The formation of Science, Technology, Engineering and Mathematics Teacher Identities: Pre-service teacher's perceptions

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Declaration

This thesis results entirely from my own work and has not been offered previously for any other degree or diploma

Signature

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Page

Contents

Page

Chapter Two (continued)

Chapter Three

Abbreviations and Glossary of Terminology

Abduction	Reasoning that begins by examining data and following scrutiny, having examined all possible explanations forms hypotheses that can then be utilised to realise the most plausible interpretation
Abductive reasoning	A process, central to constructivist grounded theory, of finding the best explanation of a set of observations
ATI	Approaches to Teaching Inventory
Axial coding	The second stage (or level) in the coding paradigm in which themes and categories of data are created by grouping open codes and labels into meaningful theoretical categories
Beginning teacher	A classroom teacher who has less than two years' teaching experience
BERA	British Educational Research Association
Blank slate	Also referred to as 'tablua rasa'
BOS	Bristol Online Survey
CGT	Classic Glasarian Theory
Coding	The process of defining data and attaching concepts to the qualitative data
Coding families	A strategy to support the process of relating categories to each other
Coding paradigm	Proposed initially as a mandatory analysis process by Strauss and Corbin (1990), this was the cause of the split between Glaser and Strauss. In Glaser's view this approach would force the data
Constructivist	A form of grounded theory which assumes that neither data nor grounded theory theories are discovered but are constructed by the researcher and participants in the context in which research takes place
CS	Computer Science

Concepts	Slices of data that have been coded
DES	Department of Educational and Skills
D&T	Design and Technology
DfE	Department of Education
DfEE	Department of Education and Employment
EBacc	English Baccalaureate
Experiential learning	The process of making meaning from direct experience. learning
Forcing	The term applied (Glaser 1992) when data is forced to align with theory
GCSE	General Certificate of Secondary Education
GTA	Graduate Teaching Assistant
GTM	Grounded Theory Method
Grounded theory	The systematic research methodology involving the discovery of theory through analysis of data
HE	Higher Education
HEI	Higher Educational Institution
Hidden	Unstated norms, values and beliefs that are transmitted to pupil's curriculum through the underlying educational structure
HSR	High Self-Regulation
Inductive	The process of reasoning from detailed facts to general theoretical reasoning principles
IT	Information Technology
ICT	Information Communication Technology
ITE	Initial Teacher Education
ITT	Initial Teacher Training

IOP	Institute of Physics
LSR	Low Self-Regulation
Memoing	Researcher's records of analysis which attempt to derive meaning from data
NAHT	National Association of Head Teachers
NQT	Newly Qualified Teacher
NVivo	A qualitative data analysis software package
OECD	Organisation for Economic Co-operation and Development
Ofsted	The Office for Standards in Education
Open coding	The first level coding in which concepts are identified and then properties and dimensions are discovered in or constructed from data
PCK	Pedagogical Content Knowledge
PGCE	Postgraduate Certificate in Education
QTS	Qualified Teacher Status
Reflective practice	The act of reflecting on one's own practice through a continuous cycle of self-observation and self-evaluation to help understand one's own actions and reactions to teaching situations
School culture	Traditions, beliefs, policies and norms within a school
SCITT	School Centred Initial Teacher Training
SD	School Direct
Self-efficacy	Belief in one's own capability as a teacher
SKE	Subject Knowledge Enhancement
STEM	Science, Technology, Engineering and Mathematics
Symbolic Interactionism	A view of social behaviour that emphasises the role of interactionism language and cultural cues and symbols as core elements of human interaction

Tacit knowledge	Knowledge people have gained from activities which cannot be easily or readily codified
TEF	Teaching Excellence Framework
Teacher ‘persona’	A teacher’s projected self
Teacher ‘voice’	A stage in teacher development in which the teacher has belief in their teaching abilities
Theoretical Sampling	The procedure where participants are selected in order to sampling inform the researcher’s developing understanding of the research field
Theoretical	Refers to the personal experiences the researcher might have in sensitivity relation to the research field in question, and relates to the researcher’s interpretation of data
TSM	Teacher Supply Model
UK	United Kingdom
USA	United States of America
VLE	Virtual Learning Environment

Page

Tables

Figures

Abstract

Set within the context of Science, Technology, Engineering and Mathematics (STEM), this study explores the personal teaching philosophies of students (pre-service teachers) training to become qualified teachers, with the purpose of better understanding how participant's perceptions of teaching are shaped by their previous experiences. It goes on to consider how these experience-related beliefs influence the formation of their individual identities as teachers. Outcomes emerging from the study show that the meaning pre-service teachers assign to their lived experiences play a significant role in their development. Nascent themes discussed include; subject knowledge, disciplinary differences and engendered approaches to STEM pedagogy.

Presented as theoretical insights, this study highlights three key findings which are discussed within the context of policy and practice. The first describes the impact 'weak' subject knowledge has on an individual's development, and findings show that where an individual believes their knowledge to be limited, development is restricted. The second presents a taxonomy of *'self-sabotaging'* behaviours which arise from an individual's inability to challenge their perceptions of *'what a teacher should be'.* Perceptions that have the potential to impact negatively on their identity formation. The third presents the concept of '*identity drift'* and describes the incidence where an individual's ideological values and beliefs and the reality of their classroom practice become unaligned. With the potential impact over time being that an individual is unable to reconcile their internalised identity from their external one, with teacher attrition being the likely consequence.

Exploring the interrelations between outcomes, findings indicate there would be tangible benefits in facilitating strategies designed to support pre-service teachers to become more aware of the meaning they have assigned to their experience related-beliefs to support the development of their professional identities as teachers of STEM.

Chapters

1.0 Chapter One

1.1 Introduction to the Chapter

The introductory chapter of this doctoral research study presents the research focus, the rationale which underpins it, and the context within which the phenomena being studied subsequently resides.

This study sought to explore the personal teaching philosophies of students (pre-service teachers) training to become qualified teachers of Science, Technology, Engineering and Mathematics (STEM). The purpose being to understand better how their experience-related beliefs, and perceptions, influence the formation of their identities as teachers. In seeking to achieve this, the study considered how their experiences shape their approaches to their own learning and subsequently the development of their individual pedagogical approaches to teaching. With the specific intention of exploring, for illumination and analysis, potential implications of pre-service teachers' approaches to the teaching and learning of STEM, within and across secondary school age phase subject disciplines in England and Wales.

Specifically, this considered STEM education and its associated pedagogies, focusing on the perspective of students as they trained to become teachers. Recognising that the formation of teacher identity is a complex and multifaceted subject, this work began by exploring how STEM related subject knowledge and content is learnt by pre-service teachers. Finally, using these findings, the study subsequently moved to consider how

pre-service teachers translated this subject knowledge into content driven pedagogy used to teach pupils.

Set within the context of secondary age phase education in England and Wales the curriculum (DfE, 2017) for the purposes of this study subjects classified as STEM are as follows: Computer Science, Design and Technology, Science (including Biology, Chemistry and Physics) and Mathematics.

In seeking to explore factors which influence the formation of pre-service teacher identity, as pre-service teachers transition from student to newly qualified teacher in order to contextualise the rationale behind the research the rest of this chapter outlines the importance of STEM as perceived from a global perspective. In addition, it presents key changes to education and educational policy reform, including changes to teacher education and competency-based training standards which have had a direct impact on STEM. It also investigates issues of teacher supply, and in doing so presents not only the context but also the rationale for undertaking the study itself.

1.2 Rationale

According to Lortie (1975) our values and beliefs about teaching, how a teacher should act and be, form at an early age (Hargreaves, 2010). Within the literature, appertaining to the development of teachers and lecturers the focus has been very much on approaches to teaching and the development of learning and teaching (Prosser & Trigwell, 1999; Trigwell *et al.* 1999; Lindblom-Ylänne *et al*. 2006; Van Driel & Berry, 2012), the impact of educational reform (Van Veen *et al*. 2005; Lee & Yin, 2011; Lee

et al. 2013), cognitive, social, and emotional processes (Beauchamp & Thomas 2009; Yuan & Lee, 2015), stress and emotion (Zembylas, 2003a, b; Van Veen & Sleegers 2006; Timoštšuk & Ugaste 2012), efficacy (Bandura, 1994; Tschannen-Moran *et al.* 1998) and also motivation (Nevgi *et al.* 2004).

While previous studies have been undertaken to explore the influence experiences have on identity construction (Bukor, 2015), and teacher commitment (Day *et al*. 2006), Yuan and Lee (2016) suggest that how pre-service teachers construct their identity is still a topic largely unexplored.

In preparation for this study a review of the literature revealed very few studies specific to the role personal learning histories play in determining how pre-service teachers approach their own learning (access new knowledge) in relation to the development of teacher identity and subject knowledge. Furthermore, there is no discernible work to explore the impact reflection on their experiences as pupils have had on their emergent practice (as pre-service teachers).

Finally, with respect to the relationship between pre-service teacher beliefs and their teaching behaviours, little or no attention has been paid to the role subject discipline plays in this symbiotic relationship and this area of research also remains largely unexplored.

Through this research, undertaken with pre-service teachers training within subjects which fall under the definition of STEM subject disciplines, it is anticipated that the

findings from this work will add to the growing body of literature on teacher identity. The purpose of which is to better understand how perceptions and experience-related beliefs influence the formation of pre-service identities of STEM teachers.

1.3 STEM: A brief background

To provide a background to the research it would be useful at this point to provide a brief outline of the origins and emergence of STEM.

Originating as a government initiative in the USA (Kimbell, 2011), in its simplest terms STEM is an acronym, which describes the study of Science, Technology, Engineering, and Mathematics, a term whose original derivation is accredited to Judith Ramaley (Christenson, 2011; Koonce *et al.* 2011).

There is a global perception by some that STEM is the key to a nation's long-term economic viability (Kelly, 2012; Bruce-Davis *et al.* 2014; Tight, 2012), hence the supply of highly qualified scientists, technologists, engineers, and mathematicians is perceived internationally as being vital in securing the future of a nation's increasing economic productivity, prosperity, security and social well-being (Roberts, 2002; Obama, 2013; Li, 2014; Marginson *et al*. 2013). Concurrent to this are reports of students' declining interest in the study of STEM related subjects (Perry & Irwin, 2015), with young people becoming increasingly disengaged with the study of Science, Technology, Engineering, and Mathematics (STEM) beyond compulsory schooling (Bell, 2016).

In the United Kingdom (UK), where some blame teachers for the decline in the uptake of STEM subjects (Busby, 2016), according to Dunn (2016) the *'pipeline of talent for the ever-changing technological workplace is not equipped with the skills needed to be globally competitive'*. These findings are echoed by the Organization for Economic Co-operation and Development (OECD) who report that in England 9 million adults of working age in England have low basic skills, which for numeracy are well below average relative to other OECD countries (OECD, 2016). Furthermore, at every qualification level, low basic skills are more common among young people in England than in many other countries (Kuczera *et al.* 2016). Driven by the challenges of a changing global economy and fueled by predications of an impending global shortage of STEM based workers (Kennedy & Odell, 2014; Ritz & Fan, 2014), if predictions are correct (BRT, 2014; Stevenson, 2014; Australian Industry Group, 2015) an insufficient number of young people will be equipped to study or will decide not to follow STEM based education programmes (THE, 2013; Henriksen *et al*. 2014; ACT, 2016) to sustain a skilled workforce.

In search of a solution and to reverse this decline in the uptake of STEM education programmes, many organisations and government-backed initiatives have been tasked with identifying barriers that contribute to this. Additionally, they have been challenged to develop innovative approaches to successfully remove these barriers and effectively increase the uptake of study in STEM disciplines (IET, 2008; Capraro *et al*. 2013; Clark, 2013; Mansell, 2014). Whilst each initiative approaches this issue from a distinct perspective, all seek to secure change that will lead to an increase in the number of young people actively seeking to engage with STEM related subjects. Here in the UK,

as is the case globally, one way that the government is working to meet the challenges of labour shortages is through education, and the process of STEM educational reform (Banks & Barlex, 2014) and teacher supply.

1.3.1 Addressing STEM through teacher supply

Integral to the success of STEM educational reform is the supply of well-motivated, highly qualified STEM teachers (National Science Foundation (NSF), 2015; Handlesman & Smith, 2016). In the UK, evidence of this political drive in practice can be seen through the Department for Education (DfE) teacher training bursary scheme, with those seeking to pursue a career as a teacher of Biology, Chemistry, Computer Science, Design and Technology, Mathematics and Physics eligible to receive tax-free bursary payments of up to £30k (DfE, 2017). Specified by the Teacher Supply Model (TSM) recruitment targets for *'popular'* subjects such as English, History and Physical Education, which carry no bursary payment, are met consistently, yet against the backdrop of uncapped trainee teacher targets, and despite generous financial incentives, the STEM related subjects (Biology, Chemistry, Computer Science, Design and Technology, Mathematics and Physics) continually fail to recruit sufficiently.

	2015/16r			2016/17p		
Subject	Recruited	Target	Contribution to target	Recruited	Target	Contribution to target
■ Mathematics	2,452	2,581	95%	2,605	3,102	84%
■ English	2,370	2,253	105%	2,207	2,253	98%
■ MFL[10]	1,392	1,583	88%	1,487	1,583	94%
■ Biology	1,058	1,178	90%	1,356	1,178	115%
■ Physics	740	1,055	70%	851	1,055	81%
■ Chemistry	985	1,053	94%	1,038	1,053	99%
■ History	918	816	113%	910	816	112%
■ Geography	642	778	83%	904	778	116%
■ Computing	504	723	70%	495	723	68%
Other	902	1,777	51%	808	1,285	63%
Design & Technology[11]	513	1,279	40%	423	1,034	41%
Physical Education	1,235	1,227	101%	1,098	999	110%
Art	506	794	64%	522	633	82%
Religious Education	413	650	64%	435	544	80%
Music	353	481	73%	359	399	90%
Business Studies	200	313	64%	215	252	85%
Total Secondary	**15,183**	**18,541**	**82%**	**15,713**	**17,687**	**89%**
Primary	**12,578**	**11,245**	**112%**	**11,516**	**11,489**	**100%**
Total	**27,761**	**29,787**	**93%**	**27,229**	**29,176**	**93%**

Table 1.0

Initial Teacher Training census for the academic year 2016 to 2017, England, SFR 57/2016. New entrants to postgraduate initial teacher training by subject compared to the mid-point of the TSM, 2015/16 and 2016/17 (DfE, 2017:7d).

Utilising the most recent data available, Table 1.0 illustrates the percentage under-recruitment of secondary age phase subjects in England and Wales (against government DfE TSM targets) between 2015 and 2017 demonstrating, according to statistical research (Mason, 2016; Morris, 2017), an insufficient number of students began courses to train as teachers for the fifth consecutive year (Cater, 2017). Teacher shortage is undoubtedly a national issue, with the National Association for Head Teachers (NAHT) reporting significant recruitment issues for the third year running (NAHT, 2017), with particular difficulties experienced in the recruitment of candidates to train to deliver the STEM related subject disciplines.

However, it must be noted that there are significant differences in teacher numbers within the primary and secondary school age phase sectors and there are lesser concerns in relation to the number of retained teachers working within primary education. Statistics show that in real terms "*Teacher numbers are going up in primary and down in secondary"* (Des Clayes with Full Fact, 2017:3) with the number of qualified teachers in the state primary sector increasing by 13% since 2010. However, during the same period, statistics show a continuous shortfall in recruitment to train secondary age phase teachers (Cater, 2017), with secondary schools' teacher numbers in decline by 6% overall (Des Clayes with Full Fact, 2017). Specific to the STEM subject disciplines of Computer Science, Design and Technology, Mathematics and Physics, the situation is significantly worse with statistics showing a shortfall of at least 15% for the recruitment cycle 2016-2017 (Gov.uk, 2017a).

1.3.2 STEM Subject Knowledge Enhancement

In addition to tax-free teacher training bursaries, to help entice those with a potential interest in teaching, but who do not yet hold sufficient subject knowledge, Subject Knowledge Enhancement (SKE) courses are available to aid aspirant candidates' transition into teaching. SKE courses are designed specifically to attract potential candidates with a University degree related, but not specific to, the subject they are seeking to train to teach, or a relevant A-level qualification. These courses attract additional tax-free bursary payments and can be completed prior to, or even during, the training period. Mirroring the training bursary scheme, these SKE courses are available to those seeking to pursue teaching training courses in Biology, Chemistry, Computer Science, Design and Technology, Mathematics and Physics (DfE, 2017).

1.4 Teacher attrition

Another issue of concern within the context of teacher supply for consideration alongside under-recruitment is that of teacher attrition (House of Commons Education Committee, 2017; Roberts & Foster, 2017).

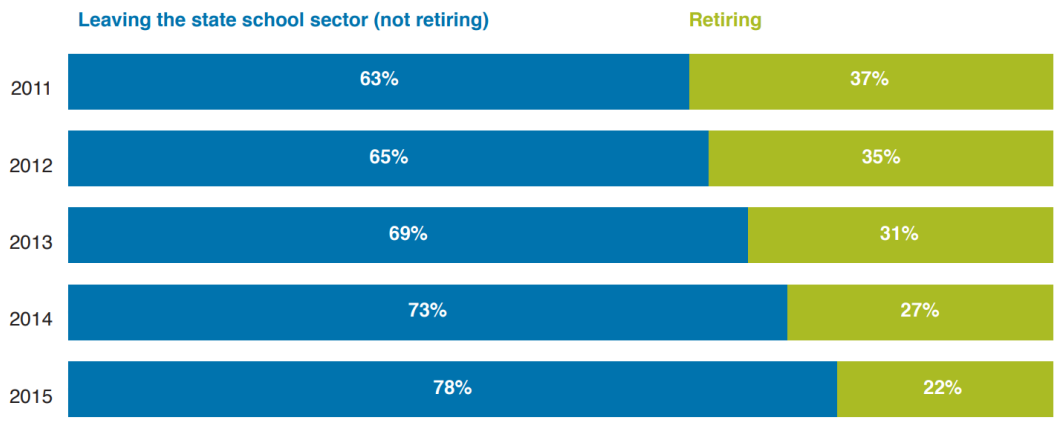

Table 1.1

Why are teachers leaving? Proportion of qualified teachers going "out of service" of English state funded schools or retiring. Department for Education School Workforce in England (November 2015), Table 7a in Des Clayes with Full Fact (2017:3).

As illustrated by Table 1.1, a significant number of teachers are leaving the profession, and according to Fearn (2017), over half of teachers in post are considering leaving the profession with almost a third of early-career teachers' leaving the profession within five years of qualifying (Weale, 2016). Statistics reveal that leaving rates of Mathematics and Science teachers are above average in their first five years in the profession (Lynch *et al.* 2016; Sellgren, 2017), but the attrition rate for early-career teachers of (design) technology subjects (non-EBacc subjects) is below average (Worth & Lazzari, 2017:6). Coupled with recruitment challenges (Table 1.2), and the projected

growth in the secondary school population (Table 1.3), poor retention will serve only to compound the concerns relating to teacher supply.

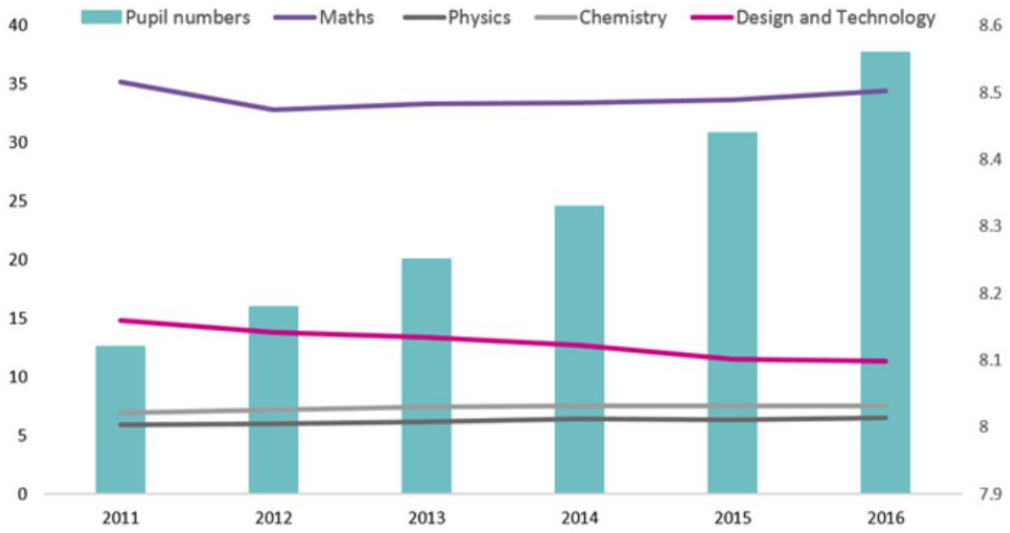

Table 1.2

Teacher numbers in STEM subjects have remained stagnant whilst pupil numbers continue to grow. Source: DfE, 2016 in EEF, Bharkhada (2017).

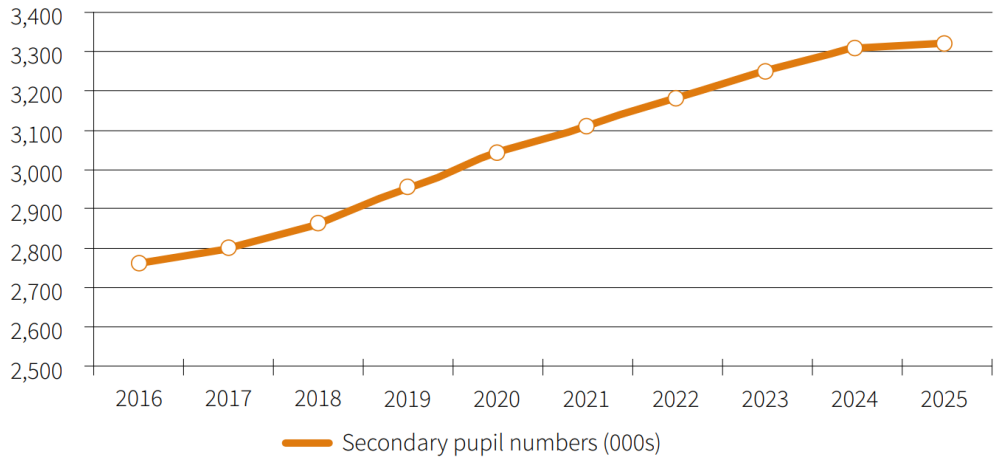

Table 1.3

Projected growth in secondary school population between 2016 and 2025. Source: Department for Education SFR25/2016, National pupil projections – future trends in pupil numbers: July 2016 (Baker, 2016).

1.5 Educational Context: Changes in teacher training and education

Having contextualised the importance of STEM from both a global and national perspective and considered STEM education teacher recruitment and attrition. Given that the UK has seen a significant period of educational reform and curricula change (Morgan, 2015; DfE, 2016a) over recent years, it would be useful at this point to give an overview of the national context within which this research study resides.

Following the introduction of the English Baccalaureate (EBacc) in 2010 (DfE, 2016b, c; Long, 2016), there have been several revisions to the national curriculum, and changes to the General Certificate of Secondary Education (GCSE) suite of qualifications (Gov.uk, 2015a), alongside wider school and school workforce reform (Gov.uk, 2015b). Legislation has enabled schools to become independent of local authority control, to become academies and free schools, where the employment of qualified teachers is no longer a legal requirement (Harrison, 2012; Gov.uk, 2017b).

In addition, with regard to the recruitment and training of teachers, planned changes that include the introduction of *'teacher apprenticeships'* (Whittaker, 2017), signal the drive of teacher education out of University and into, and under, the control of schools. Increased choice for individuals to select the most appropriate route into the classroom would appear to be a strategy that would serve to boost teacher numbers. However, since the expansion of teacher training routes (which include School Direct (SD) and School Centred Initial Teacher Training (SCITT)), which are *"not always well understood by applicants and can be confusing"* (Cater 2017:1) applications to train to teach have fallen consecutively.

In the UK, as is replicated in a considerable number of countries across the globe (Caena, 2011), teacher training is focused heavily on meeting a set of measurable core standards and competencies. Within the UK, the same teaching standards (competencies) are shared across both primary and secondary education phases and subsequently they focus heavily upon the development and testing of generic teacher competencies rather than specialist aspects of a subject teacher's role. Hence, in reaching a level of competency against the teaching standards, less attention is given to the development of specific subject expertise. From the perspective of secondary age phase teacher training, measuring achievement in this way has served to marginalise the importance of the individual subject discipline. Within the secondary age phase those training to teach STEM subjects are in short supply (Worth & Lazzari, 2017). As teacher recruitment continues to fail to meet the country's needs, more teachers are being asked to deliver subjects beyond the subject bounds for which they were initially trained or recruited, and in some schools, it is increasingly common for teaching assistants to be asked to cover lessons (Bousted, 2016). While there are no statistics to confirm that lesson delivery by non-subject specialists has a negative impact upon pupil perceptions of a subject, or pupils academic progress, it is feasible to suggest that without access to highly motivated, qualified subject specialist's pupils are less likely to be inspired to study that subject area at a higher level.

Given that it is already difficult to encourage sufficient numbers of young people to engage in the study of STEM beyond their compulsory schooling (Bell, 2016), the issue of non-specialist teachers delivering lessons is a concern.

1.6 Personal motivation

Interest in this area of focus stemmed from my own personal curiosity. As a qualified teacher of a STEM related subject, and as an educator of STEM subject pre-service teachers, I have been involved in secondary age phase education since 1994, and Initial Teacher Education (ITE) since 2006. I have seen first-hand the steady decline in STEM subject-related teacher training applications, and as a direct consequence have seen the increasing difficulty faced by schools to appoint suitably qualified teachers.

Globally there has been a reported decline in the uptake of STEM-based courses (ACT, 2013) while simultaneously there is an increased demand for workers with STEM skills (United Kingdom Commission for Employment and Skills (UKCES), 2015). Internationally, governments recognise that without access to well-motivated, knowledgeable teachers, children are less likely to have access to a high-quality STEM education, and hence without intervention the situation regarding establishing a strong STEM literate workforce is unlikely to improve (Bell, 2016).

Coupled with worrying rates of attrition for those embarking upon STEM based Initial Teacher Training (ITT) courses (Chen, 2013), and the projected lack of capacity to deliver enough graduates equipped to undertake STEM based occupations (UCEA, 2017), this potential crisis in capacity is a significant concern for policy makers worldwide (Lord Sainsbury of Turville, 2007; Gonzalez & Kuenzi, 2012; Office of the Chief Scientist, 2013). As someone who holds a passion for STEM, the focus of this study originates from my desire to explore the reasons why, internationally so many people are seemingly reticent to engage with STEM related subjects.

Are STEM related subjects perceived as boring? Is there a global misconception that you must have a *'math's'* brain or be 'clever' to study in STEM related fields? Are the constituent STEM subjects perceived as being only subjects for boys? Are they genuinely harder to understand? Is it because of a lack of specialist teachers? Or is there something fundamentally wrong with how these subjects are taught to children that makes them switch off from their study?

With the *'flattening'* of the global economy much of the emphasis to address the STEM issues are focused upon education (Kennedy & Odell, 2014). Through this research I sought to ascertain if there are were common factors that served as influences and influencers for pre-service teachers, in their aspiration to become teachers of STEM related disciplines; disciplines which are, according to research, in globally decline (Henriksen *et al.* 2014; Dunn, 2016; Wood, 2017). Specifically, the aim of this study was to explore the power of personal narratives in seeking to explain the phenomena under investigation and in doing so, to consider how pre-service teacher's individual needs, values, beliefs, preferences, social circumstances, and explicitly their experience-related beliefs shape their decision to embark upon a career in teaching. This study then went on to look at how the meaning that pre-service teachers assign to those experiences influences the formation of their professional identity, and makes them who they are, and in so doing, discover who they have the potential to become.

1.7 The research question

This study sought to instigate debate, in and around STEM education. Specific to the training of teachers and the formation of their professional identity, this study sought to

engage those with an interest in the development of teacher education and training to consider their own practice, to foster awareness of the perspectives of others, and to encourage cross disciplinary thinking. In addition it sought to highlight commonality and support a developing awareness that will impact upon practice, and ultimately encourage more children to engage in the study of STEM related subject disciplines.

The purpose of this research was to explore what, if any, influence personal histories have in shaping pre-service teachers' professional identity. In so doing, it sought to understand behaviours and attitudes toward learning, as professional identities developed. Specifically, seeking to investigate:

- how an individual assigns meaning to an experience and how an individual's experience-related beliefs inform the development of their identity and support the development of self-efficacy,
- how external structures and context influence and shape identity formation in pre-service teachers,
- the impact of subject knowledge and how it shapes and informs the development of identity,
- the barriers encountered by pre-service teachers that restrict their learning and development and how these may be overcome.

Leading to the formation of the following research question:

> *What influence do the meanings assigned to previous learning experience, including personal perceptions relating to subject knowledge, have on the formation STEM pre-service teacher professional identity?*

1.8 Chapter summary

This introductory chapter set out the rationale and research focus for this study, and it presented the context within which the phenomena being studied resides. I outlined my personal interest and in doing so presented my motivation for undertaking this area for investigation. Having laid the foundation, this chapter concluded by defining the research questions to be considered in pursuit of the aims of the study.

2.0 Chapter Two

2.1 A review of the literature

This study adopts an approach that is informed by grounded theory. Traditionally within this method, a review of the literature is not undertaken prior to collection and analysis of the data, in order to avoid stifling, forcing or contaminating the research data (Glaser & Strauss, 1967:37). However, it was not Glaser and Strauss's (1967:3) intention that researchers be expected to approach their work as *'tabula rasa'* (blank slates), but that research undertaken should be approached with an "*open mind, not an empty head"* (Dey, 1993:63). The point being that analysis of research should be undertaken not to either prove or disprove findings in relation to pre-existing literature, but rather undertaken with an open mind to the emergence of new theory and original category generation.

Within research the literature review provides an opportunity to look at the field from different perspectives, and within this study its purpose was to select and critique key issues, define terminology and identify salient concepts used to inform my thinking and ensure that that my research is grounded in the work of others (Royal Literary Fund, 2016).

In preparation for the review, based upon my existing knowledge I drafted a plan of potential themes to explore. They were identity, learning and teaching, and subject knowledge. At first glance these appear to be an unrelated, disparate collection of literatures therefore, before presenting the relevant literature relating to each theme this

introduction seeks to establish the scope of the review (what is included and what isn't), why specific themes were chosen, and how each comes together to form a coherent whole, presenting a complete literary picture of the area under study.

Based upon the research question the review itself begins with an exploration of the research related to 'identity'. Mindful of the large amount of literature relating to this theme, because the focus of my research is specific to the socially constructed development of teacher identity, papers falling outside of this field were not reviewed in detail and were only referred to as and when appropriate. As exploration continued I examined the emotional aspects of identify which in turn led to an investigation of efficacy and self-regulated learning. This led to the subsequent investigation of new areas of study for example attrition, not originally identified as a theme, but emergent as relevant within the context of my work.

Positing 'identity' as a central theme I then examined approaches to learning and teaching. Because of the interest in the influence experience-related beliefs play within identity formation this was undertaken from the perspective of both the student and the teacher. Subsequently, again selected because of the relationship to the research question the review moved to explore the STEM subjects from the perspective of pedagogical approaches and disciplinary differences. To note, throughout the review, where literature specific to the STEM subject disciplines and secondary age phase education was scarce, I actively sought to explore the theme under investigation through a similar (but appropriate or relevant) lens. This in turn led to the identification of new

themes (for example gender) but I was also able to situate these themes with those reviewed earlier, to triangulation the findings and in effect close the literary loop.

2.2 Defining identity

> *"A major hurdle in gaining an understanding of identity is resolving a definition of it"*
>
> Beauchamp and Thomas (2009:176).

As a term, *'identity'* is used to define how people perceive themselves, and how society perceives them (Gross & Hochberg, 2014). It is a form of self-understanding (Kelchtermans, 2005) or a shifting dynamic informed through interactions (Rodgers & Scott, 2008:736). According to Beijaard *et al.* (2004) identity is multi-faceted, and emerges from an ongoing process of interpretation and re-interpretation, of who one considers oneself to be, and who one would like to become:

> *"An amalgam of personal biography, culture, social influence and institutional values which may change according to the role and circumstance"*
>
> Day (2002:689).

In their work Beauchamp and Thomas (2009) explore the link between identity and agency, the role emotion has in shaping identity, and the power of stories and discourse in supporting our understanding of identity. They determine that *"identity is an ongoing process... identity is dynamic rather than stable, a constantly evolving phenomenon"* that involves both a person, and a context and *"is shaped and reshaped in interaction*

with others in a professional context" (Beauchamp & Thomas, 2009:177, 178). This area is also explored by Nghia (2017) and Körkkö *et al.* (2016) who also refer to the shaping and reshaping of identity, and in securing a definition the literature supports the notion that identity is not something that is fixed or unchangeable. It is both fluid and organic, and socially constructed throughout one's life; changing constantly as new meanings are made as a result of an individual's interpretation of new experiences. Teacher identity is deeply embedded within one's own personal biography, which in itself is an *"intricate and tangled web of influences… rooted in personal and professional life experiences"* (Bukor, 2015:323), that appear from the collection of stories people tell themselves about their lives (Sfard & Prusak, 2005).

According to Sachs (2001) identity is not a single entity, but consists of many sub-identities, and in that respect, one should utilise the term *'identities'* rather than identity. Specific to teaching, Lasky (2005:901) defined identity as how a teacher defines their professional identity to themselves, and to others. An individual's belief of how society views the role of *'the teacher'* is significant in forming identity, which according to Gee is being *"recognised as a certain kind of person"* (Gee, 2000:99), and from my personal perspective one's own personal beliefs about how a teacher should act or behave has considerable influence on the development of an individual's professional identity.

2.2.1 Identity: Becoming a teacher

Symbolic interactionism explains how an individual's identity forms following reflection on their interactions with others, especially those who have had a significant influence on their lives (Mead, 1934 in Hargreaves, 2010). This is particularly important

from the perspective of pre-service teachers, whose identities are *"deeply embedded in their personal biography"* (Bukor, 2012:305), and because *"newcomers learning to teach enter teacher education looking backward on their years of school experience and project it into the present"* (Britzman, 2007:2). Identity may be expressed in the form of *"beliefs, assumptions, values, and actions as well as in the various ways one perceives and interprets oneself and the world"* and for anyone new to teaching, the responsibilities that come with being a teacher can be overwhelming (Bukor, 2012:306).

Both Beijaard *et al*. (2004) and Coward *et al.* (2015) discuss difficulties experienced by pre-service teachers who traverse a dichotomous role; expected to exhibit expertise as a teacher, while also being a student. This duality is explored further in a study of pre-service science teachers, where the dilemma of feeling like a student while assuming the role of teacher is investigated (Volkmann & Anderson, 1998). The tensions that arise from that study are categorised as:

- Feelings like a student while being expected to act like a teacher
- Wanting to care for students while being expected to be tough
- Feeling incompetent in her knowledge (of chemistry)

Volkmann and Anderson (1998).

The dichotomy of managing different *'identities'* can impede a teacher's professional development (Timoštšuk & Ugaste, 2010) and developing a strong sense of self is essential in helping to ensure pre-service teachers are equipped to cope with the constant challenges of a career in teaching.

Viewed through the lens of self-determination theory, Deci and Ryan (2017) explore the concept of having intrinsic control over one's destiny, and the agency to construct identity, whereas within self-discrepancy theory (Higgins, 1989) three categories of identity are presented; the actual, the ideal and the ought self. Similarly, Markus and Nurius (1986) introduce the notion of *'possible-selves'* and explore identity from the perspective of what they (a teacher) might become, what they would like to become, and what they are afraid of becoming. While showing subtle differences, each theory presents a conceptual link between cognition and motivation that is useful in supporting our nascent understanding of teacher identity.

