration depends on leadership attunement to local culture and educators’ sense of agency.

These studies invite us to view curricular and technological change not merely as technical implementations but as hermeneutic processes through which teachers interpret, adapt to, and sometimes resist innovations. However, few studies have examined these processes in the specific context of physical computing, where the material and embodied dimensions of teaching are central. Longitudinal, phenomenological accounts of how computing teachers' professional identities evolve in response to curricular and technological change remain scarce, leaving important questions about how such meanings are negotiated over time. Peters' (2019) study illustrates how computing identity is constructed relationally within disciplinary spaces, shaped through encounters with peers, practices, and institutional contexts. Although her focus is on students, the insight is transferable: teachers, too, negotiate their identities through such relational processes, where professional meaning emerges in a continual fusion of horizons with the communities, artefacts, and traditions that frame computing education. This study builds on that inquiry by examining how secondary computing teachers engage with physical computing.

2.7.3 Becoming a Teacher

Hermeneutic phenomenology has also shed light on the ontological journey from novice to teacher. For example, an analysis of Brazilian primary-education applicants' written memories demonstrated how cultural narratives and personal values influence career entry choices (Da Silva and Portilho, 2020). Furthermore, Lakateb (2014) and Al-Issa *et al*. (2016) extended this work in Thailand and Oman, respectively, showing that supportive relationships, or conversely, unacknowledged emotional labour, can determine whether early-career teachers persist. Moreover, Stephenson *et al*. (2018, p. 261) synthesise these insights through the concept of "being-in-practice," which highlights how identity and pedagogy co-construct one another and emphasises the importance of situating teacher development within both institutional contexts and personal histories.

Although these studies sit outside computing education, they suggest that becoming a teacher is always a hermeneutic process in which past experiences, professional encounters, and institutional demands are brought into dialogue. In computing, where technical practices and curricula evolve at a pace, this fusion of horizons is heightened as identity, disciplinary knowledge, and classroom practice intersect. This study examines how such processes of Being-in-practice take shape in the context of physical computing.

2.7.4 Affective Dimensions of Being a Teacher

Explorations of being a teacher reveal how emotion infuses pedagogical choices. Girdzijauskienė's (2021) study with music teachers showed how nostalgia, pride, or anxiety around performance shaped both present teaching and teachers' future aspirations. Similarly, Wei's (2015) study of two A-level English literature classrooms in an urban comprehensive school illustrates how high-stakes examination pressures create layers of affective complexity in teaching and learning. Drawing on lesson observations, interviews with teachers and students, and analysis of policy documents, Wei uncovered a misalignment between the rich, interpretive conception of literature held by curriculum designers and the narrowly focused, exam-driven enactment in the classroom. Teachers described a palpable tension, frustration at having to streamline thematic inquiry into exam techniques, relief when students achieved target grades, and unease over the loss of broader literary engagement.

Although conducted outside computing, these studies demonstrate the capacity of hermeneutic phenomenology to reveal the emotional labour involved in translating policy into practice. In physical computing, where teachers work at the intersection of exploratory inquiry, technical setbacks, and accountability demands, comparable affective tensions might be anticipated. A phenomenological lens offers a way of attending to these dimensions without reducing them to technical or procedural concerns.

2.7.5 Computing Teachers' Lived Experiences

Specific to the English computing context, Sentance and Waite (2021) remain among the few who apply hermeneutic phenomenology to classroom discourse, uncovering how shared code artefacts mediate teacher-student talk. Law's (2023) Canadian case study, although not strictly phenomenological, highlights similar dynamics in micro:bit enactments, where ethical reflection and community-building emerge through technical work. Collectively, these studies suggest the value of a hermeneutic perspective for uncovering the subtle, and at times contradictory, ways in which computing teachers make sense of their practice while negotiating policy mandates, technical challenges, and shifting professional identities. Yet this line of research remains limited, particularly in relation to physical computing, where the embodied and material dimensions of practice invite further inquiry into how teachers' meanings take shape with the ongoing interplay between self, artefact, and institution.

2.8 Positioning the Study

Research in computing education highlights the importance of reflective practice in teachers' development. In contrast, studies of physical computing emphasise its embodied and material character, learning that unfolds through engagement with artefacts and the rhythms of classroom life. Collectively, these strands support an interpretive inquiry that seeks to understand physical computing as lived practice.

Prior work has evaluated discrete interventions and surveyed broad shifts in teacher identity. What remains comparatively underexplored are sustained accounts of how teachers make sense of physical computing over time and across institutional settings. This study responds by foregrounding teachers' lived experience.

Teaching physical computing is inherently interpretive, and situated, with professional meaning shaped through everyday interactions with hardware, institutional expectations, and students. A hermeneutic-phenomenological approach is therefore apt, treating pedagogy as an ongoing process of sense-making in practice. It provides a framework for attending to how meaning is negotiated in and through classroom life. This positioning leads directly to the research questions that follow.

2.9 Returning to the Research Question

This literature review has examined the emergence, evolution, enactment, and institutional support of physical computing in English secondary schools through a hermeneutic-phenomenological lens. It traced the philosophical foundations, curriculum reform, multi-academy trust governance, mentoring frameworks, and the formation of computing teachers' professional identities before considering studies on teachers' lived experiences. Together, these strands show how policy, hardware adoption, professional networks, and identity intersect to shape teachers' experiences with physical computing. The review highlights hermeneutic phenomenology as an appropriate framework for investigating these lived experiences and for examining how professional meaning develops in classroom contexts.

Three gaps emerge. First, research on physical computing in secondary schools remains primarily short-term and outcome-focused, offering few sustained accounts of how teachers construct and reconstruct professional meaning through their lived experiences with hardware and classroom practice. Second, much existing work treats identity and affect as separate from the practical, technical, and social realities of physical computing, leaving only a partial picture of how confidence, care, and professional values are negotiated in day-to-day teaching. Third, governance and accountability, such as MAT arrangements and inspection regimes, are typically examined at the system level, with little insight into their direct influence on teachers' pedagogical judgement in physical-computing contexts.

Taken as a whole, the literature suggests that sustained change in physical-computing practice depends on teachers' meaning-making in context: how they interpret policy shifts, negotiate material constraints, and navigate identity and affect in classrooms and within departments. On this basis, the study adopts a hermeneutic-phenomenological approach and asks:

What is the meaning of teachers' lived experiences with physical computing in English secondary schools?

To guide this exploration, the following sub-questions were posed:

(1) How do teachers describe their experiences with physical computing?
(2) What themes can be uncovered through the study of teachers' lived experiences?

Chapter 3 Research Approach and Design

3.1 Introduction

This chapter describes the research design and methods that underpin this hermeneutic phenomenological study. It begins by articulating the philosophical foundations of phenomenology and justifies the selection of a hermeneutic approach for data collection and analysis. My positionality as a researcher and its implications for interpretation are then made explicit. Next, the chapter profiles five teacher participants, outlining their demographic characteristics, the sampling criteria used, and the recruitment procedures employed. It describes the instruments and protocols to gather data, including a detailed account of the three-interview pilot study and its refinements.

The remainder of this chapter unfolds in two parts. Sections 3.2–3.5 outline the hermeneutic-phenomenological design, pilot work and refinements, researcher positionality, sampling and recruitment, and data collection procedures. Section 3.6 details the analysis framework and concludes by linking these analytic moves to the crafted stories presented in Chapter 4.

3.2 Design and Rationale

3.2.1 A Phenomenological Approach to Research

Heideggerian, hermeneutic-phenomenological studies centre on the participants' everyday experiences (Vandermause and Fleming, 2011). Accordingly, understanding is developed through reflective dialogue with participants in their natural settings, which is highly pertinent for reporting teachers' school-based experiences. Moreover, a phenomenological approach facilitates the discovery of new meaning through reflexivity and the exploration of contextual meaning through the situational knowledge of teacher participants (Creswell and Poth, 2016). Furthermore, phenomenology differs from other qualitative methods in that findings can become an ontological description of the significance of a phenomenon from the first-person perspective. Adopting a phenomenological approach ultimately provides access to more direct contact with teachers' lived experiences in this study, as the researcher reflects phenomenologically on physical computing as a teacher, rather than an ethnographer seeking depth through prolonged observation (Van Manen, 2017).

Adopting a qualitative approach enables researchers to gain an understanding of how teachers interpret their experiences, construct their lifeworld, and attribute meaning to those experiences (Tisdell *et al.*, 2025). To amplify teachers' voices as a contribution to the research field and to balance researcher power within the study, Catalano and Creswell (2013) argue that qualitative methodology is most appropriate and, in this context, to uncover new meanings within an interpretivist philosophical position centred on the lived experiences and understandings within a computing teacher's world to see ordinary things in a new light (Moustakas, 1994, p. 11). However, although phenomenological researchers generally share a central concern to return to embodied, experiential meanings, aiming for a detailed description of a phenomenon as it is concretely experienced, disagreements abound when selecting methods (Finlay, 2009).

3.2.2 Pilot Study and Lessons Learned

Before embarking on the main study, I conducted a pilot with a single teacher, an experienced head of computing in an independent 11–18 school. Her dual identity as a former non-specialist who converted to teaching IT through a postgraduate teaching qualification and later to teaching computing reinforced her suitability, given her longevity of engagement with physical computing and the capacity for sharing and reflecting on that lived experience. Over three consecutive weeks, I met her online using Microsoft Teams for sixty to ninety minutes of semi-structured interviews. I began each session by summarising my reflective notes on the previous transcript, then invited her to share more experiences of her journey of adopting physical computing for teaching and learning. I listened to the audio recordings in full between interviews, sketched a chronological timeline of her career and key physical computing encounters, and recorded methodological insights, emergent codes, and questions in an analytical and reflexive file. This iterative cycle deepened both our rapport and my interpretive attunement. As each new session began with clarifications of my summaries and her elaborations, I practised van Manen's (2016, p. 318) “hermeneutic alertness” and guarded against premature closure or researcher-led bias.

Pilot adaptations included three changes: (1) shortening question stems and shifting from ‘why’ to ‘how’ prompts to elicit pre-reflective descriptions; (2) re-timing the interview schedule to 60–75 minutes to allow more sustained attention to concrete episodes; and (3) standardising follow-up prompts to avoid leading language while leaving space for participants' own terms.

Engaging in the pilot's first analytical cycle enabled me to practise "indwelling" in the hermeneutic circle (Gadamer, 2013, p.202). I organised three linked files: raw transcripts, a personal career timeline, and analytical memos and traced emergent themes through line-by-line coding. An illustrative example under the theme 'Communities of Practice' turned the pilot teacher's recollections of *Picademy*, a teacher professional development programme designed and delivered by the Raspberry Pi Foundation, into one of the first crafted stories below:

Picademy for me, I can't rave about it enough. It was a really, really rewarding experience and two fun days of CPD with the opportunity to network with teachers I would never have met before. It gives you a student's perspective when they start a new project independently. It can feel like sitting down as a writer with a blank page, whereas in a small group we'd ask, 'What's our idea? What do we need to know to do this?' That teamwork is a key skill our students need for learning with physical computing in school.

Three refinements emerged from this trial. First, bracketing participants' immediate assumptions required an explicit invitation; in Interview 3, the prompt 'Let us revisit what physical computing looked like in your earliest memories' effectively foregrounded foundational experiences. Second, interview durations of 60–75 minutes struck a balance between allowing for narrative depth and preventing fatigue, with the flexibility to extend to ninety minutes when rich material emerged, such as further recounts of the teacher's lived experiences. Spacing three semi-structured interviews a week apart elicited detailed, vivid reflections while minimising the burden on participants across a school term. Third, question wording was sharpened to avoid leading formulations: for instance, "How frustrated were you?" was reframed as the more open-ended "Can you describe a difficult moment?" These adjustments established a robust protocol that underpinned the main study interviews.

As an insider with prior experience in physical computing, I found that my familiarity with terminology and pedagogy facilitated the elicitation of probing questions, which in turn prompted clarifications. For example, I was able to determine whether a frustration with a GPIO pin was ontological (“What actually happened?”) or if comments about technical challenges were based on personal experiences or anecdotal evidence. Yet I remained vigilant to avoid imposing my interpretive frames: after each interview, I compared my reflexive notes against the raw transcript, and in the following session, I routinely asked, “When you said … did I understand that correctly?” This dialogic checking balanced the epistemic advantages of shared background against the risk of confirmatory bias. Ultimately, the insights from the pilot study informed the design of the final study, validated the use of three semi-structured interviews per teacher participant, established a two-year minimum threshold of physical-computing experience for inclusion, and developed the phenomenological interview protocol and data-analytic procedures.

3.3 Researcher Role

Knowledge co-production with teachers underpins the study’s axiology and its aim of developing an emic view of physical computing in secondary school settings. Consequently, my dual role as computing educator and researcher necessitated continual reflexivity.

Reflexivity is essential in the planning and execution of hermeneutical phenomenological research (Ajjawi and Higgs, 2007). Throughout the study, I critically examined the relationships between myself, participants, and the research process. As the researcher, I needed to maintain *hermeneutic alertness* (Bjorbækmo and Mengshoel, 2022), which refers to the reflexivity required to examine my assumptions and biases. This reflexive approach provided a deeper understanding of the research processes and insights into how my biases and preconceptions may have influenced data interpretation. The use of reflexivity and critical analysis of the research experience was thus essential in ensuring the rigour and credibility of the research findings.

Hermeneutic phenomenology recognises that the researcher's own experience forms part of the interpretive act. Moving through successive turns of the hermeneutic circle, I revisited the data repeatedly, each reading opening a slightly different perspective. Keeping a journal from the outset helped me identify and record how my assumptions about physical computing evolved and how those changes shaped the questions I brought to the process. These journals documented shifts in my thinking and provided a record against which analytic decisions could be checked, thereby supporting the trustworthiness of the study.

Because I had previously worked alongside many computing teachers, I was aware of potential power dynamics in the interviews, such as the risk of slipping into an expert–novice relationship. To mitigate this, I drew on the participants' own words when framing prompts, pausing to clarify meanings as we talked, and kept notes whenever I sensed that my own assumptions might be shaping the direction of the conversation. During analysis, these memos were cross-referenced with transcripts to ensure that interpretations remained grounded in participants' accounts rather than in my assumptions.

3.4 Participants

As shown in Table 2, all five teachers work in secondary schools in the North of England, and three have a sixth-form centre. Although it was not stated in the criteria, every teacher has a responsibility in school as the head of the computing department. During the interviews, it was revealed that all of them had previously worked outside of education before becoming teachers. Because they obtained Qualified Teacher Status (QTS) before the 2014 curriculum reform, none of the participants were initially trained to teach Computing or Computer Science.

Table 2: Participants' Demographic Data

Pseudonym	**Age range**	**Gender**	**School**	**Students**	**Role in school**
Marcia	41 - 50	Female	Independent co-ed	3 – 18	Head of Computing
Tom	51 - 60	Male	Academy co-ed	11 – 18	Head of Computing
Pete	31 - 40	Male	Voluntary aided co-ed	11 – 18	Head of Computing
Jenny	41 - 50	Female	Academy co-ed	11 – 16	Head of Computing

3.5 Sampling

The pilot study served as a valuable evaluation mechanism to refine the methodology and assess recruitment channels, thereby increasing my experience with phenomenological interviewing and providing evidence for sample size calculation in preparation for the main research. According to Polkinghorne (2005, p. 140), qualitative research employs purposeful sampling to select participants who can provide meaningful accounts of the collective experience under consideration. In this study, I employed purposeful criterion sampling to select participants who had a strong connection to the central phenomenon under investigation. Furthermore, to contribute a shared and lived experience of the phenomenon, teacher participants had to meet a predefined benchmark, which was a minimum of at least two years of adopting physical computing in their teaching (Creswell and Poth, 2016; Moser and Korstjens, 2018). As a result, criteria for identifying potential teachers with significant backgrounds in physical computing were critical (Seidman, 2006), and dialogue began before consent was given to judge how participants qualified based on the predetermined criteria listed below:

1. Be teaching in a secondary school in England.
2. Have at least two years of experience with physical computing in the secondary curriculum.
3. Have the capacity to reflect on and provide descriptions of their lived experiences.

3.5.1 Sample Size

The sample size for phenomenological interviews is generally considered to be between three and ten participants (Polkinghorne, 1984; Seidman, 2006). Moreover, Speziale *et al*. (2011) argue that the sample size in phenomenological research should be small enough to allow for an in-depth examination of each experience. As a result, the pilot study served as an evaluative process for reflecting on the correlation of results to the research question, indicating that a sample size of four new teachers in the main study would generate sufficient data. Furthermore, rich data from the initial phase contributed to the main study by providing in-depth insights into physical computing.

Consequently, data analysis from five teachers enabled me to better interpret the meaning and context of the findings, create detailed descriptions of themes, and capture the essence of teachers' lived experiences (Moser and Korstjens, 2018). Thus, the final number of participants in this study was determined by achieving saturation, as described by Malterud *et al.* (2016): saturation is defined as the point at which the researcher no longer receives new information that contributes to the theory developed in the study.

3.5.2 Recruitment

Archibald and Munce (2015) advocate for ongoing engagement with participants before recruitment, citing the importance of long-term relationships in fostering participant trust. Although I leveraged existing contacts and networks to recruit participants for this study, I still needed to establish rapport with each teacher before their participation. Some were familiar from past events or Computing Hub courses, while others I had never met. To establish a research relationship and clarify the study's aims before they committed to the full interview schedule, I offered every teacher a preliminary phone call or online meeting. All agreed to this initial conversation; however, four of them were subsequently unable to join the study and complete the scheduled data-collection interviews, three due to scheduling conflicts and one due to persistent technical problems during online sessions.

For recruitment, I also shared an online link for teachers to learn more via social media, communities of practice, networks, and school contacts. Potential participants were approached through my education networks, which included connections with classroom practitioners, school leaders and Computing at School. Snowball sampling was used to recruit eligible and willing teachers. Pilot interviews were conducted online and continued into the main study, with the impact of COVID-19, thereby expanding the potential number of eligible teachers and their geographic locations. Moreover, the study prioritised depth of engagement over numerical breadth, consistent with a hermeneutic-phenomenological approach. Working with five experienced teachers enabled multiple interviews and extended interpretive engagement, resulting in detailed, context-rich accounts across diverse school settings. Recruitment ceased when it became evident that additional participants were unlikely to contribute perspectives beyond those already emerging in the analysis.

3.6 Data Gathering

3.6.1 Instrumentation

In this hermeneutic phenomenological study, I served as the primary instrument for data collection and interpretation, consistent with the traditions of qualitative inquiry (Pezalla *et al.*, 2012). My prior engagement with physical computing, both as a practitioner in communities of practice and as an educator, provided fore-understandings (Gadamer, 2013) that enabled me to recognise and resonate with participants' descriptions while remaining reflexively alert.

I gathered data through three in-depth, semi-structured interviews with each teacher participant, conducted online via Microsoft Teams, as summarised in Appendix 1 (List of interviews with dates). By adopting a triadic interview design, I facilitated progressive deepening of the enquiry: in the first interview, I elicited biographical reflections and first contact narratives concerning physical computing; in the second, I focused on concrete classroom practices and the pedagogical affordances of physical computing tools; and in the third, I revisited earlier reflections to surface pre-reflective insights and to validate emergent meanings. Guided by an open-ended question protocol (see Tables 3, 4 and 5), each interview lasted approximately sixty to seventy-five minutes, although actual durations ranged from forty-two to eighty-two minutes. All sessions were video-recorded with participants' informed consent, and I subsequently transcribed the recordings verbatim.

In keeping with van Manen's (2016) call to stay receptive to unforeseen insights, I interspersed periods of reflective journaling and supervisory debriefings between each interview wave. These reflective intervals allowed me to critically assess the interview process, identify opportunities to refine my questioning techniques, and calibrate my interpretive stance. Throughout the three-interview series, I continually adjusted prompts to favour participants' own terminology and avoid leading language, thereby deepening descriptions and maintaining alignment with phenomenological objectives. Consequently, the finalised interview protocol struck an equilibrium between rigorous methodological standards and the adaptive flexibility necessary to elucidate teachers' lived experiences of physical computing. Interview prompts are summarised in Tables 3-5.

3.6.2 Interview Questions

Guided by hermeneutic phenomenology's emphasis on eliciting "pre-reflective experiential accounts" (Van Manen, 2016, p. 311), each teacher was invited to participate in a series of three online, semi-structured interviews. This triadic design enabled me as the researcher to follow the development of each teacher's lived experience with physical computing, beginning with their initial primordial encounter, progressing through their adoption in the classroom, and concluding with a reflective return to those formative experiences. Instead of a fixed set of questions, I used indicative question guides (Tables 3, 4, and 5) as prompts and a scaffold; the conversation followed participants' unfolding descriptions. For example, one guiding prompt invited teachers to talk about integrating physical computing into their curriculum:

"How does physical computing feature in your current curriculum and teaching plans?"

Open-ended questions allowed participants to articulate their experiences in their own voices, unencumbered by my assumptions or leading language. As King (2001) observes, this style is particularly well suited to phenomenological studies, allowing participants to articulate their everyday experiences without feeling constrained by overly rigid question structures. Although Tables 3, 4, and 5 present the indicative prompts employed across the three interview waves, their role was solely heuristic. By Gadamer's (2013) view that genuine dialogue must be free to take unexpected turns, I remained prepared to depart from the guide whenever a participant's narrative suggested new avenues of meaning. Likewise, van Manen's (2016) emphasis on openness to emergent insights emphasises avoiding questions that presuppose particular outcomes or evaluations. Consequently, the interviews employed exploratory prompts that encouraged teachers to provide rich, detailed descriptions, allowing the phenomenon to emerge in participants' language.

Table 3: Guide Questions from Interview 1 of 3

Interview Focus	**Aims**	**Guide questions**
How did the teacher participant become a teacher of computing and adopting physical computing?	To understand the journey to becoming a computing teacher	Tell me about your experiences as a teacher in a secondary school. To start, how did the idea of you first becoming a teacher arise?
		How did you decide on becoming a teacher?
	To map the route taken in becoming a teacher of computing	Did you always assume that you'd teach computing?
		Tell me about your first role as a teacher of computing.
	To understand how and why the teacher adopted physical computing into their teaching	Can you describe how you first began integrating physical computing into your teaching and what motivated you to adopt it in your classroom?
	To recognise past experiences of physical computing	How many years of experience have you got of teaching with physical computing?

Table 4: Guide Questions from Interview 2 of 3

Interview Focus	Aims	Guide questions
How do teachers describe their lived experiences of physical computing?	To understand the meaning that physical computing holds for teachers	Tell me what physical computing is all about. What does it mean to you?
		Why do you adopt physical computing in your practice?
	To develop an understanding of what physical computing looks like in the teachers' schools	How is the integration of computing into the teaching of computing accomplished in your school? How does physical computing feature in your current curriculum and teaching plans?
		How do you design curricula/lesson plans with physical computing?
		Tell me about a typical lesson when you're teaching with physical computing.
		Describe a positive use of physical computing in the curriculum.
	To understand the uniqueness, commonalities and divergences of teachers' experiences with physical computing in schools	Can you tell me about the resources that you use for physical computing? What hardware and software do you use? Lesson activities etc.
		Describe a successful outcome as a result of integrating physical computing into your teaching.
		What are the challenges that you've faced as a teacher introducing physical computing into your practice, if at all?

Table 5: Guide Questions from Interview 3 of 3

Interview Focus	Aims	Guide questions
What might the implications of these experiences be for future physical computing practice?	How does physical computing feature in future plans?	Do you require any other on-going support for your inclusion of physical computing to teach computing?
	What are the challenges faced by a teacher when introducing physical computing into the classroom?	Are there other challenges that need to be addressed in your school in order to make the integration of physical computing easier?
	Identify possible implications for education, policy and future research based on study findings	Are there are other challenges that need to be addressed for all teachers in all school in order to make the integration of physical computing easier?

3.6.3 Follow-Up Questions

In hermeneutic phenomenology, the interviewing approach extends beyond the administration of pre-scripted questions and moves to a dynamic, responsive dialogue in which the researcher and participant co-construct meaning (Van Manen, 2016). After each teacher responded to the initial open-ended prompts drawn from the indicative guide (Tables 3, 4, and 5), I remained attentive to emerging themes, inviting further elaboration with follow-up probes. For example, when Pete described his experiences of head-teacher work scrutiny, I asked, “You mentioned that work scrutiny felt like being ripped to hell by book looks, could you walk me through a particular lesson observation or work scrutiny process and tell me more about it?” Similarly, when Jenny reflected on her mentoring year, she was asked, “Tell me more about the moment you realised joint lesson planning gave trainees the freedom to experiment. What did that look like in practice?”

Such follow-up questions drew on the original guide’s structure, “You mentioned …, tell me what that was like for you,” and “In what way?”—but were reframed in the moment to match each teacher’s unique language and lived context. This approach served two goals simultaneously: it deepened the narrative richness by foregrounding specific, concrete episodes and upheld Gadamer’s (2013, p. 248) injunction to maintain an open “fusion of horizons,” wherein the researcher's fore-understandings and the participant's experiences continually inform one another.

Between each series of interviews, I engaged in reflective journaling, revisiting the transcripts and audio recordings to identify emergent themes and discussion points to take into supervision meetings (see Figure 2). Field notes captured impressions of nonverbal cues, pauses, hesitations, and laughter that indicated an understanding of teachers’ embodied experiences. By the third interview, prompts were deliberately designed to bracket earlier descriptions and invite pre-reflective recollections: “Let's revisit what physical computing felt like in your first lesson. What stands out now?” These iterative, recursive conversations within the hermeneutic circle led to further analysis within the evolving thematic framework, as ongoing immersion in the data refined my research questioning techniques and the framework itself.

