

**Threshold concepts and the troublesome transition from GCSE to
A level: An Interpretative Phenomenological Analysis of
students' experiences in secondary school biology**

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by

Matthew James Dunn MA, BEd (Hons)

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Abstract

Despite an acknowledgement in secondary education that the transition from GCSE to A level brings with it a noticeable increase in the difficulty of work, there is a paucity of research literature exploring this aspect of transition from students' perspectives. In higher education, research into threshold concepts has been shown to offer productive insights into those aspects of curricula which students find troublesome, providing practitioners and curriculum designers with a growing body of evidence to inform improvements in teaching and learning. This study, situated predominantly in the subject of biology, explores the lived experiences of six students in the UK during their first year of A level study, through the lens of the Threshold Concept Framework (TCF) (Land, 2013).

A longitudinal hybrid design frame is employed, drawing from both case study and Interpretative Phenomenological Analysis (IPA), to illuminate the affective dimension of threshold concepts (TCs), an aspect of this research field which is notably underdeveloped. This thesis advances the argument that students' encounters with TCs are significant for them, posing a level of cognitive and affective challenge which serves to exacerbate the difficulty of transition already caused by increased workload and pressure. The findings offer insights into what the students describe as 'the jump' to A level, presenting detailed accounts of their struggles adjusting to increased workload and pace, intensified by encounters with TCs.

Critical consideration of the TCF leads to the proposal of an original exploratory model for the identification of TCs, and several TCs are identified in the findings, including *scale*, *cell structures*, *biochemistry*, *troublesome language* and *specificity*. Recommendations are made for further research exploring TCs and the affective dimension of transition in a range of other subjects in secondary education, to inform improvements in transition and teaching and learning.

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Chapter 1 - Introduction

In this chapter, I outline my personal and professional reasons for undertaking this research study, as well as providing a rationale for the selection of threshold concepts as the academic focus and theoretical lens. I discuss aspects of originality, and briefly outline the structure of the chapters. Throughout this thesis, my aim is to ensure clarity and avoid ambiguity, thereby rendering the research accessible and credible (Gardner, 2011). To this end, definitions are offered at appropriate points in the research as the need emerges. However, there are two aspects of language use which require clarification from the start to characterise semantic differences between educational phases. Firstly, in higher education, the term *student* is most often used to refer to those individuals engaged in learning, whilst the general convention in UK secondary schools is to use *pupils* as the more common nomenclature. It is also fairly common for school sixth-form or post-16 learners to be called *students*. For the sake of clarity, the term *student* is used throughout this thesis to refer to those in both the post-16 secondary and higher education sectors, whilst younger children are referred to by the term *pupil*. Where any age-related distinction is less relevant, *learner* is used. Secondly, where reference is made to specific areas of study in the different phases of education (e.g. biology), the term *subject* is employed to refer to the body of knowledge taught and studied in schools, whilst references to higher education use the term *discipline* to describe a branch of academic study.

1.1 Personal reasons for the research

It has been noted that a wide range of factors may influence an individual's decision to undertake a professional doctorate (Lee, 2009). The inspiration for my doctoral journey began with reflection on my own experiences of the transition from GCSE to A level study. My time at school was a largely positive one, and I performed well in my GCSE examinations, going on to enrol in the Sixth Form to study four A levels. However, shortly after starting the first year of my advanced programme of study I was diagnosed with glandular fever and the resulting fatigue and inability to concentrate had a major impact on me, both personally and academically. This stage in my life was extremely trying and remains today one of

my clearest memories of experiencing self-doubt. Eventually, I overcame the glandular fever, but the results I obtained at A level meant that I was forced to undergo a major rethink of my future career choices.

As a qualified secondary school teacher of 22 years, currently employed as a Vice Principal and having held the role of Head of Sixth Form, I have noted with interest how a large proportion of students also find the transition to the first year of A level study difficult. Having thought at the time that I was going through something unique to me, I now realise that this period in other young people's lives can be equally challenging for a variety of reasons. My own observations suggest that many students appear to struggle to cope with the sudden increase in the difficulty of work and a shift towards an expectation of more independent study. One of the key drivers for undertaking this research was to explore these experiences to inform improvements in teaching and learning and the transitional journey for students.

1.2 Professional context of the study

In England and Wales, children in mainstream education attend compulsory education from the ages of 5-18, which is comprised of five Key Stages (see Table 1). Only schools maintained by Local Authorities are required to follow the national curriculum at Key Stage 3, but all schools must teach a broad and balanced curriculum. Typical entry requirements for students taking Advanced level courses in England and Wales at the time of writing were five A*-C grades at GCSE and generally a grade B in the subjects to be studied, although these requirements varied as they are determined by individual educational settings. Students build a 'programme of study', typically three or four subjects and, at the time this research was conducted, they would then take 'modular' GCE Advanced Subsidiary (AS) qualifications in the first year of study (Year 12) and GCE Advanced Level (A2) qualifications in the second year (Year 13). In many schools, students would have then decided after the first year which of the courses studied they wish to continue to study as full A levels, informed by their grades achieved at AS. The AS qualification counted towards the overall Advanced Level GCE (A2) and under this modular system, students could 'retake' specific modules to improve their overall

grades. At the time of the research conducted for this thesis, the above system was in effect and all participants were enrolled on AS programmes of study.

Age	Year	Key Stage	Education Level	Assessment / qualifications	QCF Level
3		Early Years	Early Years		
4	Reception		Foundation Stage		
5	Year 1	Key Stage 1	Primary	Phonics screening check	
6	Year 2			Teacher assessments in English, Maths and Science	
7	Year 3	Key Stage 2			
8	Year 4				
9	Year 5				
10	Year 6			National tests and teacher assessments in English, Maths and Science	
11	Year 7	Key Stage 3	Secondary	Teacher assessments	
12	Year 8				
13	Year 9				
14	Year 10	Key Stage 4		GCSE or equivalent qualifications	1-2
15	Year 11				
16	Year 12	Key Stage 5	Sixth Form or other Further Education provider	A Level (AS) or equivalent qualifications	3
17	Year 13			A Level (A2) or equivalent qualifications	
18+	Year	Higher Education	University or higher education provider	Degree level qualifications	4-8

Table 1 - Educational stages and qualification levels in England and Wales, 2015

However, it is important to note the changing landscape of A level qualifications that was taking place at the time of writing. Government policy changes in 2014 led to reforms in advanced qualifications which started to come into effect on a rolling programme from September 2015, with all subjects changing from 2017 (Ofqual, 2014). These changes meant that all A levels would become 'linear', effectively changing the full A level into a two-year course. The AS was to be decoupled and no longer form a part of the overall GCE, but remain as a separate one-year qualification. As the full A level will then be a two-year programme, students will not have the option to re-sit modules to boost results. Whilst these changes do not immediately impact the research here, it is important for the professional context of this study. It is also essential for the sake of clarity that terms used throughout this thesis such as 'AS' and 'A2' are understood in the context of the point in time that the research took place.

This study was conducted in an 11-18 secondary maintained school in the UK, in a semi-rural setting in Lincolnshire. At the time of the research the school had around 900 students on roll, with a sixth form consisting of around 150 students. The school falls within a selective catchment area with three grammar schools within accessible range to students. Consequently, students enter the sixth form with broadly below-average attainment, and many of them have difficulty adapting to advanced level study, this being one factor leading to below average AS level performance over time. Whilst the school has put measures in place to address the difficulties students experience upon entry to the sixth form, such as study skills programmes and mentoring, results remain a concern. Of particular interest in the context of this study are students' encounters with difficult knowledge within specific subject curricula, and how recommendations from research might contribute to improving the teaching and learning experience and outcomes for students.

In my experience, students find progression onto A level courses challenging, and difficulties with the transition from GCSE to A level study are not purely a local phenomenon. Even outside the teaching profession it is widely recognised that A levels are hard (Samuel, 2012; Scott, 2012), with other organisations referring to A levels as a "considerable step up" from GCSEs (NUS, 2014). Reasons for the difficulty students experience are various, but include the need for more developed analytical skills and the large increase in workload (Scott, 2012). A simple Internet search unearths a wide range of induction programmes on offer from A level providers, along with professional development programmes (MEI, 2015), specifically aimed at addressing the transition from GCSE to A level. It is therefore somewhat surprising that this transition point has received only limited attention. Some studies have attempted to investigate these difficulties from a subject-specific perspective, for example in mathematics (William et. al., 1999; Mendick, 2008; Hernandez-Martinez et al., 2011), languages (Clark, 1993; Thorogood & King, 1991) and biology (Overton & Reiss, 1990). However, most of these studies do not provide sufficient insight into the issue from a student perspective. For example, the latter study in biology (Overton & Reiss, 1990), involved a survey of teacher's views on changes from the old CSE and GCE 'O' level qualifications to GCSE's in 1988 and did not consider student perspectives

on their difficulties, whilst Rushton & Wilson (2014) investigated this transition point through the perspective of teachers and employers. Hernandez-Martinez et al. (2011) did seek student views in the transition from GCSE to A level in the UK and reported that students described a process of ‘overcoming problems and troubles’ (p.127). There is, however, still a gap in the literature around transition from a student perspective, to which this study aims to contribute through the generation of new knowledge.