2.2.2 The influence of personal narrative and experience of education

The influence of personal narrative and prior experience of education is explored by Pajares (1992), who noted that conceptions of teaching and personally constructed theories of education are influenced by many years of classroom observation and prior knowledge about learning and teaching is also understood to serve as an *'interfering filter during teacher education'* (Hollingsworth, 1989).

Postareff *et al.* (2007) found that pedagogical training has a positive effect on teachers' learning-centred approaches to teaching. However, some researchers suggest that these personally held theories about teaching are difficult to change, despite the best efforts of teacher training programmes, which according to Pajares (1992) may lead to the assumption that an individual's personal beliefs can have a 'predictive value' with regard to their conceptions of teaching, and their teaching approaches.

Others disagree and according to Nghia (2017), personal *"beliefs did not automatically translate into teaching practices"* (Nghia, 2017:113).

2.2.3 Identity: Defining emotion

The development of a strong identity is important to securing a teacher's well-being (Thomas & Beauchamp, 2011), however, becoming a teacher is a *"highly emotional experience that can generate both negative and positive emotions"* (Timoštšuk & Ugaste, 2012:422) and according to Zembylas (2005) teacher identity formation is fraught with and fundamentally interrelated with emotions (Zembylas, 2005), especially as the pre-service teacher negotiates their personal narratives which are used to create their professional identities (Zembylas, 2003a, b; Beauchamp & Thomas, 2009). Many authors agree with Nichols *et al*. (2016) who assert that:

> *"Teachers' emerging identities not only influence their actions and emotions, but their actions and emotions also influence their professional identity formation. Teacher identity and emotion are not linear or unidirectional; rather, they are inextricably related to each other through an ongoing, multidirectional, transactional process"*
>
> Nichols *et al.* (2016:407).

Emotions are deeply entwined in an individual's identity (Zembylas, 2005; Hong, 2012; Yuan & Lee, 2016), yet according to Frenzel (2014) limited attention has been paid to the influence and pivotal role emotion plays in a teacher's development and the empirical evidence in relation to teacher emotions is not extensive.

While there is growing interest in this field, there is surprisingly little known about the role emotions play in learning to teach (Timoštšuk & Ugaste, 2010; Yuan & Lee, 2016). Within the context of this research *'emotion'* relates to the articulation of participants feelings, it may be useful therefore, at this point to explain the term *'emotion',* as it is observed within the context of teacher identity. Also, to note, in line with terminology advocated by Putwain *et al.* (2013), to avoid misunderstanding when discussing positive and negative emotions, unless contained within a direct quotation, I have distinguished the recollection of emotions as either *'pleasant'* or *'unpleasant'*.

Emotion is a social construct (Dewey, 1922), biological in nature, that describes an individual's *"heightened state of being that changes as individuals interact with their immediate context"* (Lasky, 2005:901). Exploring emotion within the context of emergent teacher identity, Yuan and Lee (2015:823) discovered that the focus of feeling centred on the teachers themselves. Exploring the range of emotions experienced by pre-service teachers during their training, whether recalling a recent or previous experience (from childhood) negative emotions attached to an event were recalled more intensely than neutral or positive ones, with negativity tending to hold more influence over identity formation than positive emotions (Timoštšuk & Ugaste, 2005, 2012).

Moving to explore pleasant emotional episodes, Sutton and Wheatley (2003) found a correlation between positive emotions and an ability to cope better with unexpected situations. However, Timoštšuk and Ugaste (2005, 2012) found that successful engagement with pupils was the foremost positive source of emotion, findings echoed by Hagenauer *et al.* (2015), who also found that positive feelings were stronger in those

teachers who formed strong connections with their peers, who were able to validate their position and status as a teacher. *"Appreciation from students"* was also cited by van Lankveld *et al.* (2017:332) which along with teaching awards and developing strong relationships with other teachers, are believed to be significant in confirming an individual's sense of self-identity as a teacher.

Isolating the causes responsible for the creation of feelings of unpleasant emotional episodes, demonstrated that these tended to be derived from external sources, which according to Poulou (2007) manifest most frequently as *'anxiety'*. Typically, these included interactions with other colleagues, contextual arrangements (for example the curricula), and one's own reflective thoughts about performance (Poulou, 2007; Timoštšuk & Ugaste, 2012; Yuan & Lee, 2015).

Additionally, this notion links to the work of Lasky (2005:910) who determined that a teacher's feelings of self-worth are intertwined with their identity, and consequently their intrinsic beliefs around what a teacher is. Lindqvist *et al.* (2017) present the notion of '*professional inadequacy'* and *'troublesome feelings'* (Lindqvist, 2017:275) which they describe as feelings of inadequacy, and of not being able to live up to one's own professional standards.

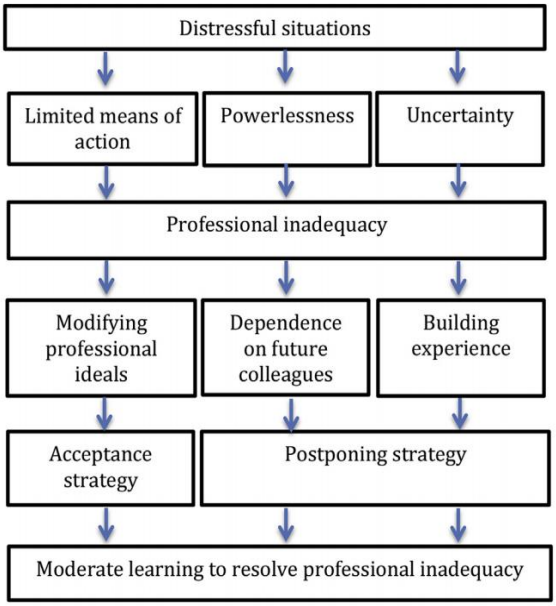

Figure 2.0

A grounded theory of resolving professional inadequacy (Lindqvist *et al.* 2017).

According to Lindqvist *et al.* (2017) pre-service teachers tend to have naïve and idealistic perceptions of teaching, and when their beliefs are challenged it is likely to impact upon their professional development. They explore how pre-service teachers develop their ability to cope with distressful situations, and in doing so present three categories; powerlessness, limited means of action, and uncertainty (Figure 2.0) that serve to support us in our understanding of this aspect of a pre-service teacher's development. Research that focuses on how teachers cope with distressful situations is sparse, and I believe there is a clear need for further exploration into this area, to investigate the impact of unrealistic expectations (Woolfolk Hoy, 2013), and the demands placed upon the pre-service teacher by the process of training to teach.

2.2.4 Identity: Attrition

According to Gross and Hochberg (2014) only a small proportion of teachers survive their first year of teaching, and in their work Beijaard *et al*. (2004), Hong (2010, 2012) and Nias (1999) explore the issue of chronic attrition that are *'deeply entwined'* with a teacher's identity. Teacher retention and attrition is a complicated educational phenomenon, and according to Hong (2012) pre-service teachers *"often felt that their school administration was not really effective or supportive and they did not think they had enough power to influence the administration"* (Hong, 2012:1541). Le Maistre and Paré (2010) explore teacher attrition within the context of teacher survival, where the issues of power and powerlessness are addressed. As a strategy to support the development of a teacher's professional identity, it is important to provide opportunities for pre-service teachers to engage in genuine decision making, leadership and problem-solving activities (Kelchtermans, 1996, 2005).

Within the context of teaching Davey (2013) explores moral purpose, moral sensitivity, and moral stress in relation to a teacher's professional ethical and moral dilemmas, which according to Colnerud (2014) forces teachers to '*act in a particular way'.* This is likely to create issues because having had to make or take a particular decision that does not align with their personal beliefs, they may still be held accountable for their actions (Colnerud, 2014). Interestingly, and of significance within both the context of attrition and teacher education programmes, findings within the same study showed that *"more female teachers have difficulty sleeping due to thoughts about work than their male colleagues"* (Colnerud, 2014:357), which suggests that female teachers are more attuned with moral sensitivity than their male counterparts; an issue that should be taken

into consideration when developing a teacher education training programme, or undertaking work to develop mentors with responsibility for supporting pre-service teachers.

2.2.5 Identity: Emotion and children

While some work has been undertaken to explore the relationship between a teacher's emotions and their approaches to teaching in Higher Education (Trigwell, 2012), a review of the literature indicates that the impact of teacher anxiety on the pupils they teach, particularly within secondary education, is an under researched field. Limited work prevails, particularly in relation to the exploration of the impact of teacher anxiety, including work that considers both teacher stress, and the impact of stress transference from the teacher onto learners; specifically, the impact on the learner's confidence, motivation, and ultimately their ability to effectively access learning.

Teacher stress may result in frustration, aggression, anxiety, avoidance behaviours, increased absenteeism and a decrease in both student and teacher performance levels (Kaiser & Polczynski, 1982; Harris *et al.* 1985). Thus, positive teacher emotions may not only be essential for the well-being of teachers, but they may also affect a student's well-being and in turn their learning (Hagenauer *et al.* 2015:398). Woolfolk *et al.* (1990) found a link between teacher efficacy and adopting a more humanistic approach to classroom control; findings echoed by Ashton and Webb (1986) who found that with higher levels of efficacy teachers were less critical of their students.

In addition to being aware of their own emotions, teachers need to be cognisant of the impact emotions have on their own pedagogical practice and performance in the classroom. They also need an awareness of how their own emotions may impact upon the children and young people with whom they are working, and in doing so, they need to be mindful that distressful situations can lead to unhealthy attitudes and harmful patterns of behaviour. In turn, these can counter the influence of teacher development programmes and lead to pre-service teacher's feelings of professional inadequacy (Corcoran & Tormey, 2012).

2.2.6 Defining identity within the context of this study

In considering the definitions of identity emergent from the literature, it is evident that there is no clear consensus as to the attributes or definition of identity in-relation to pre-service teachers. Given the significance within this study of identity, and identity transformation, it is essential to define what characteristics are considered as comprising pre-service teacher's professional identity, as such (specific to the context of this study) it is defined as:

"Pre-service teachers develop, shape and re-shape their individual professional identities in response to new experiences which they are exposed to during the process of training to teach. These influences include cultural and societal factors and they are further informed by experience-related beliefs and personal biographies which contribute to the construction of an individual's ideological beliefs. It is from these beliefs that new meanings are made in light of an individual's interpretation of current events, but how individual's approach learning, respond to and subsequently assign

meaning to new experiences is inextricably bound to meanings they assigned to experiences experienced in the past".

2.3 Efficacy

According to social cognitive theory (Henson, 2001; McLeod, 2011) humans can act entirely independently, and of their own free will. Previously, Bandura (1993) defined this as *'human agency'* and suggested that human behaviour is not a product of biology, but of a mixture of current and past behaviours and internal and external factors. For this reason, he proposed that human behavior could be influenced by an individual's own personal beliefs about how successfully they believe they can perform a task. The theoretical foundations of self-efficacy are grounded in the social cognitive theory developed by Bandura (1993), and in his later work (Bandura, 1997) he characterised self-efficacy as a belief or judgement about one's own capability or skills to accomplish a task. He goes on to discuss that this notion of self-efficacy is comprised of two components: efficacy expectations (defined as a belief in personal capacity to affect behaviour), and outcome expectations (the belief that one's behaviour will result in a desired outcome).

Later Bandura (1997) began to focus more on how self-efficacy affects teacher's performance, specifically how an individual teacher's sense of self-efficacy may affect the pupils they teach, change their engagement, behaviour or approach to learning (Bandura, 1997). Within the context of teacher education self-efficacy has been defined as "*the extent to which the teacher believes he or she has the capacity to affect student's performance"* (Berman *et al.* 1977:137) and is associated with positive emotions, and

high levels of internal control over the challenges one faces within the teaching profession. In this respect, self-efficacy is like self-confidence consisting of a teacher's belief in their own capacity to organise and execute required courses of action (Bandura 1997:3). Within this work he presents four main sources of self-efficacy:

- Mastery experiences (the successful performance of a specific behaviour),
- Vicarious experiences (that enable individuals seeing a teacher's performance),
- Verbal persuasion (including input from colleagues and supervisors),
- Physiological arousal (manifested in the form of trembling hands and increased heartbeat).

In their studies of both novice and career teachers (Tschannen-Moran & Woolfolk Hoy, 2001; Tschannen-Moran & Hoy, 2007) explore the role contextual factors such as teaching resources and interpersonal support play in self-efficacy beliefs. They found that external factors can impact upon an individual's efficacy, which can and does vary depending upon the subject taught and the teaching situation (Tschannen-Moran *et al.* 1998) and that teacher's self-efficacy beliefs are more flexible in the early career phase (novice or recently qualified), when compared to experienced teachers who are already in possession of mastery experiences (Tschannen-Moran & Hoy, 2007).

This is of interest because research shows teachers with higher levels of self-efficacy are more likely to use innovative teaching practices, which have been shown to lead to better pupil learning outcomes (Gordon & Debus, 2002).

2.3.1 Efficacy and self-regulation

Closely linked to efficacy, self-regulation or Self-Regulated Learning (SRL) describes an individual's ability to consciously control their own learning (Zimmerman, 2000), which according to Cardelle-Elawar *et al.* (2007) is necessary for teachers to understand themselves. Without an awareness of this dynamic, according to Delfino *et al*. (2010), teachers may be unable to promote this quality in the pupils they teach and Kramarski and Michalsky (2009) believe that a teacher's capacity to support learners who are self-regulated is related to the teacher's own self-regulation. If teachers themselves are incapable of self-regulation, and unable to manage their own learning, it would seem plausible that they would have trouble in developing these capabilities among their students (Perry, Phillips & Hutchinson, 2006; Kramarski & Michalsky, 2009).

Within the context of this study self-regulation is categorised as either High Self-Regulation (HSR) or Low Self-Regulation (LSR). Research suggests (Zimmerman, 2002, 2008, 2011) that teachers who possess HSR tend to be more active in their own learning, more able to challenge themselves, and work vigorously to address their own professional vulnerabilities. Where HSR is evident participation is autonomous, often born out of pure self-interest, stemming from a desire or self-identified need. Furthermore Zimmerman (2001, 2011) identifies a link between HSR and those who adopt deep approaches to their learning. Noting also the adoption of innovative pedagogies, increased motivation, demonstrating those with HSR possess a strong commitment to teaching, and have a powerful *'sense of self'*. As a consequence, the pre-service teacher with HSR, who adopts a deeper approach to their own learning, as an autonomous learner is likely to be more confident, resilient and emotionally stronger,

and a strong sense of professional agency has been related to reduced levels of stress (Pyhältö *et al.* 2015). Subsequently with respect to teacher well-being, according to Littlejohn *et al*. (2016) and Milligan *et al.* (2014), where self-regulation is high, and the *'external structures'* that control learning are removed, when learning is driven by the individual, both satisfaction and learning is increased.

In contrast, those who exhibit LSR believe that they have limited agency to initiate change within their working environments (Milligan *et al.* 2014). With respect to their own learning, surface approaches are adopted and therefore they are more likely to adopt conservative approaches to their own teaching, performing perfunctorily duties, and adopt automaton like approaches in the classroom (Zimmerman, 2002, 2008, 2011).

2.3.2 Efficacy and pedagogy

There can be no doubt that high-quality teaching is a pre-requisite necessary to maximise learning potential, and as such, the development of a strong teaching profession is critical in the delivery of that goal (Hattie, 2003). Having explored efficacy and self-regulation within the context of teacher identity, this section seeks to align pre-service teacher's efficacy, with their pedagogical approach, and anticipate the likely outcomes (impact) for learners.

Linking efficacy to learner achievement, pupils of teachers with higher self-efficacy tend to enjoy better learning outcomes (Bandura, 1997), and strong teacher efficacy has been linked to autonomy, and self-motivation (Midgley *et al*. 1989) and an increased use of *'hands on'* teaching methods (Enochs & Riggs, 1990). Guskey (1998) explored

efficacy alongside receptivity to change and found that those with efficacy were more likely to be more open to the implementation of new practices. Conversely, where teachers exhibited low self-efficacy, pedagogy tended to reflect the adoption of strict, traditional styles of teaching (Tschannen-Moran *et al.* 2007). While Baleghizadeh and Shakouri (2017:401) found that typically those teachers with stronger self-efficacy sought to enhance the learning process and thus increased satisfaction for both the teacher and student. Furthermore, they found that those with low efficacy, who considered lectures to be the most important part of their teaching, were less inclined to enhance learner autonomy and less likely to implement innovative teaching styles.

Within the context of pre-service teacher education programmes this is important because when encountering difficulties in the classroom, pre-service teachers tend to *"fall back on their traditional memories of how to teach"* based upon experiences from when they were students (Hargreaves, 2010:146). Shifting identity is a difficult and sometimes painful process, and *"fundamental changes in teacher identity do not take place easily"* (Beauchamp & Thomas, 2009:185). According to Korthagen (2004) once set, a teacher's professional identity becomes difficult to change; a belief echoed by Kember (1997) who argues that enormous efforts are needed in order to change teachers' underlying beliefs. It is desirable therefore that during the early stages of their development pre-service teachers establish a strong *'sense of self',* to help ensure they are equipped with sufficient pedagogical skills and teaching techniques to enable them to cope effectively with the constant challenges of a career in teaching.

2.4 Learning to teach: Models of teacher development

According to Izadinia (2013) little has been said in relation to the challenges and complexities of identity formation (Izadinia, 2013). Ruohotie-Lyhty and Moate (2016) agree and found that limited attention has been paid to the kind of experiences that pre-service teachers draw upon during teacher education and mechanisms that can be used to help to support the development of their *'self-awareness'* during teacher training. Following a review of the available literature this appears to be the case, however, there are numerous *'models'* that explore the stages pre-service teachers traverse during their journey from pre-service to qualified teacher (Borg, 2003; Conway and Clarke, 2003; Fuller & Brown, 1975).

Early work within this field offers valuable insights into pre-service teachers' development. Katz (1972), identified three stages that beginning teachers go through before they become confident in their teaching abilities, which resonate with those presented by Furlong and Maynard (1995):

- early idealism
- personal survival
- dealing with difficulties
- hitting the plateau
- moving on

Furlong and Maynard (1995).

Beijaard *et al.* (2004:122) identified four features of professional identity: ongoing process, person and context, sub-identities and agency; themes which are also evident in Yuan and Lee's (2015) work which present identity construction as:

- *Cognitive* (Teachers see themselves as subject matter experts, identity is inseparable from cognitive development).
- *Social* (Personal biography, shaping identity from past experiences and using those experiences as a framework to make sense of teaching).
- *Emotional* (The role emotion plays in developing identity, teachers understanding of themselves and how emotion can help them to become a legitimate teacher).

Yuan and Lee (2015:470).

Exploring the emerging professional identities of first year Mathematics and Science teachers, Nichols *et al*. (2016) sought to develop an understanding of the connections between emotional episodes, and in their comprehensive review of teacher identity (within the university context), van Lankveld *et al*. (2017) presents five underlying psychological processes they claim exist within (university) teacher identity development (Figure 2.1).

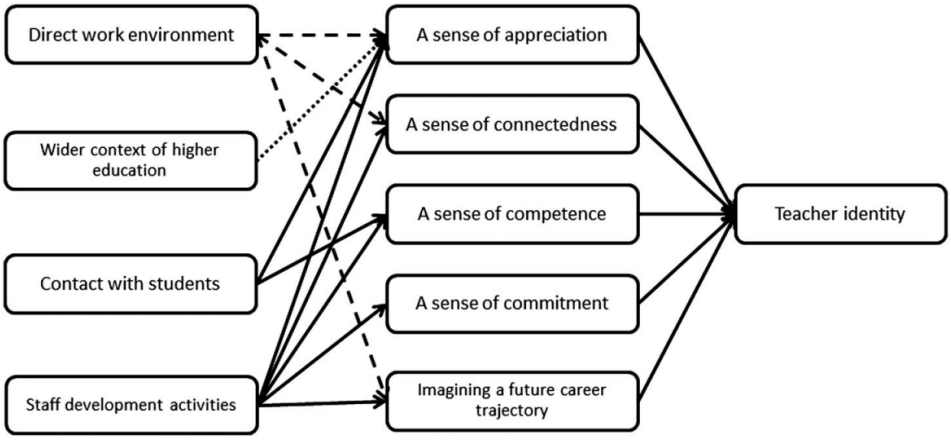

Figure 2.1

Identity development of university teachers: strengthening and constraining factors and underlying psychological processes. Adapted from van Lankveld *et al.* (2017).

2.4.1 Learning to teach: The role of the mentor

Quality support for pre-service teachers during the training period is vital, which makes the role of the mentor and teacher educators an interesting one. In theory, both positions exist to support the development of pre-service teachers, however, in practice both can prove to be a source of anxiety for pre-service teachers. Tschannen-Moran and Hoy (2000) discuss the difficulties met by those training to teach and highlight issues around external influences that lead to feelings of vulnerability and thoughts of self-protection, and where distrust *"provokes feelings of anxiety and insecurity"* (Tschannen-Moran & Hoy, 2000:550). These findings are echoed by Day (2002), who makes clear the potential negative impact that organisational cultures play in undermining teacher identity and in discussing the difficulties pre-service teachers meet during training. In the *'dark side of mentoring'* Yuan (2016) explores how negative experiences of mentoring can dismantle a pre-service teacher's ideal identity, while in her work Atkinson (2018) examines importance of strong mentors as role models.

In their study Schmidt and Knowles (1995) explore the novice teachers *'understanding of themselves'* as teachers from the perspective of failure. Utilising the stories of four female students they found that in each case the women had difficulty in *"reconciling perceptions of themselves with the behaviours they believed were required to maintain order in the classroom"* (Schmidt & Knowles 1995:433). It was clear that each wanted to be told what to do yet were unable to heed or act upon the advice provided. They also found that in themselves the pre-service teachers were not particularly confident, and their *'mood'* was easily affected by external sources, including their teaching mentors, which quickly led to feelings of ineffectiveness. Fear of failure is a common emotion, and according to Timoštšuk and Ugaste (2010) has a considerably stronger influence over the formation of identity, than positive affirmations from mentors and teacher trainers, concurring with findings from Bullough (1990:358) that pre-service teachers make *"teaching situations either productively or unproductively meaningful".*

2.4.2 Learning to teach: the professional practice

The professional teaching placement is one of the most important experiences in the formation of a teacher's identity (Coward *et al*. 2015) and according to Toom *et al.* (2017) the teacher education programme, and the influence of mentors, has a significant impact upon a pre-service teacher's development. Specific to the field of mentoring, according to Daloz's (2012) two key aspects are necessary to secure optimal learning and support within the development of identity within teacher education; these are challenge and support. Challenge refers to an individual's ability to question (in this case their mentor) and critical reflection upon their own beliefs, behaviours, and attitude. Daloz (2012) argues that for a mentee (the pre-service teacher) to learn and

grow effectively, they need a combination of high support and high challenge. In Daloz's model (Figure 2.2) support (offered by the mentor) includes empathy, active listening, and encouragement to help the pre-service teacher to resolve issues.

	Low Support	**High Support**
High Challenge	High challenge + low support = Retreat	High challenge + high support = Growth
Low Challenge	Low challenge + low support = Stasis	Low challenge + high support = Confirmation

Figure 2.2

Mentor: guiding the journey of adult learners. Adapted from Daloz's (2012:208).

Where a pre-service teacher is not sufficiently challenged and receives limited support 'stasis' occurs. Where support is low, and challenge high, Daloz (2012) suggests this is likely to result in 'retreat' from development. Finally, where support is high, but challenge is low, the pre-service teacher is unlikely to move beyond their present situation, despite any potential for growth; a condition known as *'confirmation'*.

2.5 Learners approaches to learning, teacher approaches to teaching

Within the context of pre-service teacher's identity formation, efficacy and self-regulation, this section explores the literature around learning and teaching from the perspective of the pre-service teachers as learners within higher education and then goes on to explore their approaches to teaching.

With respect to approaches to learning, studies by Biggs (1978), Entwistle and Ramsden (1983) and Marton and Säljö (1976) identify three qualitatively different ways students approach learning; surface, achieving (or strategic), and deep, each of which is explored within the next section.

2.5.1 Approaches to learning

With respect to surface approaches to learning, according to Marton and Säljö (1984), cognitive activities tend to involve the memorisation of facts and recall of knowledge. From the learner's perspective, where learning is conceived as *'increasing one's knowledge'* (Virtanen & Lindblom-Ylänne, 2010), learning is undertaken as a process involving the memorisation or acquisition of facts. Adapted from Savin-Baden (2000) and Gibbs (1992) characteristics of surface level learning include:

- The adoption of 'rote' approaches to learning,
- Concentration on the memorisation of facts, giving the impression that understanding has occurred,
- Assimilation of information, recalling chunks of knowledge,
- Remembering, or finding the 'right' answers.

However, with respect to students who adopt surface level engagement with learning, it must be noted that in some instances this approach is not as superficial as it may first appear. In some instances, the learner may seek to adopt a surface level approach to learning as a sophisticated strategy. For instance, in certain circumstances the student may choose a surface approach as a strategic learning tool to increase achievement, for

example to pre-select and prioritise only what they need or want to learn with the specific intention of achieving only a minimal pass (Biggs & Tang, 2007). Discounting the strategic (achieving) surface approach to learning, adapted from Biggs and Tang (2007), from the student's perspective factors associated with surface learning include:

- A cynical view of education,
- Non-academic priorities exceeding academic ones (insufficient time combined with a high workload),
- Misunderstanding of the necessary depth of understanding required (for example thinking that factual recall is adequate),
- A genuine inability to understand the topic or subject (at a deep level).

Moving to explore pedagogical delivery, from the students' perspective, surface approaches to teaching adopted by a teacher (lecturer) include:

- Teaching piecemeal (no genuine attempt to bring to the fore the intrinsic structure of the topic or subject),
- Providing students with insufficient time to engage in tasks (emphasis on blanket coverage, at the expense of in-depth exploration),
- Assessing knowledge against a recall of facts (for example utilising only summative assessment mechanisms to test students' knowledge for example short-answer responses to questions or multiple-choice tests),
- Creating undue anxiety or setting low expectations (of success).

Biggs and Tang (2007).

Conversely, deep approaches to learning seek to encourage learners to try to relate ideas and concepts, to understand underpinning theory, in order to make meaning out of the learning materials under consideration (Gibbs, 1992; Savin-Baden, 2000; Fry, Ketteridge & Marshall, 2009). According to Ramsden (2003), the central purpose of higher education is to encourage the adoption of strategies that will encourage deep approaches to learning:

- The ability to focus at a high conceptual level,
- Teaching and assessing in a way that encourages a positive working atmosphere, so students can make mistakes and learn from them,
- Emphasising depth of learning rather than breadth of coverage.

Biggs and Tang (2007).

Deep approaches to learning are associated with learners who can see real value in learning and aim to understand fully the concepts taught (Marton & Säljö, 1984). It is acknowledged that there is a lack of research to explore students' conceptions of teaching (Vitanen & Lindblom-Ylänne, 2010), however from the literature available research suggests that active learning materials are better remembered (Cherney, 2008). A considerable number of studies (Van Rossum & Schenk, 1984; Marton & Säljö 1997; Trigwell *et al.* 1999) have shown that deeper approaches to learning can be related to higher quality learning outcomes and may be attributed to higher levels of motivation, enjoyment, independent learning (Trigwell & Prosser, 1991; Ramsden, 1992) and Ramsden (1997, 2003) identified a correlation between a student's interpretation of high

quality teaching, the quality of student learning and approaches that support deep learning.

With supplementary benefits for learners including increased opportunities for active and autonomous learning (Lea, Stephenson & Troy, 2003), Craik and Lockhart (1982) also discovered that information gained as a result of strategies to support deep approaches to learning is better remembered than knowledge or information obtained via surface approaches. Defining the traits of deep approaches to teaching, those most likely to result in students' engagement in learning, include discourse, debate, questioning, explanation, and useful feedback (Ramsden, 1997). Furthermore, Trigwell and Prosser (2004) argue that irrespective of the quality of teaching, students who adopt deeper approaches to their learning perceive the quality of the teaching received to be higher. These findings align with work by Postareff *et al.* (2007), who found that those with a strong motivation to teach and personal commitment to teaching valued their training more and under these conditions, pedagogical training has a positive effect on teacher's learning-centred approaches to teaching.

2.5.2 Approaches to teaching

Student self-regulated learning has a positive effect on learning outcomes (Vermunt & Vermetten, 2004), however through the adoption of specific teaching approaches, teachers can encourage the adoption of deep approaches to learning and in doing so improve the outcomes of learning (Virtanen & Lindblom-Ylänne, 2010). Teaching behaviours adapt depending upon the individual's perception of their teaching context, and context variables include both intrinsic and extrinsic factors such as: the number of

students, teaching environment, the learner's ability, curriculum content (school policy) subject knowledge and the individual's perception of self (personal disposition).

In their phenomenographic study, Trigwell *et al.* (1994) identify five qualitatively different way that teachers approach teaching (Figure 2.3):

Approach A: A teacher-focused strategy with the intention of transmitting information to students;
Approach B: A teacher-focused strategy with the intention that students acquire the concepts of the discipline;
Approach C: A teacher/student interaction strategy with the intention that students acquire the concepts of the discipline;
Approach D: A student-focused strategy aimed at students developing their conceptions;
Approach E: A student-focused strategy aimed at students changing their conceptions.

Figure 2.3
Five qualitatively different approaches to teaching. Trigwell *et al.* (1994).

Ranging from *'teacher-focused'* approaches that are characterised by knowledge (information) transfer from the teacher to the student (Approach A), to *'student-focused'* which is categorised by the teacher's focus on the student, and the conceptual change in the students understanding of a topic (Approach E) (Trigwell *et al.* 1994). Later Trigwell *et al.* (1999) explored the relations between teachers' conceptions of teaching and learning and students learning outcomes and found that teachers who adopt a knowledge transmission approach to the delivery of their teaching are more likely to have students who adopt a surface approach to learning. Whereas those who adopt student-centred approaches are significantly more likely to engage their students in deeper learning (Figure 2.4).

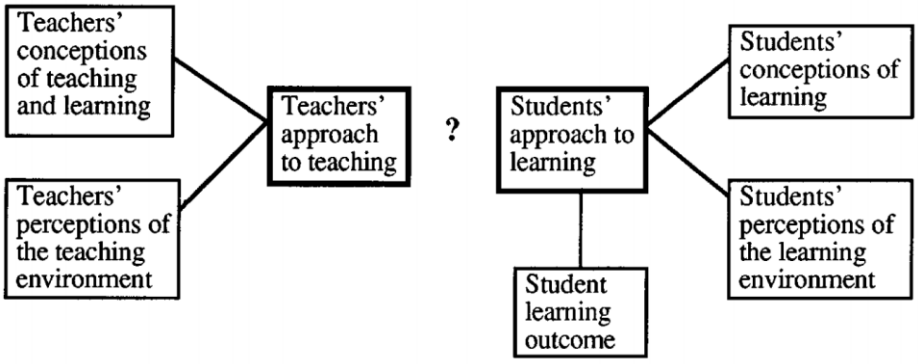

Figure 2.4
Established links between teachers' conceptions of teaching and learning and students learning outcomes. Trigwell *et al*. (1999).

In their study Kember and Kwan (2000) identified two different approaches to teaching, those being teacher-centred and student-centred. In line with similar studies (Trigwell & Prosser, 1996; Postareff & Lindblom-Ylänne, 2008) they found that where teachers conceive teaching as the transmission of knowledge, they are more likely to utilise content-centred approaches within their own teaching, and conversely where teachers conceive teaching as facilitation learning-centred approaches are employed. According to Trigwell & Prosser (1996) there are two approaches to 'teaching'; Teaching as information transmission (a teacher-focused approach) and teaching as conceptual change (a student-focused approach). These are explored within the next sections of this chapter.

2.5.3 Teaching as Information Transmission (a Teacher-Focused approach)

In this approach, the teacher adopts a teacher-focused strategy, with the intention of transmitting information about the subject or discipline, with the focus being on facts or skills, but not on the relationships between them.

Within the teacher-focused approach, the teachers view is mainly as of directing students to sources of information *"pass on ways of thinking about the discipline"* (Virtanen & Lindblom-Ylänne, 2010:367). A student's prior knowledge is not considered to be important, and within this approach students are not therefore active in the teaching-learning process (Trigwell & Prosser, 1996:80).

2.5.4 Teaching as Conceptual Change (a student-focused approach)

Within this approach, the teachers adopt a student-focused strategy, designed to help learners to change their '*world views or conceptions of the phenomena they are studying'*. The teacher understands that they cannot simply 'transmit' a conception onto the students, and those who adopt student-focused (learner) approaches tend to utilise a full range of pedagogical approaches. Within this approach, students must be active in their learning and construct their own knowledge. Hence, the teacher focus is upon the students, and teaching is a process of facilitating the learning situation (Trigwell & Prosser, 1996:80). Compared to more traditional, teacher-focused approaches, the adoption of practices that encourage more student-focused approaches have been shown to enhance the students learning experience (Trigwell & Prosser, 2004). Conceptual change or student-focused approaches are more likely to engage students in deep approaches to their learning, and subsequently are more likely to be associated with higher quality learning outcomes. In comparison, transmission or teacher-focused approaches are more likely to result in surface approaches to learning, which are perceived by students as lower quality teaching. Stes *et al.* (2014) explore not only teachers' approaches to teaching but seek to understand the personal and contextual factors that help to explain why teachers teach as they do. They assert that decisions in

relation to the selection of approaches to teaching are made in light of multiple factors, which include the individual, and their prior education and present an evidence-based framework that seeks to contribute to a better (theoretical) understanding of differences in teaching approaches in Higher Education (Figure 2.5).

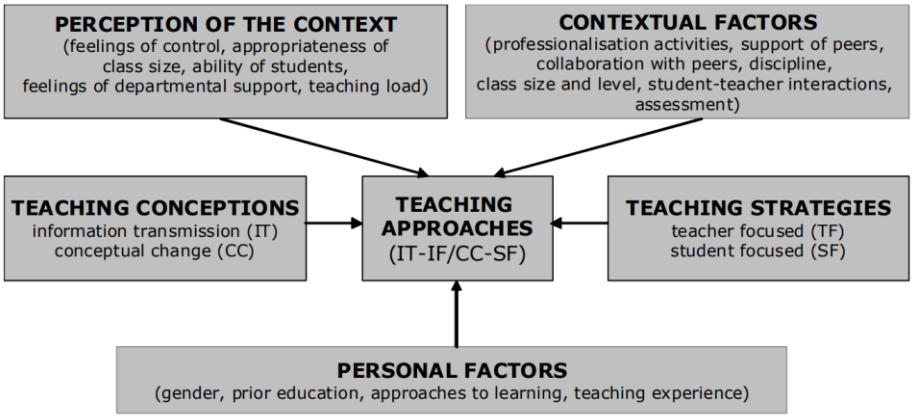

Figure 2.5
A holistic view on teaching approaches. Stes *et al*. (2014).

According to Prosser and Trigwell (1999), where teachers adopt a more student orientated approach to the delivery of teaching sessions, students adopt a deeper approach to learning, which in turn leads to higher learning outcomes, increased learner satisfaction and teaching perceived by students as being of a higher quality (Figure 2.6). Conversely, where content-centred and teacher focused approaches to teaching are adopted and teaching is presented as the transmission of information, student engagement has been shown to be lower, with learners adopting surface approaches to learning (Prosser & Trigwell, 1999; Trigwell & Prosser, 2004) and the teaching is perceived to be of a lower quality.