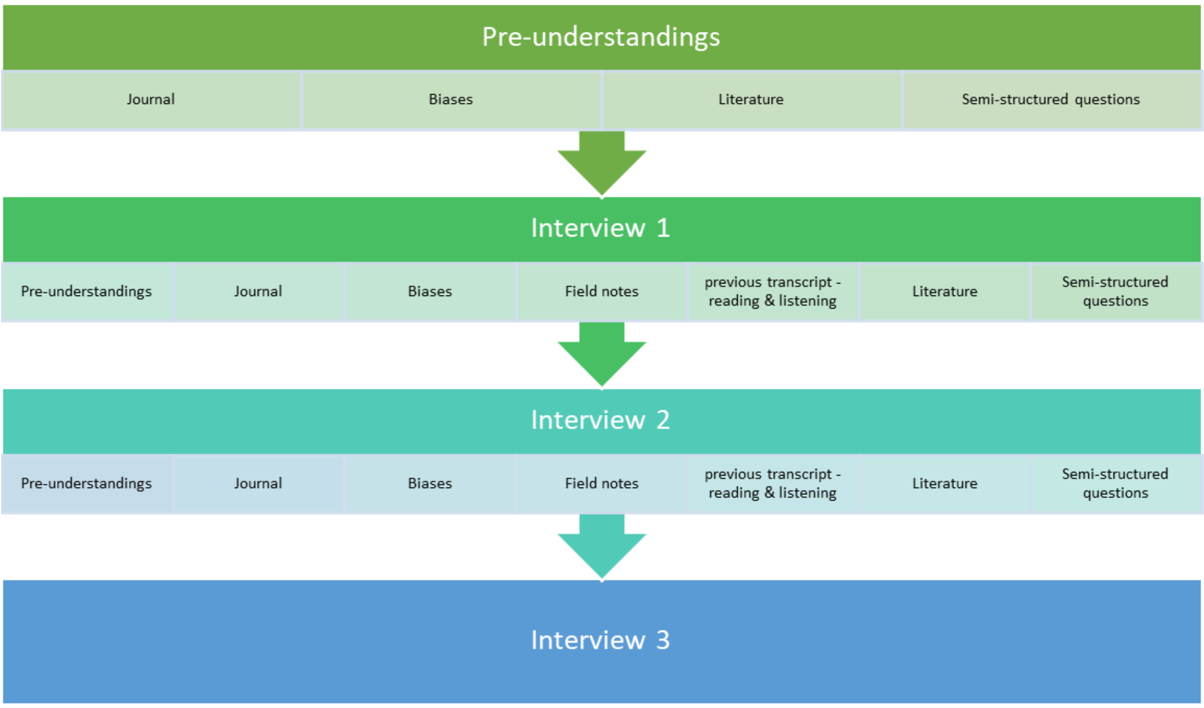

Figure 2: Immersed in textual data during each series of interviews with teacher participants

3.6.4 Journaling

In hermeneutic phenomenology, gathering and analysing information from participants occurs concurrently rather than as a separate process (Van Manen, 2017). To adhere to the methodology's principles, I referred to the process as data gathering rather than data collection for teachers, conveying a more casual setting, facilitating listening, and capturing teachers' experiences, in keeping with van Manen's (2023, p. 299) definition of data gathering as obtaining “direct accounts of the situation and experience rather than inviting reflections” on the experience. I kept a reflective journal to help improve this process by recording my thoughts, comments, questions, and notable statements or observations about the phenomenon under investigation. This journal helped surface and track emergent meanings associated with physical computing.

Throughout the data gathering and interpretation processes, I engaged in self-reflection. I reflected on my biases, assumptions, questions, values, and perspectives on physical computing in secondary schools before and throughout the study, an essential component of the hermeneutic phenomenological research process (Van Manen, 2016). We are all subject to the “spell of our fore-meanings,” as Gadamer observes, and we frequently remain unaware of the fore-meanings that shape our understanding (Gadamer, 2013, p. 267). Therefore, it is essential to state explicitly that my physical computing experiences and insights will unquestionably influence the findings of this study (Koch, 1994).

Journaling and field notes were essential to the analysis process, enabling a deeper understanding and interpretation of the textual data. This assisted in reviewing my prior knowledge and explicit biases, which had been documented at the outset of the study. The process of better understanding and interpreting the textual data was ongoing. Reflecting on my pre-understandings resulted in a greater awareness of the phenomenon and a new pre-understanding, thus closing the hermeneutic circle and emphasising the present-past relationship. To make my historical horizon of understanding explicit, I needed to refer back and forth to what I knew about physical computing before engaging with the transcripts.

3.7 Data Analysis

3.7.1 Introduction

Building on the hermeneutic–phenomenological framework established earlier in this chapter, the data analysis unfolded through overlapping phases of immersion, interpretation, and synthesis, as summarised visually in Figure 2. To ensure a rigorous audit trail, I maintained three complementary analytic records: a detailed field-note journal capturing contextual observations, a standalone reflexive log documenting methodological decisions and emergent insights, and a dynamic Sway storyboard (an example of iterative crafted storying is shown in Appendix 2) that hosted selected field-note excerpts, reflexive memos as well as successive iterations of crafted-story drafts generated from NVivo-coded transcript segments. NVivo 12 facilitated clause-level open coding of the raw transcripts while Excel housed both the master codebook and the interpretive leap matrix (examples shown as screenshots in Appendices 3 to 6). The Sway storyboard rendered each turn of the hermeneutic circle immediately visible, thereby supporting sustained indwelling and reflexive practice without compromising the original field notes and reflexive log as distinct audit trail documents. For clarity, Table 6 summarises the analysis audit trail, listing each artefact and its purpose.

Table 6: Analysis Audit Trail

Artefact/Record	Purpose in Analysis
Reflexive log	Documents methodological decisions, pre-understandings, and interpretive shifts (decision trail).
Field-note journal	Captures contextual observations and immediate reflections during data collection.
Sway storyboard	Hosts selected field-note excerpts, reflexive memos, and iterative crafted-story drafts to make hermeneutic iterations visible.
NVivo 12 project	Organises transcripts and supports clause-level open coding to surface preliminary codes and patterns.
Excel codebook & leap matrix	Houses the master codebook and tracks interpretive leaps from initial codes to higher-order phenomenological horizons.

The analytical approach in this study is grounded in hermeneutic phenomenology, where understanding emerges not from predetermined procedural steps but through a continual dialectic between immersion in participants' accounts and reflection on the interpretive whole. Guided by Heidegger, Gadamer, and van Manen, the analysis enacted Gadamer's (2013) hermeneutic circle, in which each attentive reading of a transcript or crafted narrative informs and is informed by evolving interpretive frameworks.

Section 3.6 unfolds as follows. Section 3.6.2 elaborates on the analytic phases of immersion, interpretation and synthesis; 3.6.3 details the hermeneutic circle as the guiding interpretive frame; 3.6.4 illustrates how raw transcripts were transformed into crafted stories; 3.6.5 describes the software open coding and codebook development; 3.6.6 provides two manual worked examples tracing raw excerpts to phenomenological horizons; 3.6.7 demonstrates how the codebook re-enters the hermeneutic cycle; 3.6.8 introduces the three interpretive movements of story-crafting, deeper interpretation and philosophical leaps; and 3.6.9 examines the key hermeneutic-phenomenological concepts underpinning the entire analysis.

3.7.2 General Data Analysis Phases

Analysis proceeded through three interlocking phases: immersion, interpretation and synthesis, each informing and refining the others in a continual hermeneutic movement. During immersion, I repeatedly listened to the audio recordings and conducted line-by-line readings of the transcripts, attending to the cadences, emphases and idiomatic expressions of each teacher's account. In the interpretation phase (summarised in Figure 3), these transcripts were distilled into 500–800-word crafted stories, excising extraneous detail, fusing core quotations and adding minimal narrative framing so that each story vividly evoked the lived experience of physical computing (Crowther *et al*., 2017). The synthesis phase then brought these crafted stories into dialogue with one another and with Heideggerian and Gadamerian constructs, such as *kairos* (the opportune moment), *Mitsein* ('Being-with'), and modes of solicitude (Heidegger, 1962), to articulate the ontological horizons that underlie teachers' experiences.

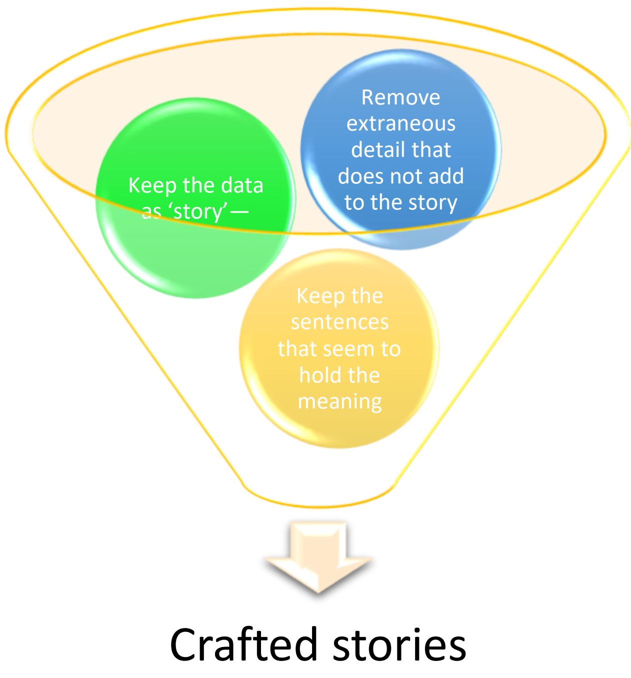

Figure 3: Collecting and Crafting Stories (Crowther *et al.*, 2017)

These three procedural phases provide the scaffold for the more detailed analytic movements of story-crafting, deeper interpretation, and interpretive leaps (see Section 3.6.8).

3.7.3 The Hermeneutic Circle

The hermeneutic circle underpinned every phase, driving an ongoing dialogue between particular passages and the evolving whole. Each provisional insight (part) was tested against complete interviews and across the corpus (whole), ensuring interpretations remained grounded in participants' voices and transparently refined. This recursive movement—immersing in discrete segments, testing provisional meanings against the broader corpus, and returning to the parts with renewed insight—characterises hermeneutic phenomenological analysis and enables rich, situated interpretation. Figure 4 presents this recursive process, in which initial readings of individual sentences or passages elicit provisional meanings, which are then tested and refined against a broader contextual horizon, whether the remainder of a single interview, a series of interviews with one teacher, or the complete set of narratives across participants.

According to Heidegger's account of Dasein (1962), interpretation cannot be conducted from a neutral or detached standpoint. Texts and phenomena are encountered as already "being-in-the-world," shaped by prior experience, assumptions, and involvement with others. In this framework, understanding develops hermeneutically through an iterative movement between parts and whole. This process requires openness to what particular passages disclose and a willingness to allow an emerging sense of the whole to reshape the interpretation of individual parts, as illustrated in Figure 4.

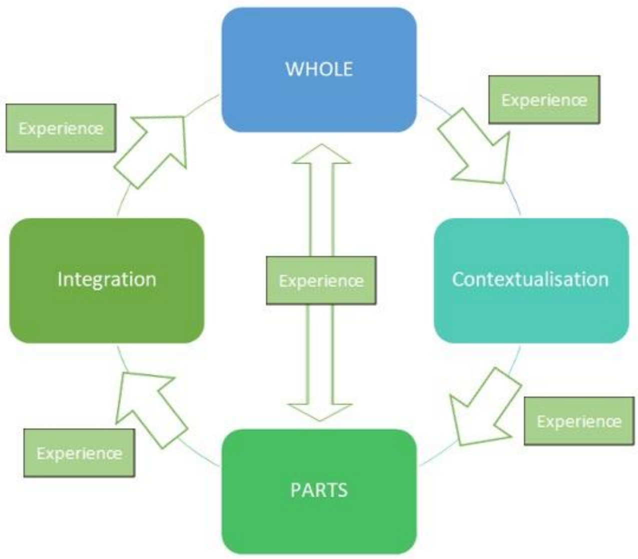

Figure 4: The Hermeneutic Circle for Data Analysis and Interpretation

In practice, I invoked this hermeneutic circle repeatedly in crafting Pete’s story from his three interviews. Initially, I isolated passages in which Pete discussed work scrutiny, underlining them in the transcript, and asked, “What is he conveying about his experience here?” This constituted my first, part-level engagement. Next, I reread the entire interview to gauge how that segment resonated within Pete’s wider narrative of departmental leadership, technical hurdles, and classroom innovation, discovering, for instance, that Pete’s frustration with “being ripped to hell by work scrutiny” echoed earlier comments about diminished autonomy. I returned to the excerpt to refine my understanding of his emotional stance. Each such pass part to whole to part was recorded in my research journal and, once thematic alignment was achieved, informed the editing of the narrative so that the final polished story retained Pete’s emphasis (“I have no work to show… it’s crap”) while clarifying its place within his broader lived experience of leading computing in a high-stakes accountability regime. This iterative hermeneutic circling ensured authenticity to Pete’s voice and enabled the emergence of deeper ontological insights into how leadership scrutiny shapes teachers’ sense of agency and pedagogical freedom.

3.7.4 Crafting Stories from Verbatim Transcripts

The study's methodological innovation lies in the use of crafted stories. These served not only as a way of presenting data but as the methodological foundation of the analysis, enabling lived experiences to be interpreted and held in dialogue with theory. The first step in constructing phenomenological narratives involved a meticulous, line-by-line review of each interview transcript to isolate teachers’ lived experiences of teaching and learning with physical computing. Phenomenologically salient sentences, where participants described lived experiences of, for example, teaching with micro:bits, mentoring colleagues using physical computing or troubleshooting physical artefacts, were highlighted in green to preserve the purity of their own words without any initial theoretical overlay. These green-coded, phenomenologically salient excerpts were then coded and added into NVivo 12 for clause-level open coding, generating provisional nodes derived solely from the data itself. Only after this data-centred coding was complete did I introduce yellow-italicised annotations, linking selected excerpts to hermeneutic-phenomenological constructs *Sorge* (care), *Mitsein* (Being-with) and *kairos* (the opportune moment).

Through successive cycles of cross-comparison testing, each green-highlighted segment was evaluated against other interviews and the emerging codebook. These discrete fragments developed into 500–800-word crafted stories that preserve teachers' voices while illuminating the ontological significance of their physical computing experiences. The colour-coding protocol ensures every interpretive decision remains traceable to the precise transcript moments where the phenomenon first emerged, providing the foundation for the master codebook described in Section 3.6.5.

3.7.5 Software-Supported Coding and Thesis Codebook

Although NVivo served to organise initial codes and visualise emerging patterns, it functioned only as an organisational scaffold; substantive hermeneutic work, including the identification of meaning units, reflexive interpretation, and the integration of insights into phenomenological theory, was conducted manually. All fifteen transcripts were analysed line by line in NVivo 12, where clause-level open coding generated preliminary codes, which were then exported to Excel to construct the master codebook. Table 7 summarises the master nodes emerging from line-by-line open coding, while Table 8 shows the analytical progression across coding cycles. Worked examples of this process are provided in Appendix 3 (Challenges with Physical Computing in the Classroom) and Appendix 4 (Teachers' Early Interests in Computing). These extracts demonstrate how early open codes were developed and brought into relation with one another as ideas began to grow. In doing so, they reveal the shift from simple description to the interpretive work that generated the meaning units underpinning the hermeneutic–phenomenological analysis.

Table 7: Node counts from line-by-line coding in NVivo

Node Name	File Count	Reference Count
Challenges	149	1,032
Computing Interest of Teachers	30	131
Strategies	187	1,882
Learning	112	740
Teaching	155	2,623
Concepts	46	448
Meaning of Physical Computing	112	1,621
Ofsted	9	35
Teacher Journey	31	542

Next, Table 8 traces two worked examples, showing how selected passages from Pete's transcripts were coded into these master nodes and distilled into higher-order phenomenological horizons.

Table 8: Analytical progression across coding cycles (worked examples)

Transcript Excerpt	Open Code	Master Codebook Node	Phenomenological Horizon
"Work scrutiny only considers the work of students…..I expect to see books or online worksheets…..and that is the only thing I look at to show the impact of teaching and progress over time".	Artefact centric evaluation	Work scrutiny → Evidence of Impact	Assessing the Quality of Education (Anxiety)
"I look back at my PGCE…neither mentor was a computing specialist….I did most of it alone…now I ensure joint planning so trainees have space to experiment together".	Mentor support variability	Mentoring → Safe Space for Experimentation	Being with trainees (Optimism)

Although NVivo's visual clustering helped identify recurring language (e.g. "I expect to see books…") and nascent affective tones, I heeded Dickson-Swift's (2005) warning against overreliance on automated tools and treated the software purely as an organisational scaffold; no substantive analytic judgments were made within NVivo. All hermeneutic-phenomenological interpretation was conducted manually, with provisional nodes guiding analysis and pinpointing areas for deeper reflective engagement.

With a master codebook established (see example screenshots in Appendices 3 and 4), the analysis shifted to a transparent audit trail, illustrated here by two worked examples that each trace one phenomenon from the raw transcript to the phenomenological horizon. This next phase involved selecting two particularly illustrative horizons of meaning from Pete's interviews, which had emerged repeatedly in NVivo clusters, and tracing them from the raw transcript to the analytic theme step by step. Doing so makes each interpretive decision explicit, from the micro-level line-by-line open codes to the macro-level phenomenological horizons of understanding.

Building on this foundation, the horizon mapping that follows traces how these evolving codes and story fragments coalesced into five analytical themes that structure Chapters 4–6. The two following examples (A and B) provide a line-by-line audit trail from verbatim excerpt through open coding to the generation of higher-order horizons of understanding, demonstrating the rigour and transparency of the analytic process.

3.7.6 Manual Worked Examples: From Transcript to Theme

In the two worked examples that follow, each step of the analytic journey, from verbatim excerpt through open coding and axial grouping to final thematic horizon, is laid out in a transparent, line-by-line audit trail.

3.7.6.1 Worked Example A: Evidencing Progression

To illustrate how a single phenomenon was traced from raw transcript to a phenomenological horizon, all twelve discrete occurrences in Pete's three interviews that explicitly mentioned work scrutiny were first identified and extracted. These verbatim excerpts were imported into NVivo, where each clause underwent close, line-by-line open coding. Codes such as accountability pressure, erosion of professional autonomy, and leadership-driven scrutiny were applied to preserve the integrity of Pete's phrasing as summarised in Table 9. Once open coding was complete, the provisional nodes were exported into an Excel workbook and examined for their co-occurrence patterns. A review of this matrix, alongside analytic memos documenting emerging reflections, revealed a consistent thread linking externally imposed accountability with the gradual loss of classroom autonomy. Successive rounds of axial coding consolidated these provisional nodes into the interpretive category 'Accountability-driven erosion of teacher autonomy.'

At each stage, I enacted the hermeneutic circle by moving iteratively between the discrete coded segments and the broader interview context: provisional meanings drawn from individual clauses were continuously tested against Pete's other transcripts, and insights arising from the global pattern prompted refinements to the line-by-line codes. Finally, iterative memo-writing and repeated cross-checks against the original audio confirmed the higher-order theme of 'accountability-driven erosion of teacher autonomy.' By linking data selection, open coding, axial grouping, and thematic crystallisation within this circular interplay of part and whole, the analytic process remains fully transparent; each interpretive decision can be directly traced back to Pete's exact words.

Raw Transcript Excerpt A (Horizon 1: Evidencing progression)

> 'Nowadays, there is much more pressure for teachers' plans and students' work to be examined by their head of department or a leadership team member, and any freedom we once had has ebbed away a little now.'

Step 1 – Open coding

Table 9: Open Coding for Transcript Excerpt A

Transcript segment	Open code
"Pressure for teachers' plans and students' work to be examined"	Accountability pressure
"Freedom we once had has ebbed away"	Erosion of professional autonomy
"Examined by head of department or leadership team member"	Leadership-driven scrutiny

Step 2 – Theme Generation

Axial coding grouped pressure, erosion of professional autonomy, and leadership-driven scrutiny into the interpretive category 'Accountability-driven erosion of teacher autonomy,' as confirmed through iterative memo-writing and cross-checks with the raw data. A parallel procedure in Example B saw codes clustering around artefact-only evidence, which were synthesised into 'Misalignment between scrutiny evidence and authentic teaching processes.

Theme 1: Accountability-driven erosion of teacher autonomy

Pete's account highlights how work scrutiny transforms into a top-down mandate that curtails the very professional freedom teachers previously enjoyed.

3.7.6.2 Worked Example B: What Work Scrutiny Is

A parallel procedure was applied to the second phenomenological horizon, concerning Pete's description of work-scrutiny. All passages in which he reflected on the artefact-centric nature of these inspections were isolated, resulting in eight meaningful segments. Within NVivo, each discrete clause such as 'only considers the work of students away from the classroom,' 'expect to see books, folders or online worksheets,' and 'show the impact of teaching over time' was assigned a provisional open code and is summarised in Table 10 (for example, focus on written artefacts, documentation-only evidence, and progress-as-product orientation).

Next, the preliminary codes were transferred into the Excel-based audit trail and examined through axial analysis to investigate points of convergence and divergence among them. This exercise clarified that an exclusive focus on written artefacts inevitably overlooks the active, embodied dimensions at the heart of physical computing lessons. Successive rounds of reflective memo-writing and comparison with the verbatim data refined these insights into the overarching theme: 'misalignment between work scrutiny evidence and authentic teaching processes.'

Raw transcript excerpt B (Horizon 2: What work-scrutiny is)

'Work scrutiny only considers the work of students, and as a head of the department, I do this away from the classroom. I expect to see books, folders or perhaps students' online worksheets, and that is the only thing I look at to show the impact of teaching and progress over time.'

Step 1 – Open coding

Table 10: Open Coding for Transcript Excerpt B

Transcript segment	Open code
"Only considers the work of students… away from the classroom"	Focus on written artefacts
"Expect to see books, folders or… online worksheets"	Evidence based purely on documentation
"Show the impact of teaching and progress over time"	Progress-as-product orientation

In this open-coding phase, each discrete clause in the raw excerpt was examined for concepts that captured either an action ('examined by head of department'), an affective stance ('pressure'), or a contextual condition ('away from the classroom'). Codes were assigned to individual meaning-units to preserve fidelity to Pete's words. Where a single utterance contained multiple meaning-units (e.g. 'Pressure for teachers' plans…' plus 'Freedom we once had…'), separate codes were created. These were logged in NVivo as provisional nodes but then transferred into Excel for transparent display in Tables 9 and 10.

Step 2 – Theme generation

Theme 2: Misalignment between work scrutiny evidence and authentic teaching processes

By privileging only written artefacts, work scrutiny fails to capture the in-class, hands-on learning that is central to physical computing. Throughout this process, I enacted the hermeneutic circle, returning from the emergent theme to the discrete clauses, testing whether the interpretive category 'misalignment between scrutiny evidence and authentic teaching processes' held across all eight excerpts, and refining code labels to preserve Pete's emphasis on hands-on practice.

Having demonstrated the micro-level coding and theme derivation for two exemplar horizons, the analysis aggregated all provisional nodes into an Excel-based codebook. This 'Codebook Summary' provided frequency counts, cross-file comparisons, and facilitated decisions about which clusters merited deeper hermeneutic engagement. The following subsection illustrates how this codebook served as a bridge between granular coding and the full hermeneutic circle.

3.7.7 From Codebook to the Hermeneutic Circle

Once the Excel-based codebook consolidated node frequencies and co-occurrences, highlighting, for instance, 'Work Scrutiny → Evidence of Impact' as a key accountability concern and 'Safe Space for Experimentation' as a mentoring dynamic, I re-entered the hermeneutic circle to refine provisional interpretive leaps (Gadamer, 2013). This involved dialectical movement between individual coded excerpts and the evolving thematic whole: repeated re-readings of selected passages, iterative rewriting of story summaries and continuous juxtaposition with phenomenological concepts like kairos and Mitsein. All reflections were recorded in my field journal, tracing shifts in understanding and affective resonance until broad codebook clusters coalesced into phenomenologically resonant themes.

3.7.8 Three Movements of Analysis

The analytic process for this study emerged as an interplay of three interlocking movements: the crafting of stories from verbatim transcripts, deeper interpretive examination of those stories to validate and uncover emergent meanings, and finally interpretive leaps guided by philosophical constructs such as kairos, Being-with (Mitsein), and Heidegger's modes of solicitude. These movements were not enacted sequentially but merged into one another in a continuous hermeneutic circle: insights arising during the third movement frequently prompted revisions to the crafted stories, and renewed immersion in participant accounts informed subsequent interpretive leaps. Throughout this nonlinear journey, I maintained a researcher's journal to record shifts in understanding, emotional resonances, and methodological reflections, ensuring that my evolving interpretation horizon remained transparent.

3.7.8.1 Movement 1: Crafting, describing and initial interpretation (Description: Crafted Stories)

Central to the first movement was the transformation of extended interview transcripts into narratives that 'show' rather than tell the phenomenon of physical computing in the classroom (Crowther *et al.*, 2017). As Figure 5 illustrates, these crafted stories occupy the first plane of Crowther and Thomson's (2020) three-level model of hermeneutic description and interpretation. While NVivo software was utilised as an organisational scaffold to cluster initial codes and visualise patterns, the analytic work was conducted through my sustained dialogue with text and theory, moving back and forth across the three stages of description, interpretation, and synthesis.

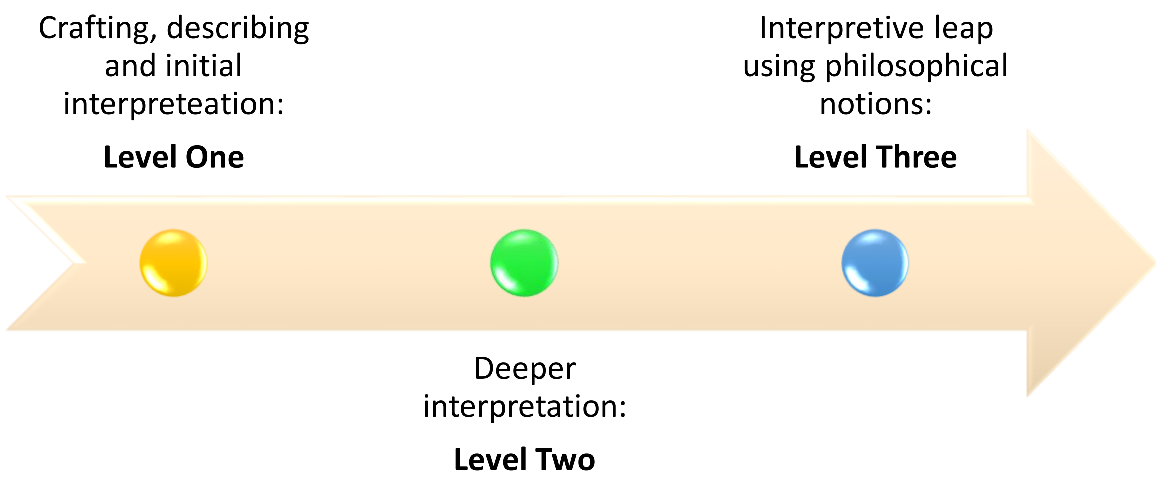

Figure 5: Three levels of data analysis (Crowther and Thomson, 2020)

In the following pages, I present one crafted story drawn from Pete's interviews to illustrate the analytic methods that transform discrete transcript sentences or sections into a final crafted story.

The story-crafting process began with a line-by-line review of each transcript. On the first pass, I read holistically to gain a general sense of each interview's narrative flow. Subsequent readings were devoted to identifying phenomenologically rich passages in which teachers explicitly described encounters with physical computing, whether moments of student engagement, technical breakdowns, curriculum planning, or affective responses. Parallel to this, digressions unrelated to the phenomenon, personal anecdotes on non-computing topics or generalised opinions, were bracketed for possible later use as contextual notes but excluded from the core narrative thread.