1.3 Academic context of the study

Two papers analysing difficulties experienced during doctoral study played a particularly important role in the development of my research proposal: Kiley & Wisker (2009) and Trafford & Leshem (2009). The term ‘doctorateness’ has been used in the higher education literature to refer to a scholarly attribute that academics look for when examining the worth of the doctoral thesis (Trafford & Leshem, 2009, p.315), although doctorateness may also be a quality residing within an individual, discreet from the thesis itself (Denicolo & Park, 2011). The notion of this difficult journey to achieving ‘doctorateness’ resonated with the nascent difficulties I was experiencing in my own transition to doctoral study, capturing the ‘step up’ in difficulty between educational phases. Of particular interest to me at the time was that both Trafford and Leshem (2009) and Kiley and Wisker (2009) based their research around the notion of *threshold concepts*, a framework at the centre of a growing body of literature.

Upon further investigation, I became convinced that the notion of threshold concepts echoed my experience of students’ encounters with difficult knowledge at A level. Furthermore, I identified a gap in the threshold concept literature regarding research in the secondary education sector, particularly exploration into the affective dimension of students’ experiences of threshold concepts. These factors contributed to my choice of studying a professional doctorate (see Figure 1).

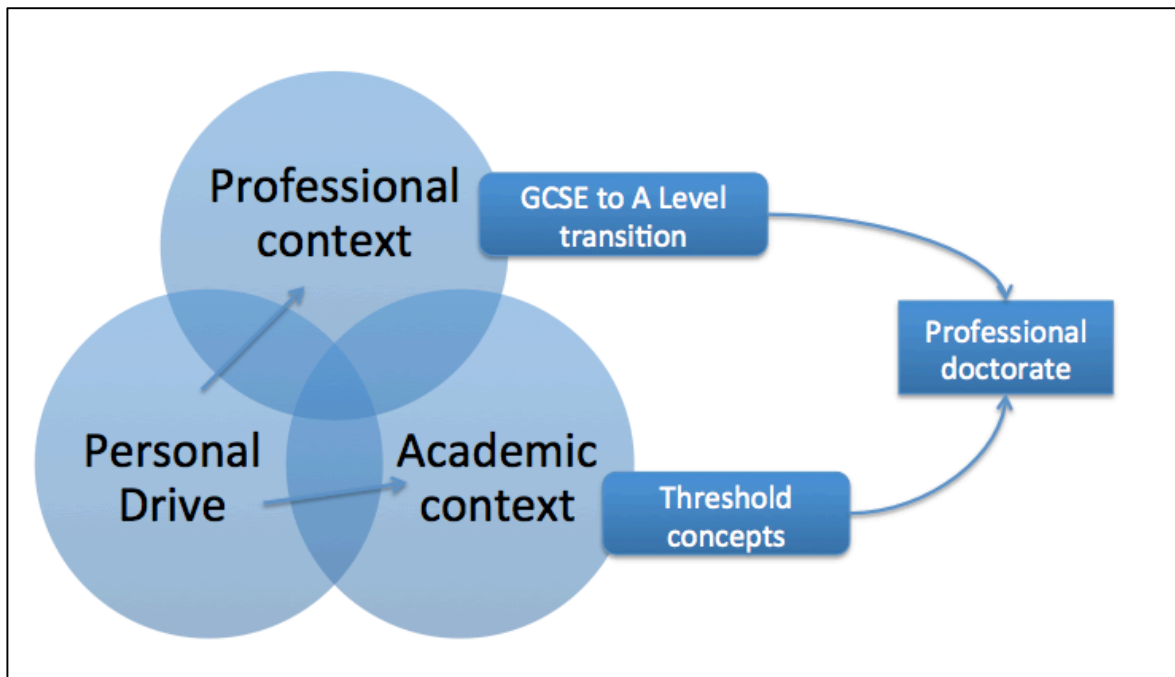


Figure 1 – Influences leading to the professional doctorate

Originally proposed by Meyer and Land (2003), the notion of threshold concepts (TCs) emerged from a national research project in the UK, focused on identifying aspects of high quality learning in higher education. The Threshold Concepts Framework (TCF) embodies a way of thinking about learning which places emphasis on those parts of a discipline which have a *transformational* effect on learning for the individual once they are understood, and which are likely to be *problematic* (Land, 2013). The italicised aspects of TCs evoked memories of my own struggles and transformation between educational stages, and fitted with professional observations of students I have taught and supported over the years. It has been suggested in the higher education literature that these concepts define critical points in a student's learning (Barradell, 2013) and are fundamental to mastery of a discipline. Due to their provocative nature (Meyer, 2016), TCs are likely to present cognitive or affective difficulties for individuals (Cousin, 2009) and may manifest as 'troublesome knowledge' (Meyer and Land, 2003).

Internalisation of TCs allows things to be brought into view that were not formerly perceived (Land & Rattray, 2017, p.63) unlocking 'a previously occluded, and integrated, view of subject landscape' (Meyer, 2016, p.463), thus allowing students to see how TCs and other concepts work together 'in an integrative way'

(Davies, 2003, p.6). The resulting shift in perspective may reveal a transformed way of understanding within a discipline which is likely to involve both a conceptual and ontological shift (Cousin, 2009). This transformation may also empower students to 'think, practise and talk' in a transformed way within a discipline (Davies and Mangan, 2008), including altered language use (Flanagan and Smith, 2008), all of which facilitates their entry into a 'community of practice' (Entwistle, 2003) within a discipline. The argument I advance throughout this thesis is that students' encounters with TCs are significant for them, posing a level of cognitive and affective challenge which serves to exacerbate the difficulty of transition already posed by increased workload and pressure. Furthermore, I argue that the TCF has the potential to be employed by teachers and subject leaders to improve the teaching and learning experience for secondary school students through the synergy of professional and academic aims.

1.4 Description of the study

This thesis investigates the experiences of six A level students' in their first year of an AS level programme of study within the context of their transition from GCSE. Positioned within the interpretivist paradigm, the research concerns those students' encounters with TCs, employing a hybrid research design to illuminate the affective dimension of what is suggested here as being a potentially major life experience. An exploratory model for identification is presented, along with a worked example generated from the findings, providing a method that can be used by practitioners and academics for identifying TCs within subject programmes.

The professional aim of this study is to explore students' experiences through the theoretical lens of the TCF, focusing on informing improvements to teaching and learning at the GCSE to A level transition point with specific emphasis on the affective dimension of the transitional process. This study may be of interest to secondary practitioners and academics interested in the broader application and theoretical considerations of TCs, a nascent field engaging a wide range of disciplines (See Flanagan, 2017).

1.5 Significance and Originality

Despite their popularity in higher education, studies focusing on TCs in secondary education are still relatively scarce. Some have been conducted overseas in different contexts: in Hong Kong (Pang and Meyer, 2010), Ireland (Sheehan, 2010), the USA (Wolf and Akkaraju, 2014) and Brunei (Haji Bungsu, 2014). Of those taking place in the comparable context of the UK secondary school system (Renshaw and Wood, 2011; Ashwin, 2008, Chandler-Grevatt, 2015), only the latter one focused on A level study, with the aim of improving transition to higher education. My thesis contributes to this gap in the literature, focusing on TCs in a UK secondary school. Furthermore, as stated earlier in this chapter, there is also a gap in academic research around difficulties experienced by students transitioning from GCSE to A levels, specifically regarding the affective dimension of adapting and acclimatising to what is commonly regarded as a significant increase in difficulty, which this study addresses.

A key aspect of originality in this thesis is the development of a hybrid, longitudinal research design that allows consideration of both cognitive and affective experiences of students, integrating case study with Interpretative Phenomenological Analysis (IPA), the latter drawn from Healthcare Psychology. Research into TCs in healthcare is growing (see Flanagan, 2017), and one doctoral study by Hill (2012) utilised IPA to investigate the educational experiences of students in prosthetics education at undergraduate level. Another study by Haji Bungsu (2014) used case study to investigate TCs in a secondary level agriculture course in Brunei, subsequently applying IPA as the analytical framework. In my thesis, taking a different methodological approach to Haji Bungsu (2014), IPA underpins both the analytical framework and the methodological framework, and I have chosen to combine this with case study, creating an integrated hybrid research design frame which offers layers of originality within the field of TCs and which provides a robust methodological approach with which to answer the research questions. There still exists a wide variety in approaches to the identification of TCs within the literature (Barradell and Peseta, 2014). Whilst this provides a huge range of methods from which to choose, there is also criticism of some of these methods (Rowbottom, 1997;

O'Donnell, 2010; Delany, 2012; Barradell, 2013; Walker, 2013), and this thesis explores and extends this critique.

This research is also significant due to its timing in the chronology of TCs. Early research into TCs since the introduction of the framework over a decade ago (Meyer and Land, 2003) centred around the identification of TCs within higher education disciplines. More recently, keynote speakers at the Fifth International Biennial Threshold Concepts Conference in 2014 argued the need for further research into the affective dimension of TCs to explore how students experience these potentially difficult encounters. Meyer (2014) argued that the field has moved beyond merely identifying TCs and that we should be considering their impact on learners, a thought shared by Felten (2014), who echoed others in arguing the importance of the affective dimension of TCs (Cousin, 2008; Rattray, 2012). My study opens an original and timely line of enquiry into the affective dimension of TCs in UK secondary education, thereby making an original contribution to this underdeveloped area of research.