Table 1 Classification of conceptions of teaching among students

1 Knowledge-centred		2 Teacher-centred		3 Student-centred	
1.1 Knowledge	1.2 Application	2.1 Scholarship	2.2 Personality	3.1 Communication	3.2 Activity
Right knowledge	Practices	Clarity	Inspired	Safe	Students can participate
Transmission	Example	Organisation	Enthusiastic	Contact	Help in learning
Right answers		Planning	Motivated	Discussion	Help to find the facts
Right facts		Flexibility	Positive attitude	Makes you ask	Consider students
		Material	Style to present		Student-centred
		Pedagogy	Charisma		Different learners
		Language			Right level
		Repetition			Feedback
		Take care of, give help to, give time to understand			Checking the learning
		Shows the entity			
		Makes one think			

Figure 2.6
Classification of conceptions of teaching among students. Trigwell and Prosser (2004).

They also found that teachers in possession of sophisticated conceptions of learning and teaching see teaching as a *'whole'*, whereas those teachers with less sophisticated conceptions see only the parts. Interestingly those with the lowest sophistication could explain their understanding of teaching, but not always what they meant by learning. There was a strong correlation between teacher's conceptions of teaching and their approaches to teaching and while there was a correlation between conceptions of teaching and conceptions of learning, this was not as strong (Trigwell and Prosser, 1996).

2.6 The concept of pedagogical content knowledge

In his work Shulman (1986, 1987), established the concept of Pedagogical Content Knowledge (PCK), which is the integration (or synthesis) of the teacher's Pedagogical Knowledge (PK), combined with their Subject Knowledge (SK), describing how teachers relate their pedagogical knowledge (what they know about teaching) to their subject disciplinary knowledge (what they plan to teach). According to Shulman (1986,

1987), PCK is a special type of knowledge that is unique, that only teachers have and is the process where a teacher transforms specialist knowledge of their subject discipline into content suitable for effective pedagogical dissemination. PCK fosters an understanding of subject knowledge for students that makes it comprehensible for others (1987:9). What is unique about the process of teaching is the teachers' ability to transform their subject knowledge into material for teaching (Shulman, 1986). This transformation occurs as the teacher critically reflects upon their knowledge, and through interpretation finds ways to represent the information to the learner, often on many levels, tailoring the material to ensure equity of access for all learners.

PCK is highly specific to the concepts being taught, and it is much more than just the transference of subject knowledge alone. Gudmundsdottir and Shulman (1987) describe this transformation process as *'a continual restructuring of subject matter knowledge for teaching'* and within the context of science teaching Buchmann (1984:21) discusses the importance of maintaining a *"flexible understanding"* of the subject knowledge in order to see a specific set of concepts from a variety of viewpoints depending on the needs and abilities of the students. PCK develops over time, and according to Wilson (1992) the '*more experienced teacher'* is likely to have a better overarching view on which to base teaching decisions, than new teachers, even those with substantial subject knowledge (Grossman *et al*. 1989; Grossman, 1990). In their comparative analysis of Mathematics teachers' development of PCK, Kleickmann *et al*. (2013) explored the distinctions between CK and PCK, viewed respectively as teacher's understanding of the subject matter taught and the knowledge needed to make subject matter accessible to students, and concluded that *"this knowledge is at the heart of their professional*

competence" (2013:91). Although it is worthy of mention that there is no solution within the literature offered as to how exactly this process comes about.

Specific to STEM, research has shown (Bell, 2016) that teacher's knowledge of STEM education, their understanding, and pedagogical application of knowledge is intrinsically linked to the subsequent effectiveness of STEM delivery. Where a teacher's subject knowledge and understanding are deficient, the potential for pupil learning is limited (Rockland *et al.* 2010), resulting potentially in poor teaching where the impact on pupil progress may be severe (Barber & Mourshed, 2007). Findings from previous studies (Penuel *et al.* 2007; Bell, 2016) suggest that a teacher's perception of STEM, their personal knowledge, and understanding of that knowledge, to the effectiveness of STEM delivery within their own professional practice.

2.7 Teachers' Standards' and disciplinary knowledge

Within England and Wales, pre-service teacher's achievement is measured against a prescribed set of teaching competencies known as the *'Teachers' Standards'* (Gov.uk, 2011). Because of the way teaching competencies are used to assess teacher education programmes, there is less focus on the development of subject knowledge and more on the acquisition of generic core-competences. In practice the standards drive how teacher training is organised and as an approach, the requirement to meet a single set of standards, irrespective of the age phase or subject suggests that there is only one route to successfully secure the *'professional identity of a teacher'.* In their studies of Mathematics teaching, Hill *et al.* (2008) and Ball (2003), suggest because of the

adoption of this holistic, competence–based model of pre-service teacher education *'faith in knowledge*' has been lost.

In developing strong identities as teachers and in order to support their students learning, those training to teach must acquire a *'deep understanding of the cognitive and motivational principles of learning, teaching, and assessment'* (Paris & Winograd, 2003) and to do this effectively they must have a solid foundation of subject knowledge from which to draw. Ultimately the onus rests on the pre-service teacher to be proactive and take charge of their own learning (Lewin & Stuart, 2003), however under the current standards, the shift in focus away from subject toward a generic set of core teaching competencies has served to place less emphasis on the importance of content knowledge and more on the development of generic teaching skills such as learning to learn, and other personal attributes including attitude, and self-regulation (Leat *et al.* 2012).

This is in stark contrast to the heavy weighting of subject focused criteria in operation at the turn of the century, when commentators (Dembo, 2001; Randi, 2004) proposed that teacher education programmes should consider the development of other skills including classroom management.

With respect to subject knowledge, several studies have shown that beginning teachers (pre-service, newly and also recently qualified) have inadequate or superficial levels of pedagogical content knowledge (Gudmundsdottir & Shulman, 1987; Shulman, 1987; Carpenter *et al.* 1988; Feiman-Nemser & Parker 1990) and according to Carpenter *et*

al. (1988), pre-service teachers often rely upon subject matter extracted directly from the curriculum without modification and without a framework from which to present the information. The pre-service (beginning) teacher also tends to take pedagogical decisions without being fully appreciative of their pupils' prior knowledge or having considered carefully the pupil's existing ability levels. Poor or inadequate pedagogical content knowledge has also been found to be related to factual and simple recall questioning by teachers (Carlsen, 1987).

These findings align with work conducted by Gess-Newsome and Lederman (1993), who found that pre-service teachers find it difficult to articulate the relationships between pedagogical ideas and subject matter. Similar studies also indicated that pre-service teachers have significant concerns about pedagogical content knowledge and as a consequence struggle with how to transform subject knowledge in a way that makes sense to the students they are teaching (Wilson *et al.* 1987). Within the secondary age phase, the possession of comprehensive subject knowledge is essential in providing pre-service teachers with a solid platform from which to build during their training. However, from the learner's perspective, in terms of meeting the required teaching standards very little emphasis (importance) is placed upon the development of this area. While in no way advocating a prescribed set of subject related competencies, to be attained in addition to the *'Teachers' Standards'* (Gov.uk, 2011), the obvious danger is that without any formal competency related check on disciplinary knowledge, theoretically an individual may gain a named (subject) QTS award with insufficient knowledge of that discipline. Rather than see-sawing between sets of teaching standards that favour one approach over another (i.e.: generic competencies versus knowledge specific), the interest of pre-service teachers would be best served via the adoption of a

set of standards that embrace a balanced approach, where the holistic development of a full set of competencies can be developed equitably.

2.8 Contextualising STEM within the English National Curriculum

Within the curriculum there is an assumption that some subjects are more valuable than others (Robinson, 2011; Bleazby, 2015; Breslin, 2016), and within the National Curriculum of England the STEM disciplines the subjects of Mathematics and Science are held in higher esteem than Design and Technology, and to a lesser extent Computer Science. The reasons for this are complex, and to further contextualise each individual STEM subject discipline, this section presents the background and outlines the position of each within the English national curriculum including reference to teacher training scholarships, funding and Subject Knowledge Enhancement (SKE) bursary payments.

2.8.1 Mathematics

Introduced into the English national curriculum following the 1988 Education Reform Act as a core (compulsory) subject Mathematics is a discipline *"that has been developed over centuries"* (DfE, 2014).

As a discipline, globally, Mathematics is perceived as indispensable and is elevated above other subjects in terms of hierarchical academic importance (Bleazby, 2015). At the very heart of STEM, mathematics' status is evidenced within the national curriculum by its position within the EBacc (DfE, 2016a), where it is a *'double-weighted'* (DfE, 2016b) and as such attracts a significant proportion of curriculum time.

The subject's status is further evidenced with respect to funding for teacher education. As one of the most difficult secondary age phase subjects to recruit to, currently PGCE tax-free bursary payments of up to £22,000 are available, with an additional £10,000 tax-free early career payment upon completion of training (DfE, 2017).

2.8.2 Science

Similar to Mathematics, as a discipline within the English National Curriculum, Science (Biology, Chemistry and Physics) is perceived as academically strong and attracts a significant amount of time within the school curriculum.

Science is a core subject within the EBacc (DfE, 2016a) and for those seeking to train as teachers, there are significant PGCE tax-free scholarship and bursary payments of up to £28,000 (DfE, 2017). In addition to government funding (DfE, 2017), for those seeking to train to become Science teachers are also able to access further financial support from the subjects affiliated associations, for example the Institute of Physics (IOP). Furthermore, through the subject's professional associations (for example the Association for Science Education and the Science Learning Partnership (STEM.org.uk)) further funding to support and enhance learning opportunities, both within and beyond the school curriculum, is available.

2.8.3 Computer Science

Having fallen into *'disrepute'* (Cellan-Jones, 2014) Information Technology (IT), or as it was otherwise known Information Communication Technology (ICT) was replaced

by Computer Science as a newly established subject within the English national curriculum in September 2014 (DfE, 2013).

Devised in a bid to move away from what was perceived as an undemanding course (IT focused predominantly upon knowledge of fields and databases) in contrast the new subject has been designed to develop a rigorous depth of knowledge within young people, that align with the fundamental principles of abstraction, logic, algorithms, and data representation (DfE, 2013a). However, some ICT teachers believe that the allegations were too harsh, and the speed of the change too hasty, which has served only to *"push the subject of computing even further down the pecking order"* (Cellan-Jones, 2014).

Recent reports (The Royal Society, 2017; Wakefield, 2017) present a bleak picture of Computer Science education in England giving an indication that this has indeed been the case. Currently only 68% of teacher recruitment targets are being met and only one in two schools are able to offer computer science at General Certificate of Secondary Education (GCSE). *"Computing education across the UK is patchy and fragile"* and there are significant concerns about how the lack of computing expertise will affect the future workforce (The Royal Society, 2017:6). However, while the change was swift, and the difficulties created are without dispute (The Royal Society, 2017; Wakefield, 2017), taken from the perspective of STEM the re-branding of Computer Science has raised the subject's status and the discipline is subject to significant investment from both the government and industry (DfE, 2015; Gibbs, 2014, 2017). In addition to funding for those already qualified to teach, significant investment has been made to

encourage the recruitment of new teachers, with hefty PGCE tax-free *'train to teach'* bursary of £28,000 available (DfE, 2017). Furthermore, there are calls for the new discipline's inclusion as a core subject within the EBacc, which if successful would serve to further increase the importance of the subject within school.

From the perspective of pedagogy, Computer Science presents a unique perspective. As a new subject pedagogical research is limited which presents both challenge and opportunity for those learning to teach Computer Science, who are in the unique position of being able to influence pedagogy, while not having any experience of having studied it themselves in school.

2.8.4 Design and Technology

As a discipline Design and Technology was established over 25 years ago, created originally as a vehicle for the practical application of Mathematics and Science (DES, 1988). However, whilst Design and Technology has much to offer in supporting the effectual development of STEM literacy, as a subject in its own right, its potential has not been fulfilled. As a subject, Design and Technology is often marginalised, and has constantly struggled to keep a foothold within the national curriculum (Bell *et al.* 2017). Paechter (1993, 1995) asserts that as a discipline, Design and Technology, occupies a lower status than its STEM counterparts because of its origins in manual labour and the subject's vocational origins would most certainly appear to be a factor (Bell, 2016).

Irrespective of the reason(s) as to why Design and Technology is not viewed as being of equal status with Mathematics and Science (Benken & Stevenson, 2014), this

disciplinary difference is evident both in the curriculum (by the exclusion of Design and Technology from the EBacc (DfE, 2016a)), and in the significantly lower teacher training bursary payments available to those seeking to train to teach (DfE, 2017). Currently the training bursary for those seeking to qualify to teach Design and Technology is a maximum of £12,000 for those holding a subject related first-class honours degree.

2.8.5 Undergraduate teacher training bursaries

In addition to the teacher training bursary payments for those following PGCE routes into the classroom (DfE, 2017), for those undertaking undergraduate programmes that lead to the award of QTS additional funding is available. For those following Computer Science, Mathematics or Physics (opt-in courses only) funding of £9,000 is available (DfE, 2017).

2.8.6 SKE payments

Subject Knowledge Enhancement (SKE) courses are in place to support teacher recruitment and are offered to suitable candidates who have expressed an interest in teaching, but who, at the time of application or training do not hold enough knowledge of the subject they are seeking to teach. SKE courses are fully funded by the government, and candidates may also be eligible to receive a specific tax-free training bursary of £200 per week, for up to 28-weeks. In relation to the requirement to complete a SKE course the DfE (2017) offer the following guidance:

- your degree wasn't in your chosen subject, but is closely related,

- you studied the subject at A level, but not at university,
- you have relevant professional experience, and an SKE course would show you how to apply that to the curriculum and your teaching,
- you would benefit from a short refresher course in your chosen subject.

Subject Knowledge Enhancement (SKE) courses (DfE, 2017).

For those training to teach one of the STEM subject disciplines considered within this study (Biology, Chemistry, Computer Science, Design and Technology, Mathematics and Physics) SKE bursary payments are available. Unlike the PGCE bursaries, SKE payment levels are equitable, irrespective of the SKE course undertaken.

2.8.7 Teacher recruitment and retention

The previous sections of this study provided specific detail of the financial incentives in place to support teacher recruitment. However, after successive years of significant financial incentives designed to attract new teachers into the profession, especially those training to teach STEM subjects, year on year statistics show the consistent under-recruitment of secondary age phase subjects trainees in England and Wales against the government TSM targets (Cater, 2017; NAHT, 2017).

While governments should be mindful of teacher attrition and be prepared to implement strategies to attract new teachers into the profession, according to MacBeath (2012) they must also devise strategies that serve to retain teachers and in doing so secure an experienced teaching workforce.

2.9 Disciplinary differences

Building upon the review undertaken thus far in this section I explore the differences between each individual STEM subject discipline, which within the context of this review are explored in order to understand:

- What (if any) are 'disciplinary differences'?
- What impact (if any) do these differences have on the pre-service teachers learning, and their teaching (pedagogy)?
- What impact (if any) do these differences have on the pre-service teacher's efficacy and their sense of self particularly as identity forms?

In seeking to advance understanding in relation to the questions posed, the literature reveals several disciplinary differences between the STEM subjects (as defined within the context of this study) and these are explored under the following sub-headings:

- Approaches to teaching
- Subject status
- Engendered approaches to the delivery of STEM

2.9.1 Disciplinary differences: Approaches to teaching

It is widely acknowledged (Trigwell & Prosser, 1996; Prosser & Trigwell, 1999; Lindblom-Ylänne *et al.* 2006; Stes *et al.* 2014) that the pedagogical approaches associated with the well-established disciplines of Mathematics and Sciences tend to be more *'teacher-focused'*.

Utilising the Approaches to Teaching Inventory (ATI), Prosser and Trigwell (1999) found that lecturers working within the traditional, long established subjects of Mathematics and Science, defined by Biglan (Biglan, 1973a, b) as *'hard-pure'* disciplines where pedagogical approaches tend to be more teacher-focused scored significantly lower on the student-focused scale of the ATI, than those teachers working within subjects considered to be *'soft'* disciplines, such as history and education (Trigwell & Prosser, 1996; Prosser & Trigwell, 1999; Lindblom-Ylänne *et al.* 2006; Stes *et al.* 2014). These findings align with Lueddeke (2003) who found that teachers of those subjects classified as *'hard'* disciplines are more likely to adopt content-focused (teacher-centred) approaches to teaching that focuses on the memorization of facts within lesson delivery (Virtanen & Lindblom-Ylänne, 2010), whereas teachers from *'soft'* disciplines (within which Design and Technology resides (Bell, 2016)), took a more student-centred approach to teaching, with learner focused approaches linked to the variable conceptions of learning, with an emphasis on personal growth and intellectual breadth. These findings are echoed by Trigwell (2002) who in his study of design and physical science teacher's approaches to teaching found that those delivering the design-based subject were more likely to adopt student-centred approaches than their science teacher counterparts.

However, there is limited research to indicate which pedagogical approaches are adopted within the newer curriculum subjects of Computer Science and Design and Technology. Furthermore, limited literature prevents the emergence of a clear picture of the impact disciplinary difference have on the formation of a pre-service teachers' identity. Within Design and Technology, because of the practical and problem-solving

nature of the subject content, it is associated with student-focused pedagogies (Davidson *et al.* 2002). However, as an embryonic subject within the secondary school curriculum (DfE, 2013), Computer Science pedagogies are still evolving, and because it is so new, those currently training to qualify to teach it in secondary age phase schools in the UK have not themselves experienced it as pupils.

Although a fledgling subject within the English national curriculum (Cellan-Jones, 2014), as a discipline Computer Science is shown to fall within the *'hard pure'* territory of subject knowledge (Biglan 1973a, b). Within the context of STEM education, this is important because research to explore the subcultures that exist between Design and Technology and its associated STEM curricula counterparts (Bell *et al.* 2017) show that in contrast Design and Technology does not sit within the 'hard-applied' disciplines. Hence when compared to Computer Science, Mathematics and Science based upon the predictions of research (Prosser and Trigwell, 1999; Lueddeke, 2003) is likely to exhibit significant difference with respect to pedagogical approach.

2.9.2 Disciplinary differences: Subject status

Within the UK, the hierarchal status of academic disciplines, and what defines valuable or legitimate knowledge within the school curriculum results from a well-defined, long established body of knowledge, which according to Bernstein (1971a, b), remains consistent over time. This results in the curriculum domination by subjects perceived to be more *'academic'* than others. This assertion resonates with Paechter (1993) who states that as a STEM subject discipline Design and Technology has a lower status than its counterparts because of its origins in manual labour, and because technology-based

subjects are understood as *'subjects which had a history of being of low status, non-academic'*, and aimed mainly at *'less able'* working-class students.

Considering the STEM subjects within the context of the classification and hierarchal status of academic disciplines, there are clear sub-cultures that exist between the STEM subjects. With the well-established curriculum disciplines of Mathematics and Science being of a higher status (evidenced via their inclusion in the EBacc) than their counterparts of Computer Science, and Design and Technology.

But what does this mean for those pre-service teachers training to teach in these disciplines? In financial terms, the difference is significant. With larger tax-free training bursaries available to those studying Mathematics and Science, it would seem feasible that those pre-service teachers in receipt of lower bursary payments may question the equity of their status as a teacher in training.

Aside from the financial implications, some pre-service teachers may experience difference in training opportunity due to variation between each STEM subject's status; for example, via access to funding for additional learning resources, variance in class size, or access within the learning environment to newer facilities and equipment.

In practical terms, from the perspective of the pre-service teacher, one may speculate that over time once in *'the job'*, the higher status of Mathematics and Science with access to better resources and more curriculum time, may impact change on an

individual's identity. Furthermore, those training to teach the STEM EBacc subjects may have access (in the longer term) to improved employment opportunities.

With respect to pedagogical approaches, according to Paechter and Head (1996), pre-service teachers training to teach subject disciplines that are perceived to be of lower status tend to locate their professional identities within general (teaching) approaches, rather than within subject specific pedagogies.

2.9.3 Disciplinary differences: Engendered approaches to the delivery of STEM

Deconstructing educational discourse from a feminist viewpoint, Paechter (2002) explores the school curriculum through an engendered perspective. Explaining hegemony as *'thinking as usual',* from Paechter's perspective this explains the unquestioned approaches to the delivery of subjects within education. Hegemonic views may be defined as how a dominant class or group maintains control through the use of language and actions which perpetuate the status quo. Because hegemonic views are so heavily embedded within education, they appear to be *'common sense',* hence anything that challenges the hegemonic perspective seems to be quite *'odd'*. Engrained with deep-rooted hegemonic attitudes that sustain unquestioned approaches to the delivery of subject disciplines, particularly mathematics and science, control is maintained through approaches to teaching which serve to marginalise girls.

Within this context, exploring the use of Prosser and Trigwell's (1999) Approaches to Teaching Inventory (ATI), Nevgi *et al*. (2004) found that there were significant engendered differences between men's and women's approaches to teaching. In their

study men scored significantly higher than women on the teacher-focused approaches and in a similar study undertaken utilising the VanTilburg / Heimlich Teaching Style Preference Inventory (cited in Heimlich, 1990), Lacey *et al*. (1998) reached similar findings when questioning university lecturers about their preferred teaching styles. Studies identified differences and found that male teachers preferred to utilise teacher-focused approaches (involving teacher control), while female teachers preferred to adopt flexible, open student-focused pedagogical approaches (Prosser & Trigwell, 1999; Nevgi *et al.* 2004). Stes *et al*. (2014:25) conclude *"earlier studies from various countries show an influence of gender on teaching approach, with women being more inclined than men to adopt an approach focusing on the student".*

Within the context of this study, considering the subjects under investigation are disciplines which are perceived to be *'masculine'*, it would be foolish to overlook an investigation into the influence potential engendered differences may have upon the formation of the pre-service STEM teachers' professional identity, and in particular the differences in pedagogical approach between male and female teachers. While generic pedagogies are utilised across a breadth of subject disciplines, it is acknowledged that teaching style varies depending upon the subject taught (Norton *et al.* 2005) and that there are distinct pedagogical practices adopted to support the effective delivery in order to enhance student learning, specific to an individual discipline (Lindblom-Ylänne *et al.* 2006). However, research shows that within the long-established subjects of Mathematics and Science, which are located in the *'hard-pure'* territories of knowledge (Biglan 1973a, b), pedagogical approaches tend to be more teacher-focused (Trigwell & Prosser, 1996; Prosser & Trigwell, 1999; Lindblom-Ylänne *et al.* 2006; Stes *et al.*

2014). This has potential significance for female teachers training to deliver STEM subjects.

Sutton and Wheatley (2003) explore the difficulties experienced in introducing new teaching strategies and for the novice pre-service teacher, where their pedagogical approaches are in conflict with the expectations of their academic colleagues', this may generate unforeseen obstacles; particularly, in light of the research (Nevgi *et al*. 2004; Stes *et al*. 2014) that highlights engendered differences with respect to pedagogical approaches. For example, in developing pedagogical skills, those training to teach the high-status subjects of Mathematics and Science may be encouraged to draw more heavily upon traditional teacher-focused pedagogies, associated with intellectual and academic rigour, because of preconceived expectations of how best to teach those disciplines. However, for female pre-service teachers of Mathematics or Science, in particular who may be *'encouraged'* to utilise traditional teacher-focused pedagogies within their emergent practice, this may lead to conflict if their natural tendency is toward a student-focused approach; internally within themselves, as they negotiate their own values and beliefs, but also externally as they manage the expectations of mentors and departmental colleagues. For those pre-service teachers with strong approaches to their professional development, these circumstances would likely prove testing and perhaps provide a platform from which to grow, however for those who adopt *'surface'* approaches to their own learning, have low self-regulation, and low confidence, opportunity for development will likely be limited.

2.10 Chapter summary

The purpose of this review was to synthesize different materials, summarizing key aspects of existing literature (within the context of my research) in order to explore areas to be addressed with the specific purpose being to illustrate how through further study the literature could be extended, leading to an informed judgement of what needs to be investigated and why (Cohen *et al.* 2018).

Having identified three key areas a review of each revealed several additional areas worthy of investigation. For example, 'identity' expanded to include additional literature appertaining to emotion, and how pre-service teachers manage their expectations which then subsequently linked to the literature around efficacy and self-regulated learning. Learning and teaching included reference to work-based learning that occurs within professional practice, and the potential impact of teacher anxiety on learners. Subject knowledge moved to explore pedagogy and the disciplinary differences between the STEM subject areas.

Having explored each theme, selecting literature I believed would help shape my thinking, I was able to identify gaps which I recognised with further study would expand upon the existing body of knowledge within the field and through my research would enable me to make new and original contributions to knowledge.

3.0 Chapter Three

3.1 Methods and methodology

Having laid out the rationale for the study, to illustrate congruence with my methodological approach, this chapter outlines my ontological and philosophical position and presents a justification for my chosen research design.

Having set out my thinking behind the chosen theoretical framework (used to explore the research participant's experience of the phenomena under investigation), the work moves to describe the methodological approach, research methods, analytical strategies, and heuristic devices used to gather and analyse data during this study. Procedures and techniques utilised during the process of coding are clarified, including an outline of the role memo writing, situational mapping and integrative diagramming and the part they all played in supporting the analytical process.

The chapter then outlines how my personal ontology has influenced the research design, and the role self-reflection and reflexive writing has had in shaping my thinking and supporting my development as a writer and researcher. It demonstrates how the research has been designed to assure the rigor and quality of the data and the study itself, in terms of both data collection procedures, processes and all ethical aspects of this study.

Finally, having presented the study's rationale, this chapter summarises the research cohort, outlines the criteria for participant participation and describes the procedures that were adhered to during the process of data collection and transcription.

3.2 Presentation of self: Perceptions and objectivity

To ensure the integrity and rigor of the data collected, an awareness of how a researcher positions themselves in various roles during fieldwork is essential (Unluer, 2012). According to Glitrow (2014) this shows that the researcher has an awareness of being part of the process, as it is impossible to be *'a disembodied researcher'*.

The choice of method, and presence of oneself within the research, can and will shape the outcomes of the research. This perspective is echoed by Flick (2014:158), who maintains that a researcher cannot assume a neutral role when engaging with participants of any study during the process of data gathering. Personal beliefs are considered to have a profound influence on a researcher's analytical and interpretive practices and as a teacher educator, and a former secondary age phase school teacher, throughout this process there is awareness that in conducting this research it would be extremely difficult, if not impossible, to extricate personal theoretical beliefs, biases, and values. Therefore, rather than trying to '*bracket out*' my own perceptions (Beech, 1999) I sought to recognise assumptions and identify potential for bias in order to view the data from multiple perspectives.

I believe that research cannot be observed objectively from outside of a phenomenon, to be truly understood it must be observed from the inside, through the first-hand experience of those taking part in the research study itself. This belief aligns with the findings of Bonner and Tolhurst (2002), who conclude that an *'insider researcher'* is better able to understand the phenomena under study. Based upon my current and

previous professional roles, I must consider myself a partial inside researcher and as such, I am actively engaged in the co-construction of knowledge.

3.2.1 The role of reflexivity and self-reflection

The starting point for this study originated as a direct result of my personal involvement and experience of STEM education. As such from the outset, I was acutely aware of the potential to interpret data to produce findings that echoed my own preconceived perceptions and it is through this awareness that I maintained neutrality in both the research design and the interpretation of data.

During the process of textual analysis to help avoid any bias in my research I utilised strategies including the use of a research diary (as advocated by Charmaz (2006:36)), which helped me to chart the development of my own personal STEM philosophy. I also adopted the strategy of reflexive, self-reflective writing (Bryant & Charmaz, 2007; Alvesson & Sköldberg, 2017), which supported me to continually and critically shape and re-shape my thinking and as work progressed I became increasingly aware of significant shifts in my outlook.

Establishing, and being cognisant of, my personal ontological and epistemological positions has been fundamental, as these principles have shaped the design and structure of this study.

3.2.2 My Beliefs and Role as a Researcher

In research, the researcher uses many methods to establish the variance in participant viewpoints of the phenomenon under examination, and focuses on the meanings, trying to understand what is happening within the context, seeking opinions and subjective accounts (Charmaz, 2014). Within the context of this study, I sought to understand how pre-service teachers interpret and 'make sense' of their experiences, and in so doing construct meaning from them. I believe that learning is an active, not passive, process. It is a process whereby using reflection, pre-service teachers seek to make sense of their experience, which in turn leads them to create and construct their own new knowledge. This thinking aligns closely to a sociological tradition that emerged from Chicago University during the 1920s and 1930s, known as the Chicago school of sociology. The school fostered a belief that social life is emergent and determined by the dynamic relationship between action and interpretation. Ethnographic work undertaken at the time laid the foundations for methodological principles that spawned a rich tradition of symbolic interactionist qualitative research (Charmaz, 2014). In summary, this is a theoretical perspective that can be defined as being how humans act toward things based on the meanings they ascribe to those things, and this is an idea to which I subscribe and attest.

3.2.3 Ontology

Ontologically, I believe that reality is socially constructed, with meanings emerging and in turn being constructed from our engagement with the world around us. Epistemologically, my philosophy is that through our own unique, lived experience and

reflection on that experience, we construct our own individual knowledge and understanding.

I believe that there are multiple perspectives of a single event and different people interpret that one instance of social phenomena in diverse ways (Berger & Luckman, 1967; Lincoln & Guba, 1985). Building on that premise, I believe that there is no single external reality or truth. I believe that an individual, based upon their experiences and their reflection on those experiences, constructs their own knowledge around any phenomena or event. I do not believe that individuals experience the same phenomena in the same way and, consequentially, I do not believe that meaning can be assigned or interpreted in the same way by different people in consideration of that shared phenomena. From this perspective, to ensure my personal philosophy aligned with the phenomena under investigation, I adopted a research approach, methodology and research methods that reflect my ontology.

3.2.4 Symbolic interactionism

As an approach, symbolic interactionism fosters an empathetic understanding of participants and their worlds (Bryman, 2015). It places emphasis on the symbolic meaning that people, individually or in groups, attach to an experience that influences their behaviours, rather than any external structural effects that might influence the way they may otherwise act. Derived from pragmatism, symbolic interactionism is a theoretical perspective that refers to the belief that people interpret their social world through their own interaction with it. Based upon their experience and their interpretation of the world, they subsequently create and then assign meaning to the

perceptions they derive from that experience (Blumer, 1969). Dewey (in McDermott, 1981) believed that humans are best understood in an interactive environment. Through the act of dealing with issues and challenges in a logical way, people interact with, and assign meaning to, an experience and it is through this process, because of their social interaction with themselves, others, and society, that meanings and understandings are developed, and people create their own constructed reality (Kuhn, 1962). From this perspective, the world is socially constructed, with the observer being party to what is being observed. There is, therefore, no single one true reality which exists *'out there'* (Mead, 1934). So, in turn, meanings arise out of action, and those meanings in turn influence further actions.

3.3 Research design, methodology, and methods: establishing a theoretical framework

In creating my research plan, I adhered to guidance advocated by Clarke and Braun (2013), Ernest (1994), Grix (2010, 2004), Pring (2000). Grix (2010) promotes setting out the relationship between what the researcher thinks can be researched, what is known about it, and how to go about acquiring it. He theorises that the reason for doing this is to be able to understand the impact one's own ontological position can have. Not only what is studied, but also to consider decisions that are taken with respect to how to study (Grix, 2004:68).

In designing my research, I devised a plan that allowed me to concurrently collect and analyse my data. This allowed me to use initial findings from one research phase to influence the direction and purpose of the next. As such, I structured my design to be

sufficiently flexible to capture, understand and interpret the meaning behind the participants' perceptions (Black, 2006), rather than to predict or explain them.

To support the articulation of my research design Figure 3.0 presents a visual interpretation of each phase of my research design.

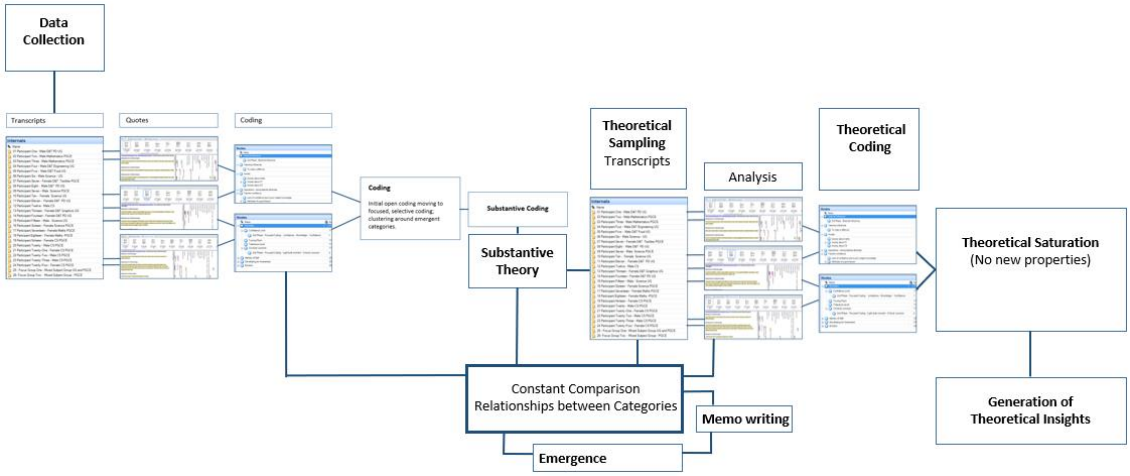

Figure 3.0

Visualization interpretation of the research design.

3.3.1 Methodological approach and research methods

This study adopts a non-dualist perspective, where the meaning assigned to the phenomenon under study is because of the individual's relationships between their experience, their perception of that experience, and how in turn it informs and influences their current situation.

In this chapter, I expand upon my methodology, and explore in detail the rationale behind my chosen research methods. In the selection of those methods my aim was to:

- Establish a rigorous but flexible system of research that supported the concurrent gathering and analysis of rich data
- Establish a system that considers both the participant and researcher reflexivity, and the influence this may have in deriving the data set
- Provide in-depth analysis of the data sets to conduct concurrent data gathering to identify subsequent research phases, discuss and support dissemination of the work under investigation.

3.3.2 Constructivist grounded theory

The method selected for this study is one informed by constructivist grounded theory, which is regarded by many (Charmaz, 2008; Aldiabat & Le Navenec, 2011) as the most suitable methodology for uncovering the meanings individuals' may make about particular social situations or about the environments in which they operate. Because of this focus, grounded theory has close methodological attachments to exploring the symbolic interpretations of peoples' behaviour. Hence grounded theory data gathering, and analysis methods were adopted specifically to establish the symbolic meanings pre-service teachers have about aspects of their emergent practice.

In research, the positivist researcher seeks to explain social phenomena, while the interpretivist researcher seeks to understand it. Within the positivist form of grounded

theory, the researcher sits outside of their research and is *'detached'* from the data and the social context within which it is emerged.

In practice, this disconnects the researcher from both the data and their research participants and in doing so assumes that all data is *'real'*. Therefore, in this study, to ensure congruence between my ontological and epistemological position, I rejected the positivist approach and instead I opted to explore an interpretivist form of qualitative research enquiry, underpinned by an interpretivist qualitative epistemology.

3.3.3 The origins of Grounded Theory

In its original form, grounded theory method (Glaser & Strauss, 1967) commonly known as *'classic'* or *'Glaserian grounded theory'* (Charmaz, 2014), is an inductive methodology, defined as *"the discovery of theory from data, systematically obtained and analysed in social research"* (Glaser & Strauss, 1967:2). In its original form (Glaser & Strauss, 1967) grounded theory emphasised concept generation from data without recourse to prior theoretical knowledge using an inductive methodology. Bryant (2002) suggests that grounded theory is not actually a theory but a research method that produces or generates theory which is grounded in the data. Since its introduction many derivatives from the original method defined by Glaser and Strauss (1967) have emerged, with many centering on variance in data coding procedures (Strauss & Corbin 1990; Charmaz, 2006; Bryant & Charmaz 2007; Corbin & Strauss 2008). Included in these varieties are those derivations that introduce additions to coding families (Glaser, 1978, 2005).