Once the essential passages had been isolated, I assembled them chronologically into a single, unified narrative for each teacher. Transitional phrases (e.g. "At the start of term…") were inserted sparingly to preserve coherence without obscuring the teacher's voice. Throughout this process, minimal contextual annotations in italics indicated time, location, or class size but deliberately refrained from veering into interpretation. The resulting stories typically spanned 500 to 800 words, rich in lived-experience detail yet streamlined for analytical focus.

I used colour-coded highlights to aid reflexivity, marking phenomenologically salient text in green and flagging potential contextual or opinion-laden material in yellow, as illustrated in Figure 6. I also used Microsoft Sway to develop emerging crafted stories, with an example of this workspace shown in Appendix 2 (Sway Environment for Iterative Crafted Storying).

Reference 1: 0.37% coverage
It's almost, if it was an app I could justify it, why I was doing it but if I looked at it, on my intention documents then yeah, I probably would struggle.
Files\\Pete 3
30 references coded, 27.40% coverage
Reference 1: 0.66% coverage
I think when I first started, there wasn't as much of a thing of the idea of drop-ins or work scrutinies and being able to justify everything that you're doing.
Reference 2: 1.19% coverage
And even this term, we're seeing now - I've got to go and do 4 drop-ins on Thursday on colleagues, and I've already had to do a work scrutiny - and it is a lot more pressure for things to be scrutinised now, and really, you have to be able to justify where something fits in on why you are doing a lot more.
Reference 3: 0.58% coverage
Kind of that little bit of freedom that we had because no one was really doing these kind of things, it's kind of just ebbed away a little bit now.
Reference 4: 0.63% coverage
The work scrutiny is a very difficult one because it's about how you document progress in physical computing and it's a lot easier to see on an observation.
Reference 5: 0.76% coverage
You can see kids, how they're getting on and how they are progressing, or if can't do something and then they can do something, and it's not always something you can tell by a work scrutiny.
Reference 6: 0.75% coverage
You can try and evidence in little code diaries almost, or little debugging activities, but you've got to put a lot around a basic activity to try and prove that they've done something.
Reference 7: 1.94% coverage
So doing Scratch with my Year nines, because we were meant to have done that in Year seven, but because they've had one and a half years of no computing, we've had to go back and when I'm putting these lessons together, I've got to almost think, well, actually, OK, we're doing a maze game, but that maze is gonna be dragged out for four lessons and I know I could build it with them in a minute in the lesson, but it's kind of thinking, what are the bits around that I need them to take away?
Reference 8: 1.90% coverage
So like, I know the next thing, we're going to focus on variables, what variables are, the two blocks to control that and then the idea of debugging with variables and they'll implement it on their game, and you just try to put a lot of extra things around it because you're conscious just you've got, if somebody came and looked at your stuff and they say, Well, if you just give them an instruction thing on how to do something, and they just do it, there's no

Figure 6: Sample of references about work scrutiny from transcripts of Pete's interviews

In the next phase (illustrated in Figure 7), I refined the emerging crafted story by adding in transitional phrases and, where necessary, reordering clauses to restore coherence following the excision of extraneous material. Equally critical to this process was revisiting the original transcripts and audio recordings to ensure that each grammatical refinement and syntactic adjustment remained faithful to Pete's wording. Combining these stylistic refinements with checks against the raw data, each crafted story retained the immediacy and texture of the teacher's experience while achieving the polished fluency required for subsequent philosophical interrogation.

I first became a teacher before drop-ins or work scrutinies to justify everything you're doing became a thing. There's a lot more pressure nowadays for teachers' planning and students' work to be scrutinised by their head of department, or a member of the senior leadership team, and any freedom we once had has ebbed away a little bit now.

Just this term, I've already completed work scrutiny across the computing department and 'drop-ins' to observe four colleagues teaching. We might get deep dive as a department, but we may get books or work called for, and it's that thing of someone looking at it that doesn't understand the computing curriculum. We never used to worry about this as a department until about three years ago, when we got screwed, we got ripped to hell by work scrutiny when the feedback given was, "You've got no work to show and you can't prove anything, it's crap", so yeah.

Figure 7: Second phase of story writing

The excerpt below is presented as a polished, crafted story. In hermeneutic phenomenology, 'polish' is not merely a matter of stylistic refinement, but a deliberate phase of analysis: it is the process by which the raw transcript is edited into a coherent account that remains true to the participant's own words and rhythms. Crowther *et al.* (2017) explain that this involves judiciously inserting connective phrases, adding minimal contextual detail, refining grammar, and reordering sentences to preserve narrative flow without imposing interpretation. The result is a polished story that shares Pete's experiences with workload and work scrutiny activities and changes since first entering the teaching profession. Notables are the complications he associates with documenting the progression of students' learning when they use physical computing.

I first became a teacher before drop-ins or work scrutinies to justify everything you do became a thing. Nowadays, there is much more pressure for teachers' plans and students' work to be examined by their head of department or a leadership team member, and any freedom we once had has ebbed away a little now.

I have already completed work scrutiny across the computing department and drop-ins to observe four colleagues teaching this term. We may get a deep dive as a department, with books or work called for, and it's that thing of someone looking who doesn't understand the computing curriculum. We never had to worry about it as a department until about three years ago. We were ripped to hell by work scrutiny when the feedback was, 'You have no work to show, and you can't prove anything; it's crap,' so yeah.

A big challenge in planning physical computing lessons is to prove that we are teaching something new and that students have understood it. We have used little code diaries and debugging activities to demonstrate progress and learning. Still, teachers must put a lot of effort into a basic activity to prove that students have done something over time, including the skills they learn and the level of challenge that increases. You are always aware that someone is looking at your planning and saying, 'Well, if you just give them instructions on how to do something and they just do it, there is no evidence.'

Figure 8: Crafted Story – Being a Head of a Computing Department in School

This excerpt is presented here to illustrate the crafting process; the full set of selected crafted stories is presented in Chapter 4.

3.7.8.2 Movement 2: Deeper Interpretation (Validation and Interpretation)

Having crafted concise narratives that show teachers' lived experiences of physical computing, the next analytic phase focused on verifying the authenticity of those stories and uncovering the deeper meanings they held. Throughout this stage, I remained guided by Koch's injunction to continually ask "what is going on?" (1998, p. 1182), moving between readings of each crafted story and reflection on the whole corpus of transcripts. As Crowther *et al.* (2017) remind us, crafting phenomenological stories does not end once the raw narrative is assembled; it must continually be polished so that every word contributes to conveying the essence of the lived experience without extraneous detail or inadvertent distortions. Accordingly, in my re-readings of each crafted account, I paid close attention to grammar and syntax yet resisted every automated suggestion to correct teachers' colloquial turns of phrase (for instance, retaining descriptors like 'most able students') to preserve the unmistakable authenticity of their voices. Filler words and disfluencies ('erms,' 'ahs') were excised. Yet, any momentary hesitation that signalled genuine emotional resonance was noted in my research journal rather than removed outright. Hence, the polished text remained true to the affective nature of the original account.

Deeper interpretation also involved layering the crafted stories with thematic insights. As I re-engaged with the narratives, I highlighted emergent themes shifting language around student capability, evolving professional autonomy, and the ambivalent support of senior leadership (SLT). I tracked how Pete's descriptions of classroom freedom receded over time as work scrutiny increased, a theme that surfaced repeatedly across interviews. Each iteration of story revision was informed by these patterns: a narrative in which SLT “ripped us to hell” by demanding evidence of progression became an exemplar of the tension between pedagogical innovation and institutional accountability. In this way, the analytic process moved beyond surface coherence into an interpretive space where the stories themselves pointed toward broader phenomena of how curriculum enactment, leadership practices, and teacher identity coalesce in the lived reality of physical computing.

An illustrative example emerges from Pete's narrative on work scrutiny. His recollection begins with the relative absence of formal lesson observations when he first entered teaching, then shifts to the present day, in which ‘every bit of planning and every piece of students' work’ must withstand SLT inspection. He recalls preparing for deep dives akin to Ofsted inspections, only to dread reviews by non–subject specialists who “don't understand the computing curriculum.” This crystallises his anxiety: the imperative to document every micro:bit activity and code diary not for pedagogical insight but to demonstrate measurable progress to those outside the discipline. Upon re-reading and refining Pete's story, I ensured that his emotional arc, from recounting autonomy in the past to his frustration with bureaucratic oversight, remained, grounding the emergent theme of eroding teacher freedom in an affective, phenomenological account. This deepened interpretation set the stage for the subsequent leaps into philosophical constructs, in which these themes would be further illuminated.

3.7.8.3 Movement 3: Taking an Interpretive Leap

In the third analysis phase, I aimed to maintain descriptive accuracy while uncovering the deeper meanings embedded in the crafted stories. This undertaking, termed an interpretive leap, is grounded in the hermeneutic conviction that understanding emerges not through further textual trimming but through sustained engagement with philosophical concepts that provoke fresh insights (Crowther and Thomson, 2020). As illustrated in Figure 9, this phase unfolds as a cyclical, iterative process of reading, reflection, writing, re-reading, re-thinking, and re-writing. In contrast to a one-off revision cycle, each turn through the hermeneutic circle refines and enriches understanding, allowing the phenomenon at hand — teachers’ experiences with physical computing — to leap off the page into heightened clarity.

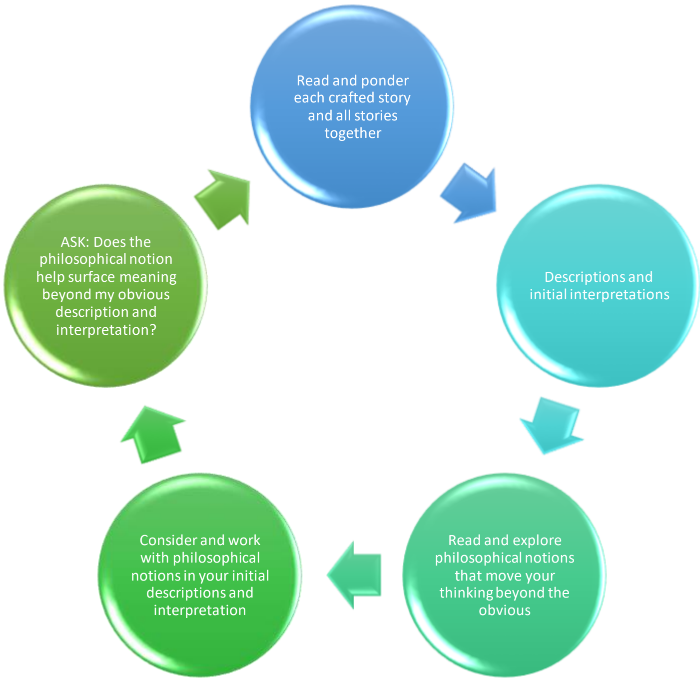

Figure 9: Taking an interpretive leap (Crowther and Thomson, 2020)

In practical terms, I worked through each crafted story already pared back to its essential narrative arc while deliberately invoking three interrelated philosophical lenses: kairos (the felt moment of experience), Being-with (*Mitsein*), and the modes of solicitude or care (*Fürsorge*), distinguished by Heidegger as inauthentic *leaping-in* and authentic *leaping-ahead* (Heidegger, 1962). Each lens functioned as a heuristic: kairos attuned me to the pivotal instants in the narratives where time seemed to stand still, Being-with foregrounded the ways teachers' experiences are inextricable from their relationships with students, colleagues, and institutional authorities, and Fürsorge drew attention to the caring dynamics both supportive and oppressive that inflect those relationships.

For example, in one crafted story, Pete's anxiety about work scrutiny emerges as a persistent fear: he describes how, three years earlier, negative feedback on his department's evidence of student progress "ripped us to hell," instilling a dread of any future 'drop-ins' or book checks. Through the lens of Being-with, this fear is not simply an individual response but a communal phenomenon: Pete's concern extends to "my colleagues in the computing department", whose teaching he must protect and account for. By applying Heidegger's concept of inauthentic solicitude, what he calls *leaping-in* care, I recognised how Pete felt 'done to' by senior leaders whose cursory scrutiny 'didn't understand the computing curriculum', leaving him feeling both powerless and responsible for making the subject legible to those outside it. At the same time, a second form of care, *leaping-ahead*, became visible when Pete, as head of department, described how he now scaffolds work scrutiny processes to shield his team from undue criticism, thereby taking proactive responsibility for their welfare and pedagogical autonomy.

In parallel with the more granular, line-by-line crafting of narrative passages, I adopted a kairotic lens to examine felt moments in Pete's interviews where time itself seemed to contract - where an observation in a mentee's classroom, where micro:bits are being distributed, or an unexpected routine check became the fulcrum for deeper pedagogical insight. These ‘felt’ instances are not merely procedural routines or technical challenges; they are openings in which teacher and learner jointly confront uncertainty, embrace emergent possibility, and recalibrate their understanding of what counts as learning in a physical computing context. Table 11 presents three exemplary crafted excerpts from Pete's interviews, each accompanied by a first-order interpretive insight, the corresponding philosophical lens (e.g. *leaping-in* vs. *leaping-ahead*, Mitsein, Kairos), and examples of emergent themes. Together, these demonstrate how physical computing lessons can become kairotic moments, charged with both anxiety and opportunity, through which multi-layered understandings of teaching and learning are realised.

The interpretive leap matrix and full codebook (see Appendix 5) trace how connections between ideas emerged across the data. They capture the movement from early coding to more integrated interpretations, showing the evolution into the themes discussed later in the thesis. To illustrate this process, Appendix 6 (Interpretive Leap Matrix Example and Final Themes) demonstrates a cluster of related codes as they were developed into one of the themes examined in Chapter 4.

Table 11: Multiple layers of understanding emerging from crafted stories

Crafted Story Excerpt	**First-Order Insight**	**Philosophical Lens**	**Emergent Theme**
"Teachers have to put a lot of effort into a basic activity to prove that students have done something over time, including the skills they learn and the level of challenge that increases."	Anxiety over 'invisible' learning in physical computing	Leaping-in vs. Leaping-ahead	Tension between standard assessment or assessing the quality of learning and embodied learning
"I would like to teach more physical computing lessons in Y9 after the half-term in May when we have built up enough evidence for progress and done the more traditional stuff."	Frustration at technical gatekeeping.	Being-With (*Mitsein*)	Care, control, and co-construction of pedagogical spaces
"It was watching one of Katie's lessons with micro:bits that changed how we distribute and collect equipment."	Kairotic spark of classroom organisation insight reshaped the pace of future lessons.	*Kairos* Time	Reflecting on the mentor–trainee relationship in lesson planning

Finally, these interpretive leaps coalesced around an affective response, a sense of care intertwined with vulnerability, that would recur across participants' stories. As the analytic process deepened, this mood became a central theme in the study's findings, revealing that 'being a physical computing teacher' is as much about navigating care-laden relationships as it is about mastering hardware, software, or pedagogical techniques.

Figure 10 synthesises how the three philosophical lenses converged in the data from this study: kairos illuminates the felt moments, Being-with maps the relational context, and Fürsorge exposes the dual modes of care that shape teachers' lived experiences. Together, they form the third interlocking movement of analysis, taking interpretive leaps that lead to a rich phenomenological account of physical computing in the secondary school classroom, in dialogue with crafting and deeper interpretation. In this sense, crafted stories stand as both a contribution in their own right and as the methodological foundation of the Unified Model of Care-Driven Physical Computing Pedagogy.

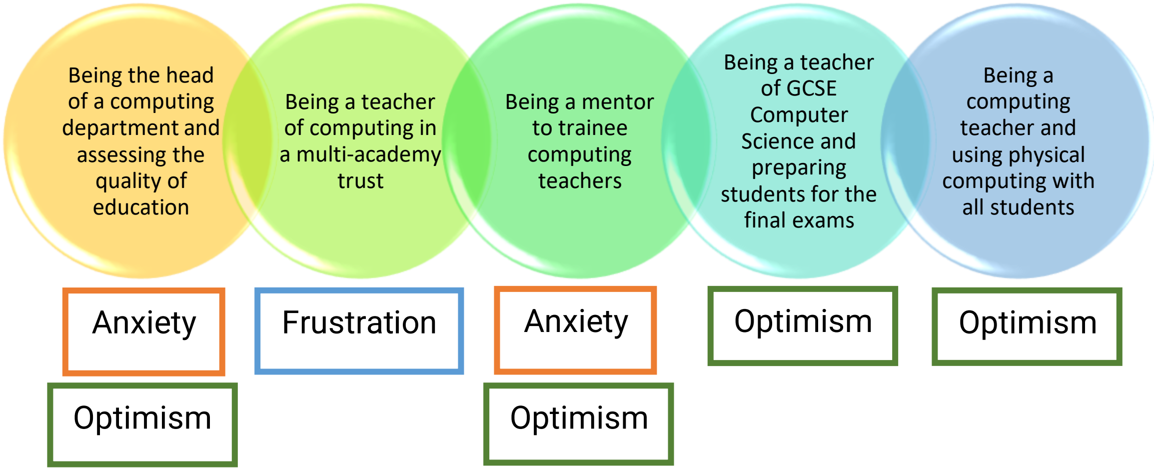

Figure 10: Thematic summary with feelings attached to 'Being-with' physical computing

3.7.9 Key Hermeneutic Phenomenology Concepts

3.7.9.1 Introduction

In hermeneutic phenomenology, analysis is not a mechanical application of pre-set steps but an ever-circling movement in which interpretation, reflection, and re-interpretation co-construct understanding (Gadamer, 2013). The following subsections unpack the key philosophical foundations of this approach: the temporality of truth, hermeneutic phenomenological writing, indwelling, squaring the hermeneutic circle, and the fusion of horizons. They illustrate how Pete's crafted narratives emerge from and enact these principles.

3.7.9.2 Temporality of Truth

Heidegger (1962) distinguishes between veritas, the propositional, distinguishable truth and aletheia, the truth of unconcealment or meaningful disclosure. Van Manen (2016) nuances this latter concept as the truth that emerges through attunement, a process in which phenomena reveal themselves in their own time. Gadamer (2013) extends this by insisting that revealing and concealing are dialectically intertwined: what is shown today may be hidden tomorrow, and vice versa. Thus, truth in the hermeneutic sense is neither static nor universal but perpetually unfolding within the lived horizon of the interpreter.

This temporal dynamism becomes palpable when we attend to Pete's reflection on work scrutiny. In his early years of teaching, Pete describes a period when his department "never had to worry" about book checks or drop-ins. Three years later, however, "we were ripped to hell by work scrutiny," a verdict that he recalls as a sudden and disorienting shift. His crafted story captures this temporal fracture:

'I first became a teacher before drop-ins or work scrutinies to justify everything you do became a thing. Nowadays, there is much more pressure for teachers' plans and students' work to be examined by their head of department or a leadership team member, and any freedom we once had has ebbed away a little now…'

Here, the before-and-after rhythm in Pete's narrative exemplifies how aletheia unfolds: the phenomenon of professional oversight is unconcealed in two distinct temporal phases, each carrying its valuation and emotional weight. By attending to these moments of temporal disjuncture, hermeneutic phenomenology honours how meaning emerges in time, always conditioned by past experiences, present understandings, and future projections.

3.7.9.3 Hermeneutic Phenomenological Writing

The philosophical orientation to hermeneutic phenomenology that frames this thesis is introduced in Chapter 1 (see Table 1) and situated in relation to the literature review in Chapter 2. In this section, I focus on how hermeneutic-phenomenological writing was operationalised in the analysis process—specifically, how transcripts were transformed into crafted stories and then re-read iteratively to refine interpretive claims. Laverty (2003) argues that hermeneutic phenomenology aims to understand and reconstruct experience, and to show the phenomenon through writing rather than only reporting it. Writing was therefore treated as an analytic practice: drafts were repeatedly revised through movement between transcript extracts, interpretive summaries, and whole-story coherence, with the aim of producing accounts that remained faithful to participants' meanings while being readable and analytically useful (van Manen, 1999). To make this process transparent, I outline below the specific writing decisions used in crafting and refining stories (e.g., narrative smoothing, clarification of chronology, and minimal connective wording).

Furthermore, Crowther *et al.* (2017, p. 14) introduce the notion of a "polished story," a term I adopt here with gratitude. Polishing, in their usage, refers to the careful refinement of narrative smoothing transitions, restoring colloquial speech, and inserting only minimal contextual cues so that the reader is immersed in the experience without distraction. In Pete's account of work scrutiny, polishing maintains the immediacy of his frustration and irony, while ensuring coherence:

> *'We may get a deep dive as a department, with books or work called for, and it's that thing of someone looking who doesn't understand the computing curriculum… the feedback was, 'You have no work to show, and you can't prove anything; it's crap.''*

By preserving Pete's spoken words and rhythm in interviews, the final crafted story bears both his voice and its resonant meaning, drawing readers into the affective core of his experience. Additionally, each narrative was shared with its teacher for feedback and revision, ensuring that the final versions reflect the teachers' lived experiences, meanings, and voices. This co-creative validation not only confirms the accuracy of interpretation but also positions teachers as co-authors of their experiences, enhancing the methodology's authenticity and rigour.

3.7.9.4 Indwelling

Heidegger's notion of *Sorge* ('care') implies that researchers do not stand apart from their materials but dwell within them (Heidegger, 1951, p. 147). Gadamer (2013, p.202) refers to this process as "indwelling," a deep, intuitive immersion in the data that transcends mere intellectual analysis. For me, indwelling took shape in extended periods of reading and re-reading Pete's transcripts alongside fieldnotes, allowing unexpected thematic bubbles to emerge (Dibley *et al.,* 2020). These reflective moments were not idle reveries but active meditations, akin to Smythe's (2012, p.126) "walking along with the philosophy," wherein each return to the text opened up new perspectives on meaning.

3.7.9.5 Fusion of Horizons

Gadamer's (2013, p.202) metaphor of Horizontverschmelzung ("fusion of horizons") captures the convergence of the researcher's pre-understandings with the participant's lived experience. Upon entering this study with my experiences as a Computing Hub Leader, I brought expectations about technical barriers and pedagogical autonomy. Pete, however, emphasised the emotional toll of high-stakes scrutiny. In the fusion of our horizons, a richer picture of the phenomenon emerged, showing that autonomy, accountability, and affective caring coexist. This effective history (wirkungsgeschichte) became foundational to the crafted story that finally stood at the intersection of Pete's experiences and mine.

3.7.10 Bridging to Chapter 4

These analytic moves culminated in forty-two crafted stories, of which seventeen are presented in Chapter 4. They were selected for how vividly they exemplify the horizons developed here (*leaping-in*, *leaping-ahead*, affect, identity, institutional contexts). Chapter 4 applies this framework to interpret teachers' lived meanings in situated practice.

3.8 Validity and Reliability

The researcher in hermeneutic phenomenology describes the phenomena and interprets the entire process of understanding them with the participants. As a result, the validity of the interpretation is necessarily scrutinised (Creswell and Creswell, 2017). In this study, an interpretive summary is written for each interview to summarise the teacher's story. Significant points from the conversation and early patterns or themes are then documented through a writing process that begins with verbatim quotes and moves as closely as possible to the text throughout the interpretive writing cycle. Cross-checking interpretations with original transcripts from participant interviews promotes authenticity and trustworthiness, thereby maintaining closeness to the teachers' constructs (Lincoln and Guba, 2000).

According to Roulston (2010), reflexivity refers to the researcher's ability to reflect on themselves when self-consciously producing knowledge about research topics. Furthermore, Creswell and Poth (2016) agree that researchers position themselves in a qualitative research study by communicating their background, how it informs their data interpretation, and what they gain from the study. However, reflexivity extends beyond simply reflecting on our observations of the world. In the context of teachers participating in this research study, my experiences as a researcher influence how meaning is understood and what is significant for us and others. I documented another layer of understanding and how findings emerged by applying the Lincoln and Guba (1985) criteria and providing an account of this process to ensure rigour and trustworthiness.

Journal entries and field notes were written before, during, and after each interview with a teacher and became an essential part of the hermeneutic phenomenological process. This awareness of how our biases as researchers interact with the data analysis phase helped inform the meaning. Furthermore, recording observations, reflections, and questions about the interview schedule while continuously reviewing and evaluating techniques and analysis promotes critical thinking about the research process and practices (Cohen *et al.*, 2000).

As a result, reviewing thoughts and understanding can lead to the discovery of new ideas and the anticipated contribution of this study. Bogdan *et al.* (2011) value such fieldwork-related reflections, making them an integral part of the process throughout each series of teacher interviews. In this case, notes, colour-coded annotations, and questions in the margins, from a researcher's perspective, become part of the analysis toolkit to examine the meaning of transcripts. According to Heidegger (1962), interpretation is a continuous revision. As a researcher, my reflections on my understanding of the whole went hand in hand with analysing and abstracting it into parts.

Emerging themes were documented during data analysis, broken down into parts from individual transcripts, and synthesised as the whole was re-examined, including all transcripts, NVivo nodes, and field notes from every teacher in the study, where new understanding was gained. Throughout the analysis process, the parts make sense of the whole, and the whole makes sense of the parts, thereby continuing the hermeneutic circle's circular rotation and providing insight into the phenomenon of physical computing in the world.

To ensure trustworthiness, being explicit in journal entries about pre-understandings of physical computing in secondary schools was an essential part of the research process. In interpretation, revising one's biased judgement as a researcher continues to understand and make sense of new information from teachers' experiences, which is also a circular process. Furthermore, textual data are analysed individually and as a whole, allowing a researcher to revise and refine their understanding of the entire text by considering all the transcripts simultaneously as separate parts.

The concept of thick descriptions in ethnography, denoting a comprehensive and contextualised account of field experiences, was first introduced by Geertz (1973) and later elaborated upon by Ryle and Tanney (2009). It serves as a means of achieving external validity, allowing the assessment of the transferability of conclusions to other times, settings, situations, and people, according to Lincoln and Guba (1985). Following that, Holloway (1997) argues that thick descriptions provide explicit details about cultural and social patterns and their contextualisation. This contrasts with the thin descriptions, which lack depth and require expansion. Furthermore, the level of detail provided by thick descriptions helps reduce researcher bias and errors in interpretation. This enhances the research's credibility by allowing others to assess the reliability and validity of the data. Furthermore, rich descriptions provide a method for triangulating data, thereby increasing the validity of the findings.

Finally, hermeneutic interpretation necessitates the researcher switching back and forth between two or more levels of analysis, interpreting the context in terms of its elements and context, so it is critical to dwell on the data and become immersed in the process. The longer we use different levels of analysis, the more likely our interpretations will evolve, with a greater chance of reaching an 'aha' moment of enlightenment if a new meaning is discovered.