This thesis argues that transition from GCSE to A level is a particularly transformative and emotive one for students, due in part to their encounters with TCs, hence the development of an original research design drawing significantly from IPA which is particularly suited to explore participants' major life experiences (Smith, Flowers & Larkin, 2009). Whilst Haji Bungsu (2014) applied IPA as an analytical framework to the investigation of secondary level TCs in Brunei, my study differs by using IPA to explore the affective dimension of students' experiences. My research design also fully embeds the IPA approach, as opposed to only using it as an analytical tool, in order to surface the affective dimension of students' encounters with TCs in secondary education in the UK.

1.6 Reflexivity and the structure of the thesis

IPA is grounded within hermeneutics and phenomenology, aiming to interpret individuals' personal experiences through an 'insider's perspective' (Smith and Osborn, 2003, p.53). The role of the researcher in IPA is active and dynamic, centrally involved in both the process and the outcome at an idiographic level

(Reid, Flowers & Larkin, 2005). Whilst the participant is making sense of their own experiences, the researcher is in turn aiming to make sense of the participant's sense-making and is therefore involved in a 'double-hermeneutic' process of interpretation (Smith et al., 2009). IPA researchers aim to understand what it is like to take the side of the participants, from their perspective (Smith & Osborn, 2007) through inductive and iterative analytical procedures. Therefore, engagement in a process of self-reference or 'reflexivity' is vital to acknowledge the role of the researcher in the study, thus providing a greater degree of 'transparency' to the reader.

As a practitioner-researcher I am conscious of my own position in the research process and am committed to developing as a 'reflective practitioner' (Scott, Brown, Lunt, & Thorne, 2004). As such I have taken several steps to provide a reflexive account of the research process, by acknowledging my role as an 'insider-researcher' (Mercer, 2007) throughout the thesis. In this first chapter I have outlined the research and my position within it, both physically and biographically. I have also described the academic and professional contexts of the study, including my personal rationale for undertaking the research. In chapter two, I outline and critique the literature and its influence on my thesis design, providing a broad overview before focusing specifically on a thorough and critical examination of the definitions and limitations of the TCF.

The third chapter presents an overview of the methodological landscape of TC research and I discuss my journey through the exploration of literature and pilot studies which led to the final methodological choices and selection of research tools. I aim to engage the reader with a sense of the decision-making process and reasoning behind those decisions alongside examples of the data and methods used in these pilot studies. Research methods are explained in detail along with ethical and sampling considerations, and the analytical framework is presented. The research tools used are critiqued and exemplified with examples of the actual interview scripts and journal pages. Examples of data analysis are presented alongside an explanation of the interpretative and analytical process used. I also outline quality issues in greater detail including participant bias and my role as an 'insider-researcher' (Mercer, 2007).

In chapters four and five findings are presented in a style appropriate to an IPA study using detailed quotations from actual participant responses to exemplify the interpretative stance. Analysis of the findings is structured such as to examine cross-case themes whilst retaining individual narratives. I also make clear my interpretation of the data throughout the analytical process, acknowledging that others may arrive at alternative interpretations of the data collected. In chapter six, the findings are discussed in relation to the literature, and answers to the research questions are provided. Chapter seven concludes the thesis, discussing the potential impact of the new knowledge created and suggesting areas where further research would be of benefit to both the professional and academic communities.

Chapter 2 - Literature Review

This chapter begins by considering the origins of the Threshold Concept Framework (TCF) with a view to providing a historical setting for it as a contemporary field of research. Literature relating to the definition of TCs is then reviewed critically, with a focus on the characteristic features of a TC and how these have been interpreted and applied within the field. My own criticisms of TCs are presented alongside those from other authors to ensure that the limitations of this study are clearly acknowledged. A range of theoretical contributions from within the TC literature are then discussed and a theoretical framework is proposed, drawing mainly from the literature on TCs. Literature directly related to secondary school education and the discipline of biology is then critically reviewed to situate this research within the field of TCs and to illuminate what existing research has already discovered, and the gaps to be addressed.

2.1 Threshold Concepts

The notion of threshold concepts (TCs) emerged from a national research project involving academics from universities across the UK. Conducted between 2001 and 2004, the 'Enhancing Teaching and Learning Environments in Undergraduate Courses' (ETL) project sought to identify features of high quality learning environments in higher education, with the purpose of employing this knowledge to drive improvements in curriculum and course design. A report authored by Noel Entwistle (2003), a member of the project team, outlined one of the ETL project objectives concerned with developing theoretical frameworks. The report argued that these frameworks should consider skills and ways of thinking as well as conceptual understanding, referred to as 'ways of thinking and practising in the subject' (Entwistle, 2003, p.3). With a focus on the quality of learning achieved in specific subject areas, the report also called for the establishment of 'crucial topics or concepts that affect how the teaching is carried out and how understanding develops in that subject area' (Entwistle, 2003, p.3). Two of the pedagogical concepts to emerge from the ETL project, the report suggested, may support this identification: *troublesome knowledge* and *threshold concepts*. Whilst initially the project team considered these separately, they were eventually synthesised into

what is now more widely known as simply 'threshold concepts', or the 'threshold concepts framework' (TCF).

Working within the discipline of economics as part of the ETL team, Jan Meyer and Ray Land proposed that TCs were fundamental to mastery of a subject discipline and had the potential to empower learners to view the discipline from a new perspective. They subsequently published their assertions as an ETL report entitled 'Threshold Concepts and Troublesome Knowledge' (Meyer & Land, 2003). The basis of their position was that TCs are distinct from core concepts, which they defined as necessary conceptual building blocks within a subject which do not '...lead to a qualitatively different view of subject matter' (Meyer & Land, 2003, p.4). An example of a core concept in economics at the time of their report would have been 'capital' (see Ekins, Sandrine, Deutsch, Folke, & De Groot, 2003). Conversely, Meyer and Land (2003, p.1) argued that a TC holds the potential to transform learners' views of their subject, describing such as a metaphorical '...portal, opening up a new and previously inaccessible way of thinking about something.' They provided 'opportunity cost' as one example of such from economics.

The intention of Meyer and Land's report was to 'open up discussion of TCs as an important but problematic factor in the design of effective learning environments within disciplines' (2003, p.10). The wide range of investigations by other academics following their report suggests that their intention to generate scholarly engagement was successful. Initially focusing on economics (Shanahan & Meyer, 2006; Reimann & Jackson, 2006; Davies & Mangan, 2007), subsequent work explored the potential of TCs to be present within a range of other academic disciplines (see Land, Meyer, & Smith, 2008). These included: accounting (Lucas & Mladenovic, 2006, 2007), mathematics (Worsley, Bulmer & O'Brien, 2007), statistics (Bulmer, O'Brien & Price, 2007), biology (Taylor, 2006; Taylor & Cope, 2007), physics (Park & Light, 2009), computer science (Flanagan & Smith, 2008; Zander, et.al., 2008; Rountree & Rountree, 2009), geology (Truscott, Boyle, Burkill, Libarkin, & Lonsdale, 2006), design (Osmond, Turner & Land, 2008), engineering (Carstensen & Bernhard, 2008; Baillie & Johnson, 2008), law (Webb, 2008), English (Orsini-Jones, 2008; Wisker, Cameron & Antoniou, 2008), cultural

studies (Cousin, 2006b), doctoral education (Trafford, 2008; Kiley & Wisker, 2009) and health care (Clouder, 2005). Most of these early exploratory studies aimed to identify TCs within disciplines. Since then, research into TCs has continued to generate interest amongst academics in higher education as a way of exploring pedagogical content within their subject areas. The TCF embodies a way of examining curricula 'where specific elements that are tricky for students to understand have a transformational impact on their learning once they are understood' (Land, 2013, p.1).

The idea of focusing on what students find difficult in disciplines is not new. Indeed, there are bodies of literature within science education (e.g. Driver, Leach, Millar & Scott, 1996) and conceptual change (e.g. Carey, 1991; Vosniadou, 2008) for example, that have considered just that. What makes the notion of TCs of particular interest to this study, however, is the implicit premise that a TC is likely to be transformative, occasioning an ontological and epistemological shift in the learner's view of the world and potentially their own identity (Meyer & Land, 2003). Certainly, TCs have generated fervent dialogue in higher education, building on existing theories of learning, whilst bringing a new perspective from which to scrutinise the learning experience within disciplines.

There is now a substantial and increasing body of literature claiming to offer empirical evidence for TCs across a range of disciplines in higher education. This is aptly demonstrated by the TC website maintained by Mick Flanagan at University College London (Flanagan, 2017), which provides a frequently updated list of papers, conference proceedings and theses drawing from a wide range of disciplines and contexts, currently numbering well over a thousand. Whilst the majority of references listed originate from the United Kingdom (36%), Australia (21%), the US (13%), Sweden (5%), Ireland (5%), Canada (4%) and New Zealand (4%), there are contributions from 51 countries in total. The 2014 Innovating Pedagogy Report published by a team at the Open University placed TCs in their list of ten educational trends with 'the potential to provoke major shifts in educational practice' (Sharples, et al., 2014, p.3). Interest in TCs is further demonstrated by the continued popularity of the 'Biennial Threshold Concepts Conferences', organised by academics from around the world. These conferences

have now been held in the UK in 2006 and 2014, Ireland in 2012, Australia in 2010, and Canada in 2008 and 2016, with a further conference planned for 2018 in Ohio, USA. Harnessing the enthusiasm and collaborative momentum generated by the TCF and applying it to the secondary sector is one of the main intentions of this thesis. Whilst considerable interest has been generated in higher education, research in secondary schools is less prevalent, and this is one of the gaps in the literature to which this study aims to contribute.