However, the event which arguably had the most significant impact on the evolution of grounded theory, occurred in 1990 when Strauss advocated axial coding in favour of the traditional theoretical coding techniques, which according to Glaser created *'forced data'* (Urquhart, 2013).

In contrast, constructivist grounded theory acknowledges the use of the researcher's prior knowledge and experience of the research setting and theoretical notions gained primarily from literature, which may be used to inform the direction and outcomes of data analysis. In constructivist grounded theory, both inductive and deductive theory generating procedures are considered. According to Starr (2007:79), grounded theory is an excellent method for understanding *'invisible things'* and Charmaz (2006, 2014) describes how the adoption of this approach ensures that theoretical concepts are constructed, rather than being discovered. This conceptual construction also explains how a researcher's biographic and reflexive relationship to data generation can influence research outcomes.

In practice, this approach means that theoretical frameworks derived from a review of literature and other sources can be used to orientate research design and analysis. Within the abductive methodology supporting the problem-solving process, it helps the researcher to explain new ideas. Reasoning begins after scrutiny of the data and all possible deviations are considered. As a hypothesis emerges, following further analysis and / or the addition of more data, the hypothesis either confirms or disconfirms a theory for the researcher to present the most conceivable interpretation of the observed data.

3.3.4 Abductive methodology

'Abduction' is a process where to develop the strongest hypothesis, empirical findings are tested against new, emergent data and are linked to create new theory in order to make it understandable and to explain *'what is going on'*. Referring to abduction as a *'creative leap'*, Peirce describes the abductive process as putting things together in new ways (Peirce in Anderson, 2013:17). This contrasts with induction, which is concerned with extrapolating patterns and drawing generalisations from the research data to generate new theory, or deduction, where reasoning starts with a hypothesis and seeks to verify a preconceived theory or concept rather than allowing one to emerge through analysis of the data. In my study, an abductive methodology has been adopted because it encourages the researcher to consider all possible theoretical outcomes. In practice, utilising heuristic devices, I employed abductive reasoning to make connections in and between the data. The rationale being to observe the emergent theory and seek the most likely explanation for it, using this interplay to build and refine categories.

3.3.5 The notion of reflexivity

An advantage of adopting an approach informed by constructivist grounded theory is the notion of reflexivity (Charmaz, 2006; Finlay & Gough, 2008; Alvesson, 2011; Alvesson & Sköldberg, 2017). Put simply, this approach takes account of the reflexive and biographical stance of the researcher and acknowledges that contextual factors contribute to the way in which social knowledge can be described. Knowledge is believed to be constructed between the researcher, and those being researched. In her work Charmaz (2014) describes how theoretical concepts are constructed, rather than being discovered, and goes on to explain how the researcher's biographic and reflexive

relationship to data will influence research outcomes (Charmaz, 2006, 2014). In practice, this means that theoretical frameworks derived from the literature may be used to orientate research design and analysis. In my study, this offered significant benefit as, due to the notion of reflexivity adopted, it sensitised me to emergent issues within the data set.

Central to this approach is the constant iteration of the conceptual insights that emerge during analysis both within and between the data. This allows outcomes from each phase of the research to influence the purpose and direction of subsequent phases and in doing so generate theory, which is grounded in the data (Urquhart, 2013). Some commentators (Finlay & Gough, 2008; Alvesson & Sköldberg, 2017) attest that this reflexive stance helps make the researcher more sensitive to issues naturally occurring within the data set. Within this study this approach was selected because of its relation to the notion of reflexivity; the advantage being that that it supported theory building and allowed me to apply existing insights and experiences to the subject matter. In so doing, this made the research outcomes more applicable to the realities of the perceptions and experience of pre-service teachers.

3.3.6 Grounded theory: Controversies, myths, and my thesis structure

Urquhart (2013) explores some of the controversies and myths around the use of grounded theory as a research method, significant within the context of this study, as a failure to address it could lead to the accusation that the underpinning principles on which the data are analysed are uncertain.

Aside from the most common misconception that grounded theory is *'a theory',* rather than a research method, the second common misconception is that a grounded theory study is '*un-academic'* in some way (Urquhart, 2013:29). It is believed that this latter misconception occurs because in their original work (Glaser & Strauss, 1967:37) and later (Glaser, 1992:31) suggest that an in-depth review of literature should be avoided prior to undertaking the research to prevent stifling, forcing, or contaminating the data in any way.

Numerous researchers (McCallin, 2003; Andrew, 2006; Urquhart & Fernandez, 2006) have sought to address this issue. However, as Urquhart makes clear, a footnote in the original work (Glaser & Strauss, 1967:3) states that although grounded theory emphasised the generation of data without recourse to prior theoretical knowledge researchers were not expected to approach their work as blank slates. Rather the point being made was that research should not be undertaken to either prove or disprove, but it should be conducted with a mind open to the emergence of new theory.

Therefore, while adhering to an approach associated with constructivist grounded theory (Charmaz 2000, 2006), where the use of the researcher's prior knowledge and experience and theoretical notions gained from primary literature are used to inform the direction and outcomes of data analysis, I did not wait until the end of the study to undertake a review of the literature (Figure 3.1), and as such would refer to my research as a study undertaken and informed by grounded theory.

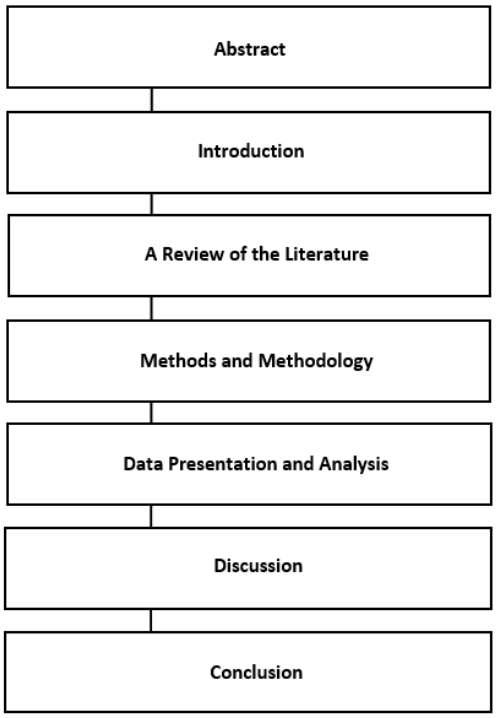

Figure 3.1

Thesis Structure.

3.4 Ethics and Ethical conduct: Assuring the quality of research

In this section, I give detail of how the quality assurance of my research has been considered in terms of ethical conduct, reliability, and validity. The academic ethical authorisation process undertaken prior to commencement of the study and how research participants were engaged, and their consent secured.

I present elements of my personal ontology and articulate specific considerations of the research design that were put in place to specifically help assure adherence to ethical guidance, appertaining to both the accuracy and consistency of my data collection, validity, reliability and the avoidance of researcher bias. This section then moves on to

explain the ethical strategies and procedures undertaken to ensure participant well-being, confidentiality, and anonymity.

3.4.1 Securing ethical approval

Prior to undertaking my research, ethical approval was sought and secured from both my own institution (where the majority of research was undertaken), and a secondary institution where the research was designed and formulated into a doctoral thesis (Please see Appendix A).

3.4.2 Informed Consent

The effective adherence to ethical practice and guidance rests on the principles of assuring the free and informed consent from research participants. Informed consent refers to the situation where *"subjects know and understand the risks and benefits of participation'* and that they understand that *'their participation is voluntary"* (Flynn & Goldsmith, 2013:10). In practice, this means that the researcher must ensure that appropriate measures for obtaining informed consent and permissions are in place and that participants' confidentiality is guarded to ensure they are protected from any harm that may ensue from their participation.

3.4.3 Securing participant access

Prior to engaging in the research, written informed consent was obtained from each participant. Each was informed about the aims and purpose of the study and potential methods of dissemination (including conference presentation and journal article publication) prior to their agreement to take part. Additionally, all participants were

informed that any involvement they had would be on a voluntary basis and that they would be free to withdraw from the study post-participation in accordance with the agreed timescales.

In line with the chosen methodology, concurrent data gathering occurred. This took the form of distinct research phases, which included an online pilot study, face-to-face interviews and focus group research.

3.4.4 Potential for bias within the research

Research undertaken did not involve the engagement of peers, co-workers, or colleagues I line manage, therefore issues traditionally associated with power relationships within research that may occur when researching within one's own work place did not apply.

The research cohort comprised of pre-service teachers undertaking a formal teacher training qualification. I was not engaged in any direct teaching or supervision of any of the participants engaged in the study, however theoretically there was potential for participants to view the position I held within my institution as being of influence and therefore someone who holds power. Mindful of this potential perception, I was aware that some participants might have sought to provide me with answers to my research questions they assumed I would have wished to hear. Therefore, to avoid any potential consequences where a participant may have inadvertently presented a refined reflective account of their experience, rather than their actual views and opinions, I adopted a strategy during interview to counter this potential skew in response.

During all interviews, once a participant had answered a question I actively sought clarification of their espoused theoretical response, by asking further questions designed to encourage them to expand upon their initial answer, by requesting examples of their perceptions in practice.

In conducting all interviews myself, whilst avoiding issues relating to inter-rater reliability, this approach has the potential for bias from the perspective of the researchers own ontological perspective. In line with the chosen research method, the co-construction of knowledge between the researcher and those taking part in the study was encouraged to support the development of theory. To counter any potential bias in this respect and to help ensure that outcomes were representative of the realities of the participants' perceptions and experience, at the end of the data collection phase a focus group was convened which sought to validate the emergent collective theory.

To further support the unbiased analysis of my research, as outlined within the next two sub-sections, I utilised a series of strategies to support the process of data analysis, transcription, and interpretation.

3.4.5 Theoretical sensitivity

In its simplest terms, within grounded theory, *'theoretical sensitivity'* refers to the process of taking a step back from the data. In practice, this meant taking a break to stop and look at the data with fresh eyes. I adopted this approach throughout my work as it gave me the opportunity to step outside of my work and reflect about *'what is really going on here?'* Through the adoption of memo-writing, diagrammatic memos, and

integrative diagrams, I maintained a healthy skepticism in relation to the analysis of my data affording me the opportunity to ensure that I was being truly analytical and reflective.

3.4.6 Memo-writing, diagrammatic memos, and integrative diagrams

As my research progressed, to support the interpretation, I adopted the process of writing theoretical memos to break apart the data and to support the process of sorting and exploring the properties and characteristics of my emerging categories.

According to Glaser (1998), memo writing is a pivotal intermediate step between the data collection and writing the drafts of papers. As a technique, memo writing provides a methodological link to the analytical interpretation of data that demands attention. Memo writing usually runs parallel to the second and subsequent phases in the analytical process as it helps to identify categories, properties and dimensions, helping to form interconnections to bridge codes that, in turn, support the process in building and constructing reflexive theories (Urquhart, 2013).

In practice, using the techniques of clustering and free writing to draw out the data meant taking an analytical break to stop and analyse ideas exploring the properties and characteristics of each emergent category. This process helped me ensure that my codes moved beyond those of mere description. In turn, this allowed for the drafting and re-drafting of discoveries in light of the ongoing analysis in order to bring fresh insights into the phenomenon being studied. This technique helped further analysis and through the process of sorting, I was able to conceptualise the data in a narrative form. This

helped me to capture ideas about my codes as they emerged and support the crystallization of meanings to form categories (Bryant & Charmaz, 2007:245). This highlighted anomalies that demanded attention (Star, 2007:87) and created compelling original arguments, developing plausible relationships between the emergent concepts and sets of data.

According to Strauss (1987), integrative diagrams, or diagrammatic memos, are useful tools that can be used to inspect emergent theories as they arise. In the simplest of terms, this is an integrative diagram which is an annotated sketch that may be created during analysis and the process of coding. Its purpose is to support and develop further thinking as the research progresses. In my own work, alongside memo-writing, I used diagramming extensively to support my thinking; to organize the flow of my work, to enable me to visually map the emergent data, coding, and categories and to visually see the relationships emerging between the categories (Please see Appendix B).

As a process, this technique helped me to begin to understand my thought processes and work in a truly reflexive way, especially when revisiting my data to add in new information. The diagrams made it very easy to see my research and make clear previously unseen connections. An additional advantage was that using diagrams to explain aspects of my research when speaking to colleagues aided their understanding; a mechanism that in itself further helped me to further shape and formulate my ideas.

3.4.7 Impartiality of thesis findings

Whilst research in this study was conducted within an aspect of my own practice, the focus did not emerge at the suggestion, or requirement, of my employer. Whilst my employer was supportive of the study, and during the initial stages made a small financial contribution, there was no requirement to report back or present the findings in any form.

3.4.8 Anonymity and confidentiality

To protect each participant's confidentiality and anonymity, robust procedures were adhered to. Assurances were given that dialogue would remain confidential and identities were concealed. Data was anonymised and in accordance ethical guidance outlined within described by British Educational Research Association (BERA, 2011), and all data was securely stored in a format that was not accessible to others.

3.4.9 Validity and Reliability; Researcher and research participant interaction

To establish a diverse and valid research cohort, participants were selected to ensure as wide a demographic range as possible. Careful consideration was given to ensure an even gender distribution between, and across, the STEM subject disciplines. English was the language of delivery used throughout the study. To help ensure consistent communication and interaction between researcher and research participants, I conducted all interviews and focus groups myself, therefore issues relating to inter-rater reliability with regard to linguistic interpretation was removed.

In accordance with guidance, research did not take precedence over the well-being of the participants (Smythe & Murray, 2000; Lankshear & Knobel, 2004). Interviews and focus groups took place in neutral spaces and occurred at mutually convenient times, so as not to be of detriment to my participants, their studies or professional placement activity. Following transcription, in order to clarify and validate the emergent data and to ensure accuracy, follow up email discourse occurred.

3.4.10 Safe storage of data

During all stages, data collection and safe, secure storage of audio recordings and transcripts was undertaken in accordance with the ethical guidance described by BERA (2011).

3.5 Methods of data collection

During my research, the following methods were used to gather data:

- An online (pilot) survey
- Semi-structured interviews
- Email discourse and electronic correspondence
- Validation focus group interviews

In designing my research, and in keeping with my chosen research methods, I recognised that it was important for me to ensure that I included a data collection mechanism that would allow me to concurrently collect and analyse data. By adopting an approach to the research design which had a series of distinct research phases, it was

possible to form emergent findings from my first research phase to set the direction and purpose of the next. This approach also facilitated the recognition of the need for me to undertake further theoretical sampling as necessary in the latter stages of the study. Table 3.0 presents an overview of each research phase undertaken during the study.

Research Phase	Sampling Technique	Number of Participants
Online pilot survey	Email	53
First phase interviews	Convenience moving to purposeful	20
Second phase interviews	Purposeful moving to theoretical	10

Table 3.0

Research phases, sampling techniques and participant engagement.

3.6 The Research Cohort

Within grounded theory data is collected and analysed concurrently and to gain access to *'good data'* within qualitative inquiry, Morse (2007) highlights the necessity to locate *'excellent'* participants in order to obtain excellent data and that sampling techniques must be targeted and efficient (Morse, 2007:227).

In line with my approach, to gain access to excellent data at each stage of the study I utilised a series of different sampling techniques to engage research participants. These are outlined within the subsequent sub-sections of this chapter, and in addition to Table 3.0, full demographic and biographical detail of research participants is presented within Appendix C, Figures C.0 and C.1).

3.6.1 Criteria for participant selection

The main criteria for selection was that at the time of their engagement participants were registered on, and active in undertaking a STEM subject discipline initial teacher training programme, leading to the formally recognised award of Qualified Teacher Status (QTS). This is the qualification needed for those seeking to secure employment within mainstream education (secondary schools) in England and Wales.

3.6.2 Locating participants: Convenience sampling

To locate participants for the pilot survey and initial phase of data collection, a method known as convenience sampling was used. This is a method, which according to Richards and Morse (2007), is the process of finding individuals who have experience of the phenomena under observation.

In practice, this meant deriving a research cohort from pre-service teachers currently engaged in teacher training. Having gained ethical approval I used two mechanisms to contact potential research participants:

1. Email correspondence to pre-service teachers studying in neighbouring institutions. This occurred via a third party (pre-service teacher's programme, course and subject leads), who were known to potential participants and forwarded the survey link.

2. Blackboard (the University's virtual learning environment) utilising the announcement tool using to approach potential participants within my own institution.

This approach yielded a sufficient number of pre-service teachers, across the full range of STEM subject areas to undertake the pilot survey and first phase interviews. According to Morse (2007), a common error at this stage is the researcher's failure to move beyond this initial sampling stage, with potential consequences being to risk:

- Ignoring variation within the experience, or within the sample
- Defining the phenomenon too narrowly, because of the lack of variation, and not scoping adequately to identify the boundaries.
- Terminate sampling too soon (premature closure) because no new data are emerging believing that saturation has been reached.

Richards and Morse (2007:237).

A unique feature of grounded theory is the concept of simultaneous data collection and analysis. Within my study, as soon as was possible after each interview transcription occurred and through analysis I began to explore the emergent theoretical strands associated with each participant. Clarke *et al.* (2016) define this process as situational analysis and it begins as soon as research and coding is undertaken. In my study, these initial findings were used to inform the direction and purpose of the next research phases.

As these early findings emerged, to avoid becoming stuck in unfocused data, I continued to bring new participants into the study and in so doing, the research moved into the second phase.

3.6.3 Identifying participants: Purposeful sampling

The second phase involved the collection of data from participants who were selected using a method known as purposeful sampling. This is also known as selective or snowball sampling, a technique which outlines a process whereby one research participant identifies additional, new potential future participants (Morse, 2007:235) who could potentially take part in the study.

During the second stage, purposeful sampling supported the selection of participants who were able to provide useful insights into the phenomena under study. During this phase, I was mindful to ensure the full range of STEM subject disciplines continued to be represented and to include an even representation of gender, and teacher education training routes.

At this stage an iterative process allowed more abstraction to occur between the groups of data, so that following the refinement of my initial codes and in the light of new data, through an iterative process of refinement in and between categories, new categories could emerge. Through this process some categories began to emerge more strongly than others, and I was able to begin to solidify the emergent theories.

3.6.4 Identifying participants: Theoretical sampling

During the final phases of my data collection, I utilised theoretical sampling to interview an additional group of participants (n=8). This is a technique utilised by Glasser and Strauss (1967), where a further group of participants are chosen to secure progress and support the refinement of research.

At this stage I had a very clear picture of my data and to further refine my categories I actively set out to select participants whose experiences could help validate my data and allow me to refine my emergent findings, so they could transition into fully formed categories. Theoretical sampling enabled me to continue gathering data and undertake subsequent analysis, which according to Cresswell (2013) and Seale (2003), adds both validity and reliability to the research outcomes. This process ensured that there were no new emergent categories and I deemed at this point that theoretical saturation had occurred.

3.7 Data Collection

Having laid out the phases of data collection, this section presents for analysis the data from each interview research phase.

3.7.1 The Online Pilot Survey

Prior to conducting the interview phases of my research, I undertook an online pilot study, the purpose of which was twofold. Firstly, to help validate the potential of my research findings within an international context, I wanted to assure myself that pre-

service teachers of STEM subjects from other countries held perceptions, beliefs and views that were similar to their counterparts in England and Wales.

Secondly, I used the survey as a pre-interview pilot to hone my research questions in advance of the face-to-face individual and group interviews.

Using an institutional online survey, I established the pilot survey, observing all the necessary ethical considerations. In securing participants for this survey, initial contact was instigated via personal email correspondence to colleagues engaged in the training of pre-service teachers in Europe, the United States of America (USA), Australia and New Zealand. To ensure I did not create an online survey completed by only students training to teach outside of England and Wales, I also circulated the survey link to colleagues delivering ITE courses in English and Welsh higher education institutions.

In total 53 participants responded to the online survey, with 17 returns obtained from countries outside of England and Wales.

Geographically responses were received from Europe (including England, Ireland, Scotland and Wales, Finland, France, Germany, Malta, the Netherlands and Sweden), Australia, New Zealand and The USA (Appendix C, Table C.0). Those respondents from England and Wales were pre-service teachers training in neighbouring ITE institutions.

Following interrogation of the data findings showed that irrespective of the participant's biographical background, or geographical location, there are no significant differences between the motivations of those training to teach outside of England and Wales, when compared directly to those training in England and Wales.

3.7.2 The participants

In total 30 pre-service teachers were engaged in the interview phases. Participants were divided almost equally in terms of gender and were selected to ensure a diverse range of personal qualities in terms of culture, religion, and age. This was done to encompass a breadth of past personal experience of schooling, and consideration was given to each participant's biographical background. The sample included participants with experience within and beyond the UK, with experiences of both public and private education, experience of boarding, free, state and academy status schools. A full breakdown of participant biographical data, including training route, STEM discipline, age and gender is presented within Appendix C, Table C.1.

To ensure all viewpoints were equally represented and subsequently captured participants were drawn from a range of ITE institutions and training routes leading to the award of QTS.

The majority of participants (n=26) were drawn from a pool of pre-service teachers training within the Faculty of Education at my home institution. To ensure diversity a small number (n=4) were students studying at neighbouring ITE institutions.

At the time of commencing this study, within my home institution there were almost one thousand pre-service teachers registered on courses leading to either a post or undergraduate secondary age phase teacher training qualification. Of these approximately three hundred were engaged in STEM subject teacher training.

Having responded to announcements on my institution's Virtual Learning Environment (VLE), and email communication via their subject leads 20 participants were selected via convenience sampling during the first phase of data collection.

At this stage, research was gathered via a series of semi-structured interviews or conversations with a purpose (Webb & Webb, 1932), which were conducted with questions designed specifically to encourage participants to be reflective about their experiences. This approach enabled the research participants to articulate their personal stories and convey narratives of their own experience-related beliefs. Interviews provided an opportunity to journey into another perspective, and through the process, participants were encouraged to reflect upon their childhood recollections as pupils in order to capture the participants' experience and the meaning they assigned to it through their interpretation and re-interpretation.

Participants were chosen for their ability to provide rich and varied accounts of their own experience (Geertz, 1973) and their ability to articulate how these experiences influenced aspects of their personal development as they trained to become teachers. In gathering data, procedures advocated by Charmaz (2000, 2006, 2014) and Kvale (1996), and the interview strategies outlined by Bowden and Green (2005):

- Identical opening questions, followed by a series of semi-structured questions.
- Other than to explore issues raised by the participants, there is no deviance from the structured interview sequence.

Utilising similar opening questioning to those posed via the online survey, initial questioning sought to ascertain the participant's biographical detail and sought to illuminate the participant's educational background and their motivation to teach, specifically their chosen STEM subject. When compared and cross tabulated directly with the findings from the online pilot survey, analysis of these questions and participant responses (specifically with respect to gender, age, subject discipline, training route or motivation to teach) demonstrated no statistical difference of any significance between responses.

Questioning then sought to explore the individual participant's perceptions of their learning, as experienced from their perspective as a pupil (or student). Participants were asked to speculate as to whether they would seek to teach as they were taught. Individuals were asked to discuss and to try to explain the meaning they had assigned to their experiences and the influence pleasant (positive) or unpleasant (negative) recollections of those experiences had on their developing identities as teachers.

Typically, interviews lasted between 25 and 45 minutes. Each was recorded using an encrypted device (on loan from my institution), and all data collected was transcribed verbatim**.** During the initial stage participants were selected via convenience sampling, and as the study progressed, participant selection moved from convenience to

purposeful sampling, with participants being selected for interview based on their potential to contribute specific information around the emergent themes to help build the data to create strong theoretical categories.

As this occurred analysis of the data moved from open coding to selective coding, and finally into theoretical coding (Figure 3.2). At each stage, further refinement of questioning was undertaken in order to ensure the most accurate and meaningful outcomes were deduced from the data being analysed.

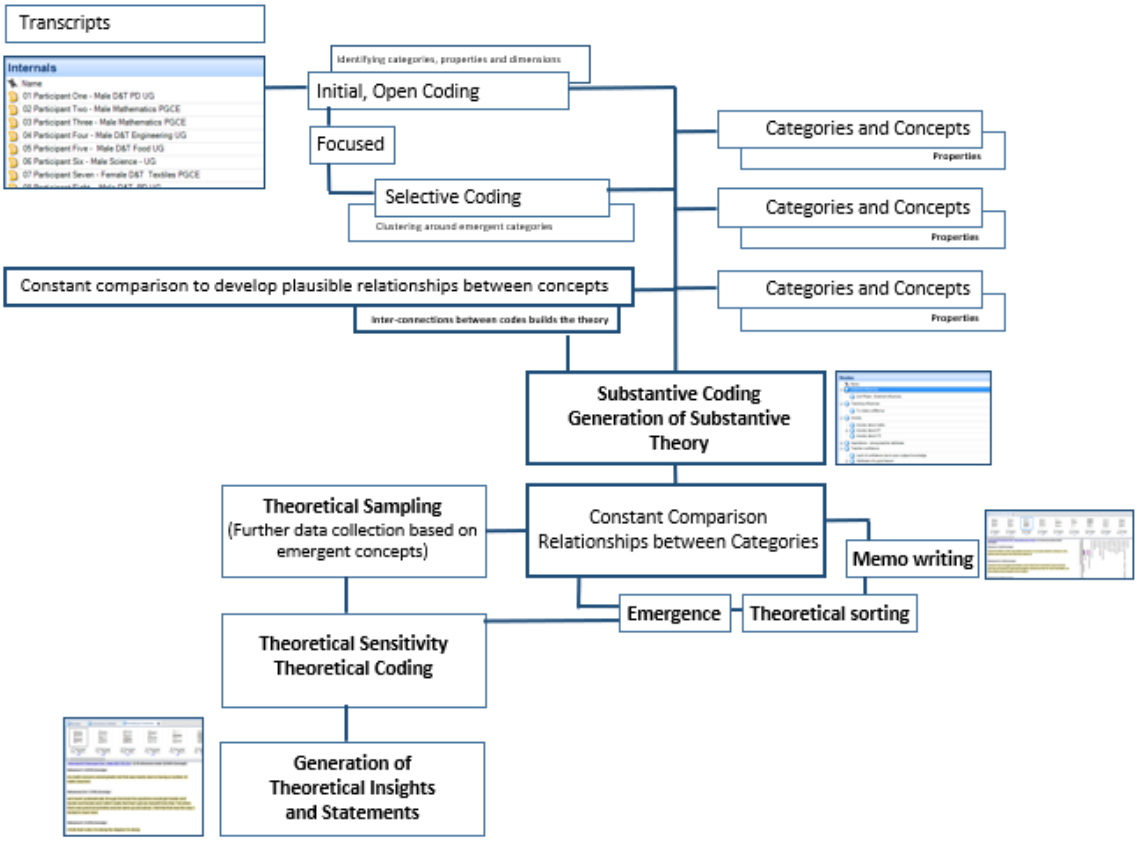

Figure 3.2

The process of data analysis and phases of coding.

3.7.3 Focus group interviews

To gain collective dialogue about my participants' experience (Bryman, 2004) it was my original intention to undertake simultaneous focus group interviews during the initial research-gathering phase. Utilising research to determine the optimum focus group sample size (Bryman, 2004) I drew together a focus group of eight participants. The group was split equally in terms of gender and mixed in terms of STEM subject discipline, so inclusive of Computer Science, Design and Technology, Mathematics, and Science.

However, following transcription of the first group interview, I realised that as an approach this method was less than successful in yielding the rich data I had originally anticipated. It proved difficult to steer the conversation without influencing what was being said and I also harboured concerns with respect to the concept of *'shadowed data'* (Morse, 2001), a phenomenon that can occur in focus groups whereby participants engaged in a group situation may elicit responses in line with those held by the group rather than voicing their own opinions, views and beliefs. Finally, when compared to the transcripts I had already gathered during the one-to-one interviews I found the quality of the data to be particularly weak.

To ascertain if a smaller focus group would yield higher quality of data I held two further focus group interviews, each with three participants. Following transcription, while the smaller groups were better (and hence yielded data that has been included for analysis) it became clear that as a strategy to gather rich data, the group environment was not as successful in eliciting a participant's articulation of their individual story in

any great depth or detail when compared to one-to-one interviews, and at this point, I ceased focus group interviews as a data-gathering tool.

As such, findings from the single larger focus group were discounted from the study; however, the eight participants were keen to continue their involvement and were subsequently interviewed individually.

3.7.4 Validation group interviews

While the focus group approach proved to be less than successful during the preliminary stages of my research, I had read about the advantages of focus group interviews as a tool for the effective validation of research outcomes (Morse, 2007:244).

During the final stages of my study two small validation group interviews were undertaken, the purpose of which was to present findings from my research, with the intention of further validating the outcomes. Engaged in this process of authentication were eight participants (two groups of 4 participants), which were split equally in terms of gender and STEM subject discipline, each of whom had been involved in generating the research data during earlier phases of the study.

Each focus group was held at a mutually convenient time and lasted for a little over an hour. The purpose was to present emergent theories to the group, and in doing so ascertain their perceptions of the study's findings.

3.7.5 Transcription

Following procedures advocated by Bowden and Green (2005), during transcription care was taken to accurately record participant responses to avoid misrepresenting the given meaning of their spoken words, so as not to influence any of the data by my own pre-conceived ideas or misinterpretation of their thoughts.

As soon as was possible after each interview, the audio recordings were transcribed verbatim with follow up email correspondence being used to confirm the authenticity of transcripts. During the process of transcription, each individual and focus group interview was anonymised prior to its importation into the NVivo analysis software package.

In undertaking my research, I conducted all the interviews and focus groups myself and therefore issues relating to inter-rater reliability, the method used to assess the degree to which different observers consistently assess the same phenomenon were not applicable. Similarly, I transcribed each interview and focus group recording, which proved useful as I could recall not only the way something was said, but also how it was said.

3.7.6 Discourse Analysis

When a person verbalizes their thoughts, often there is as much meaning conveyed in the way something is said as there is in the actual words which are spoken.

During the process of interviewing, care and attention was taken to observe participants as well as listen to what they had to say in order to explore, as far as possible, the fullest true meaning behind what was actually being said. This included consideration of non-verbal cues including the participant's body language and facial expressions, pauses in the pattern of speech, combined with the pitch, tone, and pace of the voice.

3.8 Procedures for data analysis and coding

Within grounded theory, analysis of data is undertaken via a process of coding. As a process, coding is about defining what the data is about, with the aim being to derive conceptual understandings of the phenomena under investigation.

In its original form, grounded theory analysis (Glaser & Strauss, 1967) involved a simple three stage coding process: open, selective, and theoretical coding. However, following the publication of the *'coding paradigm'* by Strauss and Corbin (1990) there is a variety of different approaches open to those undertaking analyses within the framework of grounded theory method.

In practice, coding is the process of analysing data by attaching significance and concepts to individual segments of the data. Within grounded theory, coding is the mechanism used during analysis to help build and support the generation of theory. In its simplest terms, during analysis the researcher assigns a code (or identity, or name) to individual segments of the data. Then through a process of constant comparison, and the addition of new data, plausible relationships and interconnections can be derived

from between differing codes. Which in turn can be used to help further develop emergent concepts and categories, going on to help generate the theory.

Irrespective of the iteration of grounded theory used (Glasser, 1978; Strauss, 1987; Charmaz, 2006; Corbin & Strauss, 2008), open coding is the term assigned to the first stage in the data analysis process.

During this initial phase, I examined my transcribed data at a surface level word-by-word and line-by-line to identify categories, properties and dimensions within the narrative. As a process, open coding breaks down and fractures the data analytically, the aim of which was to bring out, amongst other factors, similarities and differences in participant's experience of the phenomena under investigation. These initial codes provided a basis for higher order coding and as my main categories emerged they were classified and through analysis reconnected; brought back together to form categories and sub-categories.

During the preliminary stage of analysis I made the mistake of using descriptive rather than analytical classifications to summarise and organise segments of data. However, recognizing my error I turned to the use of coding families to avoid labelling my data descriptively and avoid creating weak data sets (Figure 3.3).

In his seminal work *'Theoretical Sensitivities'* to support grounded theory researchers in the process of data analysis Glaser (1978) introduced 18 coding families, which were later expanded to incorporate 7 more, giving 25 families in total (Glaser, 2005). Coding

families help a researcher to see how categories may relate to each other and during analysis, they are used to undertake the process of coding, I referred constantly to coding family descriptors to assist me in assigning *'names'* to segments of my data.

I am not at all sure if I used the codes as Glaser intended, but crucially referring to and using the codes in this way helped me to analyse my data analytically rather than descriptively. Having had a *'false start'* where my initial attempt of analysis was weak, producing largely descriptive outcomes this helped me to really get underneath, and in-between, segments of my data. Enabling me to assign a code based on the meaning behind the statement, rather than simply attaching a name to the surface of the data segment itself.

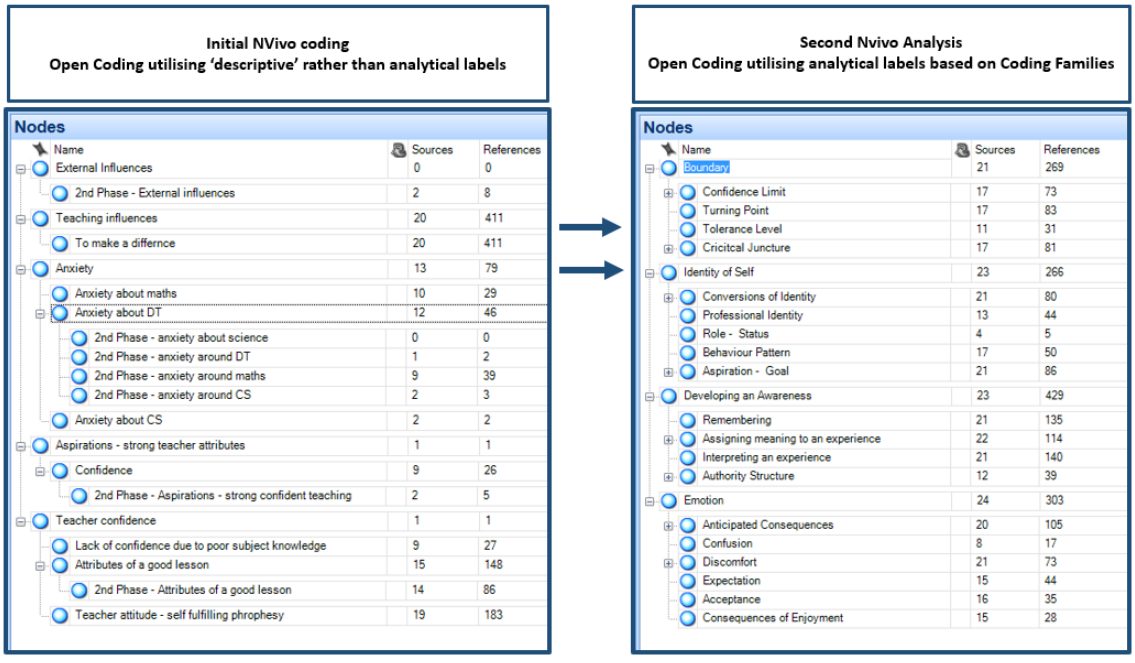

Figure 3.3

An example of descriptive versus analytical coding.