I have taken measures to maintain the trustworthiness of my research, upholding a high level of rigour and transparency in my methodology to support the credibility, dependability, confirmability and transferability of my findings. In qualitative research, however, it is acknowledged that the researcher's subjectivity can influence the collection and interpretation of data (Farrelly, 2013). Therefore, I have adhered to Lincoln and Guba's (1985) principles, which stipulate that credibility, dependability, confirmability, and transferability are indicators of trustworthiness in qualitative research. Additionally, I have followed the guidelines established by Cohen et al. (2017) to document my methods and approach, thereby demonstrating their transparency and consistency. Furthermore, I have taken steps to ensure that external evidence can be used to test my conclusions, further reinforcing the trustworthiness of my research project.

Even though it possesses subjective and intersubjective characteristics, hermeneutic phenomenology is frequently criticised for its perceived lack of scientific rigour in research. Despite this, proponents of this approach, such as Heidegger (1962), Gadamer (2013), van Manen (2016), argue that it is impossible to eliminate researchers' biases and assumptions from the study. Instead, it is more important for the researcher to be aware of these biases and to consider how they might impact data collection, analysis, and interpretation. Consequently, my subjectivity as a researcher has been emphasised throughout the study to distinguish it from the perspectives of the teacher participants. Varela et al. (2017) argue that a qualitative study is invalid if the researcher disregards their own beliefs and experiences. On the other hand, some researchers, such as Cohen et al. (2000), advocate for a reductionist approach based on Edmund Husserl's (Husserl and Moran, 2012) philosophical concept of bracketing. Since this understanding is based on prior knowledge and understanding of the phenomenon, I decided not to disregard my physical computing experiences. In rejecting this position and accepting my previous beliefs and experiences, rigour is demonstrated by connecting the hermeneutic phenomenology philosophical framework to the study's findings (Heidegger, 1962; Gadamer, 2013; Van Manen, 2016).

The significance of rigour is emphasised in this study to ensure its credibility, and all aspects of the study are grounded in the theoretical framework of hermeneutic phenomenology, which is made clear. In addition, the techniques, examination, and interpretation are aligned with the perspectives of hermeneutic phenomenologists to ensure a consistent approach throughout the study. Ultimately, it is up to the reader to determine whether the phenomenological description is accurate (Schmidt, 2016). Nevertheless, in this section, I will demonstrate rigour with my chosen methodology and adherence to the standards of trustworthiness in phenomenological research.

3.8.1 Credibility

Credibility refers to the true value or internal validity of qualitative research, specifically how the participants in this study experienced physical computing (Korstjens and Moser, 2018). Hermeneutic phenomenology is often criticised for lacking rigour and transparency. However, only the participants can determine the validity of the findings, so I selected procedures and methods to mitigate this (Noble and Smith, 2015). In addition, I demonstrated that the research results accurately reflected the perspectives and experiences of the participants (Korstjens and Moser, 2018). To ensure the reliability of the study's results and mitigate concerns about researcher bias or evaluative criteria, I implemented several strategies cited in the literature to enhance the research's credibility. Moreover, to maintain the study's credibility, hermeneutic alertness was employed by stepping back and reflecting on the meanings of situations rather than accepting them at face value (Van Manen, 2016, p. 48).

To test the findings and interpretations with teachers (Lincoln and Guba, 1985), I employed techniques such as extended engagement, reflexivity, and journaling, as well as triangulation and member checking. I used all these techniques to establish my credibility throughout the study, from listening to the participants' experiences to analysing the original transcripts and writing the final narratives (Creswell and Poth, 2016). In addition, member checks were conducted to validate the data, analysis, and conclusions with the participants who provided the initial data through interviews (Lincoln and Guba, 1985). Firstly, I shared transcripts after each teacher interview to gather additional feedback. Second, to strengthen the validity of my research findings and interpretations of the discussions, I asked participants to critically review some of the stories I had crafted from their recounts.

Data triangulation is an essential factor in improving the quality of a qualitative research study by utilising multiple data sources, techniques, and researchers to strengthen the validity and reliability of the research findings (Lincoln and Guba, 1985; Patton, 2014; Honorene, 2017). In my hermeneutic phenomenology research, I utilised triangulation of sources to identify recurring themes and experiences by comparing the data collected from each participant (Lincoln and Guba, 1985). I could compare the results by conducting multiple interviews with each teacher participant to identify common themes and experiences. Another approach was to use various data collection forms, such as incorporating written reflections or journal entries from the teachers, in addition to the interviews. Thus, triangulation has helped eliminate potential biases, making the results more trustworthy, credible, and generalisable. Furthermore, by combining multiple data sources, triangulation provides a more comprehensive and holistic understanding of physical computing, thereby enhancing the robustness of the findings (Denzin and Lincoln, 2011).

Finally, the trustworthiness of this study is established through various techniques that demonstrate my competency as a researcher in analysing data (Bowen, 2005). For this reason, I have included supporting documentation in the appendices that provides evidence of the research's validity, thereby reducing the possibility of researcher bias.

3.8.2 Transferability

Transferability, or the extent to which other researchers can generalise findings to different contexts, is a crucial aspect of qualitative research that I have considered throughout this study (Miles et al., 1994). By analysing the information provided about the study, the reader can determine whether the crafted stories are transferable to their settings (Patton, 2014). I employed purposive sampling and provided thorough descriptions of the data collection and analysis processes to facilitate the transferability of the findings. Additionally, I have utilised teacher narratives to illustrate the themes, thereby enhancing the transferability of the findings (Holloway and Wheeler, 1996). The reader, not the researcher, decides the transferability of the findings (Korstjens and Moser, 2018). Therefore, I have provided detailed descriptions of the collection process and the findings to enable the reader to make an informed decision about transferability (Erlandson, 1993). Furthermore, by connecting details such as teachers and setting, the reader can identify similarities and assess the likelihood of transferability (Creswell and Poth, 2016).

Finally, as a researcher in this study, I understood the context and its impact on physical computing, an essential aspect of hermeneutics. This was important to me because it helped maintain the transferability of the crafted stories to other similar situations, given that qualitative study findings are difficult to generalise due to the uniqueness of each participant's situation.

3.8.3 Dependability

Korstjens and Moser (2018) define dependability as the stability of data over time and the consistency of findings when a study is repeated under similar conditions with the same participants. In qualitative research, it is acknowledged that many factors, such as individual differences, circumstances, and time periods, are inherent to each study, making replication of an investigation impossible (Petty et al., 2012). However, dependability is a requirement for the findings to be credible, so I will outline the steps I took in this study to achieve dependability, including establishing and outlining specific procedures that other researchers can follow (Lincoln and Guba, 1985; Yin, 2016). Additionally, I maintained awareness of the possibility of researcher bias. To mitigate this, I worked closely with my supervisors to ensure that my methods and procedures were detailed enough to provide dependability, and I regularly challenged the robustness of the emerging narratives and themes. By exposing my biases to probing questions, I could explore the meanings and clarify my interpretations (Kvale, 2009). Furthermore, to improve the study's dependability, I created an audit trail in the data analysis findings, accompanied by an illustrated step-by-step guide to crafting stories from interview transcripts as a starting point. As the data analysis progressed, my understanding and imagination shifted in response to moving within the hermeneutic circle or taking an interpretive leap with the crafted stories. Guba (1981) suggests auditing the process to monitor these changes, so after interviewing participants and analysing the data I gathered, I meticulously documented my field notes.

Having a clear record of my methodology enables others to understand my reasoning better, and journaling played a crucial role in this process for me. I also established a clear data storage structure that I could refer to as I navigated through the hermeneutic circle to read individual interviews, transcripts, and series notes for each participant, as well as the data collection across fifteen interviews and five teachers. This method demonstrates data triangulation and enhances the confirmability of the study. In addition, the study employs van Manen's (2016) technique for isolating thematic statements to increase reliability.

In conclusion, this qualitative study examines the totality and complexity of teachers' experiences with physical computing in the classroom, an interpretation that can often be challenging for researchers to grasp (Petty, Thompson, and Stew, 2012). Consequently, I have taken several steps to ensure the dependability of this research and the integrity of its findings.

3.8.4 Confirmability

Confirmability assesses the impartiality of the findings and reduces the potential for researcher bias, motivation, or interests that may influence the results (Lincoln and Guba, 1985). Anney (2014) emphasises the importance of confirmability in qualitative research, noting that it allows other researchers to corroborate the findings.

Furthermore, they suggest that audit trails and reflexive journaling can be used to establish confirmability; reflexive journaling allowed me to document my own researcher's experiences in the field and evaluate the impact of my personal biases, perspectives, and interests on the research process (Anney, 2014). Importantly, Engward and Davis's (2015) distinguish between reflection and reflexivity, with the latter encompassing the researcher's self-awareness of their decisions and their impact on the research. Throughout the study, my journaling routine helped to scaffold this self-awareness and supported my thinking.

I established an audit trail to examine my research inquiry process and verify the data, ensuring confirmability and enhancing the study's credibility. This entailed documenting all decisions made during the data collection, recording, and analysis phases. Additionally, I ensured that all raw data, including field notes, were stored to enhance the effectiveness of the audit trail. Confirmability also illustrates how interpretations are arrived at through investigation (Koch, 1998). Therefore, to increase self-awareness, I kept a journal documenting my interactions and reactions to events in the study. Koch (1994) recommends leaving an audit or decision trail that outlines the theoretical, methodological, and analytical choices made during the study, thereby allowing other researchers to verify them. I followed this approach and used it throughout the study to challenge and scaffold my thinking.

3.9 Ethical Procedures

3.9.1 Positionality

According to Kellehear (1993), ethical concerns include the principles of informed consent, privacy, and confidentiality, as argued by Blaikie (1993). As a result, an application to the University of Leeds Ethics Committee was submitted on September 25, 2020, and a favourable response was received on October 22, 2020 (Appendix G).

Furthermore, in phenomenological research, participants share the meaning of the essence with the researcher. They are referred to as co-researchers (Moustakas, 1994), and the roles of the researcher and teachers were explained at the beginning of the study. To facilitate the flow of communication, I needed to establish rapport with the participants (Poggenpoel and Myburgh, 2003). This encouraged teachers to share rich descriptions of their lived experiences, which is also emphasised by Seidman (2006), who suggests building amity with each participant to allow them to feel at ease sharing personal recounts.

3.9.2 Informed Consent

Gaining consent is a fundamental ethical consideration (Felzmann, 2009); therefore, I provided potential participants with sufficient information to make an informed decision about participating in the research study (Davies, 2008). I sent interested teachers a participant information sheet (see Appendix B) so they could make an informed decision about participating. I also offered a phone or Teams meeting to review the study in greater detail and meet with me as the researcher. All five teacher participants agreed to an initial conversation to clarify the time commitment required to meet the intended interview schedule, which consisted of three semi-structured interviews. The information sheet detailed descriptions of the research's purpose and process, the teacher's role, and how and where the findings would be published. Using the University of Leeds-approved consent form (see Appendix C), I clarified that participation was voluntary and sought written consent for participating and recording the interviews.

3.9.3 Confidentiality

While reflecting on the recruitment processes, I realised that few secondary school computing teachers had at least two years of experience integrating physical computing into the curriculum. Furthermore, participants may have been acquainted through professional networks or communities of practice, making it critical to maintain confidentiality throughout the process. Microsoft Teams was used to conduct fifteen interviews and five pre-interview meetings online. In this thesis, I kept consent forms and digital recordings in separate secure locations and avoided identifying the schools and their surrounding geographical areas. Any names used are pseudonyms chosen by me and approved by the participant. Other potentially identifying information has been changed to avoid recognition by anyone other than the teacher participants.

In accordance with standard ethical practice, I maintained confidentiality and respected the data protection and privacy of teacher participants. I also followed the University of Leeds' research data guidelines, ensuring that all data collected was treated confidentially and in accordance with the Data Protection Act (Carey, 2018). Appendices B and C contain a jargon-free participant information sheet and consent form.

Chapter 4 Findings

4.1 Introduction

This chapter presents seventeen of the forty-two crafted stories generated during analysis. These stories illuminated five phenomenological modes of Being-with (*Mitsein*) physical computing: being a teacher in a multi-academy trust, being a mentor, being a head of department, being a teacher of GCSE Computer Science, and being a teacher who uses physical computing with all students. Grounded in teachers' lived experiences, these modes provide the organising structure for the chapter. In the interpretive synthesis that follows (Chapter 6), five experiential modes are drawn together and reconfigured into four higher-order interpretive themes, which constitute the study's original contribution to knowledge. Each narrative is an edited hermeneutic phenomenological account, designed to show rather than tell, and highlights moments of teaching, learning, troubleshooting, anticipation, affect, identity, and institutional interaction.

Before reading the stories, note that each has been shaped to convey lived experience as a raw transcript and a narrated enactment of teaching and learning, emotional nuance, professional identity work, and contextual pressures. As you move through them, notice what each discloses, allow assumptions to be tested, and reflect on how these themes resonate with your own experiences of teaching or learning with physical computing.

After a brief methodological rationale (4.2), the stories are presented thematically and linked back to the central research question. The chapter concludes with an examination of trustworthiness measures, including credibility, dependability, transferability, and confirmability.

4.2 Methodological Rationale for Crafted Story Selection

In selecting the seventeen stories, I adopted the rigour of crafted-story methodology articulated by Crowther *et al.* (2015, p.832) who insist that “developing crafted stories from transcripts is an art that takes practice and can be challenging for the nascent phenomenological researcher,” noting the necessity to polish syntax, grammar, and narrative flow to reveal the phenomenon's essential qualities. In this study, each teacher's narrative was subjected to iterative cycles of interpretation within the hermeneutic circle: extraneous details were deleted, narrative segments were reordered for coherence, and the prose was refined, adjusting grammar, smoothing transitions, and reading aloud to foreground the care-driven dynamics of physical computing. This iterative movement between parts (individual transcripts, codes, provisional drafts) and whole (the emergent horizons of care, identity, emotion, and institutional context) enacted van Manen's (2016) injunction to inspire our understanding through phenomenological writing.

Three interlocking commitments guided the selection of the final seventeen accounts. First, I presented stories that most clearly revealed the ontological dimensions of *Being-with* and *Sorge* in classroom practice, those moments in which teachers' troubleshooting (leaping-in) and anticipatory curriculum design (leaping-ahead) became expressive of authentic solicitude. Second, I sought narratives that surfaced previously concealed meanings, attending to affective resonances, frustration, anxiety, and optimism, as described by Crowther *et al.* (2017). Each story contributes a felt insight that transcends mere semantic description. Finally, each crafted story was tested for conceptual resonance across the study's horizons of understanding (Gadamer, 2013), ensuring that no account stood in isolation but instead participated in a dialogical fusion of researcher and text.

As discussed in Chapter 3, the live Sway document functioned as my core analytic journal. At key junctures, I revisited Crowther *et al.'s* (2017) guidance, which states that crafted stories must honour the participant's experiences, be congruent with philosophical underpinnings, and acknowledge the researcher's pre-understandings. Each narrative draft underwent evaluation against these criteria. The seventeen accounts that emerged from this hermeneutic scrutiny faithfully represented five analytical horizons and bore the ontic imprint of phenomenological story craft, offering insight into teachers' lived experiences and their care-driven pedagogy in secondary computing, with a focus on embedding physical computing.

Across fifteen interviews over thirteen months, I iteratively crafted narratives until further storying no longer disclosed new horizons of meaning relative to the emerging codebook and themes; new drafts increasingly reiterated already articulated structures of care, anticipation, mentoring, and identity. I therefore halted at forty-two stories based on interpretive sufficiency (hermeneutic saturation): the corpus adequately spanned participants, contexts, and the four final themes, and further stories would have been conceptually redundant within the thesis's word and time constraints. The complete set is summarised in Table 12, and the selection criteria for the final seventeen accounts are presented in full below.

4.3 Catalogue of Crafted Stories

4.3.1 Justifying Selection

As described in Chapter 3's data-analysis phase, while forty-two crafted stories were generated, seventeen were selected for complete exposition in this chapter. Given word count constraints, only a subset of these accounts could be presented in full. Next, building on the horizon–mapping procedures outlined in Chapter 3, Table 12 catalogues all forty-two narratives by participant and analytical horizon, and Table 13 identifies the final seventeen chosen for detailed analysis.

Furthermore, drawing on the three-movement analysis detailed in Chapter 3, the following bridges these summaries to two transcript excerpts, illustrating how specific data informed the selection of particular stories. The remaining twenty-five accounts span the same five horizons: *leaping-in*, *leaping-ahead*, affective responses, identity anchoring, and institutional contexts, but were set aside when they merely extended existing exemplars or reiterated variants of insights already foregrounded. Their exclusion does not diminish their analytic value; it reflects a hermeneutic commitment to inspire understanding through a focused selection that most vividly and cohesively exemplifies each horizon (Van Manen, 2016).

Moreover, because each crafted story emerged from interviews conducted within a particular academic term, these narratives capture the temporal snapshot of teachers' experiences. Had these conversations taken place at a different time, such as immediately after policy changes, high-stakes inspections, or exam seasons, the emphasis and affective tone might have shifted. In this respect, the selected stories reflect a specific moment in the teachers' professional lifeworlds; subsequent experiences would likely generate new narratives and reinterpretations of past events.

4.3.2 Illustrative Data Excerpts and Justification

Consider, for example, two excerpts from Teacher 3's second and third interviews. In the second interview, the teacher observed:

> *'I spent the first term teaching micro:bits, but every time I tried something new, the network admin would block the USB port overnight. It felt like I was two steps forward, three steps back. The children would lose confidence quicker than they gained it.'*

This frustration exemplifies Heidegger's inauthentic *leaping-in* of solicitude, where institutional gatekeeping disrupts the teacher's care-driven effort to sustain student confidence.

In the third interview, the same teacher reflected:

> *'After persuading IT to unblock the ports for a week, I planned a whole term's worth of projects. Those seven days were the most productive I'd ever seen; students were buzzing, collaboration increased, and I felt more like a teacher than a technician.'*

This shift from blocking to breakthrough, as seen in Story 8, embodies authentic *leaping-ahead* solicitude, demonstrating how the proactive negotiation of institutional constraints can restore pedagogical freedom and reignite student engagement.

As introduced in Chapter 3's coding framework, Story 9 already articulates the 'troubleshooting network restrictions' horizon. Presenting it in place of the USB-port crafted story, therefore, avoids unnecessary repetition. Including it as a separate account would have introduced undue redundancy: my horizon-mapping demonstrated that Story 9 already embodies the *leaping-in* horizon of 'troubleshooting network restrictions,' encompassing blockage and its resolution. Thus, I treated the blocked-ports account as an implicit constituent of Story 9 rather than an independent narrative. This choice respects van Manen's guidance to select only those accounts that most vividly and coherently inspire understanding of each horizon and honours Crowther *et al.'s* (2015) insistence that crafted stories must foreground phenomenological insight without diluting analytic focus.

These and other excerpts were pinned in the live Sway document alongside provisional story drafts, supervisory annotations, and horizon-mapping exercises throughout successive analysis sessions. In each iteration, I invoked Gadamer's notion of the fusion of horizons (Gadamer, 2013), engaging in dialogue with every draft until the seventeen stories that most powerfully conveyed the ontological features of care-driven pedagogy were confirmed. This process ensured that each crafted story not only embodied the distinctiveness of its horizon but also illuminated the dynamic interplay of *Being-with* physical computing, whether through troubleshooting immediate barriers or orchestrating anticipatory designs that scaffold future learning landscapes.

4.4 Presenting the Crafted Stories as Findings

4.4.1 Introduction

For cataloguing purposes, the forty-two stories were organised into nine practical categories, while five experiential modes frame the analysis. The following presentation of Tables 12 and 13 offers an overview and a focused analytical lens on the study's interpretive approach. Table 12 shows the complete set of forty-two stories, each within one of the study's five analytical horizons. Table 13 isolates the seventeen narratives selected for extended exposition in this chapter. While the remaining twenty-five narratives retain analytical value, they were not fully included as their thematic insights were already embodied within other, more vividly articulated accounts. This selective inclusion reflects a methodological commitment to van Manen's (2016) principle of phenomenological writing, to 'inspire understanding' through rich, concentrated narratives that reveal the phenomenon in its depth and nuance, rather than breadth for its own sake.

Table 12: Summary of all 42 crafted stories

Category	Crafted Story Working Title
1. Becoming a Computing Teacher	1. Tom's KS4 option choices as a student 2. Marcia's SLT perceptions of a non-specialist computing teacher at interview 3. Marcia's SLT understanding of computing 4. Marcia's SLT timetabling implications
2. Being Part of a Community of Practice	5. Jenny's reflection on being the lone computing teacher in school
3. Being Part of Politically Motivated Change	6. Tom's curricular and degree-programme decisions
4. Teaching in a Multi-Academy Trust	7. Tom's creation of a local CAS hub 8. Tom's experiences of blocked USB ports 9. Tom's negotiation of MAT bureaucracy 10. Tom's reliance on distant technical teams 11. Tom's critique of trust-wide curriculum alignment
5. Mentoring During ITT	12. Pete's trainee-mentor reflections 13. Jenny's graduate-teaching placement 14. Jenny's 'safe-space' for experimentation
6. Mentoring Trainee Teachers	15. Pete's anticipatory 'play' space for mentees 16. Jenny's early-career reflective partnership 17. Pete's joint lesson-planning innovations 18. Jenny's co-planning and critique sessions 19. Jenny's classroom environment with trainees 20. Jenny's artefact-based peer review
7. Teaching KS3 Computing	21. Jenny's carousel-model assessments 22. Jenny's GCSE suitability judgments 23. Pete's iterative progression of evidence 24. Pete's work-scrutiny practices 25. Pete's scrutiny-related challenges 26. Pete's low-stakes innovation in summer term 27. Pete's portfolio-based assessment pilot 28. Laura's non-specialist observations 29. Tom's cross-subject device use 30. Marcia's engagement through physical computing 31. Marcia's literacy-barrier strategies 32. Laura's lesson-observation adjustments 33. Jenny's Lego-based progress checks
8. Teaching GCSE Computer Science	34. Tom's KS3–KS4 curricular linking 35. Laura's KS3–KS4 bridging activities 36. Laura's GCSE Paper 2 scaffolds 37. Jenny's exam-board training experiences 38. Jenny's parental-involvement narratives 39. Tom's inclusion of all learners 40. Tom's assessment and testing pedagogies
9. Teaching A-level Computer Science	41. Tom's data-driven A-level lessons 42. Tom's A-level coursework sequencing

4.4.2 Revealing Hidden Aspects of Physical Computing

While forty-two crafted stories emerged from the hermeneutic phenomenological analysis, seventeen were selected for detailed exposition in this chapter. Table 13 below summarises these seventeen narratives, each organised by participant and their corresponding analytical horizon. In the following pages, the discussion proceeds by taking an interpretive leap, drawing on these exemplary stories to illuminate how teachers enact care-driven pedagogy in the physical computing classroom.

Table 13: Seventeen crafted stories by mode of solicitude, affect and theme

Story	Teacher	Mode of Solicitude (Leaping-in/Leaping-ahead)	Affective Orientation	Theme
1	Pete	In	Anxiety	Being the head of a computing department and assessing the quality of education
2	Tom	In	Frustration	Being a teacher of physical computing in a multi-academy trust
3	Tom	In	Frustration	
4	Tom	In	Frustration	
5	Pete	Ahead	Optimism	Being a mentor to trainee computing teachers
6	Jenny	Ahead	Optimism	
7	Jenny	Ahead	Optimism	
8	Jenny	Ahead	Anxiety	
9	Pete	In	Anxiety	Being the head of a computing department and assessing the quality of education
10	Pete	Ahead	Optimism	
11	Pete	Ahead	Optimism	
12	Laura	Ahead	Optimism	Being a teacher of GCSE Computer Science and preparing students for the final exams
13	Tom	Ahead	Optimism	
14	Laura	Ahead	Optimism	
15	Jenny	Ahead	Optimism	
16	Tom	Ahead	Optimism	Being a computing teacher and using physical computing with all students
17	Tom	Ahead	Optimism	

4.5 Thematic Presentation of the 17 Crafted Stories

For all subsequent crafted stories, this thematic analysis extends the coding framework detailed in Chapter 3.

4.5.1 Being a Teacher of Computing in a Multi-Academy Trust

4.5.1.1 Frustration: Losing Local Networks under Academisation

This first story focuses on Tom's experiences with academisation and its impact on his participation in nearby computing teacher networks. He reflects on establishing a local Computing at School (CAS) community because he could no longer attend the network meetings organised by the local education authority. Tom's academy's leadership team may not have been aware of how *leaping-in* displaced him from the professional network he had supported and helped build over many years. Disempowerment during the transition period to becoming an academy was in stark contrast to the collaborative goals of the trust, as Tom was isolated from other local computing teachers, which frustrated him until he established a CAS community as a solution. On the one hand, his frustration was an adverse, affective reaction to the *leaping-in* that occurred due to trust protocols. Still, it resulted in Tom *leaping-ahead* and establishing a new CAS community to support other local computing teachers.

The multi-academy trust I am now working for might say they are a group of collegiate schools that work together, but they are not.

It was frustrating when we first became an academy because I could no longer attend local authority subject meetings. We were developing all these new courses and computing resources at the time, and I couldn't contribute to that local network. So, I would say to teachers asking for help: 'I'm not allowed there; my trust says I can go, but the authority says I have to pay, and the trust says, 'Well, we don't pay to train you; why should we?'

So, I set up a CAS Hub as a workaround. We got some of the teachers coming along to provide training, and that looked good for the school because we were a CAS Hub, but it also meant we could continue to support local schools that wanted to develop physical computing.

Figure 11: Crafted Story - Frustration: Losing Local Networks under Academisation

4.5.1.2 Frustration: Trust-Level Curriculum Alignment Suppressing Physical Computing

Tom shares further experiences as a teacher working in a multi-academy trust. In this narrative, he discusses the significance of appointing a leading computing teacher and how that can influence the adoption of physical computing in all schools. His situation exemplifies a positive ‘Being-with’ a Director of Computing who integrates physical computing into the trust's curriculum and a realisation that where you teach can influence what you teach. Tom described instances where other schools decided not to teach physical computing and did not incorporate it into the curriculum through local and regional computing teacher networks. Important for adopting and understanding the value of physical computing in schools, this story illustrates how prescriptive curriculum and pedagogical practices can disempower a teacher in a situation of trust.

Another issue with the larger academy chains is the same approach to teaching computing in all schools. So, if you have a computing coordinator at the trust level and they do not embrace physical computing, it will not exist.

Figure 12: Crafted Story - Frustration: Trust-Level Curriculum Alignment, Suppressing Physical Computing

4.5.1.3 Frustration: Overnight USB Blocks and Lost Spontaneity

The following story illustrates an inauthentic solicitude, manifested as *leaping-in* from the technical team to care for teachers working across the trust. Tom described coming into school one day, ready to teach a lesson using micro:bits, only to discover that the trust's policy had changed overnight, preventing him from connecting the device that students would use through the USB ports. When the technical team 'leapt-in,' Tom was not consulted, and he reflected on the tensions and frustration it caused in a teaching and learning environment. He recognises the importance of a safe and secure network for teachers and students. Nonetheless, he has grown frustrated with the emphasis on security without a greater consideration for learning intentions and the impact on teaching.