It is necessary and desirable to establish a precise definition of a 'threshold concept' at this point. Many overviews are presented in the literature, and whilst there appears to be a ready acceptance of the original definition by many researchers, there is a dearth of detailed analysis. This has led to criticism of empirical work in the field, alongside criticism of the definition itself (Rowbottom, 1997; O'Donnell, 2009, 2010; Delany, 2012; Barradell, 2013; Walker, 2013). The characteristics of a TC are now discussed, followed by criticisms levelled at this emerging area of research by myself and others.

2.2 Threshold characteristics

In their first two papers, which introduced the notion of TCs, Meyer and Land (2003, 2005) distinguished between core concepts and TCs. To argue that TCs are qualitatively different to 'core concepts' they posited five main characteristics that a TC is *likely* to be (Meyer & Land, 2003, p.4):

- *transformative* – bringing about a '...significant shift in the perception of a subject...' which '...may lead to a transformation of personal identity...' and is '...likely to involve...a shift in values, feeling or attitude';
- probably *irreversible* - such that the subsequent change of view is '...unlikely to be forgotten, or unlearned only through considerable effort';
- *integrative* - with respect that it 'exposes the previously hidden interrelatedness of something';
- 'possibly often (though not necessarily always) *bounded*', in that each concept has boundaries which border other areas of conceptual space;
- 'potentially (and possibly inherently) *troublesome*'

The tentative wording of the above characteristics highlights the embryonic nature of Meyer and Land's initial proposals. Early criticism of TCs by Rowbottom (2007) focused on the vagueness of this initial definition, arguing that the imprecision makes it impossible to empirically isolate TCs based on the use of this set of attributes. Furthermore, Rowbottom argued, Meyer and Land (2003, 2005) did not define key words which they relied on in their papers to communicate the central proposition of TCs and, crucially, they offered no explanation for their understanding of what constitutes a 'concept', although Meyer has addressed this subsequently (Meyer, 2016). Other terms, which have become embedded throughout the TCs literature, and which are often employed to communicate key features of TCs were also not explained precisely by Meyer and Land (2003), such as 'mastery' and 'mimicry', although a discussion around mimicry with examples from Cousin (2003) and Reimann and Jackson (2003) followed in the second paper (Meyer & Land, 2005). Despite the uncertain nature of key terms, these do appear to have been readily adopted by subsequent authors.

This apparent haziness in some aspects of the debate throughout the early years of research into TCs has resulted in certain aspects of the academic dialogue arguably being conducted without due rigour (Barradell, 2013). Since Rowbottom (2007) raised concerns, other critics have also questioned either the validity of the TCF or its application (O'Donnell, 2009, 2010; Walker, 2013; Barradell, 2013) and these criticisms are considered in detail later in this chapter. However, the initial five characteristics were added to in 2005, such that the most current collection of literature (Flanagan, 2017) identifies eight characteristics of the TCF:

- transformative
- troublesome
- irreversible
- integrative
- bounded
- discursive
- reconstitutive
- liminality (characteristic of the journey to acquisition of a TC, rather than being a characteristic of an individual TC)

The latter three terms were introduced in the second paper on TCs by Meyer and Land (2005). As a spatial metaphor, liminality has become central to representing the journey of 'becoming' learners experience through various stages of TC acquisition within a subject (Meyer, 2016, p.465). The discursive and reconstitutive characteristics appear less frequently in the literature, and many authors draw mainly from the first five characteristics for empirical investigations, although these have been applied in a variety of ways, and with varying levels of hierarchy and inclusion. Furthermore, it appears that assumptions have been made within the field as to the existence of a shared understanding of TCs amongst academics (Barradell & Peseta, 2014, p.273).

The next sections therefore provide detailed definitions of these TC characteristics, leading to further consideration and critique of their application in the literature. Whilst this discourse takes up a significant part of the chapter, it is arguably necessary to: a) ensure clarity to the reader and to avoid ambiguity, b) contextualise the methodological approach and findings, and c) provide sufficient theoretical background to underpin an exploratory model for identification of TCs from the findings.

2.2.1 Transformative

Once a TC is mastered, Meyer and Land (2003) argued that it brings about a shift in the learner's perception of the subject, resulting in a 'transformed internal view of subject matter' (p.1). As previously mentioned, Meyer and Land (2003, 2005) did not explicitly define the term 'mastery' in their initial papers. Mastery of a TC can be thought of as 'when understanding is robust' (Higgs & Cronin, 2013, p.161), and without mastery of certain concepts it has been argued that a deep understanding of a discipline may be inhibited (Batzli et al., 2016). In addition, the potentially transformative effect of a TC may not only manifest itself through cognitive learning, but also altered behaviour (Cousin, 2010). The student becomes more comfortable with the conceptual boundaries of the discipline, as well as the language and approach required within the discipline. This resonates with Bandura's notion of self-efficacy (Bandura, 1977), central to his social-cognitive theory, concerned with learner's beliefs and motivation regarding their

own ability to achieve goals. Bandura argued that 'mastery' of a subject brings about increased self-efficacy and that the journey towards such self-belief involves strong affective processes (Bandura, 1993, p.132).

The transformation brought about by mastery of a TC may also reposition the learner in relation to 'communities of practice' (Davies and Mangan, 2007, p.712) such that they begin to shift from student to expert, or from member of one community to another (e.g. student of biology to biologist). In the context of classroom learning and from a social constructivist perspective, the student may be viewed as an 'apprentice', learning from a 'master' (Pritchard, 2014, p.29), such that through observational learning (Bandura, 1977) 'mastery' allows the apprentice to learn the skills of the trade and therefore enter a profession with the required level of preparation. Mastery of TCs therefore requires a different 'way of thinking or practising within a subject' (Meyer and Land, 2003, p.9), which facilitates entry to a community of practice. Lave and Wenger (1991) defined a 'community of practice' as a group of people learning together with a common focus through regular interaction such as a disciplinary field, area of employment, or in the context of this thesis, the students within a subject at advanced level. Wenger's work on social theory of learning suggested that the 'most personally transformative learning' is that which involves participation within these 'communities of practice' (Wenger, 2009, p.212). Wenger's social theory of learning identified four components of learning and social interaction: meaning (learning as experience), practice (learning as doing), community (learning as belonging) and identity (learning as becoming) (Wenger, 2009, p.211). These components resonate with many of the ideas within the TC literature, within which the notion of communities of practice is referred to by Meyer and Land (2003) in relation to troublesome aspects of learning, particularly those relating to language and discourse within a discipline, but the links to transformation are also clear.

Developing a way of thinking reshapes an individual's identity, not only in relation to a particular academic community, but also in relation to other communities to which that individual has belonged, and other communities they might aspire to join. (Davies and Mangan, 2007, p.712)

Meyer and Land (2003, 2005) argued that TCs are characteristically transformative as they not only transform understanding of knowledge, but the way of thinking, affecting a shift in the learner's view of subject landscape (Meyer, 2016). They bring about a change in perspective or way of viewing knowledge, as well as a grasp of the semantic nature of language used within a disciplinary discourse. Mastery of a TC may also invoke an ontological shift and Cousin (2010, p.2) argued that 'we are what we know' and that TCs become 'part of who we are, how we see and how we feel'. Potentially then, this change in ontological perspective may affect personal identity and bring about a 'reconstruction of subjectivity' (Meyer and Land, 2003, p.4), again drawing on the idea of bringing an affective component to the learning process. Meyer and Land (2003) draw comparisons with 'perspective transformation' (p.3), a term introduced by Mezirow (1978) to describe how adults can 'recognise and reassess the structure of assumptions and expectations which frame our thinking, feeling and acting' (Mezirow, 2009, p.90). The required or resultant shift in perspective during the process of mastering a TC brings with it all kinds of difficulties, not only cognitive but also affective. Further difficulties have been noted where transformation brought about by mastering a TC can result in a fixed view and cognitive bias (Land, 2016, p.20), which may act as a barrier to understanding further complexities, due to adopting a previously successful approach which has become ingrained.