In the original Glaserian version of grounded theory (Glasser & Strauss, 1978) the second stage of analysis, where one piece of coded data is compared to another, is known as selective coding. This stage is sometimes referred to as '*focused coding*' or within the Strauss and Corbin (1990) coding paradigm as '*axial coding*'.

In Glaser's view (1992), the coding paradigm prevents natural emergence and creates a mechanism that 'forces' data, which is then subject to having a theory applied. Whereas he argued that data should be allowed to speak for itself and emerge naturally. However, it should be noted that in later iterations (Corbin & Strauss, 2008) having revised their thinking, the term axial coding is no longer in use.

In this study during the second phase of the process involved constant comparison between the open codes, in order to explore the potential to cluster categories. The aim being that through further sampling it is then possible to generate core categories (Glasser & Strauss, 1967). In my study, data was analysed in line with guidance and procedures advocated by Charmaz (2014). Through the constant comparison and theoretical sorting, I highlighted similarities and differences in, and between, my data sets. This allowed me to integrate and reduce the number of categories and codes. This process is known as substantive coding and was used to support me in the generation of substantive theoretical insights.

During each phase of coding, I attached flexible working titles to describe each of my categories. Moving forward from the selective coding and following theoretical sampling, during further iterative analysis and refinement of the data links between the

categories were made. Further analysis and the constant comparison of the focused, selective codes led to the generation of substantive and theoretical codes, and ultimately the study's research outcomes.

3.9 Chapter summary

Having laid out the rationale for my study, in this chapter I made clear my ontological and philosophical position and set the scene for the exploration of my methodology and research methods.

I outlined the principles and criteria for participant selection, the biographical detail of participants engaged in the study, presented the procedures, processes and sampling techniques used during each phase of my study. I gave detail of how ethical approval and the engagement of research participants was secured with specific aspects of the research design that were put in place to ensure adherence to ethical strategy, procedures, and guidelines, to assure both the accuracy and consistency of data collection, and ensure participant well-being, confidentiality, and anonymity, were also articulated.

The chapter went onto explain the process of analysis and how coding procedures, and techniques including memo writing, integrative and diagrammatic memos were employed to support the effective analysis of my data.

4.0 Chapter Four

4.1 Introduction

In this chapter I present for consideration the study's outcomes. The chapter begins with the presentation of interview outcomes before moving to examine the study's key findings, which are further developed in light of the literature, and presented as outcomes.

To support the presentation of my data and help illustrate through the constant comparison of my data sets led to my study's outcomes I have included examples of diagraming within the main body of the text.

4.2 Phase one interview outcomes

Preliminary analysis of interview data led to the emergence of several outcomes that were grouped thematically, which at this early juncture led to interrogation of the data in response to the following questions:

- *What are your recollections of 'being taught'? (as a pupil/ student prior to higher education)*
- *How did you / do you learn best? (as a student)*
- *How do you think you will approach your own teaching? (as a teacher)*
- *What influence do you think the meaning assigned to your experiences will have on your approaches to teaching and the formation of your identity as a teacher*?

A summary of participant's perspectives in relation to these questions are presented in the next section.

4.2.1 Recollections of being taught: The influence of one's own experience

Irrespective of their age, gender, or the STEM subject they were training to teach, in recalling memories of their own experience of being *'taught'* as a pupil, participants recollections were *'vivid'*.

Usually whether recalling a pleasant (positive) or unpleasant (negative) experience, the detail given was so precise that it was as if the event had happened only days earlier rather than years ago. Captured within responses to this question were also discussions to explore how the individual participant felt that they learnt best and how, as a result, did they consider that they would approach their own teaching? what influence the meaning assigned to their experiences had on their approaches to teaching, and subsequently the formation of their professional identity. Overwhelmingly *'positive'* recollections involved pleasant memories of good teachers, and good teaching.

Attributes of a good teacher cited included patience, tolerance, approachability, and enthusiasm, someone who had a clear passion for the subject, and because of their strong subject knowledge, an ability to explain things easily. Often, pleasant experiences related to practical activities, undertaken by confident teachers, who were unafraid to take a risk, and who explored a range of teaching strategies.

"she very rarely used text books actually, she was very sort of practically minded herself and she would look for something you were interested in so she'd like try and tailor it into recipe calculations or something like that … she was really connected with the pupils, and always tried to tailor it to something they enjoyed. The best teachers were the ones that had a good sense of humour and they were much more relatable, you know human"

Male, PGCE Computer Science

When recalling pleasant memories (positive recollections) participants described wanting to emulate their favourite teachers, both in attitude and pedagogical approach. In these instances, the impact on the learner (their recollection of learning as experienced as a pupil) and learning was overwhelmingly positive, with participants talking about enjoyment, taking ownership of the work, developing a passion for the subject, personal development, and growth in confidence.

"Looking back, from my perspective it was done right, it was just a really interesting way of explaining a theoretical science concept"

Male, Undergraduate Design and Technology

With regard to unpleasant (negatively recalled experiences), recollections included accounts of poor teachers and bad teaching.

Associated with these recollections were countless examples of the impact of poor teaching on their motivation and confidence as learners:

> *"You could see the teachers with confidence who were good at Maths. The other teaches weren't very confident and they were struggling with the board work, they did a lot of text book work as well which meant there were days in class were I just wasn't interested. I copied off mates, but I was completely and utterly Maths phobic and what Maths I did learn, we were given a book, copy out a book, answers in the back, it wasn't even rote learning, it was no learning, literally you got the questions and then you checked your answers in the back. So rather than check your answers you just copied from the back. How I managed to get through five years in top set and not realise how rubbish I really was, astounds me to this day"*
>
> Female, PGCE Mathematics

Irrespective of the participant's gender, age, training route, or subject, in recalling their experiences (positively or negatively) as learners, the *'quality'* of the teacher subject knowledge was cited constantly.

Following transcript analysis, in moving from open to selective coding, emergent from iteration of data around the central axis of *'subject knowledge'* (Figure 4.0), five core themes emerged:

- Making a difference (to children and young people)
- External influences (experiences and people)
- Struggle (leading to potential anxiety)
- Aspirations and Influences (to be a good teacher)
- Attributes (of a good lesson, of a good teacher)

These themes were utilised to inform subsequent interviews, findings of which are presented in the next sub-sections.

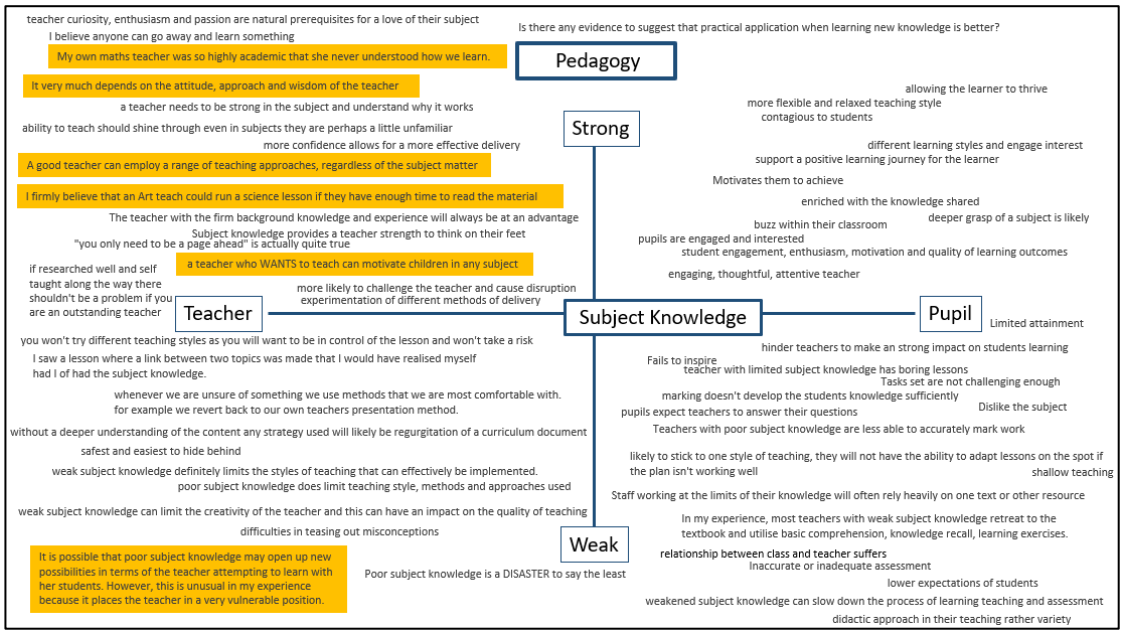

Figure 4.0

Example of diagraming: Visual analysis of data iteration the cross-correlation of pre-service teacher's perceptions around the central axis of 'subject knowledge'.

4.2.2 Making a difference

When articulating their motivation to teach, in addition to a desire to help others (to fulfil their potential), and to share their subject discipline, an overwhelming reoccurring theme arose, which I have called a desire to *'make a difference'*.

> *"I love teaching and helping people, I just like the idea of giving something back, and providing something that not everyone can offer … not everyone gets the chance to learn and this is my chance to make a difference"*
>
> Female, Undergraduate Science

When explaining why they wanted to make a difference, positive feelings and emotions were shown both verbally and physically. Participants associated making a difference with good teaching, which they identified as including strong subject knowledge, and the ability to plan good lessons.

> *"I've got a real passion for Maths and ultimately I like helping people and trying to help them to develop their skills … it's not just about the teaching of maths, but also about helping to build characters"*
>
> Male, PGCE (SD) Mathematics

4.2.3 External influences

External influences were recalled both positively and negatively. Positive recollections appeared to enable personal and professional development, boosting morale, providing self-esteem, and supporting the development of self-confidence. Specific positive

recollections included pleasant memories of strong influencers; family, teachers, and mentors in school.

> *"… he was just the best teacher ever… I would love to be able to teach on that level … his subject knowledge was amazing and if some kids didn't get it, he didn't get annoyed like some teachers did just because you didn't understand … he didn't have a problem stopping and explaining the same thing in loads of different ways"*
>
> Male, Undergraduate Design and Technology

One of the strongest positive recollections disclosed in the course of this study was because of participants' pleasant reminiscences of positive engagement with pupils.

> *"I just stood there at the front [of the classroom] and looked around and everyone was on task (working) … then I began to walk around the room … and that's when I felt comfortable"*
>
> Male, Undergraduate Mathematics (Focus Group 1)

Where positive recollections appeared to support development, the recollection of unpleasant (negative) experiences appeared to have the opposite effect. External structural barriers, such as working environment, school policy, curriculum and class size, limited participants' feelings of agency and exacerbated their feelings of

discomfort. These external barriers appear to limit an individual's ability to develop self-efficacy.

4.2.4 Struggle

Irrespective of gender, age, subject discipline, training route or espoused motivation to teach, all participants articulated feelings of struggling at some point, with a number expressing that they had experienced feelings of helplessness. At this stage of analysis, data suggested that participants who communicated feelings of unease were attributing them to internally held concerns over their own potential ability (or inability) to manage pupil behaviour, linked to the security and self-confidence relating to their subject knowledge.

> *"I experienced low confidence, low self-esteem and was very nervous … I realised I did have the subject knowledge … I felt out of my depth and wasn't confident in what I was doing … it just got really complicated really quickly (pupil behaviour). Being unprepared is a big thing and it's taking me a long time to get over that"*
>
> Female, Undergraduate Design and Technology

Participants' also harboured concerns with respect to external barriers that they perceived restricted their ability to develop, which in turn created feelings of anxiety. External barriers included difficulties encountered with pupils, and mentors in school.

"I'm in no position to do anything about that, that's the curriculum I've got to follow … I have tried to suggest things (to my mentor) that I think would work and make the scheme of work better (more interesting) … but I am only a trainee"

Female, PGCE Science (Focus Group 1)

4.2.5 Aspirations and Influences

Without exception, every participant aspired to be a good teacher, and sought to make a difference to those they teach. In explaining their choice behind their decision to become a teacher, most participants recalled significant figures who had influenced or guided them in their decision-making. Significant figures included parents, grandparents, siblings, and teachers, who were also cited as being influential with regards to their chosen subject discipline.

"My older brother was really good at Maths, so I always went to him ... it's just been, always been a passion of mine, I've always had the love for industry, engineering … my family have all come from an industrial backgrounds … my grandparents … my dad's a civil engineer … so I've always had that growing up .. It's in the blood"

Male, Undergraduate Mathematics (Focus Group 1)

4.2.6 Attributes

Through their recollection, experiences and memories, and the understanding assigned to those memories, participants began to articulate their awareness of the need to

develop a *'professional self'*. Perceived, by many, as essential in supporting the development of their professional identity as teachers, participants considered a range of attributes including a desire to be empathetic, embodied in a strong personality, leading to an ability to develop a dynamic pedagogical style, and make lessons interesting.

> *"I suspect … based on anecdotal experience, that teacher curiosity, enthusiasm and passion are natural prerequisites for a love of their subject areas … and that the resultant knowledge base has a corresponding and proportional effect on levels of student engagement, enthusiasm, motivation and quality of learning outcomes"*
>
> Male, PGCE (SD) Science (Focus Group 2)

Moving from open to selective coding analysis of the transcripts led to the identification, and exploration of the following themes; making a difference, external influences, struggle, aspirations and influences, and attributes.

Exploration of these provided the foundations upon which subsequent data collection was conducted. As such exisiting data was refined and I began to develop new categories. I used diagraming to support this process of analytical iteration from which four main categories emerged; boundary, identity of self, developing an awareness and emotion.

Figure 4.1 presents a sample of diagramming undertaken at this stage in my research. A full set of my visual illustrations, diagrammatic memos and integrative diagrams are presented in Appendix B**.**

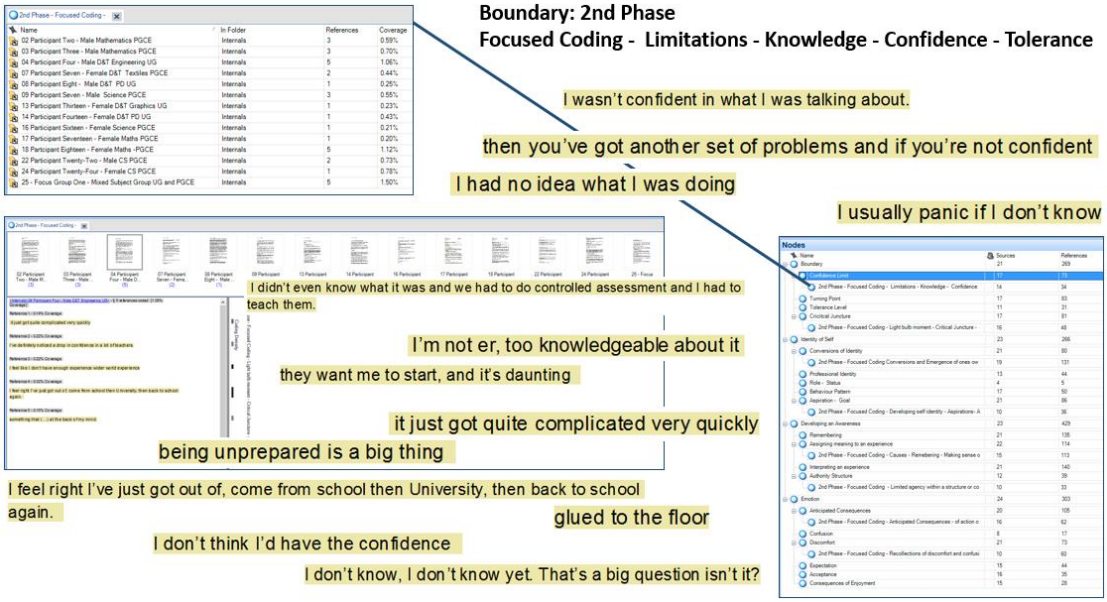

Figure 4.1

Visual example of second phase coding: Boundary: limitations, knowledge, confidence, and tolerance.

4.2.7 Boundary

Following analysis of the transcripts from the semi-structured interviews, the emergent category entitled *'boundary'* describes a *'mental'* barrier or hurdle faced by pre-service teachers. In this category boundary is not defined by referring to an individual's agency to operate within an external structure. Within this context *'boundary'* is defined as a barrier within the individual's own mind, their perception of a situation which is

significantly different from an externally imposed barrier. Within boundary, two main sub-categories emerged:

1. Limitations; Knowledge, Confidence, Tolerance
2. Critical Juncture; Light Bulb Moment, Turning Point

The sub-category *'limitations'* describes concerns pre-service teachers have in relation to their subject knowledge.

The *'limitation'* may be real or imagined, but within the mind of the participant recounting it, they perceive it as a weakness in their subject knowledge which they reported had a negative impact on their confidence, and in some instances, manifest as the individual's tolerance to cope with or overcome their (perceived) limitations.
Also falling under the category of *'boundary'*, the second sub-category critical juncture refers to instances where a participant described reaching a turning point.

This could be a moment where a participant became open to a new or previously unseen perspective, to a new point of view, or when they encountered an incident that changed their thinking and subsequently their understanding or perception of an experience or situation.

4.2.8 Identity of Self

'Identity of Self' describes the liminal moment in the participants experience, as they cross the boundary from pre-service to qualified teacher. As with the other categories, *'identity of self'* is divided into two sub-categories:

1. Conversion and Emergence; of one's own identity
2. Developing Self; Aspiration, Achievement Orientation

In the first sub-category conversion and emergence relates directly to the development of the participant's professional identity as a teacher. The second sub-category developing self-explores participants' aspirations.

Within this category, while acknowledging the sample size, the data shows that significantly more men than women articulated thoughts related to aspiration and were achievement orientated.

4.2.9 Developing an Awareness

The third category, developing an awareness, presents instances of the participants evolving cognisance of their surroundings and immediate situation (their working environment). The category explores influencing factors on the formation of identity. This category is further divided into two sub-categories; '*causes'* and *'context'*.

1. Causes; Remembering, making sense of experiences
2. Context; Limited agency within a structure

The sub-category '*causes'* emerged because of analysis of participant transcripts. Specifically, this sub-category examines the events within a pre-service teacher's personal history, because of the meaning assigned during the process of remembering, and making sense causes them to act, think and feel as they do. In the second sub-category, '*context'* refers to the structure and the environment within which the pre-service teacher is training and working. Specifically, the external forces that can restrict or enable the formation of identity.

Contextual factors that have the potential to limit professional development include the pre-service teachers learning environment (including class size), the curriculum and others views of how their subject discipline should be taught.

4.2.10 Emotion

In the fourth category, '*emotion'* relates to the feelings individual's assign to their experiences and it is further sub-divided under two categories:

1. Anticipated Consequences; of an action, inaction, or an event
2. Recollections; Discomfort and Confusion

In the first, identified as '*anticipated consequences',* this sub-category relates to the feelings participants experienced as a consequential result of an action or inaction. In the second, '*recollections'* relate to the feelings that participants assign or associate with their recollection of a memory of an experience.

In this category, when recalling experiences, unpleasant (negative) emotions of discomfort or confusion were articulated often, which correlates with the work of Yuan and Lee (2015) who found negative emotions are recalled more often than positive ones.

4.3 Phase two interview outcomes

Building on the interconnections between these plausible segments of data generated from the first phase of my data collection, *'boundary', 'identity of self', 'developing an awareness'* and *'emotion'* (Figure 4.2), prior to undertaking my second interview phase I homed in on the emergent issues that influence and impact upon the participants formation of their identities as teachers.

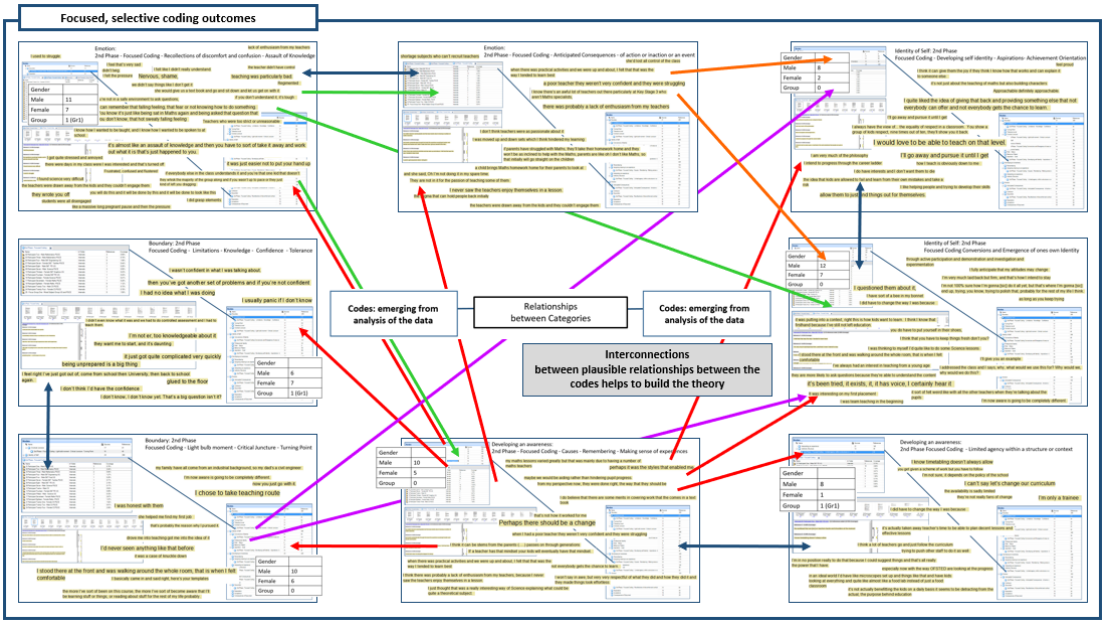

Figure 4.2

Interconnections between the emergent categories arising from second phase coding.

At this time, focused around the central theme of subject knowledge, following further analytical iteration of the categories, as iteration moved from second phase selective

coding into the generation of my substantive codes, outcomes that emerged were; feelings and behaviours, consequences, pedagogical approach and developing identity (Figure 4.3).

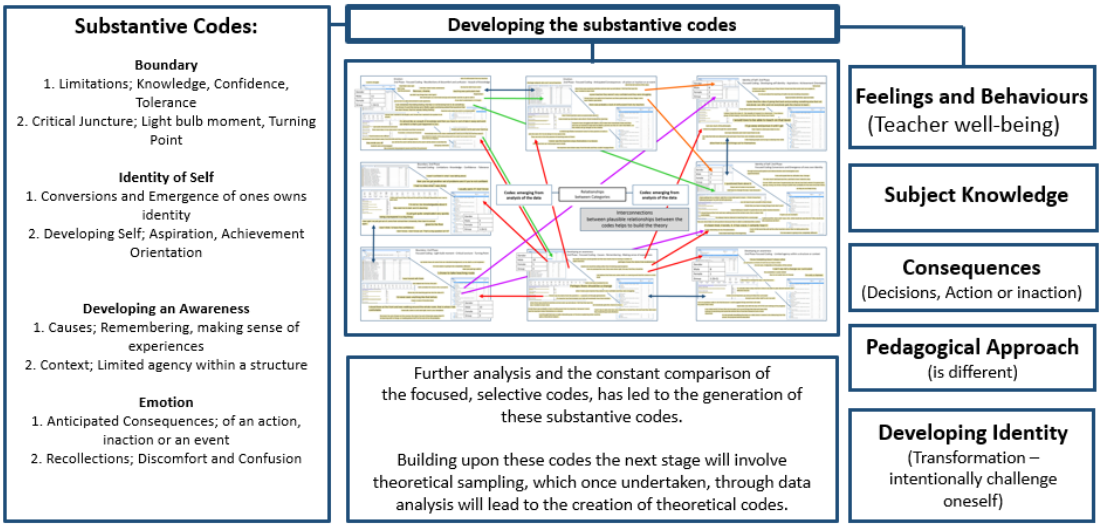

Figure 4.3

Developing substantive codes from the first phase data.

At this stage I undertook a second phase of interviews, using a series of additional questions generated based upon the first research phase outcomes, specifically to interrogate further the emerging themes. In response to the new questions which focused around STEM disciplinary subject knowledge participants were asked to consider (through recollection) their thoughts and emotions (pleasant and unpleasant), and external forces which they believed would have an impact upon how they would approach their training and professional development as teachers:

- *Does subject knowledge have any influence on pedagogical approach? (teaching style and methods used)*
- *Does weak subject knowledge have an impact on a teacher's ability to effectively manage their class?*
- *What impact do you think weak subject knowledge has on a teacher's ability to teach? (confidently and efficiently plan, prepare, mark, and accurately assess work)*
- *What impact does having weak (poor) or limited subject knowledge have on the teacher?*

To note this study did not explore the pre-service teacher's actual subject knowledge, only the participants personal perceptions around specialist disciplinary STEM subject knowledge.

In response to the question *'does subject knowledge have any influence on pedagogical approach?'* while one participant could see some potential value in poor subject knowledge if used as a tool to learn alongside their pupils:

> *"It is possible that poor subject knowledge may open up new possibilities in terms of the teacher attempting to learn with their students"*

They did go onto say:

> *"however, this is unusual in my experience because it places the teacher in a very vulnerable position. In my experience, most teachers with weak subject knowledge retreat to the textbook and utilise basic comprehension, knowledge recall learning exercises"*
>
> Male, PGCE Mathematics

Irrespective of their STEM subject discipline, participants perceived the best lessons (and hence the most effective way to learn) where those that engaged pupils in activities where theoretical knowledge could be applied in a practical way. Pedagogically, participants determined that *"poor knowledge leads to narrow and shallow teaching"* and without exception analysis of their perceptions made clear that having weak or limited subject knowledge was more likely to lead to a *'restricted curriculum'*.

Without a strong knowledge based the teacher is less likely to move beyond a 'rote' approach to lesson delivery and as a consequence, specific to the practical aspects of STEM pedagogy there:

"would be an over reliance on text books, leading to less engaging lessons for pupils, which in turn was more likely to limit pupil attainment."

Male, PGCE Science

Participants perceived that a *"deeper knowledge of one's subject allows for a more flexible and relaxed teaching style"*. It helps to make not only the teacher feel confident, but also gives the students a sense of confidence in their teacher's abilities. This in turn helped to create a relaxed atmosphere, which according to participant perceptions, is more likely to lead to a deeper grasp of a subject with more varied and stimulating lessons.

'Does weak subject knowledge have an impact on a teacher's ability to effectively manage their class?' In response to this question participants perceived that weak subject knowledge would leave them with:

> *"an element of vulnerability within the classroom, with consequences likely to lead unacceptable levels of disruption and the creation of a negative learning environment."*
>
> Female, Undergraduate Science

Specific to the practical *'hands on'* aspects of the STEM curriculum participants expressed concerns around the link between weak subject knowledge and the potential for increased issues around Health and Safety:

> *"If the teacher hasn't planned the lesson properly because they lack that subject knowledge it is more likely I'd say for children to be off task be messing about. Behaviour will suffer but more importantly there is more chance of an accident occurring and someone getting seriously hurt!"*
>
> Female, PGCE Design and Technology

In addition to having a negative impact on teacher confidence, where a teacher is unable to engage effectively with the more complex aspects of a subject area, participants believed this could disengage pupils' active participation in the discipline.

When asked *'what impact do you think weak subject knowledge has on a teacher's ability to teach?'* Overwhelmingly the *"unintentional teaching of misconceptions"* was cited as an area of concern. Participants also cited issues with planning and preparation, accurate assessment, and giving meaningful feedback:

> *"Planning is more time consuming as the teacher is themselves learning. Poor subject knowledge means that teacher are unable to assess with confidence and marking takes longer as there is uncertainty as to the correct answers and often further reading on the part of the teacher is necessary in order to be confident in their assessments of pupils work".*
>
> Male, PGCE Mathematics

Consequently, where subject knowledge was perceived to be *'strong'* participants reported feeling more able to offer in-depth help and support to pupils. Having the ability to respond swiftly to changes or unexpected pupil outcomes increased efficacy and in themselves‒participants said that they were considerably *"less worried about offering incorrect advice"* and said that they *"felt much more confident in the classroom when they fully understand the topic they were teaching."*

In response to the question *'what impact does having weak (poor) or limited subject knowledge have on the teacher?'* participants perceived that weak subject knowledge has the potential to impact negatively on a teacher's confidence in their abilities and would most certainly raise levels of stress and anxiety, which would be transferred into the classroom onto learners:

> *"Weak subject knowledge impacts on a teacher's confidence in their abilities, they are reluctant to engage fully with their pupils as there can be a fear of being asked a question they cannot answer, and this will most defiantly be transferred into the classroom. Learners will within minutes."*
>
> Female, Undergraduate Science

Pupils would be more likely to become disengaged and learning may be constrained *"if the teacher can't do it, I won't be able to do it."* Furthermore, it is likely to impact negatively upon the teacher's confidence potentially leading to stress and anxiety.

Refining the categories from the previous phases with the analysed findings from the second (Figure 4.4), during the final stages of analysis through the process of constant comparison in and between the data the following outcomes were developed:

4.3.1 Subject Knowledge

There is a specific type of *'anxiety'* around a lack (or perceived lack) of STEM subject knowledge.

To reiterate participants actual subject knowledge was not gauged, only their perceptions of the impact subject knowledge could or would likely have on teaching and learning. While some participants referred to having undertaken an SKE course (DfE, 2017) and some volunteered an opinion relating to the impact of subject knowledge had had on their own teaching, at no time did questioning seek to confirm an individual participants perception of their own subject knowledge.

Analysis of findings showed that participants perceived a strong knowledge of the subject discipline would underpin a teacher's ability to be confident. Conversely where subject knowledge was perceived to be *'weak'*, pedagogical approaches would be limited, and as a consequence pupil learning may be restricted. Specifically, poor subject knowledge has the potential to impact negatively upon:

- Pedagogy. The range of activity undertaken in the classroom, with very little 'hands on' work undertaken where pupils are engaged in the practical application of theory.
- Pupil learning and progress, their enjoyment and ultimately their longer-term engagement with STEM subjects.
- Teacher efficacy and well-being. Adverse impact on work-life balance due to increased time spent on lesson planning, preparation and assessing.

4.3.2 Becoming a Teacher

Transforming one's identity, moving from pre-service to qualified teacher means finding the strength to challenge oneself. To surmount effectively barriers to change, one must be able to admit and intentionally challenge one's own vulnerability. Specifically, feelings and behaviours differ depending upon the individual's personal approach (to learning and teaching):

- Where an individual's approach to learning is deep, and autonomy and self-regulation are high, confidence is increased and approaches to pedagogy are amplified.
- Where an individual has limited agency and their approach to learning is passive (surface), as a consumer of knowledge, self-regulation is low, and feelings of professional inadequacy and vulnerability thrive.

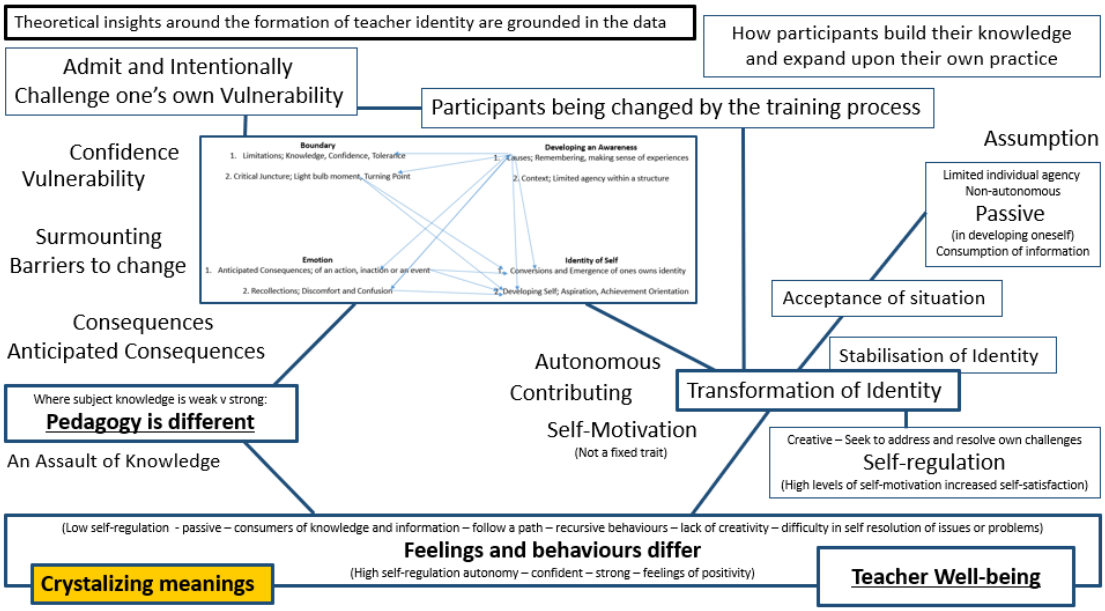

Figure 4.4

Emergent interconnections between first and second phase data
(Substantive codes leading to the generation of the study's theoretical codes).

4.4 Validation group interview outcomes

During this final stage, in order to support the authentication of the study's findings, I held two focus group interviews, each with four participants, all of whom had previously been engaged in the research. Having been presented with the outcomes participants were encouraged to discuss the findings with each other to help confirm their authenticity. Discussions became conversational as this abridged extract illustrates:

> *"Teachers with weaker STEM subject knowledge are more inclined to deliver lessons which are procedural and reliant on pupils following rules which ignore conceptual understanding. Teachers with stronger subject knowledge are more confident."*
>
> Male, PGCE Mathematics

"Yes, you are more fearful of letting the children go off and explore take a risk or experiment. In my experience if I'm not sure of what I'm doing I tend to stick to a simple activity and the lesson is teacher led board and text book work, whereas when I'm confident we do all kinds of things lots of practical … perhaps as well because I'm more motivated?"

Female, Undergraduate Design and Technology

"I agree, it's dreadful not knowing what you are doing it can make you feel awful. You worry a lot not only about the kids, but also how the other teachers will see you. It undermines you and erodes your own confidence and really can have a detrimental impact on your own self-esteem and of course it doesn't do the kids any good either."

Male, Undergraduate Science

"When a teacher has poor disciplinary knowledge they will plan to what they know. It is also difficult to mark work and accurately assess what you don't know. Marking takes a lot longer when you do not have sound subject knowledge and this impacts on the well-being of the teacher."

Female, Undergraduate Design and Technology

"definitely, my subject knowledge is stronger in certain lessons and in the lessons where I struggled I did not feel confident. I felt nervous and this came across in my teaching and affected my classroom management."

Male, Undergraduate Science

"It depends on the individual and to what extent they are conscious of their weak subject knowledge… the disposition of the teacher and the environment that they work in also has a significant impact."

Female, PGCE Computer Science

"yes it depends upon the teacher's approach… weak subject knowledge limits the range of teaching styles, if a teacher lacks knowledge they are going to spend their time filling those gaps rather than looking at new and innovative ways of delivering knowledge."

Male, PGCE Mathematics

"not necessarily … some teachers who have weak subject knowledge show more understanding of the different teaching styles. My own maths teacher was so highly academic that she never understood how we learn."

Female, PGCE Computer Science

"mmm... I see what you are saying but I'm not sure I 100% agree … I think that there needs to strong subject knowledge. A teacher must know the subject they are teaching and why they are teaching it. A teacher of maths must be able to understand 'why' a student is getting it wrong and be able to strip the problem down to its basics to explain it."

Male, PGCE Mathematics

"so … maybe what we are saying is that where a teacher is motivated and is confident … if they go and find the help if they need it they can just about teach anything… but when a teacher's subject knowledge is poor, and they don't have much about them to 'step up' they can leave themselves in a really vulnerable position?"

Male, Undergraduate Science

Analysis of the validation group transcripts revealed participants concurred wholeheartedly with the discoveries presented, and as such validated the study's outcomes.