This act of *leaping-in* negatively impacts Tom's teaching. The increased bureaucracy he mentions has increased his reliance on the technical team to help him deliver his physical computing lessons. While the incident with micro:bits and USB port blocking was recent, Tom has invested time since establishing a trust-wide technical team to liaise with them and change the mode of care to one of 'leaping ahead'. However, he is irritated that he no longer has the freedom to teach ideas that come to him at night. Tom and his colleague are collaborating with the central team to find a solution, but he is aware that their technical knowledge and skills are relatively unique. Other teachers may be unable to shift the balance back to teaching and learning while still teaching within a safe and secure computing network, which has implications for the adoption of physical computing in other schools.

Our school is part of a large academy chain; our core IT team runs on a business basis, keeping the network secure without considering how we make it most useful for students' learning. They create tensions because they always work from the place of 'No, you're not doing something,'. They never come from the opposite direction: 'What do you want to teach? We'll make that work for you, but there might be some provisos to keep it secure.'

It wasn't long ago when we came into school one day, and the trust decided to block all USB ports. We were in the middle of teaching with micro:bits, and I said to the technician, 'I plugged it in, and it doesn't work,' and he said, 'Yes, we've blocked USB ports now.' This policy of blocking things causes many problems, and physical computing is risky because if it doesn't work, you suddenly create an extra barrier you can do without.

You must remember that only some teachers, like Naomi and I, have a technical background outside of education and understand how technology works. Over the years, we have worked with the technical team to suggest how things can work. They'll say, 'Okay, we'll try that', so now there's an additional trust level to get through compared to what we used to have.

Sometimes teaching ideas come to you in the middle of the night, and you want to do it the next day, but now I've got to fill out a form and ask someone to do it. They come back to me with a no, and then I must send an escalation to the core IT manager, and we may have something in place by half past two. You lose that spontaneity. Sometimes you have a great idea that you know will excite the children, and it may be something straightforward that you want to do, but you can't because there's bureaucracy in your way, and that's frustrating

Figure 13: Crafted Story - Frustration: Overnight USB Blocks and Lost Spontaneity

4.5.2 Being a Mentor to Trainee Computing Teachers

4.5.2.1 Optimism: Joint Planning and the 'Kit-Pack' Insight

Pete's experiences of mentoring trainee teachers and learning from joint lesson planning are shared in this crafted story. He speaks positively about using the time to observe lessons, reflect on them, and modify classroom routines for himself and all teachers in the department in a way that expands his understanding. As a result, Dasein cares for the trainee teacher who is *leaping-ahead* of him, as Pete issues an open activity to investigate the possibilities of teaching with a micro:bit, which impacts others, as well as caring for other teacher colleagues and students at school. In another reflection, Pete discusses lesson observation as a means to focus on students' interactions with physical computing, which he doesn't have the opportunity to observe when teaching his classes. Mentoring is time-consuming, but Pete is optimistic. He recognises the value it brings to others and has committed to building on the formation of a mentee's *leaping-ahead* with each trainee. From this, he takes notes on various experiences. He applies what he has learned to impact teaching and learning with physical computing, nurturing the development of each trainee teacher and gaining personal benefits from his practice. Observing one of Katie's lessons, for example, led to the creation of 'kit bags' for all teachers to use when delivering micro:bit activities, which has improved the pace of the lessons and the process of distributing the devices in class.

As a mentor, I devote a lot of time to joint lesson planning and doing things with trainees, and that is different from one of my placements when I was just given lesson plans to teach. I remember setting up a physical computing project for Sam, one of my mentees, when he was training. I wanted him to think through a scheme of work about his journey with the children and how that would start. I just said: 'Here's a micro:bit. Play with it. What can you come up with?'

Every year, I ask our trainees to do a slightly different project, and the rest of us in the department can observe these different experiences.

We can see how they use the micro:bits and think about how we can adapt the activity for all of us to teach the curriculum.

You think you're aware of what the kids are doing all the time when you teach, but it's interesting when you take that step back and observe a trainee's lesson. I focus much more on students' interactions with physical computing than my classes and see what works more efficiently. Importantly, you see new ideas and think about ways to change things to make them work even better in the classroom.

It was watching one of Katie's lessons with micro:bits that changed how we distribute and collect equipment. Now we have 'kit packs' that we give students at the beginning of the activity, and they save time that we used to lose to get things out and back in. And I observed common mistakes children would make or where they got stuck, so we took them away to make changes for the following lessons with more precise teacher explanations.

Figure 14: Crafted Story - Optimism: Joint Planning and the 'Kit-Pack' Insight

4.5.2.2 Optimism: Trainee Confidence and Classroom Climate

In this example, Jenny discusses her experiences mentoring and learning from joint lesson planning with a trainee teacher on placement at her school. 'Being-with' manifests itself as optimism for novice teachers to incorporate physical computing now and in the future. Jenny reflects on her mentee's changing attitude towards the phenomenon and some of the steps they took to support it, sharing moments of joy and fun along the way. The act of *leaping-ahead* enabled him to develop his teaching practice, for which he had no prior experience, let alone experience with physical computing, with 11 to 14-year-old students. He recently admitted that when he first joined the department, he did not like the noise levels in those key stage three classes, but now he talks about his love of physical computing and the freedom it provides in those lessons. The story concludes with the trainee teacher volunteering to speak to an Ofsted inspection team at his other placement school. He wanted to share his experiences and enthusiasm for teaching physical computing at Jenny's school, her authentic kind of care based on Heidegger's concept of *leaping-ahead-solicitude*, and to acknowledge that teaching physical computing is indeed a complex endeavour.

I am a mentor this year, and my student recently told me how different it is from his first placement because we spend a lot of time teaching KS3 with physical computing. At first, he taught for 10 minutes, and then I stood up and did some bits and pieces, which worked well. It was funny when he joined us because I turned around and said, 'What are you doing?' And he said, 'I'm observing you,' and I said, 'No one sits in the back of my room with a clipboard; you can't do that. Come on; you get up, talk to the students, and ask them what they're doing' And then, over time, I've done less and less to let him take over the class, but even now, I'm in the class to sit and watch and write up.

He made me laugh because he said he didn't know how to phrase it initially. 'But when I first arrived, key stage 3 was so loud, lots of them, and I thought I didn't want to do that. I didn't like it,' and he continued, 'Now it's my favourite part of the week. I love my key stage 3 classes; they're really good.' He tells me it's lovely to have more freedom with his teaching in those lessons with physical computing. It's good for trainee teachers to get a taste of different teaching methods when they learn and observe new approaches.

My trainee volunteered to speak to Ofsted *this morning because they did a teacher training inspection at his other placement school. He volunteered to talk to them because he said, 'I want them to know that I have done physical computing, and how good it is for students to learn, and how difficult it is, but how supportive the school was and what a good experience it was.' Some of that is because I know what I'm doing and guiding him in the right direction, but it just proves it can work, and you know, it's fun*

Figure 15: Crafted Story - Optimism: Trainee Confidence and Classroom Climate

4.5.2.3 Optimism: Safe Space When Lessons Derail

The following story exemplifies Jenny's *leaping-ahead* care for her mentee. She is optimistic about the mentoring programme because it provides a safe space for trainees to refine their teaching practice and make what some, including her mentee, may perceive as mistakes. She reflects on how a micro:bit activity did not go as planned in a lesson where they were not team teaching, and how her trainee handled the situation, which improved his teaching practice. Jenny discussed the reassurance she provided as a mentor in the classroom when students proposed solutions to the computing problem and collaborated with the other teacher to contribute to debugging. She described that as a lovely situation, unlike the trainee, who thought it was the 'worst lesson ever'. The trainee teacher found it beneficial to engage in dialogue after the lesson and reflect on the teaching and learning. Jenny had provided him with a safe space to refine and test ideas in *leaping-ahead*, reinforcing this as essential for all teachers and protecting him from the feeling of failure associated with failing to deliver a lesson against the success criteria set for in-school lesson observations.

Sometimes I observe my trainee, and he'll say, 'Oh, no, that didn't work. Well, I could try this', and then he tries other things, but recently he got flustered. It was the first time he had something go wrong during a lesson with students using physical computing, and we were not team teaching. So, sitting at the back of the classroom, I said, 'It's okay, it's okay, these are nice students.' And then one of the lads said, 'Well, could I look at it, sir, and see if mine works?' And they had a small crew of them at the front to fix this micro:bit buggy, which was lovely. Bless him at the end of the lesson; he turned to me and said, 'That must have been the worst lesson ever.' I laughed and said, 'No, it wasn't because you teach students that sometimes technology goes wrong for everyone, even a teacher. We have to go back over our steps and make sure they are correct and test things, and that's okay.' This safe space is good for building teaching practice; everyone needs to learn.

Figure 16: Crafted Story - Optimism: Safe Space When Lessons Derail

4.5.2.4 Anxiety: Which Lessons Get Observed?

Jenny demonstrates optimism as she reflects on her past experiences mentoring a student teacher and introducing him to physical computing in the classroom. As she continues to leap-ahead with another care intervention, she expresses concern regarding an upcoming observation she must conduct. Jenny discusses her experiences mentoring a teacher-in-training and the classroom environment when physical computing is taught instead of programming lessons, where students use Scratch or Python for computer-based activities. In contemplating the various 'teaching climates,' she considers which types of classes a prospective teacher would prefer to be observed in. This story's dialogue falls short of caring for the student teacher by 'jumping in' to support what could be interpreted as a more manageable classroom environment, rather than evaluating his performance. In Jenny's words, 'Which one would you like to be observed?' could be a conversation worth having in the future to evaluate the quality of education and the adoption of physical computing and to reflect on school processes more broadly.

I am now mentoring a trainee who has never observed Key Stage 3 computing because his other placement school doesn't teach it. With us, he's led some programming lessons with Scratch and Python in Years 7 and 8 and the physical computing lessons with me using Lego and micro:bits. At first, he found it harder to use physical computing in classes because when you're a trainee, you expect the room to be quiet, and my room is not silent, so he is adjusting and changing some lessons.

His other programming lessons are good but almost a different culture and teaching climate. He will soon have an observation, so which one would you like to be observed? If I go into the Python one, the students will be sat down, they will be quiet, they will do a little quiz, and I will see what they have done on their screen. A robot sometimes falls off the ramp in physical computing lessons, and everyone laughs. It's a very different kind of classroom atmosphere, and I wouldn't say it's badly behaved because students respect the fact that they have this expensive equipment and love that they can do it.

Figure 17: Crafted Story - Anxiety: Which Lessons Get Observed?

4.5.3 Being the Head of a Computing Department and Assessing the Quality of Education

4.5.3.1 Anxiety: Balancing Accountability and Autonomy

This instance of *leaping-in* is related to Pete's care for his teaching colleagues and his application of the leadership team's observation and performance management processes to ensure the quality of education provided to students. Pete and the teachers in his department experience daily anxiety as they plan and deliver computing lessons. This anxiety is exacerbated by the realisation that practical lessons to teach programming with physical computing are difficult and time-consuming to evidence what students are learning through a work scrutiny exercise, especially if line managers do not understand the computing curriculum. By *leaping-in*, the leadership team has removed Pete's care and instead caused problems, as he does everything he can to demonstrate the progression of students' learning with physical computing in work scrutiny reviews, despite their good intentions to improve the quality of education. In his role as a middle leader, he then reflects on classroom observations, another process centred on the performance evaluation of teachers, but one in which he can make professional judgements by incorporating his own experiences and knowledge into the lesson. The distinction between work scrutiny and lesson observation highlights tension when either process is isolated within the school's accountability framework. The final paragraph examines a scheme of work in which students program micro:bits using Python. Due to the time required for each step of executing the code on the device, Pete discusses managing lesson pace when physical computing is employed. This refers to observations in which the pace of the lesson and the sequencing of activities are cited as essential components of a successful activity, as well as what students learn, considering the time spent on device set-up procedures before they develop more knowledge about text-based programming.

Work scrutiny only considers the work of students, and as a head of the department, I do this away from the classroom, purely based on what is written in students' books or an electronic format. In addition, it is challenging to show the impact of teaching and progress over time with physical computing because teachers need to document students' progress, which is much easier to see in an observation.

At least with a drop-in, I can go into a lesson for 15 minutes and get a feel for learning in the classroom, what the environment is like, how students are engaged or what they pick up much easier. That is undoubtedly a challenge between the two and not something you can quickly tell through work scrutiny.

With a programming unit in Python, students have task sheets and code. I also get them to document the code and what is running. It is harder for a series of physical computing lessons because it takes longer for students to do things. When I think about using micro:bits, the first lesson is just getting used to downloading and running something to the device, so is there any learning there? Probably not, it's just a procedural thing with little knowledge, and that's the same for robots we use with another platform. And when we get to the following lessons, teachers might not have the pace they want because everything takes a little more time with the additional steps involved in running things.

Figure 18: Crafted Story - Anxiety: Balancing Accountability and Autonomy

4.5.3.2 Optimism: Reclaiming Collegiality through Department Leadership

As Pete discusses the need for a 'traditional curriculum' to prepare students for GCSE Computer Science, there is cause for concern regarding the loss of freedom and the *leaping-in* with the computing curriculum in years 7 to 9. However, as he considers curriculum sequencing, he is optimistic about increasing physical computing activities for Year 9 students. During the summer term, some Year 9 students may experience their final computing lessons, and Pete authentically gives back to them by *leaping-ahead* with the freedom to learn through practical activities. This type of care provides other teachers with freedom and autonomy during the final weeks of the academic year, when more traditional material has been covered and the fear of lesson observations or work scrutiny has subsided, as sufficient evidence has already been collected earlier in the year.

There has been much more pressure to ensure that our lower school curriculum equips students with what is needed to move into KS4, so we have changed our year nine curriculum to become a precursor to GCSE Computer Science.

I want to teach more physical computing lessons in Y9 after the half-term in May when we have built up enough evidence for progress and done the more traditional stuff. That is when we don't worry so much about going through work scrutinies, and students can have the time to be practical and enjoy it. For most students in Y9, this will be their last experience in computing. Finishing with something hands-on, a little more practical, and not worrying about a theoretical aspect is nice.

Figure 19: Crafted Story - Optimism: Reclaiming Collegiality through Department Leadership

4.5.3.3 Optimism: Reframing Accountability through Collaborative Practice

In this story, Pete discusses analysing the teaching and learning activities of physical computing in the curriculum and documenting classroom learning. His reflection is optimistic, as he intends to devote more time in the future to teaching with micro:bits and a robotics programme. *Leaping-ahead* in this context refers to caring for others and documenting the progression of students' learning to mitigate risk. Pete has meticulously documented the rationale and progression of the curriculum, with a focus on students' learning progression. This will reduce teachers' anxiety during a classroom observation or work inspection, especially if conducted by a non-subject specialist. Heidegger (1962, p. 159) emphasised, “That which leaps-in ... dominates, and that which leaps forth liberates”, which mirrors Pete's aspiration to embed more tinkering time for children working with physical computing and a greater understanding of the curriculum from senior leaders within their accountability framework processes. Pete understands the complexities of integrating physical computing into classrooms and the opportunities it presents for students to learn and teachers to teach when it is part of the curriculum. He acknowledges the importance of children tinkering and playing with hardware and has committed to an increased workload to continue incorporating this into his work plans.

I remember using BitBlox in one of my year nine classes in the summer. It was the end of the year, so I didn't have to plan that lesson, and I just went: ‘Right, here's your circuit; you have to go here, here and here. Here's your bot, there's your environment – go’. But I knew no one would come in and observe me; no one would look at their books, so I could just let them tinker and play.

While I am now thinking about how we will teach with micro:bits next term or how we might have to prove robotics in the future, I must look at the rounder picture, which shows more to someone else who is probably not an expert in this field. I must show that it is worthwhile and that the children are learning something.

Figure 20: Crafted Story - Optimism: Reframing Accountability through Collaborative Practice

4.5.4 Being a Teacher of GCSE Computer Science and Preparing Students for the Final Exams

4.5.4.1 Optimism: Translating Physical Computing into Exam Readiness

Connecting learning across key stages three and four is a central theme in this story crafted from Laura's experiences. She talks about GCSE Computer Science as a challenging subject. She emphasises the difficulty of paper two for her students because they need assistance with the exam's emphasis on computational thinking, algorithms, and programming. Laura shares her experiences with Year 11 students, whom she claims have been disadvantaged by the pandemic due to the elimination of opportunities to study physical computing. In *leaping-ahead*, she expresses optimism. She reflects on creating the conditions to embed physical computing in the curriculum for years 7 and 8, which will better prepare future students for GCSE Computer Science. Laura quotes a student who said they benefited from programming an object in a programming environment, only on the computer. '……I learn better that way' is the voice of a student responding to the classroom and learning environment that she has created with a kind of care towards the students, which 'leaps-ahead' and allows them to embed gateway knowledge in this way.

At the end of KS3, I drill into the children that GCSE Computer Science is not an easy option, and I talk about paper two. Most of paper one is common sense, but my students struggle with the computational thinking, algorithms, and programming required for the second exam. It's so abstract for them.

The pandemic has disadvantaged my current Y11s by taking away opportunities for more learning with physical computing, so their understanding is behind where I would expect them to be. The advantages of physically doing something and programming an object, rather than just being on the computer, include embedding gateway knowledge and the development of computational thinking. As my year elevens say, 'I find it much better when I'm away from the computer screen. I know that sounds silly, Miss, but it's better. I learn better that way'.

As we continue to embed physical computing in Y7 and Y8, the GCSE CS (Computer Science) paper two should be easier than it is for our students now because there is not enough progress across the key stages at the moment.

Figure 21: Crafted Story - Optimism: Translating Physical Computing into Exam Readiness

4.5.4.2 Optimism: Building Conceptual bridges through Hands-On Learning

As Tom reflects on his motivation to embed teaching and learning with the micro:bit from Year 7 to Year 13, his optimism for using physical computing with all students across all key stages is evident. In *leaping-ahead*, he returns care to his students, who can embed computing knowledge and 'create a link between previous learning' using a physical device to grasp concepts like sequence, selection, and iteration. Tom has documented his planning and activities within each learning journey. Despite calling that task 'the bane of my life,' he is optimistic about the educational value of embedding physical computing in this way. In one example, he discusses students transitioning directly into a text-based Python programming environment at the start of year 10. They recap previous learning with an activity to reinforce 'for-loops,' and Tom reflects positively on the benefit when students see their code appear on a programmable object as a light or sensor reading.

I bring micro:bits into KS4 lessons when reteaching sequence, selection, and iteration because it is always nice to link previous learning. Learning journeys are the bane of my life, but I have links to previous work for my KS4 groups and include everything they will do in KS5. Whenever we teach anything in KS4, we try to remind them of the practical things they did in KS3, where these things were linked, and we try to do the same from four to five.

When we start KS4, we often get students who either didn't come to us for KS3, moved schools or need help remembering the coding they did, so we always start with sequence, selection, and iteration. We do this with the LEDs and sensors on the micro:bits, so we cover some KS3 lessons. Instead of block-based programming, we go straight into Python. We are still using this physical device to do a 'for loop' so that they flash the LED onto the micro:bit and have it in front of them to see it happening physically.

It's more interesting than just having a number go 12345 on screen. Once I have used this physical nature to grasp the concept of 'I can now write a for loop without any problems,' they do not have to use physical devices as much because it's been embedded with the micro:bit. They can remember these core skills from when they used a physical device.

Figure 22: Crafted Story - Optimism: Building Conceptual Bridges through Hands-On Learning

4.5.4.3 Optimism: Embedding Physical Computing for Exam Preparation

This is another story from Laura's experiences in which she is optimistic about using physical computing to prepare students for GCSE Computer Science Paper 2. This time, she discusses a four-hour activity she assigns to her year eleven students as part of their revision in the spring term. They receive little assistance and cannot access online resources for a Lego challenge. She reflects on how the students begin, how they collaborate, and their accomplishments before taking the external exam. Still, it is a challenge they find difficult: 'Miss, this has been so hard'. Laura resists any urge to intervene during the activity and give them the answer, but in *leaping-ahead* of her students, her care is to prepare them for paper two and give them more practice with exercises that will improve computational thinking by getting them to work through problems, to debug independently, and not to provide the answer when difficulties arise.

Problem-solving with physical computing helps students develop algorithmic thinking, abstraction, and decomposition, so we set a challenge with Lego in the spring term for our Y11 students as part of their revision.

We give them four hours of physical activity with a Lego challenge and see how they get on without online resources. First, they work independently, and then we see them interacting naturally and saying things like, 'Well, what have you done? What are you trying? Will we try this?'

They go from nothing to testing their programming and using abstraction to debug and solve problems in three hours. I hear comments like, 'Miss, this has been so hard,' but I remind them of problem-solving and how it will help them with paper two. I remember conversing with a few students who found it difficult, even though one is good at programming. They said, 'We still don't have it working, but we'll figure it out.'

Figure 23: Crafted Story - Optimism: Embedding Physical Computing for Exam Preparation

4.5.4.4 Optimism: Embedding Physical Computing as a Motivational Scaffold

Jenny describes computer science as 'a beautiful subject.' In this crafted story, she shares her plans to continue working with practical programming tasks for GCSE students, despite the exam board's non-exam assessment no longer being required. She is disappointed to hear that other teachers will remove this element of learning experiences for students and is determined to leap-ahead of her group and prepare them in this way for the final exam. Jenny extols the benefits of planning, creating, and testing in a practical sense, as this is the essence of paper two and why physical computing has been embedded into her GCSE curriculum. She is optimistic that physical computing will be included in her computer science curriculum, thoroughly preparing students for the exam. It also offers learning opportunities that are fun and exciting, and she describes them as ‘a little different,’ noting that this approach is associated with higher attainment.

We have two written papers for GCSE Computer Science, and it is a shame for a subject so beautiful that students can build things to hear computer science teachers say, ‘Oh, well, there are no programming tasks, so they don't have to program.’ Doing something from planning, creating, and testing is the essence of their exams, especially paper two. How do you get students to answer these questions confidently and understand what they are doing if they haven’t been through the process?

I talked to my trainee about the non-exam assessment (NEA) and how we don't have to do it, but I'll set it up as a task for my computer science group next year. I am lucky because we have a three-year KS4 curriculum, allowing me to do the NEA with GCSE Computer Science students. Testing something fun, exciting, and different doesn't hurt them. That should be what teaching should be, and when students are interested in what I am trying to do, they get higher grades.

Figure 24: Crafted Story - Optimism: Embedding Physical Computing as a Motivational Scaffold

4.5.5 Being a Computing Teacher and Using Physical Computing with All Students

4.5.5.1 Optimism: Using Tangible Interaction to Develop Understanding

Tom's physical computing experiences demonstrate optimism and a *leaping-ahead* approach, paving the way for his students to take action as teachers provide the possibilities that come with programming a micro:bit, in this case, to collect data. He reflects on activities with increasing interest and is optimistic about the knowledge students gain in a practical sense, which empowers and encourages their future learning.

Tom does not need to use micro:bits with his A-level class, but in the following story, he discusses the benefits of assigning students a practical task to collect data. He reflects on making the topic ‘a little more interesting’ by *leaping-ahead* and allowing students to collect their own data sets. Tom discusses expanding on previous activities with the micro:bit that students have participated in since entering the school in year 7. His experiences with embedding the microcontroller board in this way are positive, and he is optimistic about this style of teaching and learning as a means of delivering the curriculum. He uses the micro:bit to have 60 devices already in his classroom that 'just work’. However, Tom repeatedly references the *leaping-in* approach to caring for others from the central technical team. He must also mention another instance in which they blocked USB drives and prohibited the use of micro:bits for learning in classes. This led to frustration and reflection on an alternative hardware solution using a Raspberry Pi minicomputer; Tom recalled spending additional time to ‘set up the damn things’ with the Linux operating system with further irritation.

We use micro:bits with temperature sensors and tilt switches that physically do something in our Y7 computing lessons. When students enter the sixth form, and again we’ve had difficulties when the trust blocks them, we run the serial USB device for data logging. The central part of this lesson is to teach students the SQL commands to create a file and read the data in Python automatically, so let's have that data live.

They download a serial stream of data using micro:bit and Telnet or something similar, and this data could be stored as a text file or database. But then students do something with the data, so it's not just about micro:bit; the micro:bit is the device that provides the data. It makes it a little less dry, doesn't it? A little more interesting. Let's have that data coming in, swing it around their heads, see what's going up and down, and start looking at how we can use Python plotting. So, instead of just doing it in a spreadsheet or simply using Access to learn SQL commands, we do it properly and do it with some interest.

I use micro:bits this way because they do the job, and I have 60 of them under my desk, so I don't have to buy anything else. I can plug them in, and they just work. I could get the Raspberry Pis out, but then I would have to spend the next 45 minutes setting up the damn things and showing the students how to install Linux and things like that.

Figure 25: Crafted Story - Optimism: Using Tangible Interaction to Develop Understanding

4.5.5.2 Optimism: Enabling Autonomy through A-level Physical Computing

A-level students can benefit from physical computing when planning coursework projects. In this *leaping-ahead* scenario, Tom reflects on his modes of intervention by making Arduino or micro:bit devices available to spark ideas and assist his students with the practical aspects of using the hardware. He aims to care for his students and encourage them to take control of their learning. The group aims to map out their plans for coursework and submit them for a final assessment. Tom's 'leaps-ahead' of his students as an authentic means of giving back their freedom to make choices by opening up possibilities about how they complete their work, emerging as optimism from the teacher as an affective response. The following crafted story acknowledges that using a physical computing device, such as the micro:bit, can sometimes complicate the learning intention; however, a teacher's understanding can guide a student.

We try to get our A-level students to think about using physical computing in projects when they do their coursework. Some students have used Arduinos or micro:bit as control devices, and we try to get them to consider these aspects. For example, one student attempted to build a motion-tracking system to control an object on the screen using a micro:bit for processing. His coursework became complicated by using the micro:bit with Bluetooth or the radio-type thing to connect. He eventually used a webcam with a library he had found on GitHub. It was a good project that reached a point where he wore a bright red glove that could be detected on the screen, and became motion-tracking.

Figure 26: Crafted Story - Optimism: Enabling Autonomy through A-level Physical Computing

4.6 Research Question Responses

This section directly addresses the central research question and two sub-questions, drawing on the crafted stories developed through hermeneutic phenomenological analysis. These stories offer ontological insight into teachers' lived experiences of implementing physical computing in English secondary schools. Through this interpretive engagement, the findings illuminate the affective, relational, and contextual dimensions of classroom practice.

4.6.1 Central Research Question

What is the meaning of teachers' lived experiences with physical computing in English secondary schools?