2.2.2 Troublesome

TCs often prove difficult to grasp for learners, representing a challenge to common sense and existing knowledge (Walker, 2013). They might be thought of as the bits of the course where students get 'stuck', presenting themselves as 'potential blockages in the path of growing understanding' (Davies, 2003, p.2), such as 'scale' in biology (Taylor, 2006). Meyer and Land (2003) incorporated the work of David Perkins, an international adviser to the ETL team, to support their assertion that a TC can inherently represent 'troublesome knowledge' (p.5). Perkins had previously introduced the idea of troublesome knowledge whilst exploring a pragmatic approach to applying constructivist responses to difficulties with learning (Perkins, 1999). He espoused the term to describe knowledge 'which

appears counter-intuitive, alien or seemingly incoherent' and presented four reasons why knowledge may present itself as troublesome (Perkins, 1999, pp.8-10):

- Inert knowledge – when new knowledge, ideas or concepts are learned, but links are not necessarily made to everyday life or other applications, this knowledge remains inert, and will 'sit in the mind's attic, unpacked only when specifically called for'.
- Ritual knowledge – has a 'routine and rather meaningless character' and can be construed as part of a ritual, such as knowledge of historical names and dates which can be recited upon demand.
- Conceptually difficult knowledge – such difficult knowledge is likely to present because of 'misimpressions from everyday experience' and 'reasonable but mistaken expectations'. Whilst conceptually difficult knowledge is likely to occur in all disciplines, Perkins argued that it is perhaps more prevalent in mathematics and science, in part due to 'the strangeness and complexity of scientists' views'. Examples provided by Perkins related to objects in motion: objects slow down automatically (misimpression from everyday experience), heavier objects fall faster (mistaken expectations), Newton's laws, velocity and vector (complex views of scientists). Perkins views are informed by the literature on misconceptions and children's ideas in science which I expand upon in section 2.3.2. From this perspective, the existence of a 'common sense' or intuitive understanding of a TC acts to inhibit the mastery of it (Cousin, 2009, p.4). Letting go of this inbuilt understanding is also troublesome and deeply affective, as it can involve 'an uncomfortable, emotional repositioning' (Cousin, 2009, p.4).
- Alien knowledge (originally *foreign knowledge* and renamed as *alien knowledge* by Meyer and Land) – comes from a perspective that conflicts with our own, to such an extent that the learner may not even recognize the knowledge as foreign. For example: the different value systems and cultural beliefs of other nationalities, faiths and ethnic groups.

Perkins (1999) alluded to the existence of other forms of 'troublesomeness', inviting the development of further categories. Meyer and Land (2003) added two further forms of troublesome knowledge to their exploration of TCs, both of which reference Wenger's (1999, 2009) notion of communities of practice:

- Tacit knowledge - Meyer and Land (2003) drew upon Polanyi's (1958) notion of 'tacit knowing' to denote knowledge that remains personal and implicit to an individual. It may be difficult to transfer from one individual to another, to write down or visualise. Lam (2000, p.490) pointed to three main differences between implicit and explicit forms of knowledge in that
 - a) explicit knowledge can be codified, whereas tacit knowledge is intuitive and unarticulated.
 - b) explicit knowledge may be developed through formal study and logical deduction, whilst tacit knowledge requires practical experience in context, and
 - c) due to the contextual and personal nature of tacit knowledge, it cannot easily be aggregated and appropriated.

Examples of tacit knowledge might include leadership, humour or facial recognition (Lam, 2000). However, whilst tacit knowledge is personal to an individual, understanding may be shared to some extent within a community of practice (Meyer and Land 2003), due to its contextual nature.

- Troublesome language – Where language is the content of learning (such as when learning a foreign language or particular dialects), it can be seen to embody strong elements of tacit, conceptually difficult and alien knowledge. However, Meyer and Land (2003) referred to *troublesome language* as a source of conceptual troublesomeness within academic disciplines. They proposed that ways of seeing and thinking have emerged as specific discourses with disciplines that distinguish individual communities of practice (p.9), citing the use of the term 'culture' in Social Anthropology as an example. Through this notion of troublesome language then, previously familiar concepts may be rendered difficult because of the discursive practices of a community.

In exploring the notion of troublesome knowledge, Meyer and Land (2003) sought to illuminate 'what might account for the variation in student facility to cope' (p.9) with their encounters with learning barriers. Cousin (2009) argued that to encourage students to 'abandon their intuitive understandings is troublesome because it can involve an uncomfortable, emotional repositioning' (p.202). Some students adhere to the common sense understanding they bring to the learning to defend themselves from the troubling aspect of the discipline, thus preventing them from journeying too far into the subject. The pedagogical relevance of the troublesome nature of TCs arises from the importance of those concepts within disciplines and related curricular structures, leading to consideration of how these difficult aspects of learning may be best delivered. Furthermore, the troublesome knowledge attached to a TC has been posited as an 'instigative or provocative' feature (Meyer, Land and Baillie, 2010, p.xi) which is essential to 'unsettle prior knowledge' and 'render it fluid', allowing students to pass through the threshold with reconstituted understanding. Whilst necessary to provoke transformation (Land & Rattray, 2017), letting go of previous knowledge is accordingly troubling.

2.2.3 Integrative

A TC integrates with other concepts such that mastery may 'expose the previously hidden interrelatedness' of phenomenon (Meyer and Land, 2003, p.4), allowing the learner to 'make connections that were hitherto hidden from view' (Cousin, 2009, p.203) and allowing things to click into place, defragmenting the learner's view of a discipline. For example, grasping the concept of *water potential* in biology allows learners to see the links between their prior understanding of diffusion and osmosis, relating this to the osmotic effect on pressure and fluid movement. Mastery of a TC therefore allows learners to make connections in a way that they were previously unable to do, seeing new ways of viewing knowledge, which may then lead to previous ways being discarded. Davies (2003) suggested that a student can only recognise the power of a TC if 'they can see how it can act in an integrative way' (p.6).

However, there is a need to be mindful of variation between how individuals integrate knowledge according to their own internal understanding. The integrative

nature of TCs has been illustrated by Davies and Mangan (2007) as an interrelated web (see Figure 2).

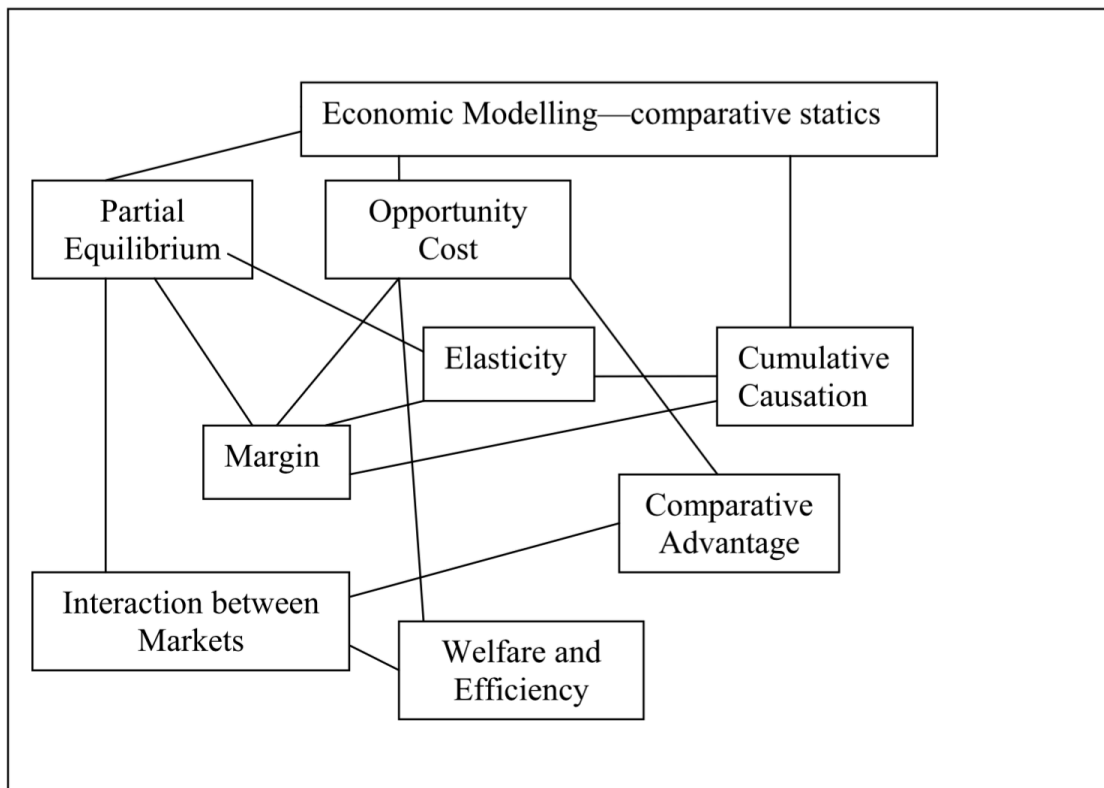


Figure 2 - A web of concepts drawn from Economics. Davies and Mangan (2007, p.722)

Understanding of a TC may be transformed through the subsequent acquisition of other related TCs (p.722) within a disciplinary web. Whilst other (non-threshold) concepts will also link in to this web, Davies and Mangan argued that TCs were central to establishing a framework within which these other concepts are used.

2.2.4 Irreversible

Mastery of TCs is often irreversible: once understood the learner is unable to forget or regress to a prior understanding of the concept, without considerable effort and reason to do so. Meyer and Land (2003) asserted that the changed perspective also makes it difficult to look back to prior conceptual understandings. However, this does not preclude a student from revising or rejecting a concept once understood (Cousin, 2010). A concept integrating a range of prior knowledge holds together an individual's way of thinking about different phenomena and is therefore more likely to be irreversible (Davies and Mangan, 2007, p.712).