4.5 Approaches to, and engagement with pre-service teacher preparation

Throughout this study, analysis of pre-service teacher's responses showed a strong correlation between an individual's experience-related beliefs, their feelings and behaviours, and the manner in which they approached and engaged with their own personal and professional development as a teacher (their teacher preparation, training or education programme).

Influenced by the ideas of Dewey (1938) and Lewin (1951), Kolb described experiential learning as the "*process whereby knowledge is created through the transformation of experience"* (Kolb, 1984:38) and Lortie (1975) describes the role experience plays in

the formation of a learner's identity, which according to Weber and Mitchell (1996) can either *'shape or distort'* identity formation.

Developed from the meanings that have been assigned to personal memories, findings from this research show that pre-service teachers enter teacher preparation with a set of pre-existent, quite often deeply-rooted beliefs that shape how they act, think, and feel.

The influence personal histories have on an individual's ability to learn, and to develop their professional identity as a teacher, is significant. Within the context of pre-service teacher preparation, past experiences (from the perspective of having been a pupil) influence an individual's approach to their learning, their approach to teaching, and the formation of their professional identity as a teacher (Samuel & Stephens, 2000; Stes *et al.* 2014; Nichols *et al.* 2016).

Adopting the *'surface'* and *'deep'* terminology utilised by Marton and Säljö (1976) developed from this study's findings, this section of the study presents a visual representation of the correlation between an individual's approach to their engagement with their teacher preparation programme (Figure 4.5**);** their approaches to learning (as a student), approaches to pedagogy (as a teacher), STEM subject knowledge (within the context of teaching), the development of self (as a pre-service teacher) and their reflections on learning (as experienced as a pupil).

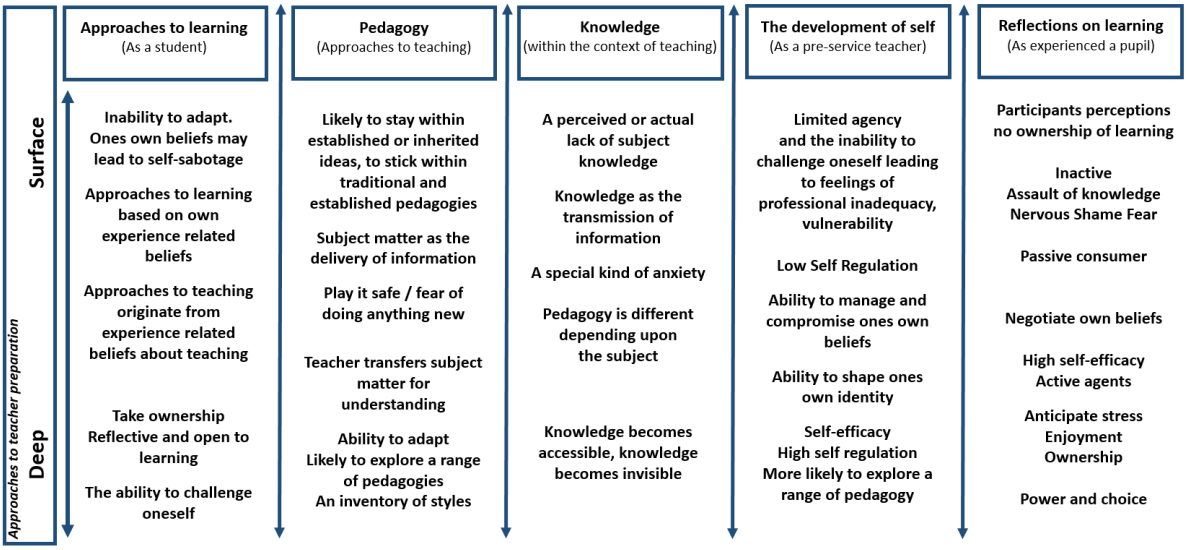

Figure 4.5

Approaches to, and engagement with pre-service teacher preparation:
A correlation between approaches to learning and teaching, knowledge, and the development of self and reflections on learning.

Within the next five sub-sections of this chapter the relationship between the pre-service teachers approach to (and engagement with) their teacher education preparation programme, their approaches to learning and teaching (pedagogy), STEM subject knowledge (within the context of teaching) with and the development of self and their reflections on learning are explored in further detail.

4.5.1 Approaches to learning (as a student)

Within the context of identity formation, very few studies consider the role *'personal learning histories'* play in determining how pre-service teachers access new knowledge and how they approach learning, but according to Lewin and Stuart (2003) effective teacher education programmes should begin by assessing the pre-service teacher's attitudes and behaviour. Findings from this study contribute to literature within the field

and illustrate the difficulty some pre-service teachers have in making the connection between themselves as learners, and their responsibilities as a pre-service teacher, further highlighting the need to develop the pre-service teacher's identity as a learner fully before working to explore the development of their professional identities as teachers.

Analysis also showed a strong link between a pre-service teacher's approach to their own learning and to their attitudes to their professional development. Where participants immersed themselves *'deeply'* in their teacher preparation programme, this correlated with an ability to challenge themselves, to take ownership, and be reflective of their own learning. Conversely, where participants exhibit surface approaches to their professional development, findings revealed that they were less likely to challenge their own attitudes and beliefs and were more likely to adopt behaviours that (unintentionally) may limit their development.

Surface approaches aligned with pre-service teachers as passive consumers of (new) knowledge and information, whereas deep approaches suggested pre-service teachers were 'active' agents in their own development. Van Veen *et al. (*2005), investigates how identity is shaped, and is re-shaped in light of the pre-service teacher's engagement with their working environment, and exploring the influence of school culture, Flores and Day (2006) highlight the powerful interaction between personal histories and the contextual influences of the working environment. Findings from this study showed that those pre-service teachers who adopted *'deep'* approaches to their own development were more open to working collaboratively within new and unfamiliar cultures, and

hence (Van Veen *et al.* 2005), were more likely to develop and to demonstrate positive attitudes towards both their own learning and their teaching.

4.5.2 Pedagogy (approaches to teaching)

According to Stes *et al.* (2014), teachers' approaches to their learning are reflected in their approaches to teaching and although the scope of this research did not examine the pre-service teachers actual teaching, it did ascertain their teaching intentions. Findings from this study showed that where it was an individual's intention to deliver student-centred lessons, they preferred to learn in a similar way.

Analysis showed that where the pre-service teacher adopted a *'surface'* approach to their own professional development, they were more likely to *'stick'* with inherited ideas formulated as a result of their existing experience-related beliefs and with respect to their teaching intentions, were more likely to adopt traditional, established pedagogies. Conversely, where the pre-service teacher adopted a *'deep'* approach to their teacher preparation programme, the likelihood was that they would be *'open minded'* and seek to develop a range of pedagogical approaches in their teaching.

Within this study, where the pre-service teacher expressed a desire to deliver student-focused lessons, they were aware of contextual factors that may prevent them from doing so. For example, restrictions due to curriculum policy, or prescribed methods of assessment which serve to reduce an individual's autonomy, thus present a potential obstacle to the emergence of the pre-service teacher's professional identity.

Contextual factors that may change a teachers' preferred style or alter their (intended) teaching behaviour mentioned by participants in this study align with those cited by Singer (1996) and Lindblom-Ylänne (2006). These include; subject discipline and prescribed curriculum, facilities and resources, ability of the children, class or group size, personal workload, school culture and the working environment (including how their mentor, and others, including departmental colleagues, expect them to behave).

4.5.3 Knowledge (context)

Findings show that irrespective of the pre-service teachers approach to their professional development, even those adopting *'deep'* approaches who were more reflective and open to changing their ideas, there is a special kind of anxiety around subject knowledge. Strong knowledge underpins the pre-service teacher's ability to be confident, and where the individual perceives subject knowledge to be inadequate, drawn from analysis of the participants teaching intentions their pedagogical approaches revealed they were more likely to select teacher-led pedagogical approaches (which were perceived as safer) but may limit children's opportunities for learning.

Moving to explore the connection between approaches to one's own professional development and subject knowledge pedagogical approaches to teaching, findings indicate there is an increased likelihood of teacher stress where a teacher is required to teach beyond the boundaries of their subject knowledge, taking them beyond the limits of their comfort zone. However, within the context of teachers' shortages (Foster, 2017; Sellgren, 2017), it is increasingly likely that, once qualified, teachers will be required to teach outside of their immediate subject discipline, hence the ability to develop strong

pedagogic capabilities and self-efficacy is essential not only to ensure the quality of teaching, but to help preserve the health and well-being of the teacher.

4.5.4 The Self (Pre-service teacher)

According to Hollingsworth (1989) prior knowledge of teaching can interfere with the formation of teacher identity and findings from this study would not disagree. Where the pre-service teacher adopts a *'surface'* approach to their own professional development, correlation of the data between an individual's emotional state and their attitudes and behaviours and the way that they approach their teacher preparation programme shows that they are less likely to be able to challenge themselves. They are more likely to perceive they have limited agency (control) over their own personal and professional development. Under these conditions, the pre-service teacher is vulnerable, and more likely to experience feelings of professional inadequacy (Lindqvist *et al.* 2017).

Potential negative emotional consequences include anxiety (trepidation), low self-efficacy leading to a loss of motivation and confidence and potentially over time these feelings may contribute to teacher attrition. A survey to explore the reasons for teacher attrition (OECD, 2009) found a strong correlation between teacher dissatisfaction and low self-efficacy and links between *'disenchantment'* of personal and professional values and beliefs (Timoštšuk & Ugaste, 2010, 2012) and motivation and commitment; where teacher commitment is low it can be an indicator of potential teacher attrition (Day *et al.* 2005).

Working within the classroom under these conditions, findings from this study found that a pre-service teacher is more likely to adopt teacher-focused pedagogies that feel safer because they facilitate feelings of increased classroom control. In turn, based on analysis of the participants' reflective perceptions as learners (pupils), teachers' emotions are unintentionally transferred onto their pupils, which manifests (within pupils) as stress and anxiety and pupils perceive both teaching and learning to be *'poor'.*

Conversely, analysis of data found where the pre-service teacher adopts a *'deep'* approach to their professional development, they are better able to manage their own beliefs and believe they have control in helping to shape their own identity. They are self-regulated, have the agency to work autonomously, to challenge their own vulnerability, which leads to increased confidence, higher levels of motivation, and feelings of self-satisfaction (Littlejohn, 2016). They are more likely to be open to explore a range of pedagogy in their teaching and are more likely to be better able to anticipate and cope with work related stressful situations. Those pre-service teachers with *'deep'* approaches to their own professional development are also better able to manage their internal beliefs with regard to external social pressures, for example while working with mentors, or managing their emergent identity against popular cultural and social stereotypical *'norms'* and society's view of *'what a teacher is, how they should act and how they should behave'.*

Where teachers develop strong self-efficacy early in their careers, they are more likely to be open to innovation later (Bandura, 1997), and according to Chong (2011), there is a correlation between strong professional identities and reduced teacher attrition.

However, even for talented, creative teachers, where personally held beliefs become unaligned with the cultures and practices of their working environment teachers are more likely to become disillusioned with the job and teaching becomes frustrating and unrewarding (Fantilli & McDougal, 2009).

4.5.5 Reflections on learning (as a pupil)

The link between teacher stress and its impact on student learning is reasonably well-documented (Coates & Thoresen, 1976; Kyriacou, 1987; Devon, 2017). While within this study the direct questioning of pupils was not undertaken, utilising analysis of the participants recollections of their own experiences of learning (as children), provides an invaluable insight into the impact of teaching on children and young people. Within this study, their reflections are of particular value because of the participant's status as teachers in training.

From the perspective of participants (recollections as a pupil), where teaching was perceived to be of *'poor quality'*, this was often as a result of lessons delivered by *"weak, ineffective, lazy or dispassionate teachers"*; utilising teacher-centred, rote learning pedagogies. Recollections frequently uncovered unpleasant experiences, where anxiety or frustration (the participant's recollection from the perspective of having been a pupil) was increased, and their confidence and engagement in the lesson (opportunities to engage in effective learning) decreased. In recalling the teachers (negative) emotional state, be that discomfort, anger, aggression, stress or anxiety, those feelings were transferred onto the participants (as pupils) and the impact of unpleasant teacher interactions frequently manifest as;

- poor-quality teaching; articulated as boring and unengaging, often utilising rote pedagogies, *'an assault of knowledge'* leading to poor quality learning
- pupil discomfort; fear, nervous, stress, anxiety, or shame, bullying (of the pupil by the teacher), leading to pupil misbehaviour, a loss of confidence and/or disengagement with learning

These findings align with Harris *et al.* (1985), who when exploring teacher characteristics found a causal relationship between teachers who adopted *'authoritarian'* pedagogical approaches to teaching and teacher stress.

In recalling pleasant (positive) experiences, *'good'* teaching leading to high quality learning was perceived as enjoyable and inspirational. It comprised of student-focused practical learning activities, delivered by excellent teachers, who had the ability to explain the same fact or process in different ways. They had a good rapport with the class, were approachable and had strong subject knowledge.

Correlating the pre-service teacher's recollections with their approaches to their own professional development, analysis showed that those pre-service teachers adopting *'deep'* approaches were more open to the re-interpretation of their experiences as children, to create new interpretations of their original views and beliefs, than those pre-service teachers who adopted *'surface'* approaches to their professional development. Pre-service teachers who engaged in 'deep' approaches to their own teacher preparation were more able to negotiate their own beliefs and as a consequence developed agency and efficacy and were more able to anticipate situations likely to create or cause *'stress'.*

Where pre-service teacher's active engagement in their own professional development was low, and surface approaches to teacher preparation programmes were adopted, the individual had difficulty in revisiting their prior experiences with *'fresh eyes'* and subsequently had difficulty (or were unable) to alter their experience-related beliefs.

A reoccurring example of this was evident during interviews, where participants recalled unpleasant experiences of learning. For those pre-service teachers who adopted *'surface'* approaches to their own professional development they had *'fixed views'* and it was difficult for them to perceive a recalled memory in any other way to the one they had described; whereas those pre-service teachers who adopted *'deep'* approaches to their teacher development, through reflection, were able to re-interpret an existing belief or opinion, and utilising new knowledge (or experience) gained during their teacher preparation programme conceived the same incident in a new way.

4.6 Chapter summary

This chapter presented for consideration the study's main outcomes arising following the analysis and coding of the data. To aid understanding I included a sample of my visual mapping and integrative diagramming to help illustrate the process and procedures utilised during the process of coding.

5.0 Chapter Five

5.1 Discussion

While several lines of enquiry worthy of further potential study emerged from this study, mindful of the purpose of this study to contribute to new knowledge having identified *'gaps'* within the literature, only the strongest have been brought to the fore, and are presented here for discussion.

5.2 '*An Assault of Knowledge'*

Throughout this study, via the process of reflection, participants were encouraged to consider their own experience as pupils in the classroom. While inspirational experiences with exceptional teachers were cited, unpleasant incidents were recalled more vividly, with the majority recalling unpleasant experiences with dispassionate, lazy teachers.

During this process, through recollection (and drawing upon their new experiences as teachers in training) several participants reconsidered their previously held perceptions of *'what was going on'*, the most common being in relation to the delivery of subject knowledge. It came to be realised that unpleasant instances, previously recalled as poor teaching (by lazy teachers), while still recalled as unpleasant, may have in fact been a teacher with insufficient subject knowledge struggling to cope or unable to convert subject knowledge effectively for teaching.

Recalling an occasion from my own experience as a learner, I remember one of my secondary school science teachers. He was, I recall, very knowledgeable, enthusiastic about his subject and fortunately was approachable, with a warm personality and encouraging of pupils. As I recall, there was no fear or shame associated with asking for help or support and I do not recall being uncomfortable in the classroom or that the lessons were unpleasant, however, I do know that we did not learn much.

Looking back, it is obvious to me now that while clearly knowledgeable, he did not have the ability to get what was in his head, out of his head and into ours. He was unable to present knowledge in a way that was accessible to us as learners and he lacked the ability to transform his subject knowledge into content suitable for teaching (Shulman, 1986, 1987).

While not an uncomfortable experience as encountered by this participant: *"the worst lesson definitely is where the teacher's just standing there, and it's almost like* ***an assault of knowledge*** *and then you have to sort of take it away and work out what it is that's just happened to you",* the extract quotation *'an assault of knowledge'* described exactly my experience and as such resonated with me, hence the title for this theoretical insight.

Within this context the theoretical insight an *'assault of knowledge'* describes the occurrence where subject knowledge is delivered to a learner unrefined and without any attempt at pedagogical adaptation or modification. Little or no consideration of the

needs of the learner has been given and knowledge is received by the learner in an unyielding and relentless way.

5.2.1 Defining 'An assault of knowledge'

According to Shulman (1986) there is *'a growth in knowledge of teaching'* specific to the process of converting subject matter for the purposes of teaching, but what if, during the process of training, the pre-service teacher perceives that their knowledge is limited, and they do not have enough specialist subject knowledge to transform?

The first theoretical insight I present as an original contribution to knowledge as an outcome of this study is *'an assault of knowledge'.*

Bound within analysis of this study's data, findings illuminated the notion of a *'pedagogical subject gap'* which describes the *'space'*, or *'gap'*, in a pre-service STEM teacher's specialist disciplinary subject knowledge and refers specifically to the impact a gap subject knowledge has on the development of not only pedagogy, but the formation of an individual's identity as a teacher. From this perspective, the tension lies in the subject knowledge, because if during training the pre-service teacher's subject knowledge is deficient, then an individual's ability to adapt subject matter for the purpose of teaching, is compromised. Therefore, this outcome refers specifically to the liminal moment, the point at which subject matter should become PCK. Here lies the *'space'* where identity as a *'teacher'* is formed, which, if the pre-service teacher's subject knowledge is deficient, identifies a *'gap'* in the individual's ability to grow as a teacher.

Where a pre-service teacher does not have the knowledge from which to draw, they struggle to know what they are teaching or why they are teaching it and this lack of *'subject'* prevents the pre-service teacher from developing the ability to transform subject matter into pedagogical content in order to make knowledge accessible to a learner. While training to teach, individuals encounter many experiences that cause concern, however, analysis of this research identifies that there is a specific type of anxiety around a pre-service teacher's lack (or perceived lack) of subject knowledge and findings from this study show the impact of weak subject knowledge on STEM pre-service teacher's development is significant.

Where knowledge is deficient (as perceived by the individual) there is an inability to transform the subject matter into content for the purposes of teaching and findings show that this weakness (perceived or real) has the potential to limit an individual's personal development and subsequently restrict the formation of their professional identity. Under these conditions, the pre-service teacher encounters increased levels of emotional anxiety often manifested as an inability to cope. This impacts negatively upon an individual's ability to fully form a strong professional teacher identity and in turn to develop strong self-efficacy. These feelings (of anxiety) have the potential to undermine an individual's '*confidence', leading to* low teacher efficacy.

During training, the absence of strong subject knowledge prevents the pre-service teacher from having the fullest opportunity to learn to teach. Where the pre-service teacher maybe preoccupied with learning subject knowledge, they are unable to focus fully on developing their pedagogical skills as a teacher. This is likely to lead to an

inability to innovative, to push personal boundaries, or to take risks, resulting in pedagogical decisions based not on the learning needs of learners, but on their needs to *'keep safe'*, to maintain control and manage the behaviour of the class.

As teachers, they are unable to move safely beyond *'survival' (*Le Maistre & Paré, 2010), seek to stay within their comfort zones and situations are created where the teacher seeks to maintain control. In turn, pupils learning is restricted in that it does not go beyond the teachers own prepared knowledge. They prevent themselves from developing and engaging in sound pedagogical approaches to lesson delivery, which subsequently prevents them from delivering high-quality teaching. This is of particular concern when considered in light of funded SKE enhancement courses, designed specifically to attract those without STEM subject knowledge into the teaching profession, which can be completed alongside an individual's PGCE year (DfE, 2017).

Studies of science teachers' knowledge of science and the impact subject knowledge has on teaching has shown that when the teachers were asked to prepare materials for teaching that did not fall within their immediate field of expertise, more misconceptions, misunderstandings and a less organised understanding of the information was evident. However, while working within their own specialisms teachers were better able to modify the material and were more likely to discover, and act on, student misconceptions (Hashweh, 1985).

Teachers have a range of generic pedagogical approaches at their disposal, however as research shows (Prosser & Trigwell, 1999; Trigwell 2002; Lindblom-Ylänne *et al*.

2006), there are specific disciplinary differences in and between subjects and where subject knowledge is absent, the individual is unable to transform subject matter into content suitable for specific disciplinary teaching, and consequently full pedagogic development is stalled. Under conditions where pedagogical practice is restricted, teaching is more likely to be presented as the transmission of information, utilising teacher-focused, content centred, rote learning approaches to the delivery of subject material.

Where the pre-service teacher is anxious about their own learning yet is unable to challenge themselves or to explore anything other than *'safe'* pedagogical approaches, this may lead the pre-service teacher to experience feelings of inadequacy and professional vulnerability. If the pre-service teacher is unable to challenge effectively their own vulnerability, findings show that vulnerable teachers are more likely to limit pedagogical approaches when teaching, and consequently pupil learning may be restricted.

An additional, but similar difficulty, may be encountered where the pre-service teacher is asked to teach beyond the limits of their own subject, an increasingly common occurrence in secondary age phase schools in England, and given the likely deepening of the STEM teacher shortage (Lynch *et al.* 2016; McIvor, 2017; Sellgren, 2017) a practice that is likely to increase. Findings show that where an individual's approach to learning is deep, and autonomy, efficacy and self-regulation are high, confidence is increased, and under these conditions pre-service teachers may see such a request as developmental.

However, where the pre-service teacher has limited agency and is already struggling to develop strong pedagogical practices within their own specialist subject discipline, if asked to consider additional teaching, feelings of inadequacy may be compounded. In order to explore this facet of the study fully, further work is required to explore the distinct differences and difficulties encountered between those with LSR (passive consumers of knowledge who themselves adopt surface approaches to learning), as opposed to HSR and the dynamic and impact on pedagogical approaches in light of *'weak'* subject knowledge. In summary, in addition to subject knowledge pedagogy (planning, teaching, assessment, and misconceptions) absent subject knowledge has the potential to create difficulties from many perspectives including:

- the mental health and well-being of the teacher (with respect to confidence and anxiety)
- pupils (limited learning, pupil discomfort and anxiety)
- classroom management, discipline, and behaviour
- externality (the views of others)

While much has been written about PCK an extensive review of the literature reveals limited work to address the relationship between the development of subject knowledge and the emergence of pre-service teacher identity (Atkinson, 2011), and the impact of inadequate or weak subject knowledge (perceived or real) on either a pre-service teacher's conception of teaching, their approach to learning, or on the formation of their identity.

The development of strong pedagogical approaches during the early stages of a pre-service teacher's career is important because research suggests (Herckis, 2017) that once established teachers find it difficult to change teaching behaviours that they understand to be good and that they are comfortable with. Outcomes from this study have highlighted an aspect of pre-service teacher identity formation that has been hitherto overlooked; the pre-service teacher's competence (real or perceived) arising from their beliefs in their specialist subject knowledge, its impact on teaching behaviours and on the formation of teacher identity.

5.3 Self sabotage

The second original contribution to knowledge arising as an outcome of this study is the notion of *unintended (or unintentional) self-sabotage.*

Following analysis of the data, findings revealed that for pre-service teachers the meanings assigned to their personal experience, their self-constructed personal philosophy, their ideological beliefs, views and opinions, all have the potential to lead to unintentional sabotage of their own (emergent) professional identity.

5.3.1 Defining self-sabotage

Within the context of teacher-training, as defined by outcomes from this study, '*unintended self-sabotage*' is where any pre-service teacher engages in behaviour which damages the development of their professional identity as a teacher. The result being they unintentionally incapacitate their development, halting or impeding the evolution of their identity and ultimately slowing their own professional development.

At a fundamental level, '*self-sabotage*' occurs where the individual is unaware of or unable to challenge their own experience-related beliefs, their personal narratives and the stories individuals tell themselves, and their interpretations of society's view of *'what a teacher should be'* or *'how a teacher should act'*. Research suggests that teacher behaviours are influenced by underlying beliefs, values and attitudes (Reynolds *et al.* 2011) and unless a teacher is convinced of the need to alter their approach, they will avoid adapting their practice. On the other hand, according to Avalos (2006, 2011), some teachers seek to implement changes in such a way so that they align with their own beliefs about how learning and teaching should occur. The process of challenging, let alone changing, one's own personal beliefs is problematic and according to Bell and Gilbert (1994), Day and Sachs (2004), Stoll *et al.* (2006), and Pekrun and Linnenbrink-Garcia (2014) is likely to lead to an emotional response.

With respect to emotional state, self-sabotaging behaviours are likely to manifest in negative feelings. Feelings that include uncertainty and those of being powerless, which subsequently lead to the lowering of an individual's self-esteem. Building upon the study's outcomes has led to the development of a taxonomy of self-sabotaging behaviours evolved (Figure 5.0). The taxonomy presents five stages articulated as follows:

Unaware

There is no conscious awareness on behalf of the individual that their actions, attitudes, or behaviours are potentially contributing to the sabotage of their own professional development. Consequently, there is no awareness; the individual is unaware

(oblivious) to any negative impact upon the development or formation of their own identity.

Difficulty

The individual may have limited belief in their own agency to influence the structures within which they are working or believe that they have limited credence to implement their own ideas and to make independent choices or to make decisions. The individual may experience significant difficulty engaging with authentic self-reflection, which may serve to impede identity development.

Reluctance

The individual is reluctant (or there is a disinclination) to adopt new or unfamiliar pedagogical approaches. They may have a fear of failure or have limited belief in their own (pedagogical) abilities; they may be closed to the concept of adopting a pedagogical approach, or to explore new and emerging pedagogical practices.

Inflexible

The individual is inflexible in their approach, which manifests internally and externally as a resistance to change. In practice, this creates barriers to embracing anything perceived by the individual as different or new, irrespective of the origin of the idea or pedagogy being considered.

Rigid

The individual is rigid in their approach, unable, or unwilling to move from their established views and beliefs. There is an inability to change, or to challenge personal philosophy, ideology and opinions of how a teacher should be, act or behave.

A Classification of Self-Sabotaging Behaviours	
1	**Unaware**
2	**Difficulty**
3	**Reluctance**
4	**Inflexible**
5	**Rigid**

Figure 5.0

A classification of self-sabotaging behaviours.

Findings from this study show that deep-rooted personal philosophies, unrealistic ideologies or naïve expectations are likely to be a significant contributory factor in '*self-sabotaging behaviours'*. Having assigned meaning to their own experiences, only once an individual has recognised the *'mismatch'* between their beliefs and the reality of their

nascent practice, will they be aware of the potential need to *'modify'* their fixed ideas (beliefs) and only then may new (different) professional practices emerge.

There is significant power in the use of self-reflective stories in shaping one's identity, combining parts of the past with those of the present (Feiman-Nemser, 2001:1029). Nevertheless, pre-service teachers need to be supported to understand how prior experiences influence and inform current behaviours and how genuine self-reflection can be utilised as a tool to support development. In doing so, they need to see this as a mechanism which can successfully change their pre-existing perceptions in the light of new experiences gained through their training and continual professional development beyond.

Through this process of learning to understand how experience-related beliefs can, and do, shape the formation of identity, learners (pre-service teachers) can actively help themselves to be aware of and to avoid these potentially damaging (unintentional) self-sabotaging behaviours.

5.4 Professional morality; teaching as a compromise and the notion of identity drift

Identity is not a fixed trait; it is continually shaped and re-shaped by the meaning assigned to experiences of an individual. This process involves the constant negotiation between one's own ideology, personal philosophy and the reality of professional practice. Successful and sustained teaching is the careful negotiation and constant compromise of these (quite often) deep-seated views, values, opinions and beliefs within the context of each individual and their unique working environment.

The third original contribution to knowledge presented as an outcome of this study seeks to aid our understanding of teacher attrition through the lens of professional identity, building upon the concept of professional morality.

In this outcome, findings from the study developed the theory of teaching as a compromise which has led to the development of the notional concept of *'identity drift'.* Based upon insights generated directly from the data, this notion is underpinned by the belief that teacher attrition is more likely to occur when a teacher is no longer able to effectively manage the gap between their own ideological beliefs and the reality of their own professional practice.

This status is likely to occur where, irrespective of what is going on around them, the teacher has a firm belief (grounded in their own experience) that what they are doing is *'right'*. If circumstances change, or situations occur that do not align with an individual's ideological beliefs this creates an impasse. This issue is discussed by Nghia (2017) who notes "*although teacher beliefs can influence their pedagogical practice, their teaching behaviour may not be consistent with their beliefs*" (Nghia, 2017:106) and for a new teacher, trying to cope with the demands and pressure, teaching is likely to become *"frustrating, unrewarding and intolerably difficult which increases the risk of attrition"* (Fantilli & McDougall, 2009).

Referring to the mobilisation of *"occasional identities"*, Day *et al.* (2005:575) warn of the damage to an individual's professional identity as a teacher, where no consideration is given to the complex process of balancing one's own personal beliefs against

institutions priorities. Where the change of circumstance is perceived to be permanent, building upon outcomes from this study, findings suggest that the individual has no choice but to compromise their intrinsic beliefs that form an integral part of *'who they are'*. This creates a dilemma, where in the day-to-day engagement of their role as a teacher they find themselves in conflict with their professional self (personal beliefs about the role of a teacher). The moral and in some circumstances ethical issue arises with the individuals subsequent action. In reality, this is *'Hobson's Choice'* with any course of action taken likely to lead to attrition. In some instances, the compromise may be insurmountable and lead to immediate withdrawal from teaching. In other instances, the individual may try to *'stick to their guns'* and continue to work as they always have, but outcomes from this study indicate that in practice this is likely to lead to conflict within the working environment and subsequently it may also lead to attrition. In some instances, an individual may decide to *'follow the herd'* and move away from what they believe to be *'right'*. In doing so they compromise their own beliefs and professional identity; a situation that is likely to lead to frustration, discontent and eventually attrition.

According to Assen *et al.* (2016), teacher beliefs do not always translate into behaviours and in practice for some, the act of teaching is a constant compromise to manage the conflict between their own deep-seated values, views and opinions and the actuality of their experiences of life as a teacher.

Where a pre-service teacher does not recognise the potential impact that feelings and emotions (negative or positive) play in their own development, or they do not recognise the impact one's own experience-related beliefs has on the development of their individuality, issues with identity development may be created.

5.4.1 Defining the notion of identity drift

The original contribution to knowledge that lies within the conceptual notion of identity drift is where the individuals' ideological ideals and the reality of classroom practice *'drift'* so far apart from each other that the individual is no longer able to reconcile their internalised identity with their external one.

Where the link between personal and professional values, opinions and beliefs align with the direction and culture of their working environment, the individual is more likely to be absorbed into their role. However, over time, where cultural dynamics change, but internally held beliefs remain, there may come a point where the individual's internal identity differs so significantly from their external reality, the gap between ideology and actuality widens to an unmanageable degree which may lead to teacher attrition (Figure 5.1).

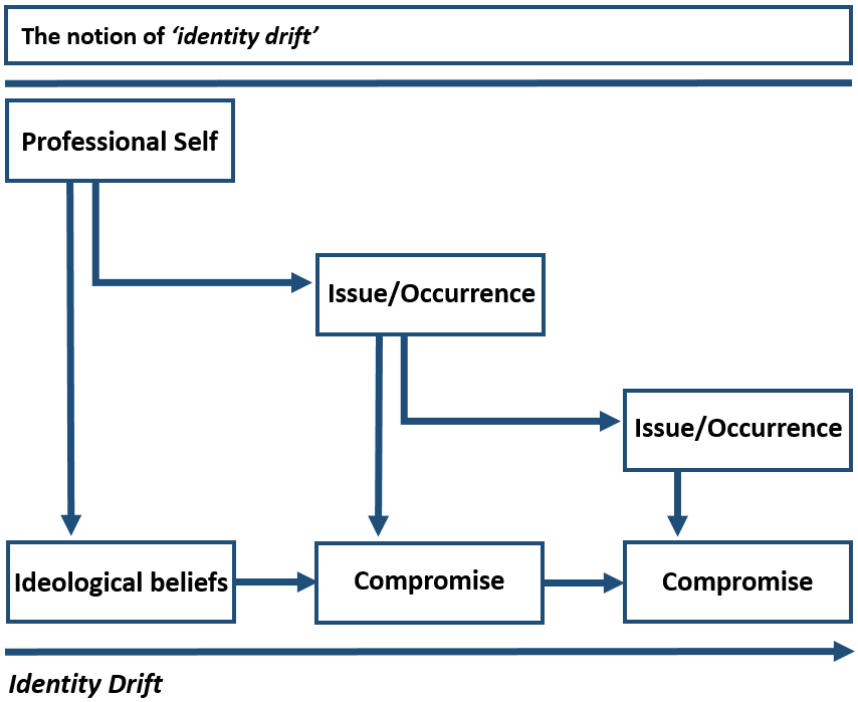

Figure 5.1

Teaching as a compromise: The notion of 'identity drift'.

Experiencing teaching as a compromise may lead to the generation of feelings of stress and anxiety and within individuals this may manifest as issues with general health and well-being. In addition to the potential stress and feelings of anxiety identity drift is likely to cause within the teachers themselves, it is necessary to consider the potential impact on those who they teach. There is limited research that explores the impact that teacher stress has on pupils (Devon, 2017). However, based upon interpretations of their own experiences as learners as recounted by those engaged in this research and contributing new knowledge to the literature in this area, this study found evidence of the impact that teacher stress (anxiety) had on individuals when they were learners (pupils). Where a teacher showed a loss of control or presented feelings within the

classroom interpreted by the pupils or students as anger, frustration or anxiety, this had a negative impact upon them as learners. Depending upon the specific circumstance, recounted manifestations included the transference of emotion caused the pupil to experience feelings of fear, anxiety, nervousness or shame.

According to Herckis *et al.* (2017) and Pajares (1992), once established teachers tend to adhere to conservative ideas of what constitutes good teaching and that once set, their practices can be difficult to change. Lortie explores the notion of conservatism and individualism (Lortie in Hargreaves *et al*. 2010:147) and found that because teachers have a stake in their own autonomy, they are unlikely to embrace activity to threaten it. Subsequently, where there is an inability to change one's own behaviour, when the *'reality shock'* of classroom practice kicks in (Veenman, 1984:143), newly qualified teachers tend to fall back on the *'apprentice of observation'* (Lortie, 1975). According to Hargreaves (2010:146), these are traditional memories of how to teach based upon their own experiences as pupils, which he suggests offer "*little hope of innovation but strong prospects for persisting conservatism"*.

The patterns of behaviour leading to identity drift affect those with both high and low self-regulation (although findings at this stage would suggest to a lesser extent in those with HSR) and a disposition open to challenging and changing ideas and perceptions of teaching. Although outcomes suggest that the patterns of behaviour leading to identity drift are more likely to impact upon those with LSR, I am mindful that within this study findings have emerged from the reflections of pre-service teachers. As such, further investigatory work to explore this outcome from the perceptions of newly or recently

qualified teachers, longer-term career teachers and those who are no longer working within the profession, would yield additional potentially interesting outcomes.

Findings from this study also support the notion that if unchallenged, experience-related beliefs can limit personal growth. However, in no way is this a call to abandon one's own beliefs. More so, this is an acknowledgment that where the requirements of a teacher's role are continually at odds with the individuals natural disposition, over time there is an inability to continue to accommodate one's own pre-conceived ideas. Where teaching has become a constant (cumulative) compromise and teaching is no longer palatable and they are tired of recurrently fighting *'the system'*, this pattern of behaviour leads to identity drift and so teacher attrition is highly likely to be the resultant outcome. Findings from this study suggest that as a strategy to support a reduction in teacher attrition, it would be beneficial for pre-service teachers to be encouraged to have an open and flexible approach toward the adaption and modification of both their personal and professional identities.