The meaning of teachers' lived experiences with physical computing, as interpreted in this study, is not reducible to a single definition or generalisable category. Instead, it is constituted through the reflective and affective accounts of practice, situated within the relational, institutional, and pedagogical contexts in which teachers operate. Informed by hermeneutic phenomenology, particularly Heidegger's notion of *Mitsein* ('Being-with') and Gadamer's idea of the fusion of horizons, these meanings emerged across five interrelated themes:

1. Being the head of a computing department and assessing the quality of education
2. Being a teacher of computing in a multi-academy trust
3. Being a mentor to trainee computing teachers
4. Being a teacher of GCSE Computer Science and preparing students for the final exams
5. Being a computing teacher and using physical computing with all students

These thematic strands reveal that physical computing is not experienced in isolation, but always about students, colleagues, senior leaders, institutional policies, and broader communities of practice. Teachers' narratives demonstrate how care, risk-taking, and anticipatory design are enacted within structures of constraint and opportunity, resulting in ontologically rich accounts of teaching as a relational mode of 'Being-with' technology and others.

The interpretive leap made possible by crafting stories (Crowther *et al.*, 2017) enabled latent meanings to emerge. For example, stories reflecting frustration over network restrictions or joy in student engagement were not merely anecdotal; they were expressions of deeper ontological movements, such as leaping into troubleshooting immediate barriers or leaping ahead to reimagine pedagogical futures. In this sense, the teachers' lived experiences exemplify what Gadamer (2013) describes as the fusion of horizons, where the researcher's interpretive stance meets the situated meanings embedded in the participants' lifeworlds.

4.6.2 Sub Question One

How do teachers describe their experiences with physical computing?

Teachers' lived experiences reveal a spectrum of pedagogical, technical, and emotional encounters shaped by their unique school contexts. While the themes were presented earlier in the chapter, this section focuses specifically on their narrative character and affective tone.

Marcia, for instance, shared that her integration of physical computing aimed to 'increase students' engagement of all abilities and make Computer Science a desirable subject to choose at GCSE,' yet felt frustrated by a senior leadership team that 'has no idea what Computer Science is.' Her story underscores a disconnect between pedagogical innovation and institutional recognition.

Tom described teaching micro:bits across year groups, highlighting both curricular continuity — re-teaching sequence, selection, and iteration — and structural impediments: 'We have a core IT team that runs on a business basis... not considering how we make it most useful for students' learning.' These reflections highlight how infrastructure and policy can shape or constrain the enactment of care in computing education.

Pete expressed anxiety around work scrutiny, particularly the challenge of evidencing progression in physical computing projects: 'I must look at the broader picture... to show that it is worthwhile.' By contrast, Jenny expressed optimism about a carousel approach, where students are not summatively assessed, suggesting that reduced pressure allows for experimentation and play.

Laura likened physical computing to music teaching, noting how observers often misunderstood the learning: 'They don't know what's happening and think it's a lot of noise.' Her crafted story offered a decisive moment where an SLT observer, after student dialogue, recognised the developmental arc of learning, prompting Laura to assert that 'the observer understood the learning journey.'

These accounts reveal a key hermeneutic insight: teaching with physical computing is an inherently interpretive act, shaped not only by what is taught but also by how it is perceived, judged, and experienced within a broader ecology of relationships.

4.6.3 Sub Question Two

What themes can be uncovered through the study of teachers' lived experiences?

The crafted stories, developed through hermeneutic analysis, reveal affectively charged themes of anxiety, optimism, and frustration, each corresponding to moments of *leaping-in* or *leaping-ahead* as forms of solicitude (Sorge). These affective responses, mooded states of Being, are central to how the phenomenon of teaching with physical computing is revealed (Heidegger, 1962).

For instance, Tom's frustration with trust-wide restrictions on professional networks catalysed his founding of a local Computing at School hub. This act of *leaping-ahead* exemplified how care can manifest through anticipatory design and resistance. Similarly, Jenny's optimism in mentoring a trainee teacher echoed across multiple crafted stories where co-planning, feedback, and joint experimentation created ‘safe spaces’ for pedagogical risk-taking.

Figure 10 (first introduced in Chapter 3, Section 3.6.8) is revisited here to support further interpretation of the data. It arranges each crafted story according to its associated mode of solicitude and affective orientation, illustrating how physical computing is enacted in classroom practice. These stories convey both the practical and emotional dimensions experienced by teachers as they navigate the complexities of integrating physical computing with resilience, creativity, and care.

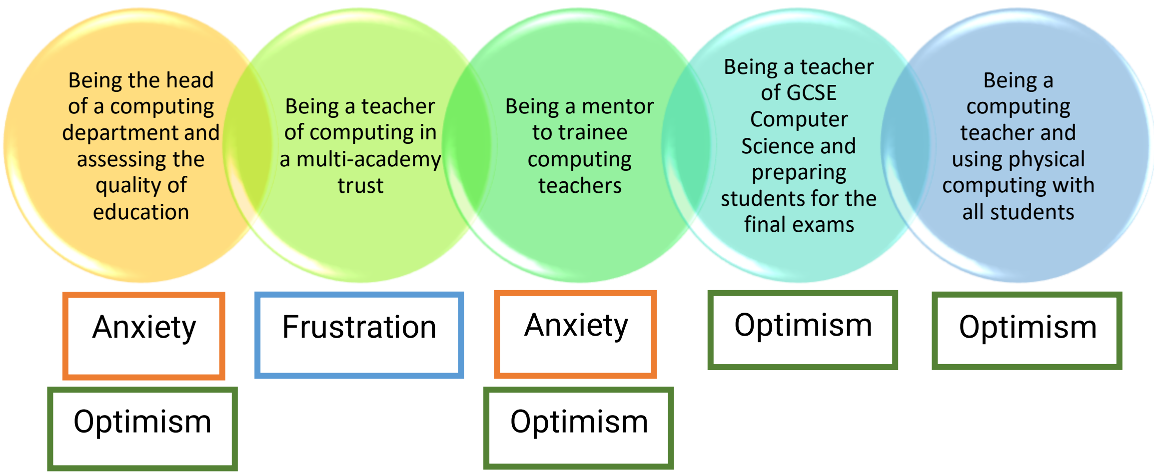

Figure 10 (reproduced for reference): Thematic summary with feelings attached to ‘Being-with’ physical computing

4.7 Summary

In this chapter, findings are presented as crafted stories with themes and affective responses, rather than simply retelling the data from teacher interview transcripts; rather, they are an interpretation that attempts to capture the essence of their experiences. The narratives are presented as interpretations of the data that aim to capture the complexity and richness of the participants' lived experiences. Trustworthiness and credibility procedures for this study (including credibility, transferability, dependability and confirmability) are detailed in Chapter 3 (Methodology) and are not repeated here.

One of the goals of this research is to bridge the gap between theory and practice in computing education, publish findings that will help other teachers, particularly those teaching physical computing in the formal curriculum, and contribute to the field of computing education research. In a phenomenological sense, Heidegger's concept of *Being-with* and Gadamer's idea of understanding horizons highlight the social and relational aspects of participants' experiences, as well as the pre-understandings and perspectives that shape their interpretation of those experiences, which serve as critical lenses for analysing and interpreting data from the teaching profession. Thus, the crafted stories created through hermeneutic writing serve as a medium for comprehending the complexities of teachers' experiences with physical computing in the classroom. Furthermore, these narratives amplify teachers' voices, enabling a more in-depth understanding of the phenomenon under study.

Chapter 5 Discussion

5.1 Introduction

This study challenges dominant cognitive and technical paradigms in computing pedagogy by advancing an ontological perspective grounded in Heidegger's concept of *Sorge* (care) (Heidegger, 1962). Whereas previous hermeneutic-phenomenological work in computing education has tended to address particular or isolated aspects of teachers' practice such as curriculum reform (Sloan and Bowe, 2015) or classroom discourse in programming (Sentance and Waite, 2021) this study foregrounds the emotional, technological, and institutional entanglements through which teachers encounter physical computing, treating these as sites where *Sorge* (care) is enacted and where new meanings continually emerge in a fusion of horizons. It does so through a collection of phenomenological accounts that illuminate how these dynamics are lived and negotiated as a single, interconnected whole.

Teachers' encounters with physical computing emerge here as deeply embodied and affective experiences, marked by optimism, frustration, and uncertainty, as well as by the affordances and constraints of technologies and institutional norms. Framed through the dual modes of *leaping-in* and *leaping-ahead*, the study articulates the temporal and relational dynamics of teacher agency, moving beyond linear or mechanistic accounts of pedagogy. At the same time, Gadamer's notion of the *fusion of horizons* (Gadamer, 2013) emphasises how teachers' current practices are continually shaped in dialogue with their past experiences, institutional contexts, and future anticipations. Collectively, *Sorge* and the *fusion of horizons* provide the philosophical foundation for understanding teaching as an interpretive, care-infused practice of meaning-making.

This chapter synthesises the findings within the broader landscape of educational theory, policy, and research, considering their implications for teacher agency, curriculum development, and the conditions for sustainable educational change.

5.2 Enacting Care Through Leaping-In and Leaping-Ahead

Whereas existing accounts frequently frame teaching as technical delivery or the transfer of discrete cognitive skills, this study foregrounds care as an ontological foundation, showing teaching as an embodied, relational practice shaped by both immediate demands and anticipatory horizons. In this thesis, I use the term relational labour to refer to the ongoing work of sustaining relationships, trust, and an ethic of care in practice, much of which remains informal and easily overlooked (Renshaw, 2017). Heidegger's core notion of care (Sorge) situates human existence as inherently relational, arising from our continuous responsiveness to others' needs and contextual demands (Heidegger, 1962). Applied to physical computing education, this ontological lens reveals that teachers and leaders move beyond narrow forms of technical troubleshooting or curriculum delivery to engage in ongoing negotiations traversing emotional, practical, and institutional terrains. Through *leaping-in* to respond to urgent, immediate challenges and *leaping-ahead* to anticipate and shape future possibilities, they demonstrate how pedagogy is inseparable from care. This perspective offers a more holistic view of teaching as a temporally layered practice, deeply embedded in affect and relationality. Despite its transformative potential, this viewpoint is still rarely addressed in computing education research.

To ground this concept, consider Tom's frustration as he described spending "more time troubleshooting cables than teaching loops" (Tom, Interview 1), a situation which led him to advocate for more adaptable IT provisions. Similarly, Jenny expressed anxiety about the pressure to demonstrate "exam-ready knowledge" in physical computing, fearing, "If the micro:bit failed, students would lose confidence in the concept and in me." These emotional responses are not peripheral but constitute forces that energise and constrain pedagogical practice, shaping teacher cognition, motivation, and, ultimately, student learning (Nias, 1996; Sutton and Wheatley, 2003). As Nias (1996) explains, teachers' emotions are rooted in cognition, feelings, and values that shape moment-to-moment judgments and long-term professional commitments by directing attention and informing decision-making in the classroom. Likewise, Sutton and Wheatley's (2003) review highlights the multi-componential nature of teacher emotion, showing that both positive and negative affect guide the adoption of instructional strategies and sustain motivation over time. The crafted stories in this study revealed three primary affective responses, frustration, anxiety, and optimism, that shaped teachers' leaping experiences.

These feelings are linked with professional identity work: frustration motivates policy advocacy, anxiety informs the redesign of lessons, and optimism reinforces creative risk-taking. Nonetheless, teacher participants warned that without leadership policies explicitly recognising this emotional practice, through the provision of technical training, protected collaborative planning time, and tolerant evaluation frameworks, the capacity for care-driven teaching risks being constrained (Evans, 2014). Consequently, policymakers and school leaders should develop supporting structures that recognise and accommodate the affective demands of embedding physical computing, ensuring that care-centred pedagogy is both sustainable and valued.

5.3 Structured Reflection ('Freezer of Waterfalls')

Jenner's (2000) metaphor of the *freezer of waterfalls*, where routine practices become invisible until consciously examined, captures the transformative power of structured reflection within teaching practice. When encouraged to pause and reflect beyond immediate classroom pressures, teachers reconsidered and integrated physical computing into their pedagogy. For example, Pete recognised that work scrutiny failed to capture the iterative nature of student learning, prompting him to introduce formative assessment portfolios that offered a more authentic account of student progression. Similarly, Tom identified how restrictive network policies limited spontaneity and successfully negotiated for more flexible IT access.

Such reflection functioned as a site of epistemic disruption and renewal, challenging routinised teaching and revealing pathways toward adaptive expertise. The findings of this study reinforce Casey's (2013) view that intentional reflection deepens teachers' understanding, promoting lasting improvements in pedagogy. Likewise, McLaughlin and MacFadden's (2014) emphasis on reflective inquiry as a means of uncovering implicit teaching routines resonates with the evidence presented here, which positions such reflection as a catalyst for developing adaptive expertise within the evolving field of physical computing pedagogy. Collectively, these insights suggest that structured reflection is not an optional add-on, but a strategic component of professional development frameworks, fostering both systemic improvement and individual growth.

5.4 Lived Experiences of Being a Computing Teacher: Contextual Insights

5.4.1 Being a Teacher in a Multi-Academy Trust

Tom's lived experiences reveal how becoming part of a multi-academy trust reshaped his enactment of physical computing. Initially, he spoke of programmable objects as engaging teaching tools that made abstract computer science concepts tangible. Over successive interviews, however, he came to recognise how multi-academy trust structures and policies mediated his classroom practice, illustrating Heidegger's notion of *Mitsein* ('Being-with') and the care spectrum of *leaping-in* and *leaping-ahead* (Heidegger, 1962).

When Tom's school joined a trust, he encountered an abrupt imposition of technical and pedagogical directives. Port restrictions and mandatory network configurations undermined his autonomy, forcing him to rely on technical staff to resolve issues he once managed independently. This disempowerment echoes Crawford *et al.*'s (2022) finding that academy teachers feel less connected to professional networks and support structures, and resonates with Greany, Cowhitt and Downey's (2023) evidence that academisation fragments teacher communities and hinders collaboration and professional development. Tom described feeling 'isolated and frustrated' when his spontaneous classroom ideas were stymied by security protocols, reflecting Jones's (2016) observation of diminished collegiality in academy settings.

Conversely, Tom enacted *leaping-ahead* by founding a local Computing at School (CAS) community of practice. His initiative aimed to rebuild collegial bonds that had been fractured by academisation. He shared resources and troubleshooting strategies through this network, extending support beyond his trust. In doing so, Tom embodied Leat *et al.*'s (2015) call for dialogic, teacher-led research engagement. This shift strengthened his professional identity and broadened his pedagogical horizon, demonstrating that agency can still be reclaimed within restrictive structures.

Tom also critiqued the trust's inflexible approach to curriculum alignment. He argued that a trust-wide computing coordinator, lacking classroom experience, imposed trust-wide schemes that marginalised physical computing. This "indentured autonomy" (Thompson *et al.*, 2021, p. 230) constrained his ability to integrate hands-on projects meaningfully, underlining Sansom's (2020) assertion that experienced teachers require flexibility to adapt practice across successive reform agendas.

Despite tensions, Tom emphasised the importance of infrastructure and support in sustaining physical computing. He recounted how clear communication with technical teams, characterised by mutual respect, enabled the swift resolution of network issues, allowing lessons to proceed without compromising security. His narrative confirms findings by Hodges *et al.* (2020) and Kaivo (2019) that reliable technical support is pivotal to successful implementation.

Tom's narrative illustrates how multi-academy trusts can inhibit and enable innovative practice. The *leaping-in* imposition of policy and technical constraints risks alienating teachers, whereas *leaping-ahead* through community building and collaborative problem-solving empowers them to align curricular, technical, and pedagogical demands. These insights broaden our understanding of how structural reforms impact teachers' professional agency and highlight the need for trust-based policies that strike a balance between security and pedagogical freedom. Further research could investigate how different trust configurations influence teachers' ability to sustain embodied computing practices.

5.4.2 Being a Mentor

Mentoring operates as a relational and reflective scaffold, enabling early-career teachers to navigate the complex challenges inherent within physical computing pedagogy (Hall *et al.*, 2008). Jenny and Pete's lived experiences reveal that mentoring is more than just technical tutelage; it embodies anticipatory care that scaffolds professional development, echoing Heidegger's (1962) notion of solicitude.

From the earliest interviews, Pete explained how observing his mentees' lessons revealed gaps in their understanding of hardware operation and their confidence in experimenting. In response, he introduced a 'kit-bag' system for distributing micro:bits, commenting that it 'made practical tasks feel manageable' and encouraged trainees to take ownership of troubleshooting. By embedding these routines into daily departmental practice, Pete moved beyond simply providing answers; he ensured that physical computing became part of the standard workflow. This approach aligns with Pantić *et al.*'s (2022) finding that embedding innovation within routine practice helps teachers internalise new methods rather than treating them as extra demands. By the final interview, Pete observed that his leadership had evolved: co-planning sessions with mentees led him to refine pacing and differentiation across Key Stage 3 computing units, a substantive *leaping-ahead* in his role.

Jenny's mentoring journey similarly highlights the reciprocal nature of care. Initially focused on her mentee's ability to connect sensors and write basic programs, she soon recognised the importance of validating early successes and failures. She recounted her trainee's excitement in demonstrating a working temperature-sensitive badge to an inspection team, noting, "I want them to see how challenging it is and how supported I felt." This anecdote exemplifies Capps and Crawford's (2013) argument that reflection on authentic student work can reinforce novice teachers' confidence. Over successive conversations, Jenny shifted from a technical instructor to a reflective partner, guiding her mentee to critique the lesson flow and student engagement, thereby deepening shared pedagogical insight.

Both mentors emphasised the necessity of ongoing professional learning. Pete echoed Mouza's (2009) evidence that research-driven practice leads to sustained change, and he organised regular 'innovation sessions' in which mentors and mentees pilot new physical computing projects. Likewise, Jenny facilitated fortnightly peer-review workshops, in which trainees presented student projects and received constructive feedback, thereby expanding their repertoires and revitalising mentors' practice. Through their lived experiences retold as crafted stories, Jenny and Pete show how mentoring transcends technical instruction. They embody forward-thinking care that anticipates and scaffolds professional growth, resonant with Heidegger's (1962) conceptualisation of solicitude.

The impact of such mentoring transcends individual relationships. The Royal Society (2017) recommended expert guidance to support computing teachers, a need met in practice by Jenny and Pete's initiatives. Additionally, Ingersoll and Strong (2011) and Callahan (2016) have demonstrated that robust mentoring is correlated with improved teacher retention, particularly in challenging contexts. Although this study did not directly measure retention rates, both mentors reported that their trainees expressed renewed commitment to the profession after completing their mentoring cycles.

In summary, Jenny and Pete's lived experiences demonstrate that mentoring in physical computing is not merely technical training but a form of anticipatory care that embeds reflective practice and co-construction of knowledge. They empowered novice teachers to build confidence, professional identity, and pedagogical expertise by structuring regular reflection, shared lesson development, and authentic artefact-based discussions.

Their experiences suggest that school-based mentoring programmes grounded in dialogue and authenticity can enhance teacher efficacy and sustain long-term engagement in physical computing.

5.4.3 Being the Head of a Computing Department

Heidegger's notion of care (Sorge) highlights the relational dimension of leadership in teaching, where the department head's responsibility extends to colleagues and learners (Heidegger, 1962, p. 158). Pete's account shows this intertwining of care and accountability. Initially, he embraced the leadership-mandated observation and work scrutiny processes as mechanisms to validate the progression of students' computing skills. Yet, over successive interviews, he became increasingly uneasy, recognising these *leaping-in* practices, designed to assure quality, inadvertently constrained his capacity to support colleagues and eroded the collaborative ethos he valued (Butler and Schnellert, 2012).

A key tension emerged between the procedural demands of work scrutiny as a review mechanism for the department and the experiential learning opportunities with physical computing. Pete described how his colleagues felt ‘on show’ during drop-in observations, obliged to document each student outcome in written records that seldom captured their lessons' iterative, hands-on nature. He reflected that work scrutiny often misrepresents students' creative problem-solving: “You can't squeeze a blinking LED or robot behaviour into a spreadsheet cell.” Pete contended that lesson observations, grounded in collective professional judgment, offer a more comprehensive and nuanced assessment of teacher expertise and pupil engagement.

Managing these dual pressures led Pete to adjust his curriculum planning. He shifted Year 9 physical computing units to the summer term, deliberately choosing a period of lower inspection intensity. This rescheduling exemplifies his protective care for staff wellbeing, shielding teachers from the surveillance stress of high-stakes accountability and allowing them to focus on open-ended exploration (Ng and Leicht, 2019). In doing so, Pete enacted a form of *leaping-ahead* care, reframing accountability not as a threat but as a scaffold for sustainable innovation. In these prioritising conditions, teachers could experiment without fear of punitive evaluation.

Pete's lived experiences show the delicate balance department heads must strike between maintaining accountability and nurturing teacher autonomy and creativity. From his reflections, three policy imperatives emerge. First, quality-assurance frameworks should be co-designed with teachers to respect the exploratory pace and open-ended nature of physical computing lessons. Second, timetabling and inspection schedules must acknowledge project-based learning, reducing the tension between innovation and compliance. Third, senior leaders may require targeted professional development to deepen their understanding of the technical and pedagogical demands of physical computing, enabling them to support teachers' professional judgment effectively.

5.4.4 Being a Teacher of GCSE Computer Science

Jenny and Laura's reflections demonstrate how integrating physical computing into Key Stage 3 can deepen students' conceptual and procedural understanding of GCSE Computer Science (OCR). Both teachers initially introduced devices such as micro:bits and Lego to spark engagement but gradually discovered that these hands-on experiences also prepared students for the rigours of the GCSE Exam Paper 2, which emphasises computational thinking, algorithms, and programming. In early interviews, Jenny described physical computing as "fun and exciting," noting its value in giving novices "a real sense of success" when their code produced tangible outcomes. By the final interview, however, she articulated how these KS3 activities became deliberate scaffolds for GCSE content, helping students internalise abstraction and decomposition before encountering formal exam tasks.

Similarly, Laura recounted a transformative moment that resembled Jenner's (2000, p.38) "freezer of waterfalls" moment when she realised that the multi-step Lego challenges she ran in Year 8, designed to encourage iteration and design thinking, mapped directly onto the sustained problem-solving demanded in GCSE assessments. Initially undertaken as an enrichment project, Laura restructured this activity into a formative assessment tool: she observed how students documented their design decisions and debugging processes, then tied those reflections back to Paper 2 question formats. She explained, "When they linked their Lego design log to pseudocode, I saw a marked improvement in their exam technique."

Both teachers exemplified Heidegger’s notion of *leaping-ahead* care, moving beyond here-and-now engagement to anticipate and prepare students for future curricular demands (Heidegger, 1962). This forward-looking stance was evident in the deliberate sequencing of KS3 projects, where physical computing tasks were chosen for their immediacy and capacity to build enduring skills in abstraction, algorithmic reasoning, and testing. Jenny’s shift from valuing novelty to foregrounding alignment with exam requirements demonstrates how lived experience prompts teachers to recalibrate pedagogy in response to deeper curricular insights.

COVID-19 disruptions further highlighted the resilience afforded by these embodied approaches. Both teachers reported that students struggled to conceptualise core ideas when remote teaching precluded the use of physical devices. Returning to in-school learning, they observed a pronounced eagerness among students to re-engage with hardware, accelerating their readiness for formal assessment. Laura reflected that ‘physical computing became our anchor point for re-establishing routines and rebuilding confidence before tackling Paper 2 topics.’

These findings advance Casey's (2013) assertion that scrutinising individual change processes reveals the mechanisms by which pedagogical innovations are embedded within everyday practice. Jenny and Laura maintained student motivation and encoded exam-relevant skills over time by interweaving physical computing into daily lessons. McLaughlin and MacFadden's (2014) caution about ‘cookbook’ inquiry contrasts with the open-ended yet scaffolded tasks these teachers employed, which balanced guided instruction with opportunities for independent problem-solving. In doing so, they avoided the pitfalls of formulaic investigations and instead embedded genuine inquiry, enabling students to transfer hands-on learning to written examination contexts.

5.4.5 Being a Computing Teacher and Using Physical Computing with All Students

Tom's commitment to inclusive computing education is evident through his use of physical computing to make complex ideas accessible to students across Key Stage 3 to A-level cohorts. Drawing on Heidegger's notion of *leaping-ahead* care, he designed Year 7 activities in which micro:bit temperature sensors trigger LEDs to transform abstract programming constructs into tangible phenomena. As he reflected, ‘When students see the LED respond to their code, they suddenly grasp loops and conditions,’ illustrating how embodied interaction cultivates conceptual clarity and motivation (Heidegger, 1962).

A formative ‘identity anchor’ moment that inspired his teaching philosophy occurred when Tom observed non-specialists being compelled to deliver ICT lessons. He recounted:

‘She said, 'I'm not an IT Teacher. I don't see why you have to do this; I'm a music teacher.' She was Head of Music. 'I only do this because I'm free.' So, they timetabled Key Stage 3 so that whoever was left free on the timetable took that lesson, and it was always somebody who had no interest. It was awful. It really was awful.’

Aligned with Kuh *et al.* (2006, p. 68), Tom’s conviction in this moment crystallised that both subject expertise and authentic enthusiasm are critical for student success. Thereafter, he committed to all computing lessons from Year 7 to Year 13 being taught by specialists with embedded physical computing.

Tom's pedagogy strikes a balance between open-ended exploration and scaffolded support. In one Year 9 unit, students built earthquake detectors using tilt switches. Novices followed step-by-step prompts, while more advanced learners extended their designs to integrate buzzer alarms or data-logging functions. ‘Even those who struggle with syntax shine when they see their device in action,’ Tom noted, emphasising that differentiated tasks honour diverse strengths and boost self-efficacy.

Despite this, Tom expressed frustration with systemic constraints and prioritised student access and choice over administrative and technical hurdles. His experience underscores the importance of teachers critically examining how their personal histories, professional experiences, and political expectations influence their professional identities (Bressler and Rotter, 2017). Moreover, his lived experiences align with findings on teacher identity under reform (González-Calvo and Arias-Carballal, 2017; Derakhshan *et al.*, 2020), showing that formative experiences, such as choosing typing as an option, anchor resilience and instructional choices. By negotiating institutional constraints, Tom exemplifies how a strong professional identity empowers teachers to preserve pedagogical integrity and advocate for the needs of learners.

In summary, Tom's account provides a compelling model of *leaping-ahead* care in computing education. He utilises physical computing to construct concrete conceptual bridges for students, grounding his pedagogy in pivotal 'identity anchor' moments that continue to shape his professional identity. He navigates institutional constraints to increase students' learning experiences with physical computing. Tom demonstrates how a reflective, identity-anchored leadership style sustains teacher agency, resilience, and student engagement by foregrounding his journey from early encounters with non-specialist ICT teaching to deliberate role modelling of specialist practice. His example highlights that by integrating personal and professional identity anchors into their practice, teachers can use their lived experiences to design computing experiences that support and include every student's learning progression.