The irreversibility of TCs presents challenges for teachers and lecturers in empathising with learners who are yet to grasp a particular concept. It is likely to be difficult for a teacher to think back to a time when they did not understand a concept and put themselves in the students' place (Walker, 2013). This raises methodological implications for researching TCs, as the same is therefore likely to hold true for students who try to recall their experiences of learning TCs retrospectively towards the end of a course or programme of study.

2.2.5 Bounded

The conceptual space occupied by certain TCs may possess 'terminal frontiers, bordering with thresholds into new conceptual areas' (Meyer and Land, 2003, p.6). This characteristic may be more complex in some subjects than others, depending on its level of complexity and interdisciplinary nature. The boundaries of an academic discipline will appear sharper where integration is stronger (Davies and Mangan, 2007), and more complex the more interdisciplinary a subject is (Cousin, 2010). Boundedness may also be relative to disciplinary language, in which respect Flanagan and Smith (2008) provide an example from computing where the term 'deprecate' is specifically used to refer to letting an aspect of programming lapse, or wither away, whereas in common usage deprecate has a more negative meaning. The bounded nature of a TC has also been linked to the *transformative* characteristic (Barradell and Passeta, 2014, p.263), in representing the demarcation of disciplinary fields through transformative behaviour evident from becoming part of that field as a result of TC mastery.

2.2.6 Liminality

In the conclusion of their opening paper, Meyer and Land (2003, p.10) proposed that in addition to the above five characteristics, difficulty arising from the transformative effects of TCs place the learner in a state of *liminality*, a spatial metaphor for the transformative state in the process of learning where students experience a shift in subjectivity (Land, Rattray & Vivian, 2014, p.1). Whilst the word originally derives from the Latin for 'threshold' (*limen*), Meyer and Land drew from Turner's (1969) use of the term to characterise the transition experienced by

adolescents during rites of passage rituals in his ethnographical studies of traditional peoples.

In a liminal state, prior to mastery of a concept, Meyer and Land (2005) suggested that the learner demonstrates understanding that may exhibit a lack of authenticity that they referred to as 'mimicry'. It has further been argued that during this period the learner experiences uncertainty and may 'oscillate between old and emergent understandings' (Cousin, 2006a, p.4), experiencing 'cognitive dissonance' (Walker, 2013, p.250) and an 'uncomfortable ontological shift' (Land, 2013), as they are required to let go of prior understandings. Demonstrating links again to Lave and Wenger's (1999) principle of situated learning and communities of practice, *liminality* and 'troublesomeness in the liminal space' (Land, 2013, p.2) play a central role in the TCF, as 'stuckness' (Cousin, 2010) can be more fully explored through the notion of liminality.

Too much uncertainty in this liminal state and the learner will not be able to progress beyond a surface understanding. Not enough uncertainty and the learner will not make the required transformation into a fully participating member of a community of practice. (Walker, 2013, p.250)

I argue then that viewing this period in a learner's journey to mastery of a TC in such a way, and embracing the liminal journey, can be pedagogically fruitful for teachers in terms of curriculum design and delivery.

The TC literature appears to demonstrate a broadly shared understanding of the notion of liminality and the liminal space occupied during the journey to mastery as an abstract representation of the learner's conceptual and ontological journey to transformation. Whilst some authors have sought to clarify this understanding through semiotic modelling (Vivian, 2012, Land, Rattray & Vivian, 2014), others, such as Akkaraju and Wolf (2016), have generated confusion in referring to liminal space both in abstract terms, but also concrete terms as a situation, such as a classroom or online community. However, many authors appear to predicate definitions around the original abstract notion presented by Meyer and Land (2003) and Cousin (2006).

2.2.7 Discursive

In a second paper, Meyer and Land (2005) introduced the suggestion that TCs are necessarily *discursive*. They argued that any shift in perspective because of transformation would be hard to imagine without (or as a result of) an extended use of language and a change in discourse (p.3). This transformed language may be developed from within a specific community of practice or discipline, or generated as a result of the learner's own internalisation of integrated knowledge. An extended use of language and transformed view of a subject then effects a shift in the subjectivity of the learner, bringing with it a 'repositioning of the self' (Meyer and Land, 2005, p.3).

2.2.8 Reconstitutive

Although listed here as a separate characteristic, the notion of reconstitution provides a useful way of illuminating the process, or journey, a learner follows as they negotiate the acquisition of a TC. Binding together the characteristics described above, such reconstitution takes place over time, requiring a 'reconfiguring of the learner's prior conceptual schema and a letting go or discarding of any earlier conceptual stance' (Land, Meyer and Baillie, 2010). The reconstitutive feature plays a key role in a relational model of TC acquisition as seen in the next section.

2.2.9 A relational view of threshold concept characteristics

The previous sections provide individual definitions of the characteristics of TCs. However, they make much more sense as a framework, when presented in more cohesive fashion within the context of the journey through acquisition of a TC. Land, Meyer and Baillie (2010) proposed the diagram in Figure 3, which they ordered according to three modes of *preliminal*, *liminal* and *postliminal* states taken from earlier work (Meyer, Land and Davies, 2008).

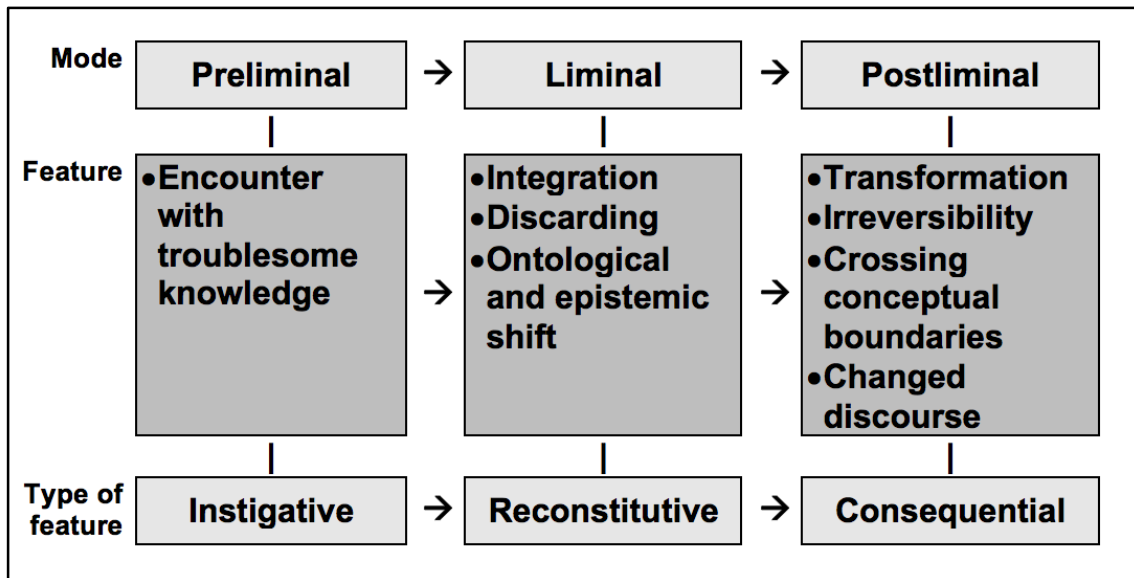


Figure 3 - A relational view of the features of threshold concepts.
(from Land, Meyer and Baillie, 2010, p.xii)

Underpinned by the notion of liminality, the diagram expounds the journey through the liminal states, categorising the TC characteristics into three types of feature to illustrate their contribution within this journey. Land, Meyer and Baillie (2010, p. xi) describe the diagram thus:

In the preliminal state, an encounter with troublesome knowledge acts as ‘an instigative or provocative feature, which unsettles prior understanding rendering it fluid, provoking a state of liminality’. In the liminal mode, an ontological and epistemological shift occurs due to the reconfiguration or discarding of prior conceptual schema, brought about by the integration of new knowledge. These reconstitutive features bring about the necessary new understanding. Consequentially, and irreversibly, conceptual boundaries are crossed and the learner and their understanding are transformed as they enter the postliminal state, resulting in altered discourse.

Despite inferring a journey with an intended destination, it is important to note that this model was never intended to signify a necessarily rigid, linear or sequential process. Land, Meyer and Baillie, (2010, p.xi) were explicit in highlighting the ‘oscillation’ that remains hidden within the recursive nature of TC acquisition. The journey towards mastery is rarely straightforward, requiring iterative, non-linear exposure (Batzli, et. al., 2016). There is likely to be ‘deviation and unexpected outcomes’ (Meyer, Land, & Davies, 2006, p.202), involving ‘messy journeys back, forth and across conceptual terrain’ (Cousin, 2006a, p.5).

It is useful at this point to draw comparisons between the relational view proposed by Meyer, Land and Baillie (2010) and existing theories of learning to see how these fit into the three stages of liminality in concept learning. Table 2 provides some example comparisons and gives an overview of how the three liminal modes fit with other models. This comparison also provides insights into the wider theoretical framework within which this thesis resides.