5.5 The interrelationships between theoretical insights

Findings obtained directly from this study have led to the formation of three outcomes. Each individual outcome is operationally independent of the others however as a tool to support, and better understand the unique facets of identity formation and potentially to examine how identity changes over time, it would be of interest to explore, as a prelude to potential future work, the potential connections and interrelationships between each of the three theoretical insights presented.

Figure 5.2

Theoretical insights: Independent influences on identity.

In addition to the independent examination of identity through the application of the theoretical insights presented in this study, exploring the interrelations in and between could serve to give a better insight into developing and changing identities.

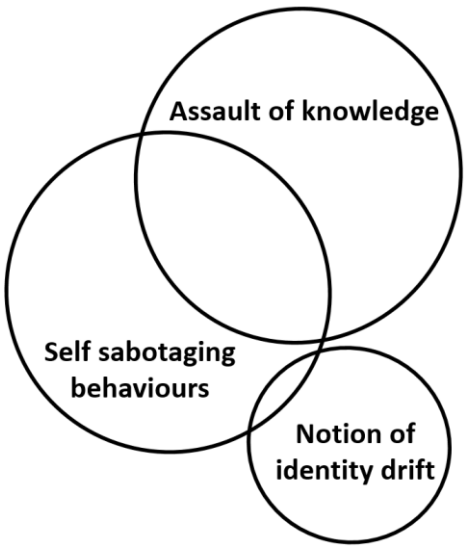

Figure 5.3

Theoretical insights: Interrelationships between theoretical insights.

Figure 5.3 illustrates the potential profile of a pre-service, or early career teacher. In this exemplar model, subject knowledge is developing, and as identity forms some potentially self-sabotaging behaviours are occurring. At this stage while ideological beliefs are challenged, they are not tested to the extent where attrition is likely to occur.

The development of a tool to explore further the interrelation between each insight could serve to highlight and potentially predict teaching behaviours, which would not only be useful in developing pre-service teacher education training programmes but could be utilised to support both recently qualified and career teachers. For example, a particular profile observed during training may indicate a likely training or developmental need or could be linked to teacher attrition. Utilisation of the tool could predict or reveal changes in profile and the findings be used accordingly. Experiences can either *'shape or distort'* the formation of identity (Weber & Mitchell, 1996) and a significant aspect of the pre-service teacher's journey should be to encourage the exploration of their personal knowledge and beliefs. To analyse the emphasis placed on the meanings that impact upon attitudes and behaviour and to better understand the way pre-service teachers interpret or act toward structural factors may be beneficial. For example, the environment within which they are working, or the stereotypes and social norms attached to teachers and teaching should be considered with a view to unlocking the pre-service teacher's personal *'history'*, so it works to support their development, instead of sabotaging it.

5.6 Chapter summary

Chapter 5 presented for discussion of this study's outcomes and in doing so brought to the fore how each contributes in a new and unique way to the existing literature, substantiating the validity of my claim to the generation of original knowledge.

Furthermore, although able to operate independently of each other, in the latter section of this chapter I introduced the potential of exploring the interrelations between each theoretical insight (outcome) as a concept to secure a fuller picture of the influence of an individual outcome impacts on another aspect of identity, and how in mapping the relations in and between each theoretical insight the dynamics of individuals identity change may be observed.

6.0 Chapter Six

6.1 Conclusion

In this closing chapter, I present an overview of my research, a summary of the rationale for undertaking the work and a summary of the theoretical insights (outcomes) that emerged. This study has gone some way towards enhancing our understanding of the facets integral to the formation of a STEM teacher's professional identity, and with respect to the study's outcomes, I explain how they contribute to the existing literature and contribute to the field with regard to the generation of new and original knowledge.

Finally, drawing this study to a close I outline my concluding thoughts, and present a framework of potential areas of future research.

6.2 A summary review of the outcomes of the study

I undertook this study because of my personal interest in STEM education and specifically my concerns in relation to the recruitment and retention of specialist STEM teachers, particularly in secondary age phase education.

The supply of highly qualified scientists, technologists, engineers and mathematicians is perceived by governments globally as being vital in securing economic prosperity, but somewhere along the line pupils are being 'switched off' and disengage with the study of STEM beyond compulsory schooling.

Improved STEM education is presented as a way forward, and the supply of well qualified teachers is perceived as integral to achieving this vision. Set against a background of policy reform and curriculum change, STEM teacher shortages, and my personal concerns in relation to the recruitment of suitably qualified trainee teacher candidates. Particularly around the acquisition and development of specialist STEM subject knowledge, and the expansion of subject knowledge enhancement courses as a means of larger numbers of candidates accessing STEM teacher training, which in many cases involve very little *'enhancement'*.

My motivation was to gain an understanding of how pre-service teachers, training to deliver STEM based subject disciplines, approaches to their own learning, and subsequently how their approaches to pedagogy, are shaped by their subject knowledge and the meaning they have assigned to their own previous experiences.

In designing this study, to align with my own ontological position I adopted symbolic interactionism as my methodological approach (because it fosters an empathetic understanding of participants and their worlds) and utilised research methods informed by constructivist grounded theory. Through an iterative process of concurrent data collection and analysis, several findings emerged and following phases of open, focused, selective, and theoretical coding data was refined to bring to the fore three key outcomes.

While work undertaken within this study has been undertaken within the context of STEM, and as such the specific challenges faced with respect to the development and

acquisition of specialist STEM subject knowledge is likely less of an issue for those training to teach non-STEM based subjects, it is likely that many outcomes are applicable to and as such may resonate with and hence be of potential interest to those engaged in the training of pre-service teachers beyond those studying the STEM subject disciplines under consideration.

6.2.1 A review of success and failures

During the early stages of my work, naïvely I envisaged the findings would converge and steer me toward the identification of a single, or cluster of the most effective pedagogical approaches to the delivery of STEM. This would in turn lead to the generation of a STEM specific pedagogical framework that could be adopted for use in the classroom to encourage more young people to study STEM beyond compulsory schooling.

In some respects, a favoured pedagogy did emerge, with the majority of participants identifying applied approaches as being the most effective and there is certainly merit in the promotion of collaborative work between the STEM subject disciplines. However, as my research progressed and my own abilities as a researcher developed, it became clear that to advocate a single approach to the delivery of the STEM subjects would be both naïve and counterproductive.

Within this study, research was undertaken within the broadest context of STEM, as defined by the English national curriculum (DfE, 2017), and this proved useful in the comparative examination of identity formation of participants working within and

between the individual STEM disciplines. The rich data gathered during the study identified many potential avenues for investigation, but within the scope of this study, it has not been possible to develop and to explore each in detail.

However, that is not to say those uncovered but not explored fully are unworthy of further development. Decisions about which themes to develop were based on the richness of participant data gathered during the study and the clustering of codes and categories, taking the strongest forward, which have been further developed as theoretical insights. These include the impact, particularly on female pre-service teacher's, of engendered pedagogical approaches to the delivery of STEM subject disciplines. The impact on identity, and subsequently motivation of teachers engaged in the delivery of those STEM subject disciplines perceived by some (Paechter, 1993, 2002) to be of lower status (or value) than their curriculum counterparts, and the impact of teacher anxiety on pupil progress, attainment and their longer-term engagement (beyond compulsory schooling) with STEM subject disciplines. So, while not a failure of this work, I am aware of areas that have not been fully explored, and plan to examine these themes in the near future.

6.3 An Assault of Knowledge

The findings from this study make several contributions to the current literature. Bound within analysis of this study's data, the first theoretical insight I present as making a new and original contribution to the existing literature is *'an assault of knowledge'*. This describes a *'pedagogical subject gap', which is in essence* a *'space'* or *'gap'* in a pre-

service teacher's specialist disciplinary STEM subject knowledge that has the potential to harm the formation of a teacher's identity.

Findings from this study show that the impact of weak subject knowledge on pre-service teacher's development is significant. Where a pre-service teacher does not have adequate STEM subject knowledge from which to draw, they struggle to know what they are teaching, or why they are teaching what they are teaching. This is potentially of more significance with the STEM subject disciplines because of the difficulty to recruit suitably qualified candidates to undertake ITE courses. Referring specifically to a type of anxiety that forms around a pre-service teacher's *'lack'* (or perceived lack) of subject knowledge, this insight refers to the liminal moment in development where if present, subject matter may be transformed into PCK, and as such is in the *'space'* where a beginning teacher's identity first begins to form. Where subject knowledge is absent, this prevents the pre-service teacher from fully developing their ability to transform subject matter into pedagogical content, which makes knowledge accessible to a learner.

The term *'assault of knowledge'* arises because within this theoretical insight, where subject knowledge is delivered unrefined without any pedagogical adaptation or refinement that takes into consideration the needs of the learner, knowledge is received by the learner in an unyielding, relentless and inescapable fashion, hence the term *'an assault of knowledge'*.

6.4 Unintended self-sabotage and the notion of self-sabotaging behaviours

The second outcome that makes a new and original contribution to literature within the field to emerge from this study is the notion of self-sabotage.

For those training to teach, the meanings they assign to their own experience, that is to say the pre-service teachers self-constructed personal philosophy and their ideological beliefs, views, and opinions, has the potential to lead to the unintentional self-sabotage of their own emergent professional identity.

Self-sabotage is where the pre-service teacher is unable to move beyond their internally imposed boundaries and damages their own development, unintentionally incapacitating themselves and halting the formation of their professional identity. Where there is an inability to challenge one's own experience-related beliefs, and personally held perceptions of *'what a teacher should be'* or *'how a teacher should act'* this can lead pre-service teachers to engage in unintentional self-sabotaging behaviours. Self-sabotage manifests as unpleasant feelings of uncertainty and of being powerless. This in turn leads to the lowering of self-esteem and conditions that serve only to limit the formation of an individual's professional identity.

6.5 Teaching as a compromise and the notion of identity drift

The third outcome and original contribution to knowledge to emerge from this study is the notion of identity drift.

Successful and sustained teaching is the careful negotiation, and in some cases the constant compromise, of one's own deep-seated views, values, opinions, and beliefs. This is where the individual's ideological beliefs and the reality of their classroom practice drift so far apart the individual no longer has the ability to reconcile their internalised identity from their external one.

Identity is not a fixed trait; it is continually shaped and re-shaped by the meaning assigned to experiences; a process that involves the constant negotiation between one's own ideology, personal philosophy and the reality of classroom practice. Findings from this study leading to the development of this theoretical insight suggest that over time, where an individual is no longer able to effectively manage the space between their own ideological beliefs and the reality of their own practice, teacher attrition has a higher propensity to be the outcome.

In summary, where the gap between an individual's ideological beliefs and their actual reality widens beyond a limit tolerable to the individual, this is likely to lead to teacher attrition.

6.6 Concluding thoughts

Teachers' beliefs are shaped by their individual sociocultural background, their childhood memories, their life and work experiences. Identity, however, is not a fixed trait and the professional knowledge and beliefs held by teachers metamorphose and are shaped and reshaped constantly, adapting in response to new experiences. There can be no doubt that the ways in which teachers achieve, maintain and develop their identity

(their ‘sense of self’) are of vital significance in understanding the actions and commitments of teachers in their work, in addition to influences they derive from the way in which they are trained (Beauchamp & Thomas, 2009; Pinnegar *et al.* 2011).

Where an individual believes they have limited subject knowledge, their ability to develop fully their own professional identity and self-efficacy is restricted. This is because a pre-service teacher’s perceived lack of, or actual weakness in, subject knowledge limits the pedagogical approach they are rather likely to adopt and then their teaching style(s) are constrained. Consequently, in relation to lesson delivery, fewer ‘risks’ will be taken, with pre-service teachers seeking to stay within their pedagogical safe space, rather than utilising innovative pedagogy and student-centred approaches that are likely to lead to the adoption of teacher-focused approaches. Where teaching is reduced to the delivery or transmission of knowledge, learning has been shown to result in a surface approach (Trigwell *et al.* 1999).

Teaching requires the emotional immersion into one’s work (Nias, 1996), and Beijaard (2000) found that identity is closely bound to personal and professional values, and there is general agreement among researchers (Kelchtermans, 2005; Day *et al.* 2006; Beauchamp & Thomas, 2009) that an understanding of oneself is a crucial element in the successful formation of a teacher’s professional identity. Consequently, pre-service teachers’ feelings of professional inadequacy grow, and the interpretation of their own performance leads them to believe that they are not living up to their own expectations (or perceptions) of what a teacher is and how a teacher should act. Under these

conditions, findings show that low self-efficacy is more likely to result in the passive consumption of knowledge, and in turn the adoption of surface approaches to learning.

6.6.1 Implications for policy and practice

Aligning with the outcomes of work by Pinnegar *et al.* (2011) and Beauchamp and Thomas (2009), findings from this study strongly suggest, that there would be tangible benefits in supporting pre-service teachers of the STEM subject disciplines to be aware of the meaning they have assigned to their own experiences and to challenge their own beliefs.

Research shows that once qualified and in post, teachers are highly unlikely to adapt their established pedagogical practice (Herckis *et al.* 2017). Therefore, it is essential to ensure that at the end of their formal training, teachers entering the newly qualified space are independent, confident practitioners, with both the desire and capability to explore and embrace novel approaches to learning and teaching.

Recommendations based upon findings from this study would therefore include implementation of policy, guidance or a code of practice that ensures a scaffolded approach to support for pre-service teachers of STEM subject disciplines to develop a comprehensive understanding of the meaning they have assigned to their experiences, forms part of their formal teacher education and training. This would include the adoption of practical strategies to support those working with pre-service teachers to examine the benefits of honest self-reflection and the role it can play in serving to self-

raise self-awareness within teacher education programmes, to help pre-service teachers understand how their identities form.

It is critical therefore, that during the training period, self-awareness is raised within the individual so that they may better understand this pivotal period in the development of their professional identity. They would then be well placed to explore how the process of interpretation and re-interpretation of their first-hand experiences, and the meaning assigned, influence how they act and feel, and contribute the values and beliefs they hold. From the perspective of those in teacher education, there is a need to ensure that they are prepared to be able to offer specific support to help effectively manage the pre-service teacher's emergent and evolving identity. In working with pre-service teachers, mentors should encourage pre-service teachers to think of themselves as learners and utilise their personal histories to better understand themselves. They should be encouraged to explore how the meaning that they have assigned to their own personal experience as learners, influences their approaches to learning now and how that in turn shapes their beliefs about what a teacher should be and impacts upon the choices they make as their identities as beginning teachers form.

Where reflection is encouraged and undertaken within a constructed scaffold of support, pre-service teachers may be afforded an opportunity that enables them to become agents active in shaping, and most importantly, become equipped with the tools (knowledge) to re-shape their own professional identities beyond the initial training period.

Through the process of structured reflection, memories can be re-interpreted and utilised to support pre-service teachers in successfully challenging beliefs that may (unintentionally) be impeding identity formation. Left unchecked in the longer-term, this research shows that this impedance will lead to identity drift and ultimately it is highly likely to lead to result in teachers leaving the profession once it becomes intolerable.

6.6.2 Implications for future research

Emerging from this study are the notions of *'an assault of knowledge', 'self-sabotage'* and *'identity drift'* and potential work designed to specifically investigate further each of these aspects of teacher identity, and also the interrelations between them which holds the potential to develop an (electronic) self-diagnostic tool, has already been identified.

However, in addition there were several areas of interest that arose within this study that I am keen to pursue, but that I due to the relatively small number of participants involved from each STEM discipline did not have sufficient data or space within this thesis to explore fully:

- the impact, particularly on female pre-service teacher's, of engendered pedagogical approaches to the delivery of STEM subject disciplines. Research shows (Jidesjö and Danielsson, 2016) that as pupil's girls tend to be more interested in the human aspects of the curriculum and findings from this study suggest that as women, this interest remains, and it is the human facets of

teaching that is a significant factor in attracting females into the profession. Examining the issues female STEM pre-service teachers face as they navigate their training, outcomes from this study indicate that particularly when working within the traditionally male dominated STEM subject discipline of Mathematics, hegemonic views curtail the freedom of some teachers to explore their preferred teaching approaches.

- Within the context of Computer Science as an embryonic STEM discipline work to examine emergent pedagogies and the experiences of those training to teach as subject they have not experienced themselves as pupils.
- the impact on identity, and subsequently motivation of teachers engaged in the delivery of Design and Technology and to a lesser extent Computer Science, those STEM subject disciplines perceived by some (Paechter, 1993) to be of lower status (or value) than their curriculum counterparts.
- the relationship between professional inadequacy (because of poor identity formation), and teacher anxiety on pupil attainment, progress, behaviour, and well-being.
- The identity formation of Graduate Teaching Assistants (GTAs). GTA's undergo a similar experience to pre-service teachers in that they are both students (learners) and teachers simultaneously. Further work could explore the development of their identity as lecturers, which with the advent of the Teaching Excellence Framework (TEF) (the mechanism through which the government can monitor and assess the quality of teaching in England's universities) may serve to influence positively learning and teaching within Higher Education.

6.7 Chapter summary

In this concluding chapter, I presented an overview of the research study, which included a summary of the rationale, methodological approach and research methods used. I presented for consideration a summary of the study's key findings and articulated how the outcomes add to current literature and as such are presented as original contributions to new knowledge. Finally, in drawing the work to a close I explored briefly my concluding thoughts, and areas of potential future research worthy of further investigation.

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Appendices

Appendix A (Ethical Approval)

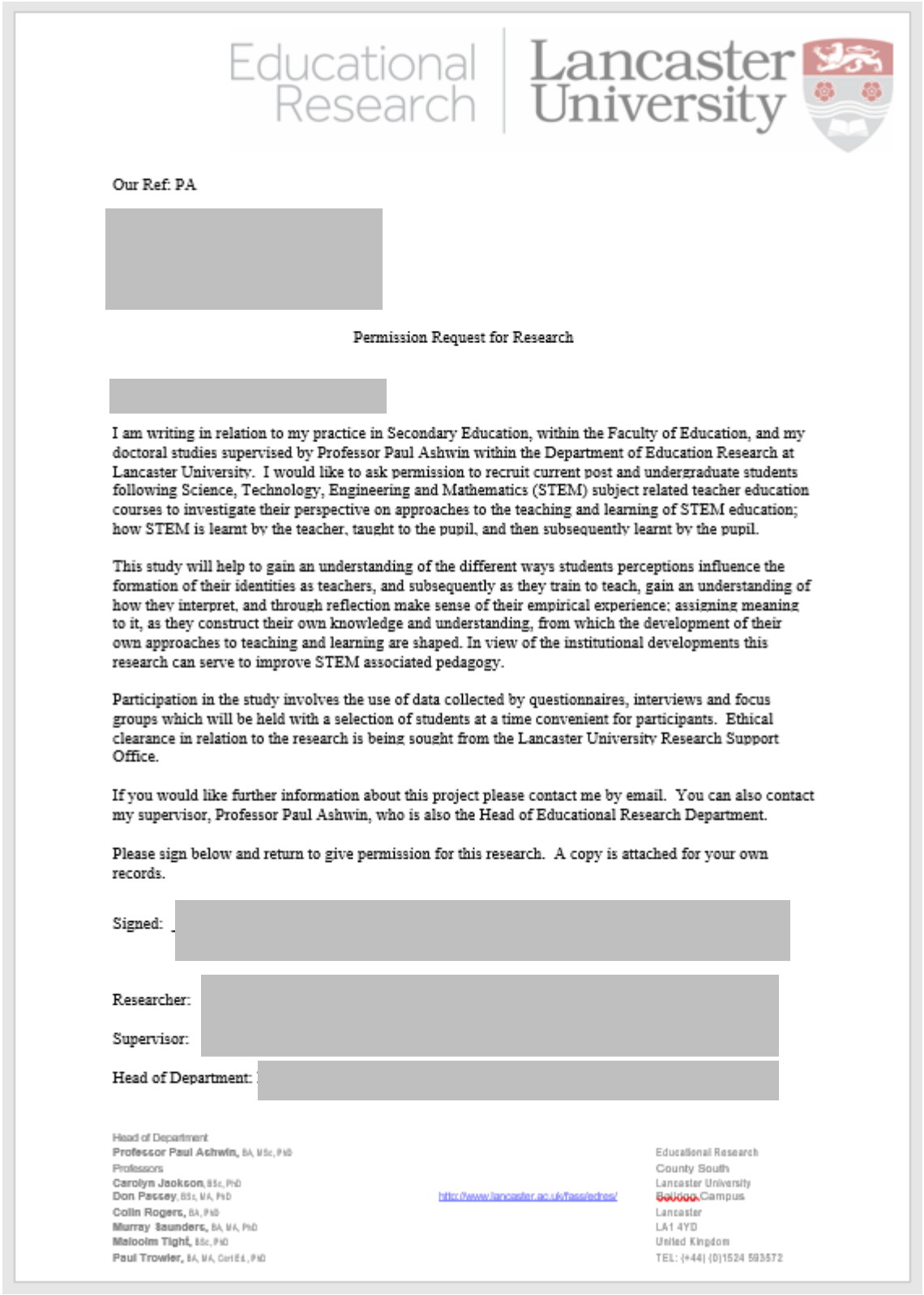
Institutional approval
Participant information sheet
Participant consent form
Confirmaiton email of ethical approval

Appendix B

Further examples of diagrammatic memos and integrative diagrams

Appendix C (Participant biographical detial)

Appendix C, Table C.0
Appendix C, Table C.1



Educational Research | Lancaster University

Our Ref: PA

[redacted]

Permission Request for Research

[redacted]

I am writing in relation to my practice in Secondary Education, within the Faculty of Education, and my doctoral studies supervised by Professor Paul Ashwin within the Department of Education Research at Lancaster University. I would like to ask permission to recruit current post and undergraduate students following Science, Technology, Engineering and Mathematics (STEM) subject related teacher education courses to investigate their perspective on approaches to the teaching and learning of STEM education; how STEM is learnt by the teacher, taught to the pupil, and then subsequently learnt by the pupil.

This study will help to gain an understanding of the different ways students perceptions influence the formation of their identities as teachers, and subsequently as they train to teach, gain an understanding of how they interpret, and through reflection make sense of their empirical experience; assigning meaning to it, as they construct their own knowledge and understanding, from which the development of their own approaches to teaching and learning are shaped. In view of the institutional developments this research can serve to improve STEM associated pedagogy.

Participation in the study involves the use of data collected by questionnaires, interviews and focus groups which will be held with a selection of students at a time convenient for participants. Ethical clearance in relation to the research is being sought from the Lancaster University Research Support Office.

If you would like further information about this project please contact me by email. You can also contact my supervisor, Professor Paul Ashwin, who is also the Head of Educational Research Department.

Please sign below and return to give permission for this research. A copy is attached for your own records.

Signed: [redacted]

Researcher: [redacted]

Supervisor: [redacted]

Head of Department: [redacted]

Head of Department
Professor Paul Ashwin, BA, MSc, PhD
Professors
Carolyn Jackson, BSc, PhD
Don Passey, BSc, MA, PhD
Colin Rogers, BA, PhD
Murray Saunders, BA, MA, PhD
Malcolm Tight, BSc, PhD
Paul Trowler, BA, MA, CertEd., PhD

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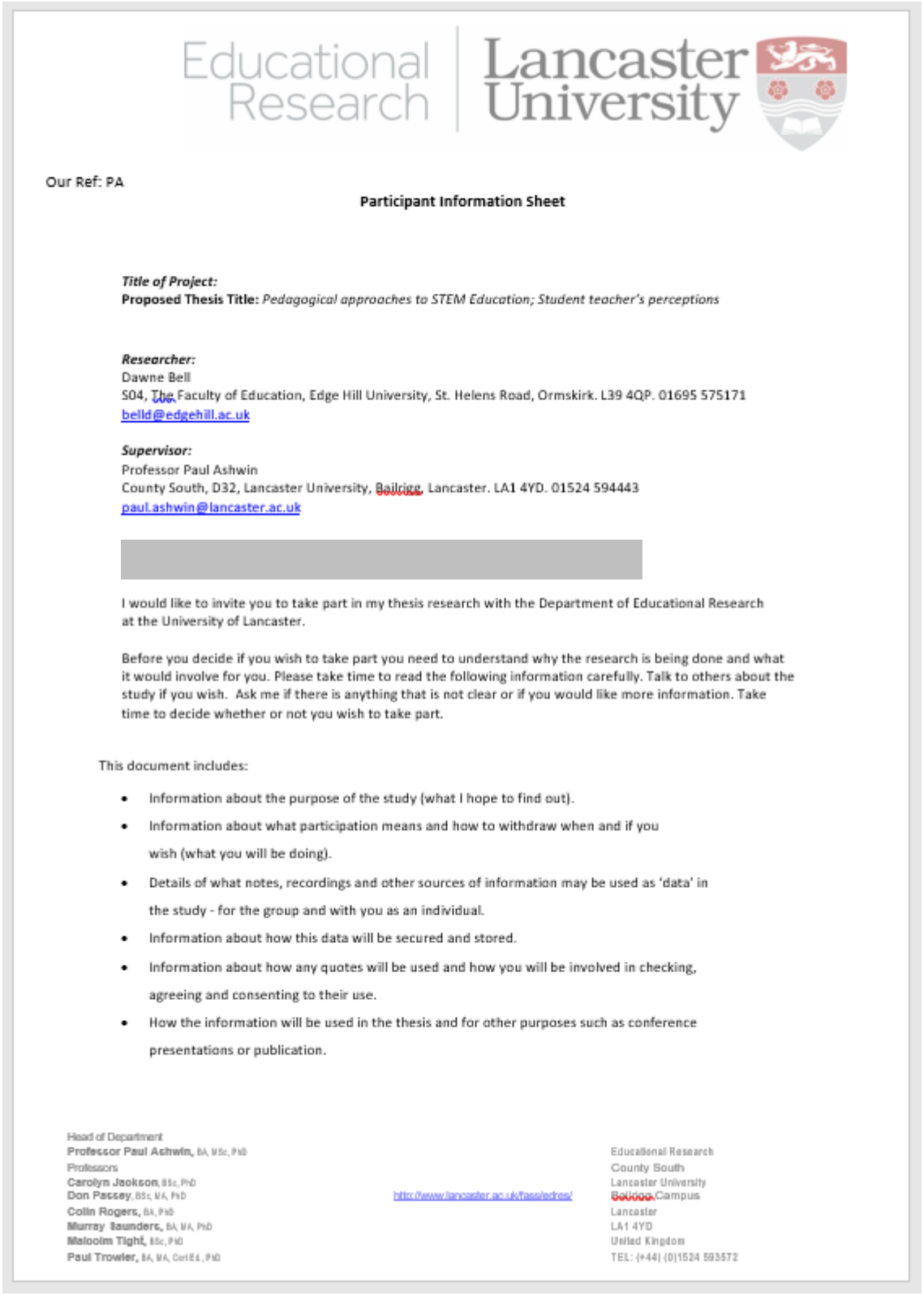
Appendix A (Ethical Approval)
Institutional approval



Educational Research | Lancaster University

Our Ref: PA

Participant Information Sheet

Title of Project:
Proposed Thesis Title: *Pedagogical approaches to STEM Education; Student teacher's perceptions*

Researcher:
Dawne Bell
S04, The Faculty of Education, Edge Hill University, St. Helens Road, Ormskirk. L39 4QP. 01695 575171
belld@edgehill.ac.uk

Supervisor:
Professor Paul Ashwin
County South, D32, Lancaster University, Bailrigg, Lancaster. LA1 4YD. 01524 594443
paul.ashwin@lancaster.ac.uk

I would like to invite you to take part in my thesis research with the Department of Educational Research at the University of Lancaster.

Before you decide if you wish to take part you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Talk to others about the study if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

This document includes:

- Information about the purpose of the study (what I hope to find out).
- Information about what participation means and how to withdraw when and if you wish (what you will be doing).
- Details of what notes, recordings and other sources of information may be used as 'data' in the study - for the group and with you as an individual.
- Information about how this data will be secured and stored.
- Information about how any quotes will be used and how you will be involved in checking, agreeing and consenting to their use.
- How the information will be used in the thesis and for other purposes such as conference presentations or publication.

Head of Department
Professor Paul Ashwin, BA, MSc, PhD
Professors
Carolyn Jackson, BSc, PhD
Don Passey, BSc, MA, PhD
Colin Rogers, BA, PhD
Murray Saunders, BA, MA, PhD
Malcolm Tight, BSc, PhD
Paul Trowler, BA, MA, CertEd., PhD

http://www.lancaster.ac.uk/fass/edres/

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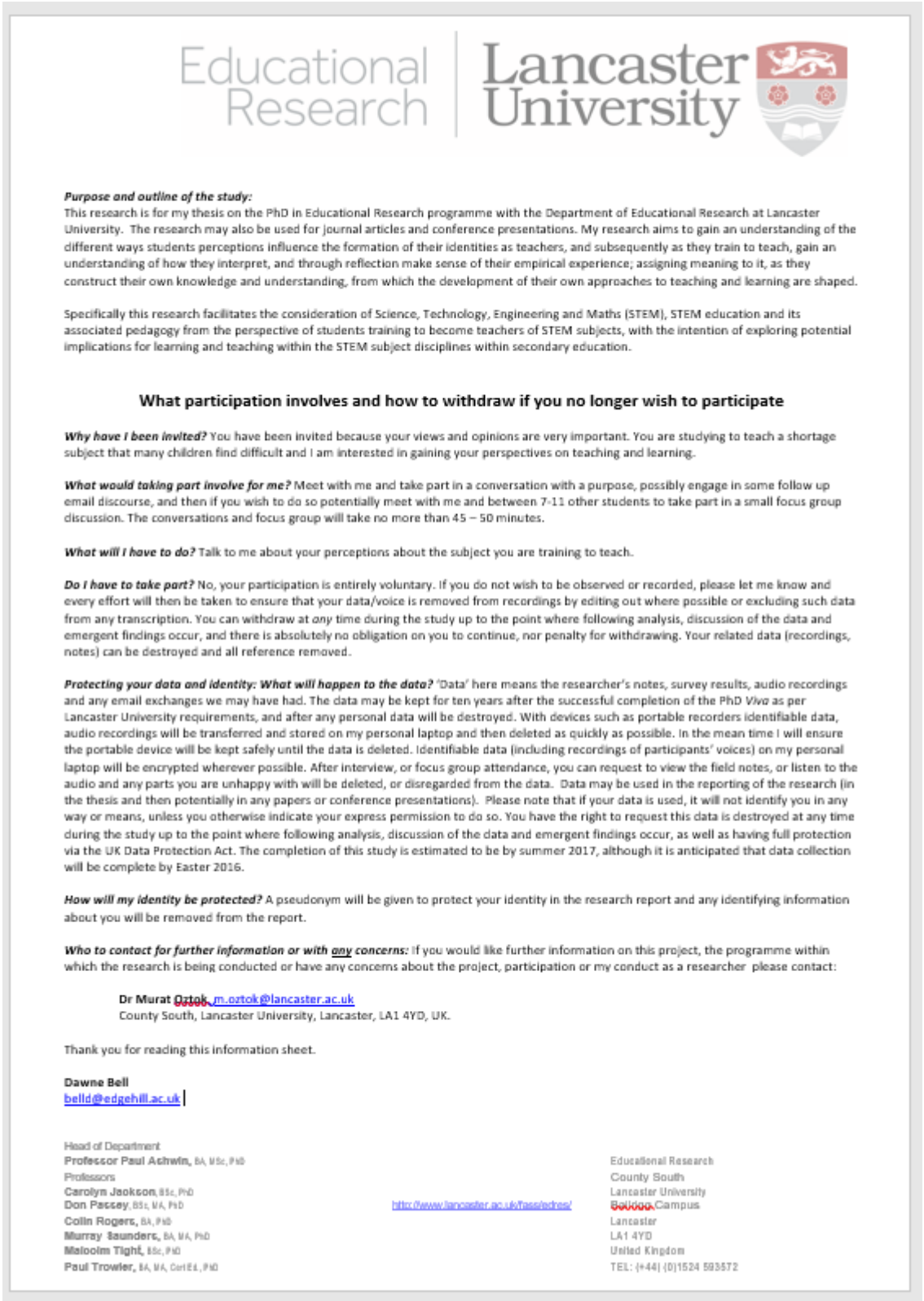
Appendix A (Ethical Approval)
Participant information sheet



Educational Research | Lancaster University

Purpose and outline of the study:
This research is for my thesis on the PhD in Educational Research programme with the Department of Educational Research at Lancaster University. The research may also be used for journal articles and conference presentations. My research aims to gain an understanding of the different ways students perceptions influence the formation of their identities as teachers, and subsequently as they train to teach, gain an understanding of how they interpret, and through reflection make sense of their empirical experience; assigning meaning to it, as they construct their own knowledge and understanding, from which the development of their own approaches to teaching and learning are shaped.

Specifically this research facilitates the consideration of Science, Technology, Engineering and Maths (STEM), STEM education and its associated pedagogy from the perspective of students training to become teachers of STEM subjects, with the intention of exploring potential implications for learning and teaching within the STEM subject disciplines within secondary education.

What participation involves and how to withdraw if you no longer wish to participate

Why have I been invited? You have been invited because your views and opinions are very important. You are studying to teach a shortage subject that many children find difficult and I am interested in gaining your perspectives on teaching and learning.

What would taking part involve for me? Meet with me and take part in a conversation with a purpose, possibly engage in some follow up email discourse, and then if you wish to do so potentially meet with me and between 7-11 other students to take part in a small focus group discussion. The conversations and focus group will take no more than 45 – 50 minutes.

What will I have to do? Talk to me about your perceptions about the subject you are training to teach.

Do I have to take part? No, your participation is entirely voluntary. If you do not wish to be observed or recorded, please let me know and every effort will then be taken to ensure that your data/voice is removed from recordings by editing out where possible or excluding such data from any transcription. You can withdraw at *any* time during the study up to the point where following analysis, discussion of the data and emergent findings occur, and there is absolutely no obligation on you to continue, nor penalty for withdrawing. Your related data (recordings, notes) can be destroyed and all reference removed.

Protecting your data and identity: What will happen to the data? 'Data' here means the researcher's notes, survey results, audio recordings and any email exchanges we may have had. The data may be kept for ten years after the successful completion of the PhD *Viva* as per Lancaster University requirements, and after any personal data will be destroyed. With devices such as portable recorders identifiable data, audio recordings will be transferred and stored on my personal laptop and then deleted as quickly as possible. In the mean time I will ensure the portable device will be kept safely until the data is deleted. Identifiable data (including recordings of participants' voices) on my personal laptop will be encrypted wherever possible. After interview, or focus group attendance, you can request to view the field notes, or listen to the audio and any parts you are unhappy with will be deleted, or disregarded from the data. Data may be used in the reporting of the research (in the thesis and then potentially in any papers or conference presentations). Please note that if your data is used, it will not identify you in any way or means, unless you otherwise indicate your express permission to do so. You have the right to request this data is destroyed at any time during the study up to the point where following analysis, discussion of the data and emergent findings occur, as well as having full protection via the UK Data Protection Act. The completion of this study is estimated to be by summer 2017, although it is anticipated that data collection will be complete by Easter 2016.

How will my identity be protected? A pseudonym will be given to protect your identity in the research report and any identifying information about you will be removed from the report.

Who to contact for further information or with any concerns: If you would like further information on this project, the programme within which the research is being conducted or have any concerns about the project, participation or my conduct as a researcher please contact:

Dr Murat Ortok, m.ortok@lancaster.ac.uk
County South, Lancaster University, Lancaster, LA1 4YD, UK.