5.5 Professional Identity: Lived Experiences and Community

Teachers' professional identities in physical computing are rooted in the moments that crystallise their sense of purpose and sustained by the ongoing interplay of emotion, reflection, and community. For Tom, a seemingly minor timetable adjustment, where computing was left to the most convenient teacher rather than a specialist, became a watershed, solidifying his belief that only those with genuine passion and subject expertise should lead computing lessons (Mockler, 2011). From then on, every Arduino project and micro:bit exploration embodied his commitment to specialist-driven pedagogy, transforming what might have been peripheral enrichment activities into deliberate opportunities to embody his core belief in enthusiastic, specialist teaching.

Jenny's journey likewise illustrates the link between emotion and identity. She described how collaborative lesson planning with trainee teachers, first tentative but then progressively confident, became a source of professional pride and affirmation, confirming Teng's (2017) claim that emotions influence teachers' decisions, reflections, and pedagogical responses.

Pete's sense of self as a leader emerged through his orchestration of a peer-led community of practice, where colleagues trialled sensor-based challenges and exchanged strategies for embedding hands-on work into the computing curriculum. These gatherings offered more than practical tips; they became spaces of collective validation, where successes were celebrated and setbacks were reinterpreted as learning milestones. Freedman and Appelman (2008) note the power of such communities to sustain reflective practice. Pete's experience confirms that identity is continuously reinforced when teachers see their values echoed and refined in the shared wisdom of peers.

Equally, the identities forged in these contexts had tangible effects on classroom cultures. For example, the teacher participants' commitment to equity was evident in the differentiated challenges that celebrated both procedural proficiency and creative risk-taking (Ni and Guzdial, 2012). Yet these evolving identities remained vulnerable to external pressures. As national reports flagged ongoing shortages of specialist computing staff (The Royal Society, 2017) and exam-focused mandates intensified, teachers navigated a tightrope between policy compliance and the freedom to develop their teaching with physical computing. Tactical decisions, such as scheduling project units in lower-stakes windows or streamlining preparatory activities to preserve exploratory space, became acts of identity preservation, enabling them to honour institutional requirements and their pedagogical convictions (Ryder and Banner, 2013).

Computing teachers construct professional identities that both steer daily practice and provide resilience amid educational reform by integrating formative beliefs, peer collaboration, and community validation. Supporting this identity work, therefore, calls for professional learning opportunities that engage teachers not merely as individuals acquiring skills, but as reflective practitioners whose personal experiences and peer-validated values are integral to sustaining inclusive computing education, particularly in the context of physical computing.

5.6 The Complexities of Teaching Computing: Policy, Materiality, and Micro-Politics

The enactment of care and meaningful teacher agency in physical computing classrooms is inextricably embedded within the material and socio-political fabric of their institutional contexts. Policy mandates, leadership visions, resource allocations, and the physical architecture of learning environments converge to shape, constrain, or occasionally extend the horizons of pedagogical possibility.

Over the last decade, system-level reforms in England, such as the introduction of the national computing curriculum and the rise of accountability frameworks, have simultaneously generated new opportunities and increased pressures on teachers (Royal

Society, 2012; Royal Society, 2017; Berry, 2018; Sentance and Waite, 2018). This study demonstrates that teachers actively engage in processes of negotiation, resistance, and reinterpretation in response to such mandates. In doing so, it positions teacher agency not as a fixed attribute but as an interpretive practice, continually renegotiated at the intersection of constraint and possibility. Here, Gadamer's (2013) idea of a fusion of horizons is instructive: teachers' enactments of policy are never mechanical but shaped by the dialogue between their prior experiences, institutional expectations, and their anticipations of future practice.

Findings from this study show that the enactment of care, particularly through *leaping-in*, requires more than technical problem-solving; it often entails ongoing negotiation with, and at times resistance to, externally imposed constraints. Teacher participants described how the micro-politics of everyday practice, including the rhythm and timetabling of the school day, the physical design and layout of classrooms, and the availability of specialist equipment, directly impacted their ability to innovate and to support students meaningfully in physical computing lessons. Such themes resonate with the arguments of van Manen (2016), who emphasises the significance of material and contextual factors in shaping pedagogical action.

A persistent theme was the tension between professional autonomy and the demands of accountability-driven policy. Teachers described the continual challenge of reconciling the need to produce measurable outcomes for inspection or reporting with their professional aspirations to build authentic engagement, encourage experimentation, and create space for students to learn from seemingly failed projects and debug them in the classroom. This tension was a recurring source of strain, as accountability frameworks sometimes conflicted with the pedagogical conditions needed for deeper learning and curriculum development. The study suggests that overreliance on compliance and performance metrics can stifle creativity, discourage risk-taking, and constrain teacher agency, concerns widely acknowledged in discussions of educational reform and the development of computing (Royal Society, 2017). From a hermeneutic perspective, these tensions are not merely obstacles but sites of interpretation: where institutional demands collide with teachers' lived experiences, horizons overlap and are reconfigured, reshaping both policy enactment and pedagogical practice.

While these tensions were analysed through physical computing, teachers' accounts indicate that the underlying constraint is sometimes computing as a subject itself being only partially legible to senior leadership. Where leadership understand computing primarily through the lens of inspection-readiness or easily evidenced outcomes, curriculum decisions can privilege compliance over disciplinary integrity, narrowing what forms of practice are supported and sustained. This suggests that some barriers attributed to physical computing may, in fact, reflect a wider issue of subject-status and leadership comprehension within computing education.

The sustainability of physical computing initiatives was frequently depicted as fragile and contingent on factors such as the presence of individual 'champions,' the level of support from school leadership, and the existence of institutional memory and structured knowledge sharing. When teachers experienced supportive leadership and strong collegial networks, they reported having greater autonomy to experiment with their teaching and to adapt practice in response to students' needs. In contrast, environments characterised by limited resources, inadequate time, or unsupportive management often result in frustration and, at times, the curtailment or abandonment of innovative approaches.

Ultimately, these findings reinforce the argument that the realities of policy, materiality, and school micro-politics must be acknowledged as central determinants of what is possible in physical computing education. Effective and sustainable integration of physical computing into the curriculum is unlikely to rest on individual effort alone; it requires organisational cultures and policy environments that explicitly value teacher agency, allocate adequate resources, and recognise the complex, situated nature of pedagogical work. Moreover, Gadamer's concept of a *fusion of horizons* illuminates how teachers mediate between past experiences, present constraints, and future possibilities, thereby sustaining pedagogy as a practice of care even under systemic pressures.

5.7 Building Organisational Resilience

Another conclusion to emerge from this research concerns the inherent fragility of pedagogical innovation when not underpinned by supportive systems and distributed forms of leadership. Teachers emphasised the difficulty of maintaining new practices over time, with initiatives that initially gained momentum often losing traction or being abandoned altogether when new leadership arrived, budgets were cut, or whole-school priorities shifted. Their accounts pointed not simply to individual frustration but to structural weaknesses: the absence of leadership succession planning, insufficient mechanisms for knowledge transfer, and limited opportunities to embed professional expertise at the organisational level. Thus, the sustainability of development with physical computing was shown to rest not solely on the commitment of individual teachers but critically on the development of adaptive organisational cultures in which new members can inherit, critique, and further develop the work of those who came before.

These findings align with Berry (2018) and Leat et al. (2015), who contend that the endurance of educational innovation depends upon distributed leadership, collaborative professional learning, and the embedding of regular routines for reflection and mentoring within school structures. Taken together, the evidence suggests that sustainability in embedding physical computing and computing curriculum development more broadly requires moving beyond a model of static persistence. Instead, sustainability should be understood as a process of continual adaptation, shared learning, and renewal across departmental and institutional levels; here, agency is distributed and organisational memory actively maintained.

5.8 Summary

This chapter has unpacked how physical computing pedagogy unfolds through a complex, affective, and institutional entanglement of care enacted as simultaneous *leaping-in* responsiveness and *leaping-ahead* anticipation. This duality challenges conventional linear trajectories of teacher development and curriculum implementation, offering instead a temporal dialectic that situates teacher agency as an ongoing negotiation of care, risk, and development within layered institutional ecologies. The findings invite critical inquiry into how these dynamics might inform transformative models of computing education that transcend compliance-driven frameworks.

Moreover, the findings reveal that emotional experiences, including frustration, anxiety, and optimism, as affective responses shared by the teachers in this study, are integral to sustaining teacher professional development and agency. Structured reflection supports pedagogical refinement and authenticity while mentoring and professional community underpin teacher identity and resilience. Institutional factors, such as multi-academy trust policies, leadership decisions, and resource allocation, significantly shape teacher agency and influence the feasibility of curriculum development when embedding physical computing into the curriculum.

Finally, beyond consolidating existing knowledge, this research opens critical avenues for inquiry into how distributed leadership structures can better support the temporal rhythms of ‘leaping’ practice, how affective responses coming from the emotional work in the adoption of physical computing might be quantitatively and qualitatively measured, and how professional identity formation can be intentionally nurtured through reflective and mentoring practices in diverse educational contexts.

Chapter 6 Conclusions

6.1 Introduction

This thesis reinterprets how physical computing is integrated into schools by placing teacher care at the centre of curriculum work. Drawing on Heidegger's philosophy alongside teachers' lived experiences, it shifts attention away from technocratic, outcome-driven accounts and toward the everyday practices through which teachers sustain their classrooms. By centring care, the thesis shows how sustainable curriculum development in computing depends as much on relational labour and professional judgement as on tools or training, reframing what effective implementation requires.

The chapter concludes the thesis by synthesising its contributions through the Unified Model of Care-Driven Physical Computing Pedagogy (Figure 27). It also reflects on the study's limitations and considers its practical, policy, and research implications within the broader context of educational debates.

6.2 Research Question

Moving from crafted stories to contributions requires an interpretive leap. As shown in Chapter 4, teachers' accounts were interpreted into four higher-order themes: *leaping-in*, *leaping-ahead*, mentoring, and identity, which together provide the answer to the research question. This marks the interpretive leap from lived accounts to theoretical contribution.

The overarching research question (RQ) for this study was:
What is the meaning of teachers' lived experiences with physical computing in English secondary schools?

Two sub-questions framed the investigation:

1. How do teachers describe their experiences with physical computing?
2. What themes can be uncovered through the study of teachers’ lived experiences?

Answer to the RQ: The analysis reveals that teachers experience physical computing as a care-driven, relational, and identity-shaping practice grounded in *Mitsein* (*Being-with*). *Leaping-in* troubleshooting, *leaping-ahead* anticipation, mentoring, and the negotiation of professional identity together constitute the meaning of *Being-with* physical computing in English secondary classrooms.

To address the first sub-question, Sections 6.3.1 through 6.3.4 revisit the crafted stories and apply Heidegger's modes of *leaping-in* and *leaping-ahead* directly to teachers' accounts of troubleshooting, anticipatory planning, mentoring, and identity work. These narratives highlight the temporal and relational dynamics of teachers' agency.

To address the second, the analysis synthesises the study's four interpretive themes: *leaping-in*, *leaping-ahead*, mentoring, and professional identity, and shows how they interlock within the unified model of care-driven physical computing pedagogy presented in Figure 27.

6.3 Synthesis of Findings

6.3.1 Leaping-In: Care at the Heart of Pedagogy

Teachers' lived experiences of teaching with physical computing revealed moments of *leaping-in* as a network of everyday acts of care. These ranged from teachers replacing malfunctioning devices to Heads of Department sharing resources and assessments, IT staff safeguarding data through network restrictions, and senior leaders conducting learning walks.

Although varied in form, each of these actions embodied *Sorge*, Heidegger's notion of care, by affirming the value of colleagues and students in moments of disruption or uncertainty. While some measures, such as work scrutiny or learning walks by senior leaders, induced anxiety, teachers conveyed that the work mattered. This dual effect illustrates the ambivalence of accountability: it constrains professional freedom while also increasing the visibility and significance of physical computing in school.

6.3.2 Leaping-Ahead: Anticipatory Practice

Alongside their immediate responses, teachers also described *leaping-ahead* planning: sequencing projects across lessons, preparing hardware kits in advance, scaffolding activities so that challenges increase gradually, and structuring collaboration to keep projects moving when equipment failed.

In one example described in Chapter 4, a robotics project was designed to start with motor control, introduce sensors later, and then integrate the two. The staging was deliberate; it created small wins early on and helped students approach the later complexity without being overwhelmed. Another teacher mentioned keeping spare kits at the back of the room, ready to be swapped in when devices failed, so that groups could continue working without losing momentum.

These kinds of anticipatory practices sustained lesson pace and gave students the confidence to attempt more ambitious tasks.

6.3.3 Mentoring: Relational Scaffold and Shared Discourse

Mentoring in this study emerged as a relational scaffold that connected the immediacy of *leaping-in* with the foresight of *leaping-ahead*, supporting novice teachers as they adopted physical computing in their practice. Through their pairings with experienced colleagues, novices absorbed practical heuristics, diagnostic routines, and lesson-planning approaches such as the co-planning session described in Chapter 4. Teachers also entered into a shared discourse that named and exchanged debugging strategies and design choices. Pete talked about setting up a 'kit-bag' system for micro:bits. Having parts neatly organised, he explained, meant that practical tasks felt less overwhelming and gave trainees the confidence to take charge of troubleshooting. In another case, a teacher recalled sitting down with a trainee to co-plan a lesson, walking through how to sequence activities and identify student misconceptions. The novice later explained that this reassurance, 'knowing someone had thought through the sticking points with them,' gave them the confidence to adapt the lesson in real-time when things went wrong.

These exchanges built a shared interpretive toolkit, enabling novices to integrate physical computing into their practice with increasing autonomy and resilience.

6.3.4 Professional Identity: Anchors and Situated Work

In this study, professional identity in computing education was not fixed but continually re-formed as teachers supported students while working under inspection regimes, multi-academy trust policies, and changing curriculum requirements. As shown in the crafted stories, teachers made sense of these pressures through the same care-driven practices that underpinned their classroom work.

Teachers negotiated overlapping roles as subject experts, inquiry facilitators, and resilience builders. Over time, these negotiations centred on what Mockler (2011) refers to as identity anchors: commitments that provided teachers with stability, such as framing computational thinking as a literacy, expanding access to physical computing, and maintaining their pedagogy's roots in care. These anchors show how teachers drew on personal histories and values to stabilise their agency as institutional contexts shifted.

Taken together with *leaping-in*, *leaping-ahead*, and mentoring, these anchors form the basis of the Unified Model of Care-Driven Physical Computing Pedagogy (Figure 27).

6.4 Contributions to Knowledge

This study makes three contributions to knowledge. First, it reframes physical computing pedagogy as relational and embodied by placing care at its centre. Second, it demonstrates the methodological value of crafted stories, which provided the interpretive foundation for the Unified Model of Care-Driven Physical Computing Pedagogy (Figure 27). Third, it offers new insights into how professional identity and affect shape curriculum development.

By integrating the four themes—*leaping-in*, *leaping-ahead*, mentoring, and professional identity—the Unified Model demonstrates how curriculum, pedagogy, and teacher identity intersect. It highlights that embedding and sustaining physical computing depends not only on equipment or directives but also on organisational cultures that value relational labour and protect teachers' capacity for professional judgement.

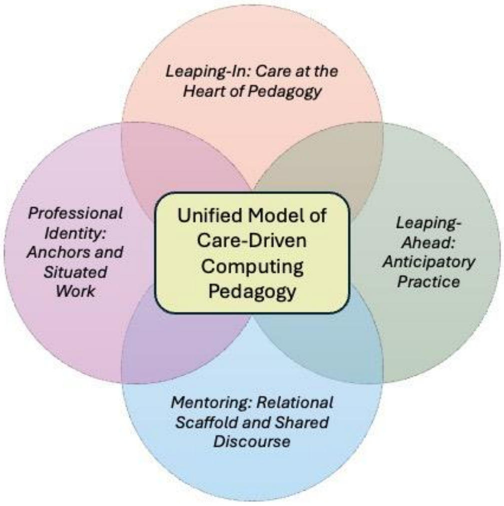

Figure 27: Unified Model of Care-Driven Physical Computing Pedagogy

The model illustrates how four interlocking dimensions —*leaping-in* troubleshooting, *leaping-ahead* anticipatory planning, mentoring as a relational scaffold, and a professional identity anchored in values —sustain teachers' work with physical computing. Together, these dimensions highlight that successful curriculum implementation depends not only on technical competence but also on relational care, professional values, and institutional support.

6.4.1 Leaping-In: Acts of Care in Troubleshooting and Classroom Support

This study contributes an ontological reframing of troubleshooting by showing that routine fixes are expressions of care. As the first theme in the Unified Model, *leaping-in* demonstrates that replacing a cable, debugging code, or steadying a class are not peripheral tasks but lived expressions of teacher solicitude. Situating Heidegger's Sorge (care) at the centre of classroom practice redirects attention from outcomes alone to the relational and existential dimensions of pedagogy.

6.4.2 Leaping-Ahead: Anticipatory Practice and Curriculum Planning

This study contributes a temporal account of planning by showing that foresight embeds care into curriculum design. As the second theme in the Unified Model, Leaping-Ahead highlights how sequencing projects, preparing spare kits, and structuring collaboration extend care into the future of lessons. Such strategies minimised disruption, sustained lesson pace, and gave students the confidence to attempt more ambitious tasks. Framed through Heidegger's notion of care, anticipatory work emerges not as mere efficiency but as relational responsibility, extending the temporal reach of care beyond immediate troubleshooting.

6.4.3 Mentoring: Relational Scaffolds and Shared Discourse

This study contributes a relational account of professional learning by showing that mentoring functions as a scaffold for care-driven pedagogy. As the third theme in the Unified Model, mentoring equipped novices with heuristics and routines, such as Pete's 'kit-bag' system or co-planning sessions, that made classroom troubleshooting more manageable and fostered professional confidence.

Mentoring was also shaped by context, and in some multi-academy trusts, prescribed schemes of work limited experimentation, while collaborative networks and CAS groups created space for shared resources and reassurance. Mentoring, therefore, reflected both personal relationships and institutional conditions, enabling novices to embed physical computing while revealing the constraints teachers had to negotiate.

6.4.4 Professional Identity: Negotiation, Anchors, and Agency

This study contributes to teacher-identity research by showing that professional identity is situated work, continually reshaped yet stabilised by enduring anchors. As the fourth theme in the Unified Model, professional identity highlights how commitments such as equity, computational thinking as literacy, and care enabled teachers to sustain their agency under shifting curricula and inspection regimes. Moments of frustration, optimism, or anxiety became turning points, prompting recalibration or defence of practice. In this sense, professional identity itself was part of care-driven pedagogy, rooted in values that helped teachers navigate change while sustaining their agency.

6.4.5 Methodological Contribution: Crafted Stories as Hermeneutic Practice

Alongside these substantive contributions, the study also makes a methodological contribution: the use of crafted stories as a hermeneutic practice that made visible the relational and affective dimensions of teaching with physical computing. As the methodological foundation of the Unified Model, they enabled the themes of *leaping-in*, *leaping-ahead*, mentoring, and professional identity to be demonstrated as lived, interpreted, and sustained through care.

Developed through dialogue with participants and refined through member checking, the crafted stories kept teachers' voices close to the surface while allowing interpretive depth. From a hermeneutic perspective, they enacted Gadamer's fusion of horizons, keeping the researcher's and participants' understandings in dialogue, while also embodying Heidegger's sense of care (Sorge) in the attentiveness given to lived detail.

This methodological contribution underpins the substantive insights discussed earlier. Without crafted stories, the ontological framing of care, the articulation of identity anchors, and the analysis of institutional conditions would have been far harder to convey. Crafted stories, therefore, stand both as a contribution in their own right and as the narrative vehicle through which the other four themes were expressed.

6.5 Implications for Practice

The findings of this thesis have implications beyond the immediate study. If physical computing is to be embedded and sustained in schools, it cannot rest on tools and training alone. It requires organisational cultures that:

- **Value relational labour** – recognise the everyday acts of care, troubleshooting, and mentoring that hold classrooms together.
- **Protect professional judgement** – give teachers the trust and autonomy to adapt pedagogy rather than reducing practice to compliance.
- **Support identity and affect** – acknowledge that teachers' sense of purpose, equity commitments, and emotional labour shape how curriculum reform is experienced and enacted.

The following subsections explore how these insights translate into implications for practice, policy, and research, with a focus on mentor preparation, professional development, identity-centred pedagogy, and leadership support.

6.5.1 Mentor Preparation and Induction

Effective mentors combine technical expertise with relational sensitivity. Recruitment and induction should therefore value not only computing knowledge but also the capacity to listen, encourage, and support novice teachers. Training should include both *leaping-in* simulations (brief, live troubleshooting tasks) and *leaping-*

ahead activities (planning resource kits or mapping sequences of lessons), ensuring mentors can help early-career teachers navigate the technical challenges and emotional demands of physical computing.

6.5.2 Professional Development

Professional development should blend technical skill-building with reflection. Workshops that combine subject knowledge with the sharing and analysis of 'crafted stories' can help teachers draw on one another's lived experiences, building resilience and strengthening both identity and pedagogy.

6.5.3 Identity-Centred Pedagogy

Initial teacher training and early-career programmes should make identity work explicit. Tools such as the Computer Science Teacher Identity Survey (Ni *et al.*, 2021) and structured group discussions enable teachers to consider how their identity anchors (Mockler, 2011) align with or resist institutional expectations. Embedding these reflective practices in continuing professional development helps preserve autonomy and sustain commitment to physical computing.

6.5.4 Leadership and Structural Support

The sustainability of care-driven pedagogy depends on organisational recognition. Leaders should allocate time for experimentation and ensure that computing teachers are represented in decision-making forums. Treating care-driven pedagogy as central rather than optional will create conditions in which physical computing can thrive.

Taken together, these implications carry forward the three contributions of this thesis. Reframing pedagogy as care-driven and embodied underlines the need to value relational labour in mentoring, CPD, and leadership. The crafted stories demonstrate that professional development is most effective when it draws on teachers' lived experiences, rather than just their technical skills. Ultimately, the analysis of identity and emotion reveals the importance of protecting professional judgment for leaders and policymakers if reforms are to endure.

In short, embedding physical computing requires more than equipment and training: it depends on the cultural, relational, and institutional conditions that make pedagogy possible.

6.6 Implications for Further Research

The dual dynamics of *leaping-in* and *leaping-ahead* suggest several promising directions for further inquiry: expanding to new contexts, tracking practices longitudinally, refining methods, and testing interventions.

6.6.1 New Contexts and Voices

Future studies should explore how *leaping-in* and *leaping-ahead* manifest across a broader range of educational settings. Primary classrooms, for example, may reveal different rhythms of care. Cross-cultural comparisons and student perspectives would also enrich understanding, highlighting whether teacher-intended care is recognised and experienced by learners.

6.6.2 Longitudinal and Comparative Studies

Tracking care-driven strategies over time and across institutions can uncover their sustainability and transferability. This study was limited to interviews conducted in a single academic year cycle, and future research could use more extended time frames to track how teachers sustain care-driven strategies throughout their careers. Longer-term or comparative studies could reveal how identity anchors shift as technologies, curricula, and governance models evolve.

6.6.3 Methodological Development

Further methodological development could strengthen the understanding of the embodied and affective aspects of teachers' work. Phenomenological approaches can be combined with survey data, attainment measures, or digital ethnography, for example, to capture the interplay between emotion, identity, and institutional context, thereby extending the analysis beyond the individual school setting.

6.6.4 Evaluating Mentoring and Anticipatory Interventions

Finally, there is scope to design and evaluate practical interventions based on the insights from this study. Co-developing mentoring frameworks, debugging grammars, or planning resources with teachers would allow their effectiveness to be tested in practice. Such work could provide evidence of how care-driven approaches support novice teachers, build resilience, and strengthen student learning in physical computing, closing the loop between phenomenological insight and practical application.

6.7 Limitations

The insights of this study are shaped by the methodological, interpretive, and contextual boundaries within which it was conducted.

6.7.1 Methodological Reflection

Hermeneutic phenomenology privileges depth of meaning over generalisation. While reflexive journaling and member-checking were used to mitigate bias, interpretation remains influenced by my professional background and philosophical stance. The findings should therefore be read as situated rather than universal.

6.7.2 Interpretive Subjectivity

Crafted stories combine participants' experiences and the researcher's interpretation. Teachers reviewed and confirmed the resonance of these narratives, but interpretation is never neutral. The stories should therefore be read as co-constructions that highlight key aspects of practice rather than definitive representations.

6.7.3 Sample Size and Scope

A purposive sample of five department heads in northern England yielded rich, yet context-specific, insights. This limits broader transferability; early-career teachers, non-specialists, or schools in different contexts may experience physical computing differently.

6.7.4 Temporal Constraints

Data were collected over a single academic year. Semi-structured interviews conducted between October 2021 and March 2022 reveal snapshots of practice but not long-term trajectories across curriculum reform cycles or leadership changes.

6.7.5 Resource and Expertise Demands

Hermeneutic phenomenology demands significant time, expertise, and institutional support. This study involved extended interviews, verbatim transcription, and iterative engagement within the hermeneutic circle processes, which produced detailed, context-rich accounts but inevitably limited breadth. It demanded sustained reflexive awareness and advanced interpretive skill, which can challenge researchers less experienced in phenomenology or working without strong institutional support.

Consequently, these limitations emphasise how the study offers interpretive depth into lived experience rather than generalisable claims. Complementary designs will be needed to test how far these themes extend and to further develop hermeneutic-phenomenological inquiry in computing education.

6.8 Final Reflections

Teachers' engagement with physical computing was shaped less by technical delivery or curriculum compliance than by attentiveness to students, forward-looking planning, and the ongoing negotiation of professional identity. As Jenny explained, ‘if the micro:bit failed, students would lose confidence in the concept and in me,’ a remark that highlights how the work of teaching in this domain is never only technical but bound up with trust, responsibility, and emotional labour. In this light, pedagogy was experienced not as straightforward delivery or policy compliance but as a relational, embodied activity, marked by responsiveness and foresight.

Teachers' practice combined immediacy and anticipation, involving troubleshooting in the moment while also planning to sustain projects and foster student confidence. These twin dynamics helped teachers navigate technical and institutional challenges, while supporting resilience and professional purpose.

Equally significant was the role of long-held values. These identity anchors (Mockler, 2011) gave teachers a compass when policy shifted or inspection pressures intensified, grounding their sense of purpose in equity, literacy, and care. In the Unified Model (Figure 27), these anchors sit alongside '*leaping-in*,' '*leaping-ahead*,' and mentoring, showing how professional identity is continually re-established through care-driven practice. Together, these dimensions frame physical computing pedagogy as a lived practice shaped as much by emotion and values as by technical or curricular demands.