	Preliminal	Liminal	Postliminal
TCF relational view (Land, Meyer and Baillie, 2010)	Encounter with troublesome knowledge	<ul style="list-style-type: none"> • Integration • Discarding • Ontological shift 	<ul style="list-style-type: none"> • Transformation • Irreversibility • Changed discourse
Type of feature	Instigative	Reconstitutive	Consequential
Cognitive constructivism Piaget Pritchard (2014, p. 21)	Assimilation New knowledge is not easily incorporated into existing mental structures	Accommodation Mental structures are altered to cope with contradictions arising from new experience	Equilibration Arriving at a stable state where there is no longer a conflict between new and existing knowledge
Vygotsky (1978)	Learner cannot do	Learner can do with instruction (Zone of Proximal Development)	Learner can do unaided
Schema theory and mental models Pritchard (2014)	New information counter to common sense	Reorganised when incoming data signal a need to restructure a concept	Schemas enable boundaries to be recognised. Malleable and changeable
Children's learning in Science (Driver, 1983, 1995)	Existing schemes are brought to the classroom	Hypothesis testing of existing schemes against new stimuli	Schemes may be modified

Table 2- Learning theories within each of the stages of liminality

2.3 Theoretical and conceptual frameworks

In this section I outline my theoretical framework, by which I mean the structure of theories and concepts which underpin my research approach (Grant & Osanloo, 2014), and the underlying definitions of terms within those theories. The TC literature exhibits a wide and eclectic range of influences, resonating with a vast number of educational theories as already illustrated briefly in the previous sections on characteristics of a TC. It has further been argued that, rather than standing alone as a field of research, the TCF may act more as a catalyst which draws upon other fields to generate a 'productive educative framework' (Lucas

and Mladenovic, 2007, p.239). I have intentionally used both the terms 'theoretical framework' and 'conceptual framework' in this section to illustrate that I have constructed my approach around an existing theory in the literature, the TCF, which forms my theoretical framework, whilst engaging with aspects of a more finely grained 'conceptual framework', allowing me to delineate those specific theories and concepts I have selected to explore the research problem.

2.3.1 The nature of concepts and concept acquisition

Within a theoretical framework concerned with scrutiny of concepts, it is prudent to consider a definition of concepts and how they are acquired, which here is drawn from cognitive psychology, the study of mental processes (Pritchard, 2014, p.18). The term 'concept' as used within this thesis denotes a simplified, abstract representation of a commonly held set of criteria, attributes, or mental models, organised into hierarchical groups or sub-groups called 'categories'. Concepts allow us to gain access to information in long-term memory which we may then apply to objects and events around us, to make predictions about and to understand new situations and objects (Murphy, 2016, p.1038). Reality in the physical world and conscious experiences within these realities inhere within concepts but the cognitive content is different for each individual (Ausubel 1968, p.505) and concepts are generated in the context of our own previous knowledge and experiences (Murphy, 2016). As the experience of each individual is different, thus the understanding of a particular concept will be internalised on a different level. The variation between individuals with respect to formation and understanding of concepts is important in this thesis as it serves to justify the epistemological approach to gaining knowledge of concept learning through exploration of individual experience. The TCF emphasises that learning is a journey which individuals undertake at varying rates of progress (Meyer, 2016, p.467). Despite this variation of understanding, concepts allow humans to communicate with each other using the shared attributes or characteristics particular to each category of ideas or objects represented by each specific concept. Without this streamlining and categorisation, humans would be unable to manage the vast amounts of information that they encounter on a daily basis (Murphy, 2002; Eysenck & Keane, 2005).

Within the field of cognitive psychology, many theories have been proposed to explain the structure and organisation of concepts in long-term memory, although the prototype and exemplar models are considered to be the two main theories (Murphy, 2016). Predating both of these approaches, the classical view (also known as the defining-attribute approach) can be traced back to the time of the early philosophers such as Aristotle and underpinned Piaget's work with children's development. The classical view has largely been discredited (Murphy, 2002) due to several limitations which cannot be reconciled through empirical work: in particular, that it relies on the argument that category members are both necessary and sufficient for category membership. This rigid reliance makes it almost impossible to find definitions for categories that are suitable for different ages and contexts and does not account for category members that are more typical than others, or for 'fuzzy' concepts (Eysenck and Keane, 2010). However, the classical view is still used as the basis of arguments in some theoretical articles, and key arguments raised against the TCF appear to take this positivistic approach (Rowbottom, 2007; O'Donnell, 2010), anticipating a set of definitive characteristics that fit all TCs and which can be 'proven'.

Whilst still reliant on a definitive list of characteristics, in the 'prototype' model, a concept can be represented by a prototypical summary description and category members exhibit some, or all, of the family resemblances from a feature list, or single best example. Furthermore, in stark contrast to the classical view, some attributes within the summary representation of a prototype may be weighted more than others, being more typical (Eysenck & Keane, 2005, p.297). If we view Meyer and Land's (2003, 2005) definition of TCs through this prototype model, links can be made with the way authors have applied the definition across the TC literature, with some of the characteristics appearing less frequently and with less emphasis than others. However, this does not appear to be as a conscious result of taking a prototypical view and is more down to the range of individual interpretations of the framework. The prototype model has its own limitations, particularly where there is vagueness surrounding the precise definition of the prototype or the application of such, leaving it open to criticism as in the case of the 'opportunity cost' example (Meyer and Land, 2003), much quoted, but criticised by O'Donnell (2010).

However, with a clear definition, a prototype approach to identification of TCs could counter many of the concerns levelled at the TCF.

The exemplar model posits that long-term memory holds several instances of each concept and relies heavily on context. This allows us to retain information about the variation between instances and better make predictions based on our experiences (Eysenck & Keane, 2005). However, the exemplar view rejects the notion that there is a representation covering the whole concept, arguing instead that a person's concept of a phenomenon is the set of phenomenon that the person has encountered. For example, a person's concept of cats does not rely on a definition of a cat, but rather on all the instances of a cat that the person has ever encountered and verified as a cat. This makes it less useful to apply to the current discussion requiring a shared understanding of TCs: if you had come across several TCs without knowing what they were, they would not be of help in identifying future TCs according to the exemplar view. Whilst there has been debate over which approach is more correct, Murphy (2016) argued that an approach which considers how both prototype and exemplar models work together in generating our memory structure would be more productive.

One further theory which links to the prototype model is *schema theory*, which holds that the meaning of a concept to an individual depends on its relationship to other concepts within existing knowledge structures or *schema* (Eysenck and Keane, 2005, p.313). These schema can be described as 'multidimensional stores', or frameworks abundant with interconnected nodes of knowledge, skills and understanding (Pritchard, 2014, p.22), or more simply, a way of describing conceptual knowledge stored in long-term memory. The adding of items to schema and the forming of new connections between existing nodes within a schema forms the basis of constructivist learning theory, which posits that prior knowledge plays a crucial role in the shaping of schema and mental models within an individual's memory. This notion resonates with and underpins earlier discussions on the integrative nature of TCs and the web of concepts proposed by Davies and Mangan (2007).

Defining my understanding of concepts and category learning in this section has allowed me to demonstrate how models of concept learning in cognitive psychology have informed my thinking on how TCs are acquired. This part of the conceptual framework underpins and clarifies my position in the broader theoretical framework of the TCF and I draw on the prototype approach later in this thesis to underpin the model I have developed to identify TCs in the findings.

2.3.2 Constructivist learning and children's learning in science

Meyer and Land's generative writings on TCs (2003, 2005) incorporated the notion of troublesome knowledge, derived from Perkins' (1999) work on constructivist learning and have been argued as being set within a social constructivist context (Davies, 2003; Davies & Mangan, 2005; Perkins, 2006), which inherently forms part of the theoretical framework of this thesis. The constructivist tradition relating to children's learning began to develop in the first half of the twentieth century influenced greatly by Piaget and Vygotsky in Europe, as well as Bruner and Ausubel in the United States, amongst others. Each of these authors approached constructivism in different ways: for example, whilst Piaget focused on stages of development relating to the individual, Vygotsky embraced the view that knowledge is constructed through social interactions. The constructivist view is that learning takes place as a result of experience which causes changes to mental associations or schema within the individual, which cannot be easily observed due to their internal nature.

Despite the differences in approach, the work of these pioneers paved the way for researchers such as Rosalind Driver, whose work greatly influenced science education in the UK throughout the 1980's and 90's. She introduced the notion of the pupil as scientist (Driver, 1983), the idea of children's conceptions as personal construction (Driver, Squires, Rushworth, & Wood-Robinson, 1994), as well as publishing findings on a wide range of research concerned with illuminating children's ideas about the nature of science (e.g. Driver, Guesne & Tiberghien, 1985; Driver, Leach, Miller & Scott, 1996). Much of the work in this field is predicated on the notion that, even prior to formal learning, children will have made generalisations about the world around them, based on empirical

observations. These observations then allow children to acquire and use concepts, and to induce categories based on sparse evidence (Murphy, 2016), although their generalisations may be simplistic or even wrong, generating errors and misconceptions. Whilst Driver's notion of the 'pupil as scientist' (1983) was widely embraced by many in the scientific community, it was also criticised from the perspective that not all knowledge constructed by the individual is necessarily scientific, nor valid (Hodson, 1998). Despite this criticism, the published works of Driver along with other authors greatly influenced science education research.