Thank you for reading this information sheet.

Dawne Bell
belld@edgehill.ac.uk

Head of Department
Professor Paul Ashwin, BA, MSc, PhD
Professors
Carolyn Jackson, BSc, PhD
Don Passey, BSc, MA, PhD
Colin Rogers, BA, PhD
Murray Saunders, BA, MA, PhD
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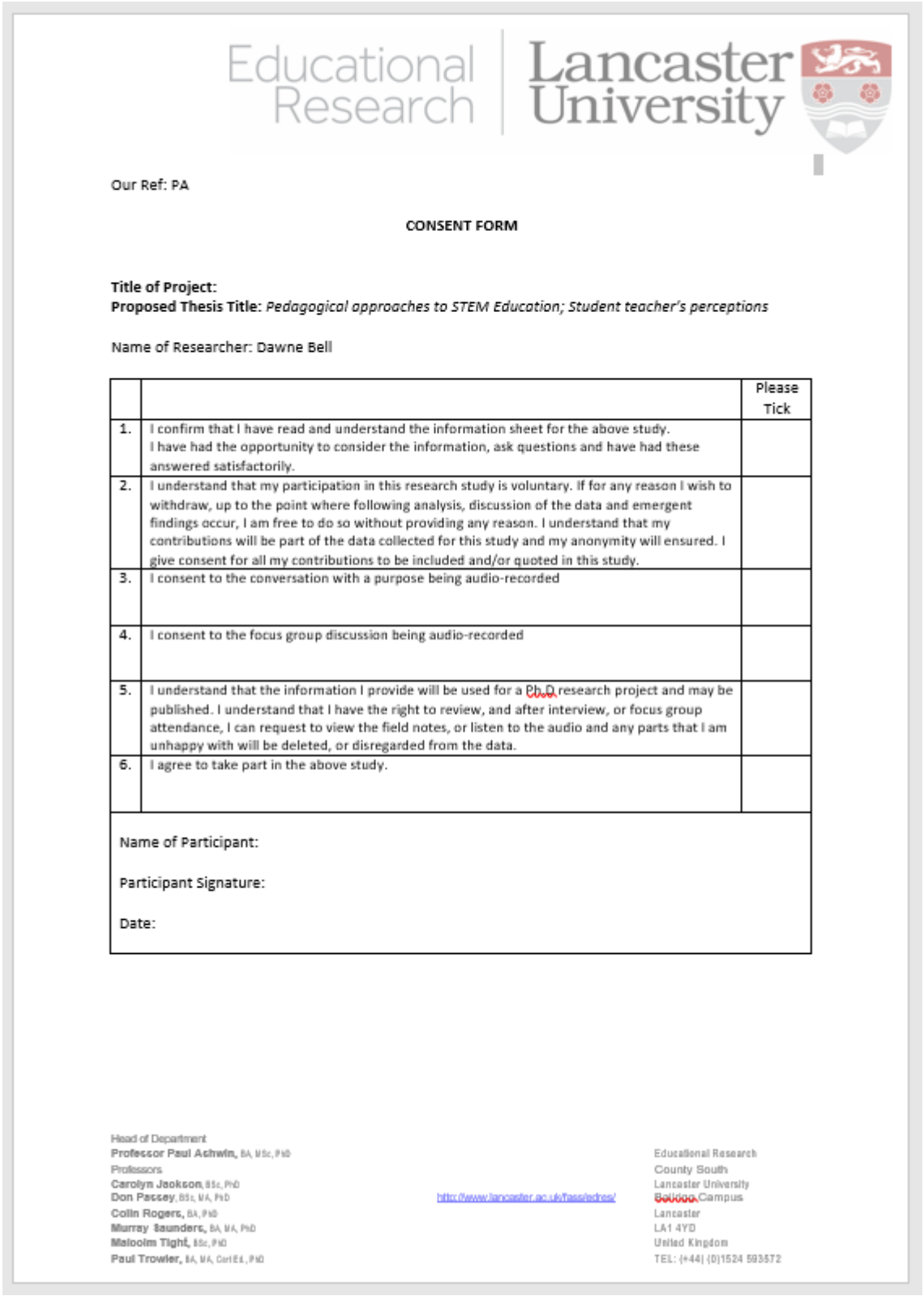
Appendix A (Ethical Approval)
Participant information sheet (continued)



Educational Research | Lancaster University

Our Ref: PA

CONSENT FORM

Title of Project:
Proposed Thesis Title: *Pedagogical approaches to STEM Education; Student teacher's perceptions*

Name of Researcher: Dawne Bell

		Please Tick
1.	I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
2.	I understand that my participation in this research study is voluntary. If for any reason I wish to withdraw, up to the point where following analysis, discussion of the data and emergent findings occur, I am free to do so without providing any reason. I understand that my contributions will be part of the data collected for this study and my anonymity will ensured. I give consent for all my contributions to be included and/or quoted in this study.	
3.	I consent to the conversation with a purpose being audio-recorded	
4.	I consent to the focus group discussion being audio-recorded	
5.	I understand that the information I provide will be used for a PhD research project and may be published. I understand that I have the right to review, and after interview, or focus group attendance, I can request to view the field notes, or listen to the audio and any parts that I am unhappy with will be deleted, or disregarded from the data.	
6.	I agree to take part in the above study.	

Name of Participant:

Participant Signature:

Date:

Head of Department
Professor Paul Ashwin, BA, MSc, PhD
Professors
Carolyn Jackson, BSc, PhD
Don Passey, BSc, MA, PhD
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Appendix A (Ethical Approval)
Participant consent form

Appendix A (Ethical Approval)
Confirmaiton email of ethical approval

Thu 24/09/2015 10:00

Ethics (RSO) Enquiries <ethics@lancaster.ac.uk>

Ethics application approved UREC REFERENCE:RS2014/127

To Dawne Bell; Bell, Dawne

Cc Ashwin, Paul; Sedgwick, Alison

Retention Policy keep for (2 years) Expires 23/09/2017

You forwarded this message on 24/09/2015 22:07.

Dear Dawne

Thank you for submitting your completed stage 1 self assessment form and additional information for **Pedagogical approaches to STEM Education; Student teacher's perceptions.** The Part B information has been reviewed by members of the University Research Ethics Committee (UREC) and I can confirm that the Chair of UREC has granted approval for this project.

As principal investigator your responsibilities include:

- ensuring that (where applicable) all the necessary legal and regulatory requirements in order to conduct the research are met, and the necessary licenses and approvals have been obtained;
- reporting any ethics-related issues that occur during the course of the research or arising from the research (e.g. unforeseen ethical issues, complaints about the conduct of the research, adverse reactions such as extreme distress) to the Research Ethics Officer;
- submitting details of proposed substantive amendments to the protocol to the Research Ethics Officer for approval.

Please contact the Research Ethics Officer, Debbie Knight (ethics@lancaster.ac.uk 01542 592605) if you have any queries or require further information.

Kind regards,

Debbie

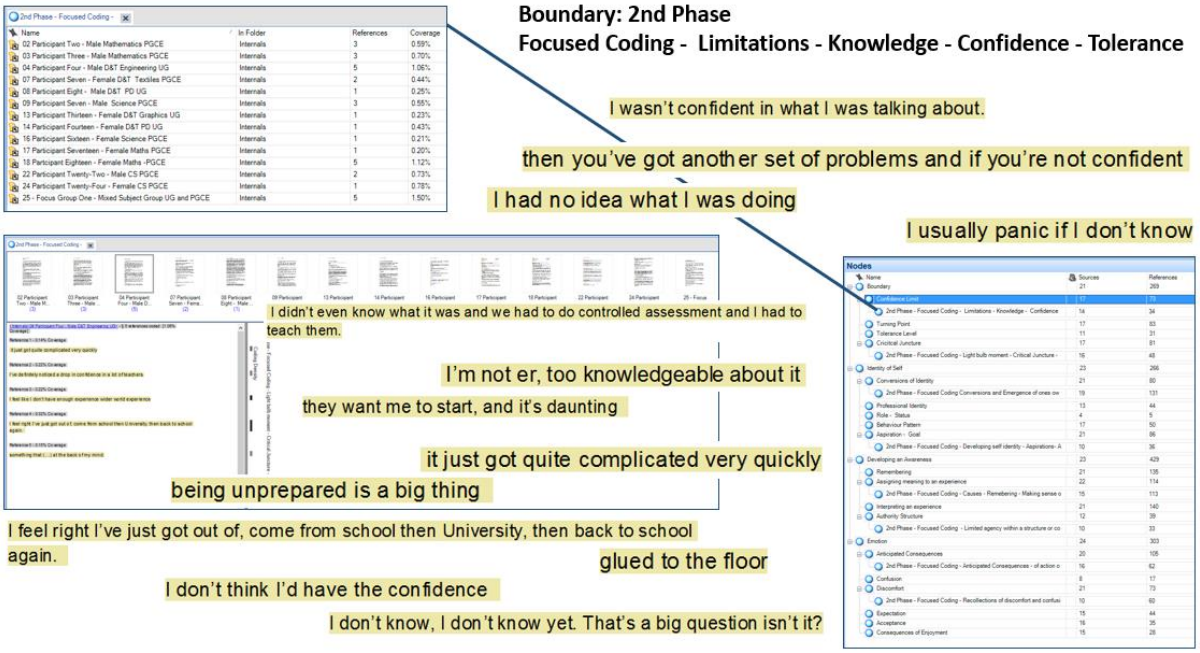
Debbie Knight | Research Ethics Officer | Email: ethics@lancaster.ac.uk | Phone (01524) 592605 | Research Support Office, B58 Bowland Main, Lancaster University, LA1 4YT
Web: Ethical Research at Lancaster: http://www.lancaster.ac.uk/depts/research/ethics.html

Lancaster University

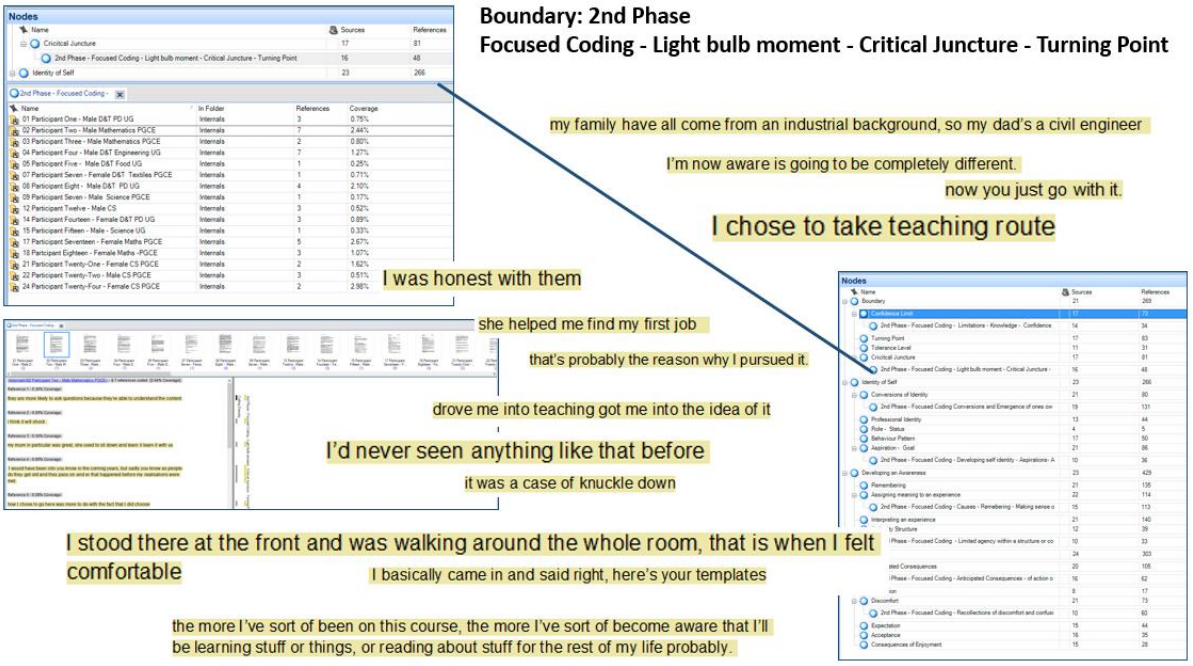
www.lancaster.ac.uk/50

Appendix B

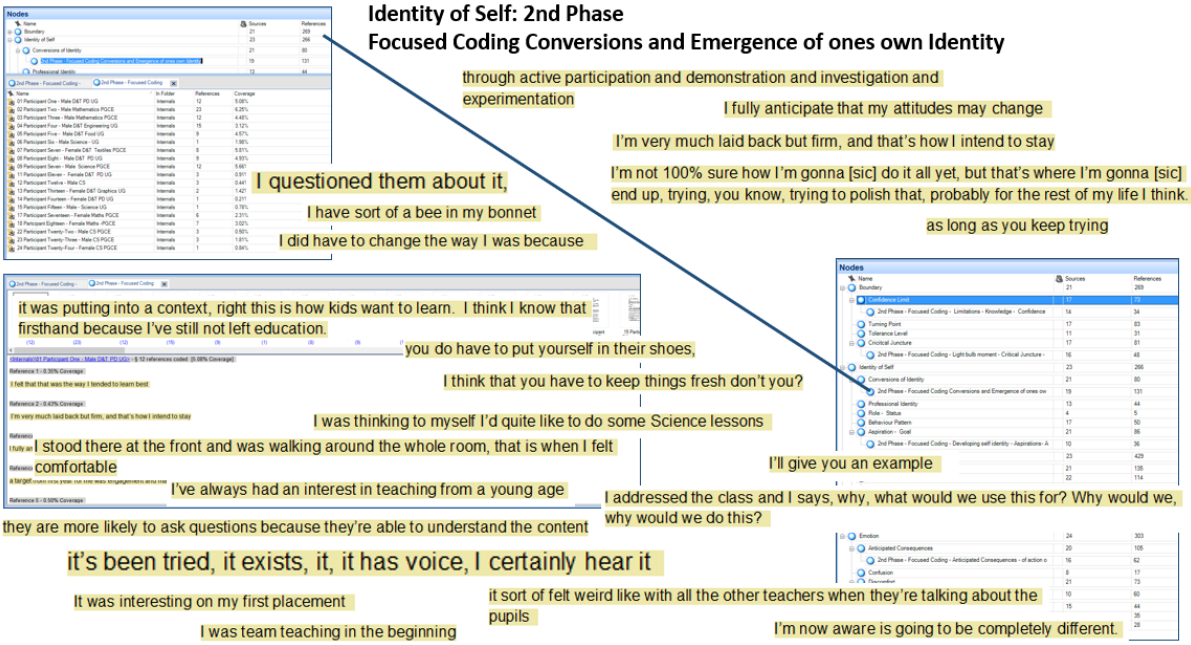
Further examples of diagrammatic memos and integrative diagrams



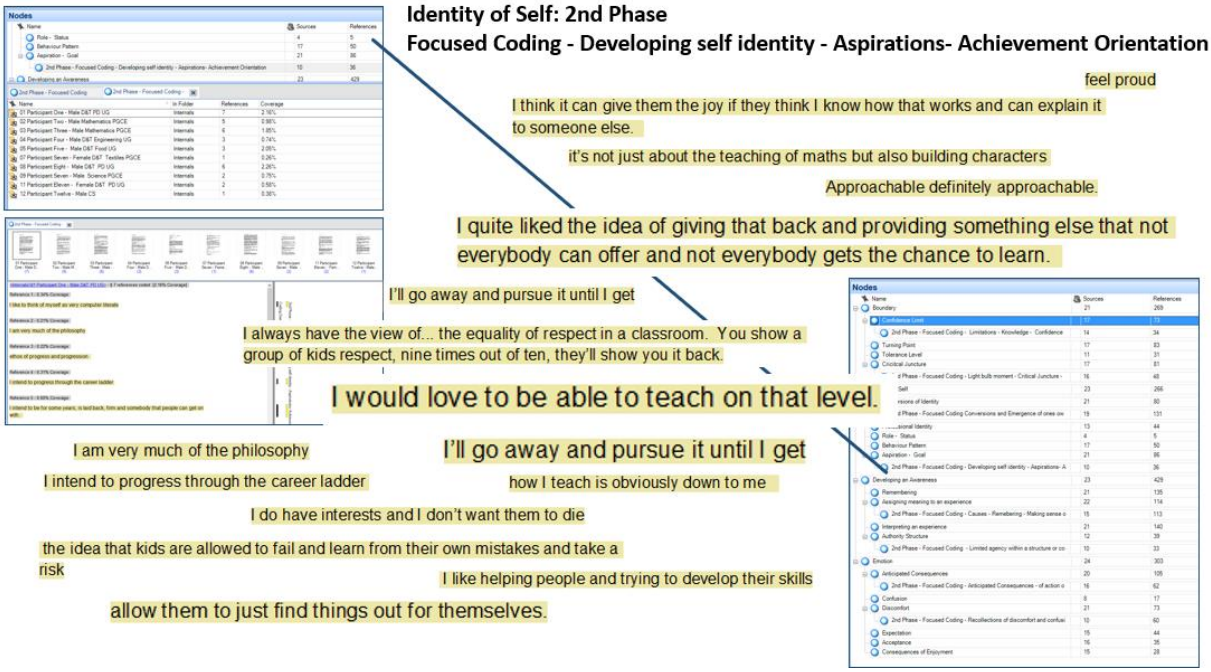
Substantive Coding: Boundary: limitations, knowledge, confidence, and tolerance.



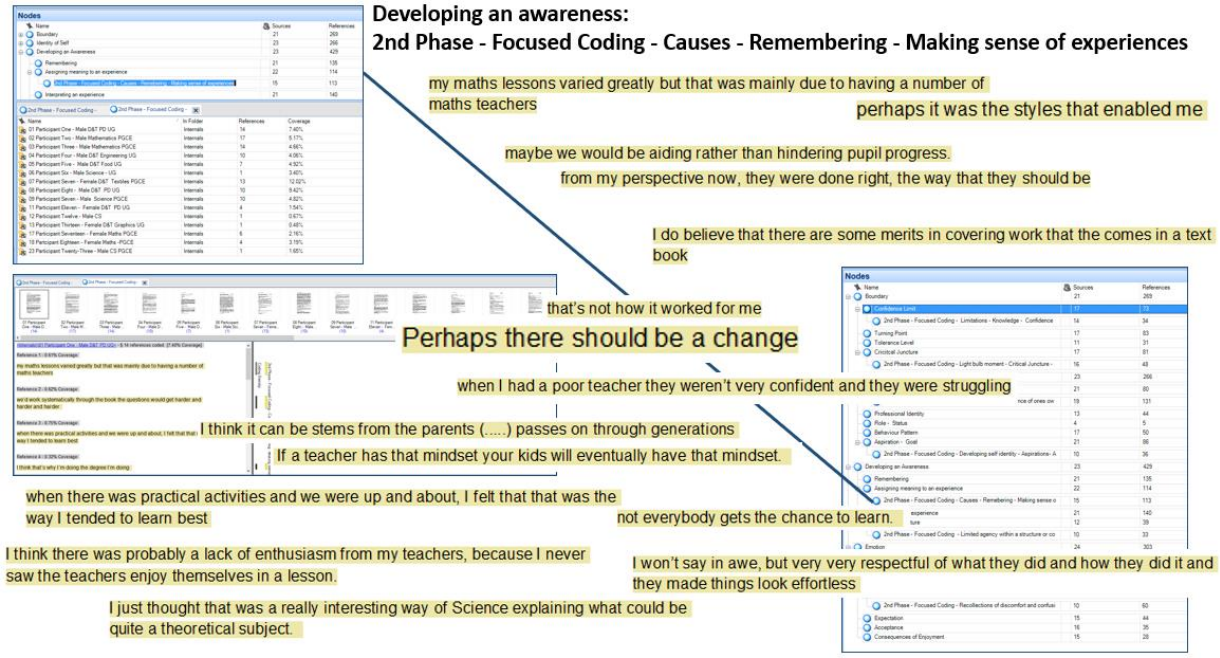
Substantive Coding Boundary: light bulb moment, critical juncture and turning point.



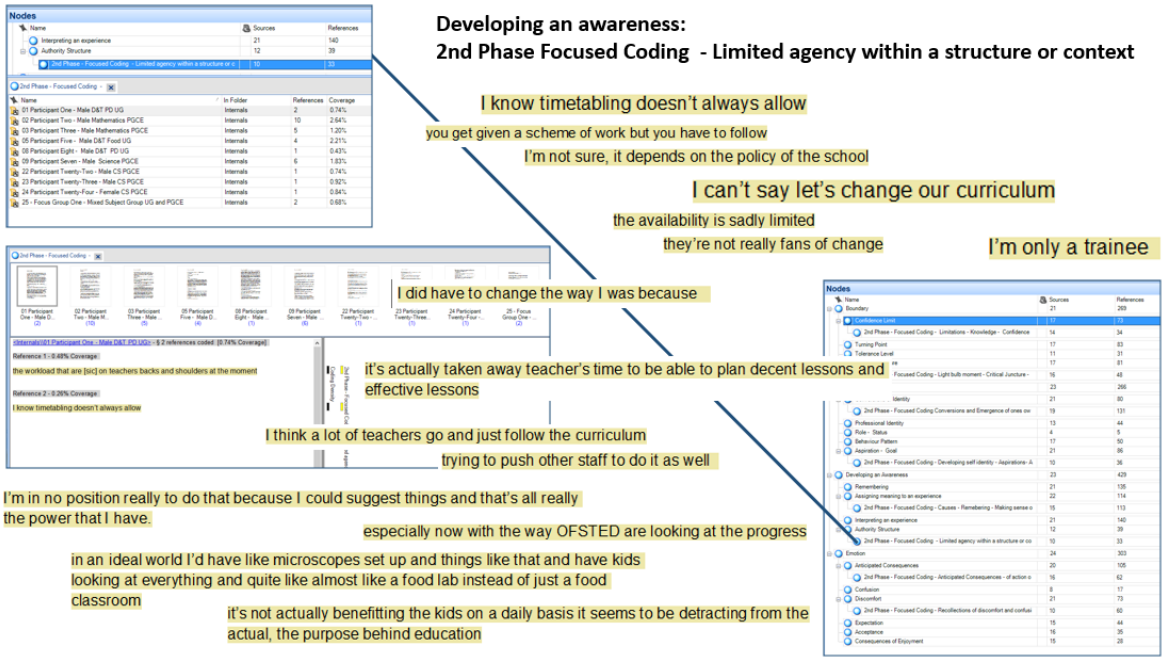
Substantive Coding: Identity of Self: conversions and emergence of one's own identity.



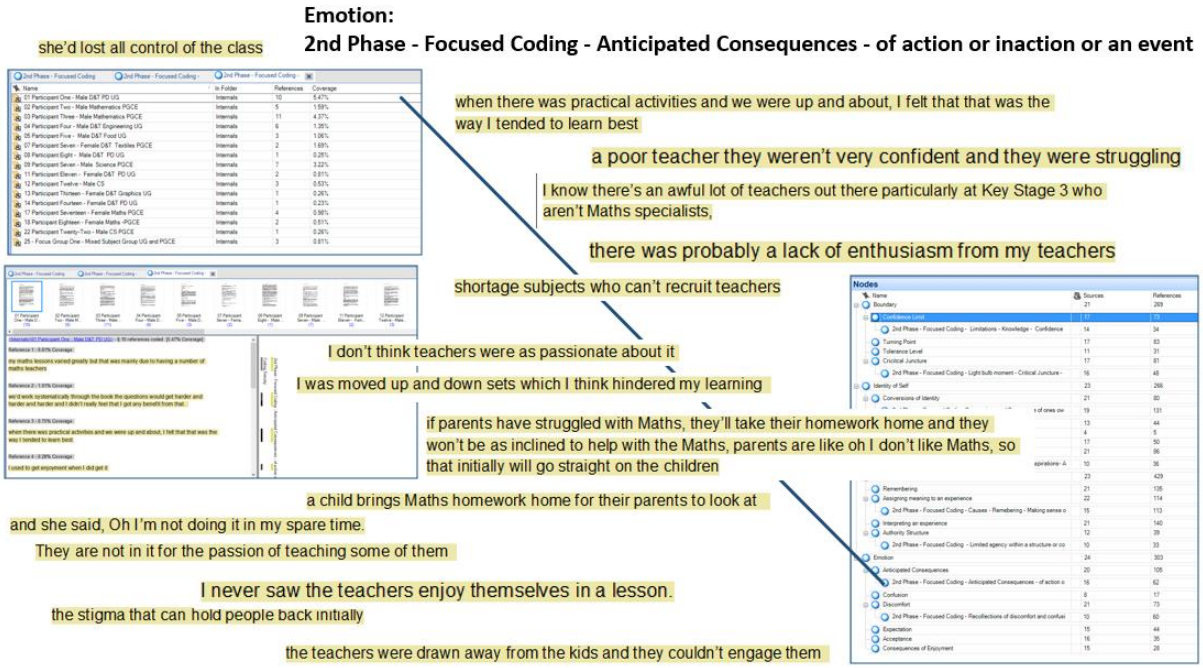
Substantive Coding: Identity of Self: developing self-identity, aspirations, achievement orientation.



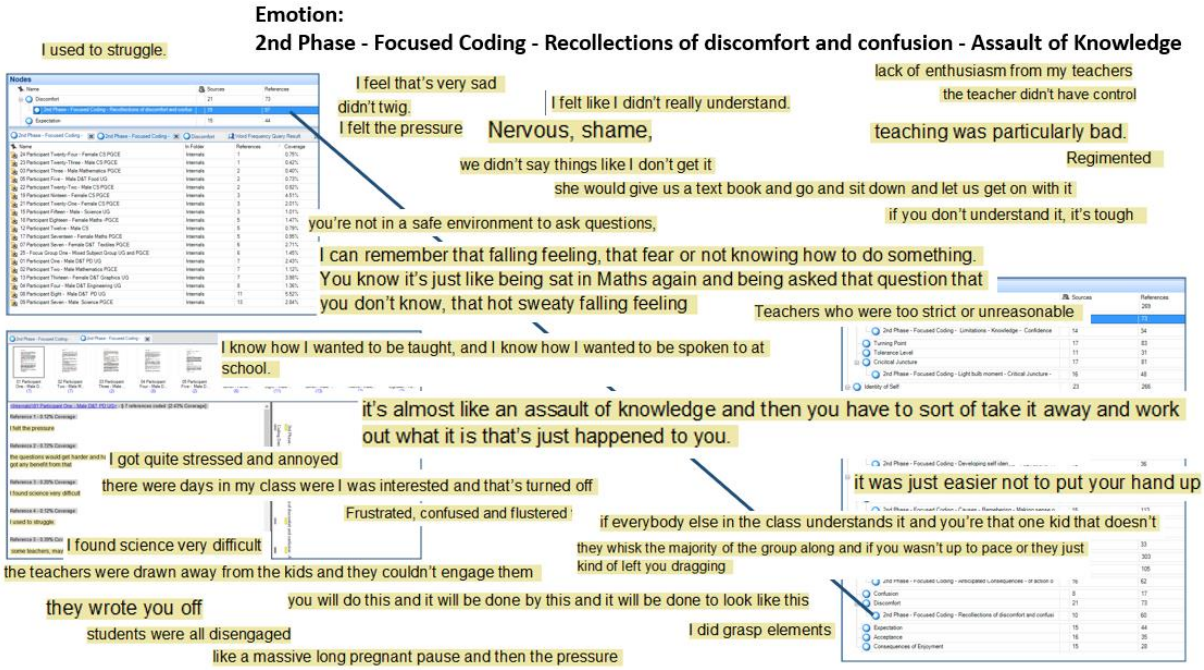
Substantive Coding Developing an Awareness causes, remembering, making sense of experiences.



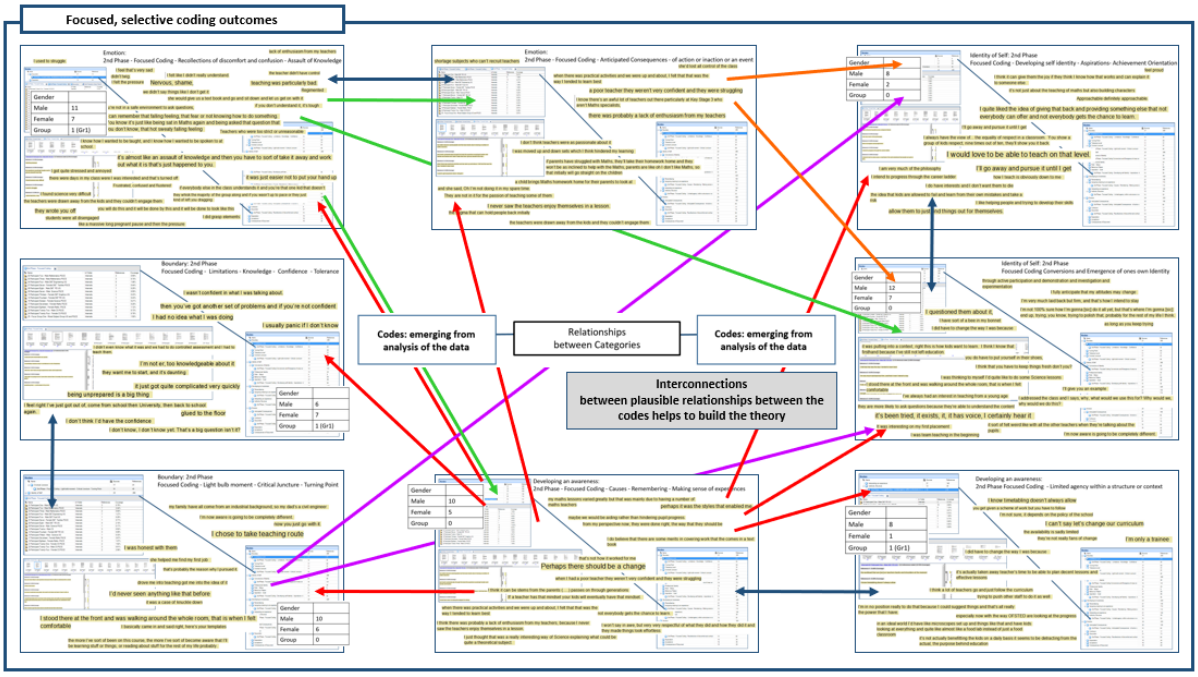
Substantive Coding Developing an Awareness limited agency within a structure or context.



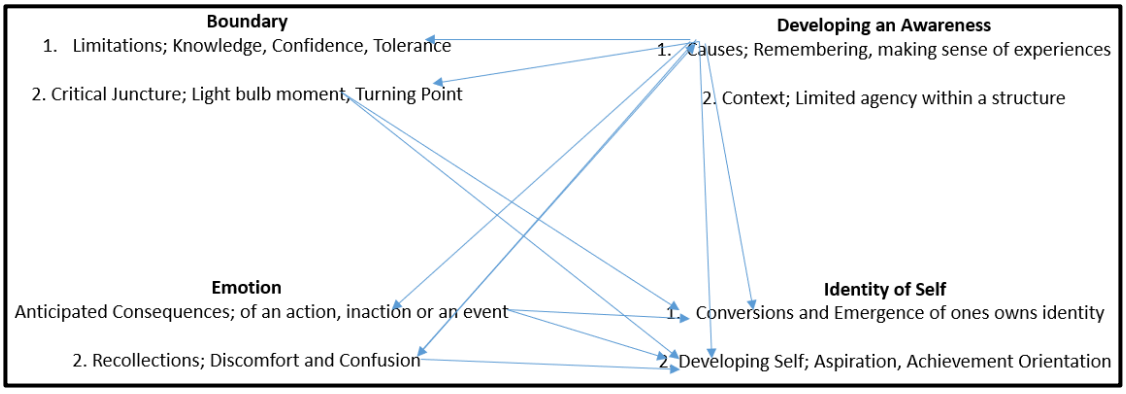
Substantive Coding Emotion anticipated consequences of action or inaction or an event.



Substantive Coding Emotion recollection of discomfort and confusion, an assault of knowledge.



Interconnections between the Substantive Codes (1).



Interconnections between the Substantive Codes (2).

Appendix C

Table C.0

Online Survey							
Subject	Male UG	Male PGCE	Female UG	Female PGCE	Did not specify route	Did not specify gender	Total
Computer Science	0	0	0	0	0	0	0
Design and Technology	2 (N. Ireland) 1 (NZ) 2 (Sweden/ Finland) 5 (England & Wales)	1 (Malta)	1 (N. Ireland) 7 (England & Wales)	1 (Europe) 2 (England & Wales)			22
Mathematics	4 (England & Wales)	0	1 (England and Wales)	9 (England and Wales)	0	0	14
Science	2 (England & Wales)	1 (Europe)	1 (England & Wales)	1 (NZ) 2 (Europe) 3 (England & Wales)	1 (NZ)	1 (PGCE England & Wales)	12
Technology and Engineering Education	3 (USA)	0	0	0	0	0	3
Engineering	0	1 (Europe)	0	0	0	0	1
STEM	0	0	0	1 (NZ)			1
Totals	19	3	10	19	1	1	53

Table Key	
UG	Undergraduate
PGCE*	Post Graduate Certificate of Education ** Postgraduate study includes those following School Direct ITE training routes*

Appendix C, Table C.0

Online survey: Participant engagement by training route, subject discipline, and geographical location.

Table C.1

Participant	Male	Female	Age	STEM Discipline	Training Route	Research Phase			
						First phase interviews	Second phase interviews	Focus Group	Validation Interviews
1[1UG]			22	Design and Technology	UG	✓			
1[2PGCE]			36	Mathematics	PGCE (SD)	✓			
1[3PGCE]			25	Mathematics	PGCE		✓		
1[4UG]			21	Design and Technology	UG	✓			
1[5UG]			29	Design and Technology	UG	✓			
1[6UG]			24	Science	UG		✓		
1[7UG]			48	Design and Technology	UG		✓		
1[8UG]			36	Design and Technology	UG	✓			
1[9PGCE]			31	Science	PGCE		✓		2
1[10UG]			23	Science	UG	✓			
1[11UG]			22	Design and Technology	UG	✓			1
1[12PGCE]			26	Computer Science	PGCE (SD)		✓		
1[13UG]			22	Design and Technology	UG	✓			
1[14UG]			29	Design and Technology	UG	✓			
1[15UG]			28	Science	UG	✓			1
1[16PGCE]			26	Science	PGCE		✓		
1[17 PGCE]			26	Mathematics	PGCE (SD)		✓		2
1[18PGCE]			31	Mathematics	PGCE	✓			
1[19PGCE]			42	Computer Science	PGCE	✓			1
1[20PGCE]			33	Computer Science	PGCE		✓		
1[21PGCE]			38	Computer Science	PGCE		✓		
1[22PGCE]			27	Computer Science	PGCE	✓			
1[23PGCE]			31	Computer Science	PGCE	✓			
1[24PGCE]			24	Computer Science	PGCE		✓		
FG2[25 PGCE]			41	Science	PGCE (SD)	2		✓	2
FG1[26 UG]			24	Mathematics	UG	1		✓	
FG2[27 PGCE]			24	Mathematics	PGCE	2		✓	1
FG2[28 PGCE]			31	Design and Technology	PGCE (SD)	2		✓	2
FG1[29 UG]			34	Mathematics	UG	1		✓	
FG1[30 PGCE]			49	Science	PGCE			✓	

Table Key	
UG	Undergraduate
PGCE*	Post Graduate Certificate of Education ** Postgraduate study includes those following School Direct ITE training routes*
SD	School Direct
	Male Participant
	Female Participant
	Focus Group

Semi-structured and focus group interview participants by gender, age, STEM discipline and training route.