Viewed as a whole, the study positions physical computing pedagogy as an interpretive practice that blends technical skill with care, anticipation, and identity, implying that sustainable reform requires organisational cultures which recognise relational labour and protect space for professional judgement, rather than reducing pedagogy to compliance.

For teachers, the study reveals that the ordinary acts of care that hold classrooms together, such as fixing a cable in the moment or planning a project across several lessons, make physical computing a practical possibility. For leaders and policymakers, the challenge is to create space for this work by giving teachers both the trust and the time to adapt their teaching without being overwhelmed by accountability demands. For researchers, the findings demonstrate how hermeneutic approaches illuminate the emotional and relational dimensions of pedagogy that are often overlooked in computing education.

This study shows that physical computing is a mode of teaching that rests on care, identity, and professional judgement. Without cultural and institutional recognition of this relational labour, however, physical computing risks remaining peripheral and unsustainable.

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Appendices

Appendix 1: List of Interviews with Dates

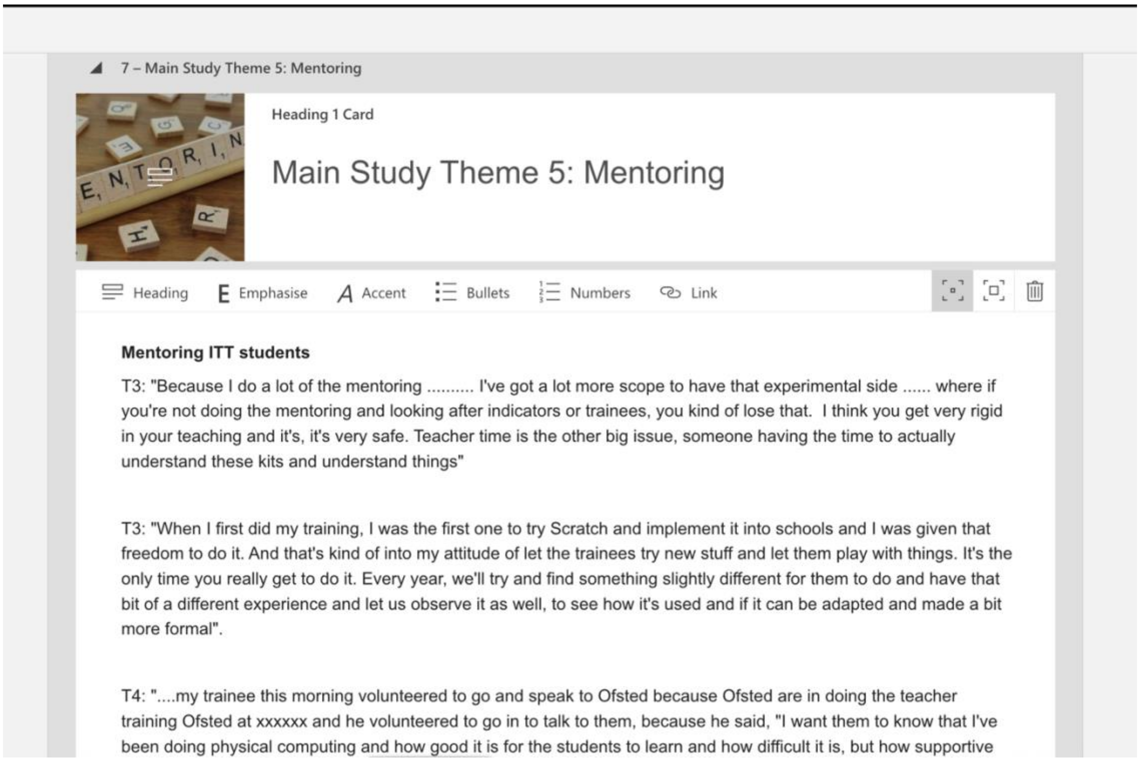
This table summarises the twelve semi-structured interviews conducted with five secondary computing teachers over the data-collection period. It evidences the longitudinal, iterative design outlined in Chapter 3: Research Approach and Design, specifically Section 3.5 (Data Gathering).

Table A-1: List of Interviews with Dates

Teacher pseudonym	Interview	Date
Marcia	1	04.02.21
Marcia	2	11.02.21
Marcia	3	18.02.21
Tom	1	12.10.21
Tom	2	19.10.21
Tom	3	02.11.21
Pete	1	03.11.21
Pete	2	17.11.21
Pete	3	01.12.21
Jenny	1	15.12.21
Jenny	2	05.01.22
Jenny	3	02.02.22
Laura	1	03.02.22
Laura	2	17.02.22
Laura	3	22.03.22

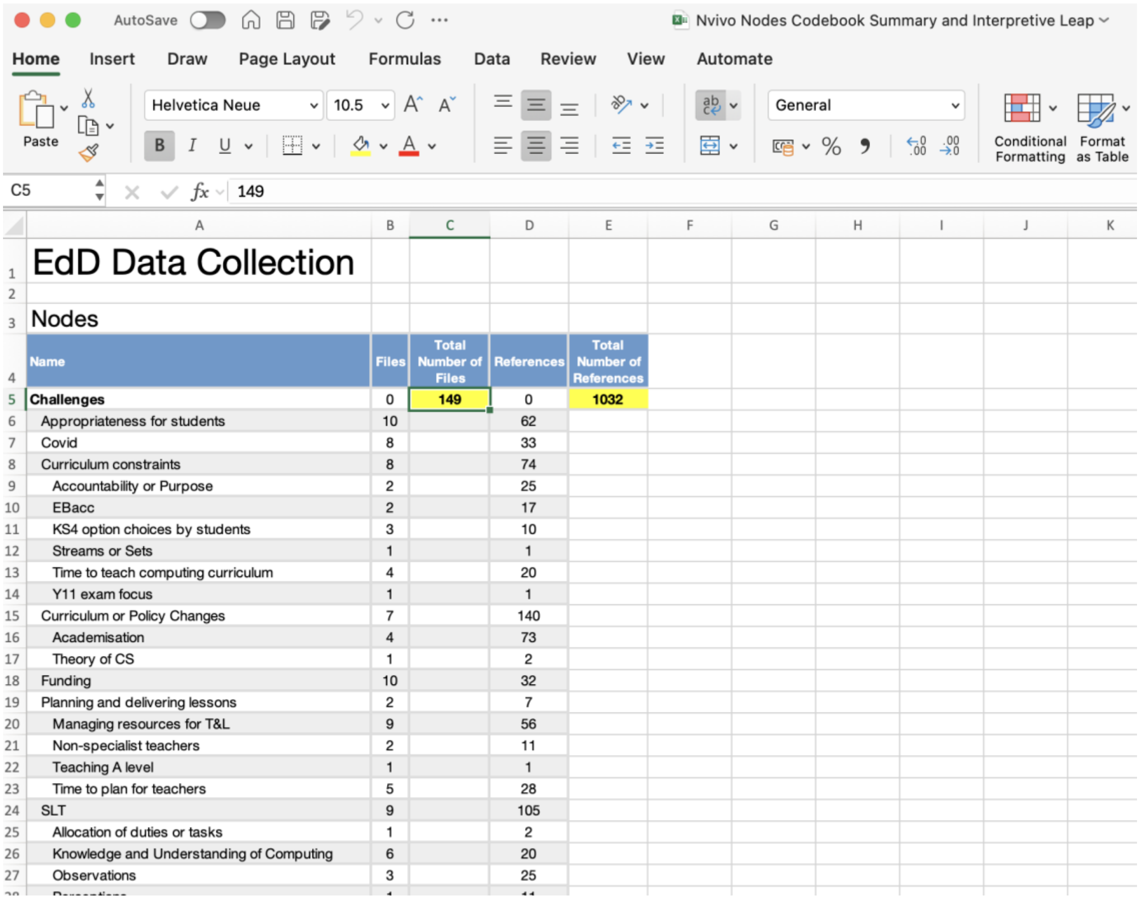
Appendix 2: Sway Environment for Iterative Crafted Storying

This screenshot illustrates the digital Microsoft Sway environment used to support the iterative co-construction and refinement of crafted stories between the researcher and participants. It demonstrates the interactive process of validation and meaning-making described in Chapter 3: Research Approach and Design, specifically Section 3.6.8.1 (Movement 1: Crafting, Describing and Initial Interpretation), where participants engaged with and responded to evolving story drafts within the hermeneutic cycle.



Appendix 3: Master Codebook Example: Challenges with Physical Computing in the Classroom

This extract from the master codebook demonstrates how teachers' accounts of practical and pedagogical difficulties in using physical computing were coded and refined. It provides an example of the analytic process described in Chapter 3: Research Approach and Design, Section 3.6.5 (Software-Supported Coding and Thesis Codebook), where NVivo was used as an organisational scaffold to trace and develop emerging patterns.



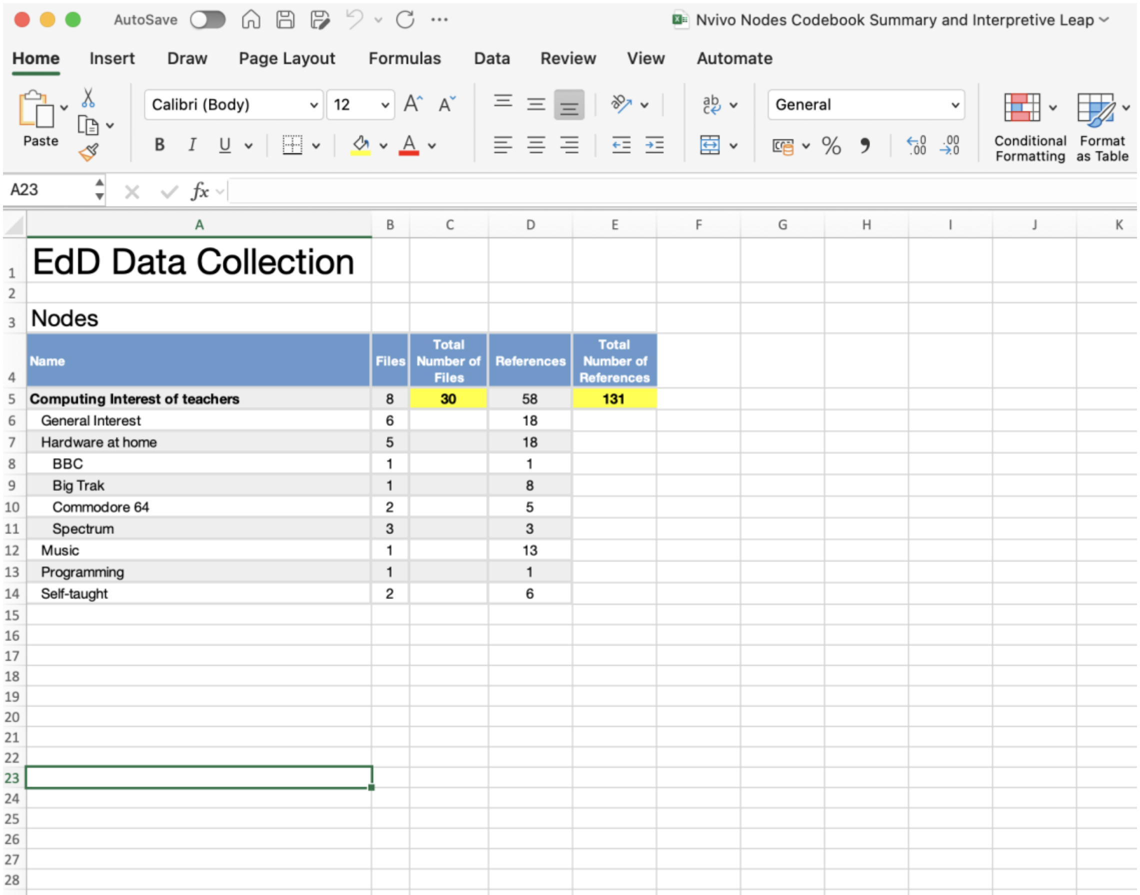
EdD Data Collection

Nodes

Name	Files	Total Number of Files	References	Total Number of References
Challenges	0	149	0	1032
Appropriateness for students	10		62	
Covid	8		33	
Curriculum constraints	8		74	
Accountability or Purpose	2		25	
EBacc	2		17	
KS4 option choices by students	3		10	
Streams or Sets	1		1	
Time to teach computing curriculum	4		20	
Y11 exam focus	1		1	
Curriculum or Policy Changes	7		140	
Academisation	4		73	
Theory of CS	1		2	
Funding	10		32	
Planning and delivering lessons	2		7	
Managing resources for T&L	9		56	
Non-specialist teachers	2		11	
Teaching A level	1		1	
Time to plan for teachers	5		28	
SLT	9		105	
Allocation of duties or tasks	1		2	
Knowledge and Understanding of Computing	6		20	
Observations	3		25	

Appendix 4: Master Codebook Example: Teachers' Early Interests in Computing

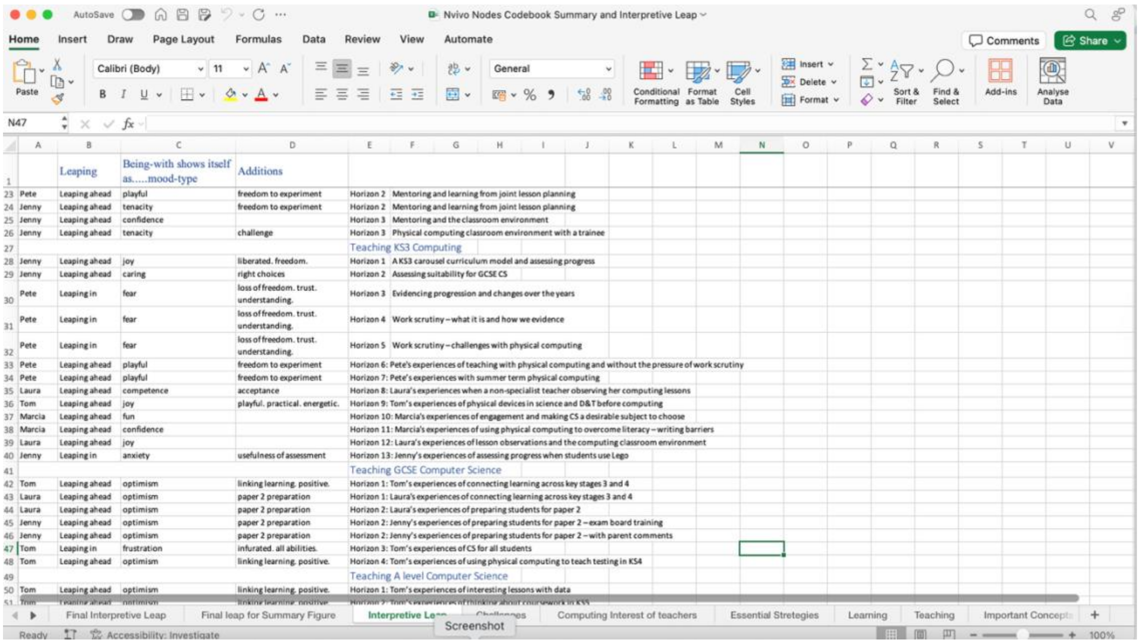
This extract from the master codebook demonstrates the analytical process used to capture and categorise teachers' early interests in computing. It shows how the coding process was supported by NVivo, as outlined in Chapter 3: Research Approach and Design, Section 3.6.5 (Software-Supported Coding and Thesis Codebook).



Name	Files	Total Number of Files	References	Total Number of References
Computing Interest of teachers	8	30	58	131
General Interest	6		18	
Hardware at home	5		18	
BBC	1		1	
Big Trak	1		8	
Commodore 64	2		5	
Spectrum	3		3	
Music	1		13	
Programming	1		1	
Self-taught	2		6	

Appendix 5: Interpretive Leap Matrix and Screenshot of Full Codebook

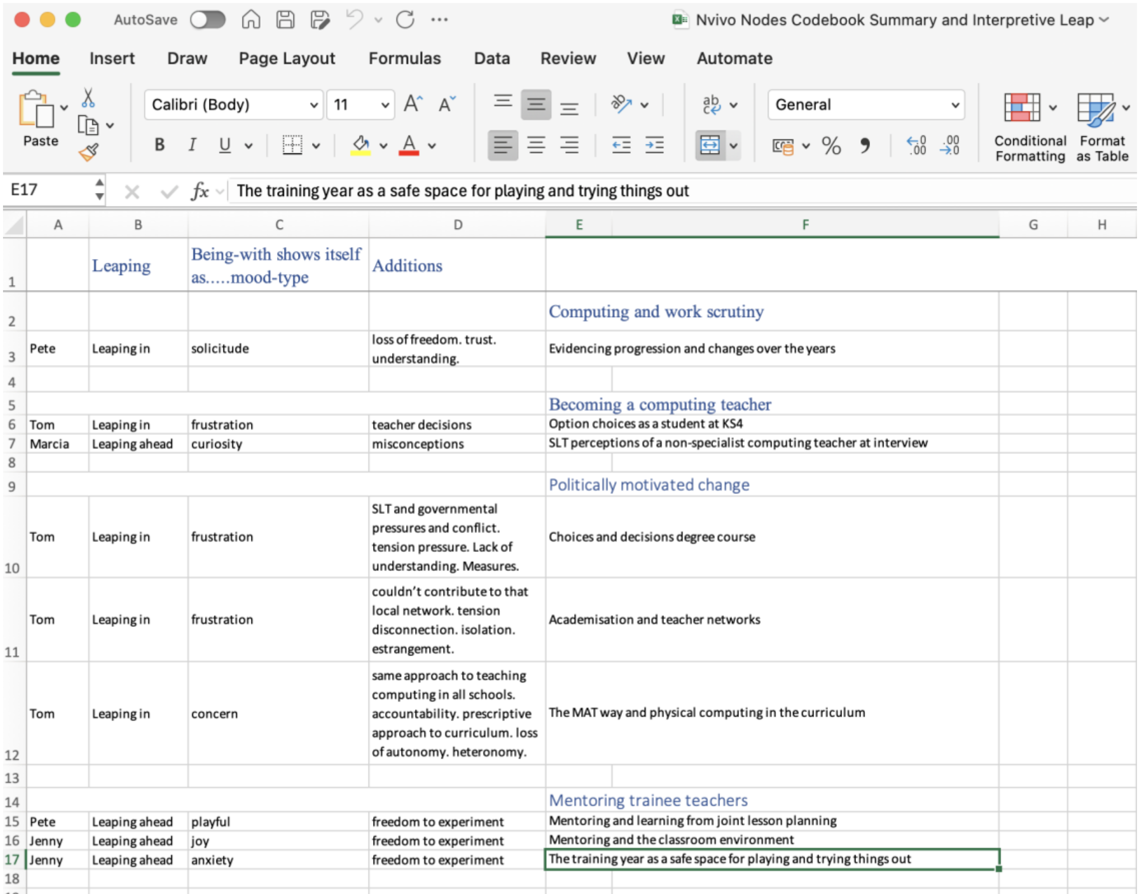
This appendix demonstrates the interpretive leap matrix, along with a screenshot of the full codebook used in the analysis. It captures how themes began to develop through the movement between coded data and interpretive insight, as discussed in Chapter 3: Research Approach and Design, Section 3.6.8.3 (Taking an Interpretive Leap). Together, these materials demonstrate the transparency of the analytic process and the iterative reasoning that connected the data to the study's final interpretive themes.



	A	B	C	D	E	F
1		Leaping	Being-with shows itself as.....mood-type	Additions		
23	Pete	Leaping ahead	playful	freedom to experiment	Horizon 2	Mentoring and learning from joint lesson planning
24	Jenny	Leaping ahead	tenacity	freedom to experiment	Horizon 2	Mentoring and learning from joint lesson planning
25	Jenny	Leaping ahead	confidence		Horizon 3	Mentoring and the classroom environment
26	Jenny	Leaping ahead	tenacity	challenge	Horizon 3	Physical computing classroom environment with a trainee
27					Teaching KS3 Computing	
28	Jenny	Leaping ahead	joy	liberated. freedom.	Horizon 1	A KS3 carousel curriculum model and assessing progress
29	Jenny	Leaping ahead	caring	right choices	Horizon 2	Assessing suitability for GCSE CS
30	Pete	Leaping in	fear	loss of freedom. trust. understanding.	Horizon 3	Evidencing progression and changes over the years
31	Pete	Leaping in	fear	loss of freedom. trust. understanding.	Horizon 4	Work scrutiny – what it is and how we evidence
32	Pete	Leaping in	fear	loss of freedom. trust. understanding.	Horizon 5	Work scrutiny – challenges with physical computing
33	Pete	Leaping ahead	playful	freedom to experiment	Horizon 6: Pete's experiences of teaching with physical computing and without the pressure of work scrutiny	
34	Pete	Leaping ahead	playful	freedom to experiment	Horizon 7: Pete's experiences with summer term physical computing	
35	Laura	Leaping ahead	competence	acceptance	Horizon 8: Laura's experiences when a non-specialist teacher observing her computing lessons	
36	Tom	Leaping ahead	joy	playful. practical. energetic.	Horizon 9: Tom's experiences of physical devices in science and D&T before computing	
37	Marcia	Leaping ahead	fun		Horizon 10: Marcia's experiences of engagement and making CS a desirable subject to choose	
38	Marcia	Leaping ahead	confidence		Horizon 11: Marcia's experiences of using physical computing to overcome literacy – writing barriers	
39	Laura	Leaping ahead	joy		Horizon 12: Laura's experiences of lesson observations and the computing classroom environment	
40	Jenny	Leaping in	anxiety	usefulness of assessment	Horizon 13: Jenny's experiences of assessing progress when students use Lego	
41					Teaching GCSE Computer Science	
42	Tom	Leaping ahead	optimism	linking learning. positive.	Horizon 1: Tom's experiences of connecting learning across key stages 3 and 4	
43	Laura	Leaping ahead	optimism	paper 2 preparation	Horizon 1: Laura's experiences of connecting learning across key stages 3 and 4	
44	Laura	Leaping ahead	optimism	paper 2 preparation	Horizon 2: Laura's experiences of preparing students for paper 2	
45	Jenny	Leaping ahead	optimism	paper 2 preparation	Horizon 2: Jenny's experiences of preparing students for paper 2 – exam board training	
46	Jenny	Leaping ahead	optimism	paper 2 preparation	Horizon 2: Jenny's experiences of preparing students for paper 2 – with parent comments	
47	Tom	Leaping in	frustration	infurated. all abilities.	Horizon 3: Tom's experiences of CS for all students	
48	Tom	Leaping ahead	optimism	linking learning. positive.	Horizon 4: Tom's experiences of using physical computing to teach testing in KS4	
49					Teaching A level Computer Science	
50	Tom	Leaping ahead	optimism	linking learning. positive.	Horizon 1: Tom's experiences of interesting lessons with data	

Appendix 6: Interpretive Leap Matrix Example and Showing Final Themes

This appendix demonstrates a focused example from the interpretive leap matrix, showing how a cluster of related codes was developed into one of the study's final themes. It offers a snapshot of the interpretive process described in Chapter 3: Research Approach and Design, Section 3.6.8.3 (Taking an Interpretive Leap), illustrating how meanings were drawn together through repeated engagement with the data. The example illustrates the transition from individual meaning units to broader thematic insights that underpin the findings presented in Chapter 4.



	A	B	C	D	E
1		Leaping	Being-with shows itself as.....mood-type	Additions	
2					Computing and work scrutiny
3	Pete	Leaping in	solicitude	loss of freedom. trust. understanding.	Evidencing progression and changes over the years
4					
5					Becoming a computing teacher
6	Tom	Leaping in	frustration	teacher decisions	Option choices as a student at KS4
7	Marcia	Leaping ahead	curiosity	misconceptions	SLT perceptions of a non-specialist computing teacher at interview
8					
9					Politically motivated change
10	Tom	Leaping in	frustration	SLT and governmental pressures and conflict. tension pressure. Lack of understanding. Measures.	Choices and decisions degree course
11	Tom	Leaping in	frustration	couldn't contribute to that local network. tension disconnection. isolation. estrangement.	Academisation and teacher networks
12	Tom	Leaping in	concern	same approach to teaching computing in all schools. accountability. prescriptive approach to curriculum. loss of autonomy. heteronomy.	The MAT way and physical computing in the curriculum
13					
14					Mentoring trainee teachers
15	Pete	Leaping ahead	playful	freedom to experiment	Mentoring and learning from joint lesson planning
16	Jenny	Leaping ahead	joy	freedom to experiment	Mentoring and the classroom environment
17	Jenny	Leaping ahead	anxiety	freedom to experiment	The training year as a safe space for playing and trying things out
18					

Appendix 7: Ethical Review Approval

This appendix presents the email correspondence confirming the conditional favourable ethical opinion granted by the University of Leeds AREA FREC (Reference AREA 20-027).

From: John Hardy <> on behalf of ResearchEthics <researchethics@leeds.ac.uk>
Sent: Thursday, October 22, 2020 4:58 PM
To: Claire Garside <edcga@leeds.ac.uk>; ResearchEthics <researchethics@leeds.ac.uk>
Subject: AREA 20-027 - Conditional Favourable Ethical Opinion

Hi Claire,

AREA 20-027 - 'New horizons in maker education: A phenomenological study of teachers' lived experiences in secondary schools.

NB: All approvals/comments are subject to compliance with current University of Leeds and UK Government advice regarding the Covid-19 pandemic, as well as any local restrictions where the study is being carried out regarding in-person data collection and travel.

I am pleased to inform you that the above research ethics application has been reviewed by the AREA FREC Committee and on behalf of the Chair, I can confirm a conditional favourable ethical opinion based on the documentation received at date of this email and subject to the following condition/s which must be fulfilled prior to the study commencing:

1. **Please clarify the wording on the information sheets / consent forms regarding 'confidentiality'. In both documents there are assurances that teachers' responses will be kept confidential, but if these are used the responses themselves won't be 'confidential'. Instead, you can say that the teachers' identities will be anonymised. The wording needs to be reviewed to make this clear.**

The study documentation must be amended where required to meet the above conditions and submitted for file and possible future audit.

Once you have addressed the conditions and submitted for file/future audit, you may commence the study and further confirmation of approval is not provided.

Please note, failure to comply with the above conditions will be considered a breach of ethics approval and may result in disciplinary action.

Please retain this email as evidence of conditional approval in your study file.

Please notify the committee if you intend to make any amendments to the original research as submitted and approved to date. This includes recruitment methodology; all changes must receive ethical approval prior to implementation. Please see https://leeds365.sharepoint.com/sites/ResearchandInnovationService/SitePages/Amendments.aspx or contact the Research Ethics and Governance Administrator for further information.

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

I hope the study goes well.

Best regards
John Hardy
On behalf of Matthew Campbell, (Chair) AREA FREC

John Hardy
Research Ethics Administrator
The Secretariat,
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