Driver's main argument holds that children act in a similar way to the scientist prior to formal tuition, gathering observational and experiential evidence to make sense of the world through their own hypotheses, which Driver summarised thus:

The process by which knowledge is constructed by the learner is broadly surmised to involve a process of hypothesis testing, a process whereby schemes are brought into play (either tacitly or explicitly), their fit with new stimuli is assessed, and, as a result, the schemes may be modified. (Driver, 1995, p.387)

This allows a child to make predictions based on expectations generated through previous experience. When they arrive at a formal learning situation such as a classroom, they bring with them this prior knowledge that they have constructed, whether they recognise it as such or not. However, in some cases their beliefs and expectations may cause the accepted theories they experience in the classroom to appear counter-intuitive. For example, a child may describe the diminishing level of water from a puddle as the liquid 'disappearing' prior to formal tuition of evaporation, based on their own observations. These beliefs have been referred to by many terms, including 'quaint distortions' (Piaget, 1929) 'preconceptions' (Ausubel, 1968), 'errors' and more widely as 'misconceptions'. Whilst different, each of these terms denotes a conception of phenomena developed from a perspective that is uninformed and that may not match the 'correct' scientific view. The negative connotations associated with these terms led to them being referred to as 'alternative frameworks' in the UK (Driver and Easley, 1978) and 'alternative conceptions' in the USA (Wandersee, Mintzes and Novak, 1994). However, in this thesis I will use the term 'misconception' as it is generally used and understood in UK secondary school education.

It is now widely accepted in science education that children bring misconceptions from previous formal or informal learning to the classroom (Oversby, 2012). For example, that 'gravity only acts on things when they are falling' (Wenning, 2008, p.11). However, despite instruction these misconceptions may remain intact, even at secondary school level and beyond (Wandersee, Mintzes & Novak, 1994). This phenomenon has been noted in biology courses at universities (Ross, et al., 2010b) where students may continue to struggle with key biological concepts despite a high level of academic tuition. The challenge for teachers and academics is to transform students' misconceptions into more scientifically 'correct' understandings. The whole field of science education research is now quite sophisticated including the development of various *conceptual change* models, predicated on the notion of children's misconceptions needing to be replaced with new scientific concepts through instruction. Conceptual change theory has informed research and pedagogy in science education since the 1980s, basing instructional techniques on the establishment of *cognitive conflict*, to provoke dissatisfaction with previous misconceptions and to encourage students into accommodating the correct information by creating new schema (Vosniadou, 2008).

TC research reflects the work on science misconceptions and conceptual change theory (Batzli, et al., 2016; Talanquer, 2015) in that students may experience difficulty with certain concepts which they find counter-intuitive to their previously held beliefs and knowledge. This imperfect cognition may become troublesome knowledge (Ross & Tronson, 2007), acting as a barrier to learning which may lead to the formation of misconceptions (Bhola & Parchoma, 2016). The relational view presented earlier in section 2.2.9 demonstrates this link, where *troublesome knowledge* is presented as the catalyst for provoking cognitive conflict at the preliminal stage, such that previous knowledge and assumptions are rendered fluid allowing students to enter a liminal state where dismantling (Talanquer, 2015), reconstitution and discarding, or modification of existing schema may occur.

Davies and Mangan (2007) theorised that viewing TCs from a conceptual change perspective would be useful in determining a framework for their identification.

They proposed three types of conceptual change: *basic*, *discipline* and *procedural*. It has been argued that TC learning exists in contrast to the transmission of large content volume (Land, 2013, p.1) sometimes referred to as the 'stuffed curriculum' (Cousin, 2006a). The building up of knowledge in the form of key concepts (Davies and Mangan, 2007, p.713) or enabling concepts (Sharp, 1996, p.688) allows students to build subsequent layers of knowledge, as in Bruner's (1960) 'spiral' curriculum. Davies and Mangan (2007) described this type of learning as an 'understanding of every day experience transformed through the integration of personal experience with ideas from a discipline' (p.715). They categorised this as *basic* conceptual change. This notion acknowledges that students will possess existing knowledge which they can relate to discipline specific ideas (Walker, 2013) and which they will bring to the learning process, as with misconceptions (Driver, 1983).

Acquiring TCs involves a complex set of interactions with both the disciplinary knowledge and the reconstitution of the students' own epistemological perspective. Davies and Mangan (2007, p.715) thus posited that 'understanding of other discipline ideas integrated and transformed through acquisition of theoretical perspective constituted *discipline* conceptual change. This argument resonates with the notion of students undertaking a 'messy journey' (Cousin, 2006a) whilst they gather knowledge which helps them to integrate and understand a particularly troublesome TC.

The third category of conceptual change, dubbed *procedural*, denoted the 'ability to construct discipline-specific narratives and arguments transformed through acquisition of ways of practising' (Davies and Mangan, 2007, p.715). Within the framework outlined above, only *discipline* and *procedural* conceptual changes would rationalise with the definition of a TC, both being transformative and integrative. For example, *discipline* changes generate a transformative and integrative overview whilst *procedural* changes act as 'enablers' (Davies and Mangan, 2007, p.715), providing students with a more complete grasp of the discipline concepts. Learners cannot simply add to prior learning, but they must *rework* prior understanding (p.721). In this way, TCs provide a productive way of thinking about conceptual change within a discipline, focusing on the

transformative changes that learners must make and the integrative perspective required to master TCs. These observations led Davies and Mangan (2007) to suggest that it may be useful for researchers to view TCs within a discipline as a web of interrelated concepts rather than as a list, a position that resonates with schema theory, suggesting that disciplinary TCs form a 'framework of reference' (Pritchard, 2014, p.23) for comparison.

The TCF thus provides a framework through which to identify concepts that are central to mastery of disciplinary knowledge and its progression, which integrate prior learning and misconceptions with more correct knowledge and understanding. Curricula and pedagogical approaches to delivery may then be designed to embrace encounters with troublesome knowledge as having the potential to be reconstitutive, encouraging cognitive conflict which provokes entry to a liminal state, leading to the reframing of existing schema and the formation of new integrative understanding. However, I argue in this thesis that, whilst productive, the cognitive dissonance resulting from these encounters with troublesome knowledge has the potential to be emotionally challenging for students, particularly when coupled with an increase in workload and expectations. The following section now considers the affective dimension of students' encounters with troublesome knowledge, as it forms a significant part of the conceptual framework of this thesis.

2.3.3 The affective dimension of threshold concepts

TCs bring about transformations in perspective once understood (Meyer and Land, 2003), and are likely to involve an affective component (Cousin, 2006b; Meyer, 2016), which I define here as relating to feelings, emotions and attitudes. It has been suggested that TC acquisition is highly emotive for many students (Felten, 2016) and may be significant enough to bring about a shift in identity within the individual through both cognitive and affective transformation. Cousin (2006b) presented a case for the importance of considering affective factors in the learning of TCs, suggesting that emotional capital and affective learner positions play a key role in the liminal journey that students undertake. Despite these compelling suggestions of the existence of a strong affective dimension, much of

the research into TCs has focused on the cognitive aspects of students' experiences and the pedagogical or curriculum influences impacting on their understanding. However, several authors have identified the value of further research into the affective dimension (Shopkow, 2010; Rattray, 2014, 2016; Macintosh Edwards, 2013; Land, 2014; Felten, 2016; Land, Rattray & Vivian, 2014).

Co-facilitating three seminars with undergraduate students at universities in the United States, Felten (2016) aimed to discover how partnering with students might expand our understanding of TCs. Each seminar involved between eight and fifteen students who were given the opportunity to read and discuss introductory literature on TCs (Meyer and Land, 2006) before reflecting on their own experiences and writing about when and how they had experienced troublesome knowledge. One of the findings to emerge from this exploratory research was the suggestion that a key element is missing from the current TCF definition of troublesome knowledge (Flanagan, 2017). Rather than describing aspects of the knowledge itself that proves difficult, as might teachers and academics, students instead described their experiences of engaging with the knowledge, a shift in perspective which Felten (2016, p.6), referred to as 'troublesome affect'. These students also emphasised the importance of feeling comfortable with newly acquired knowledge once a TC had been mastered, or 'threshold confidence'. Felten's exploratory research is important for this thesis as it suggests that there is much to be learned from the insights of students about the affective experiences of learning and how this can impact on the acquisition of TCs. Involving students in discussions about learning and troublesome knowledge is therefore posited as a worthwhile and important aspect of future TC research, echoing Cousin's (2010, p.7) call to undertake 'transactional curriculum inquiry' between subject specialists, students and educational researchers.

In another study, MacIntosh Edwards (2013) worked with eighteen students at different stages of a Master of Pharmacy qualification in the UK to explore their experiences of encounters with troublesome knowledge and assessment. She used semi-structured interviews, to which participants were asked to bring artefacts (such as a photograph, song or object) to represent their experiences of

learning in pharmacy and to prompt discussion. These artefacts were used with an episodic interview style to help explore areas of the curriculum which students found difficult. Despite not being the primary aim of the research design, the affective dimension of learning emerged as significant for the participants, who elicited a range of negative emotive phrases when asked to talk about the difficulty they had with learning and assessment. Macintosh Edwards argued that the affective dimension of students' experiences with difficult learning emerged as a clear theme that warrants further research, and this thesis aims to achieve this by exploring students lived experiences of difficulty with transition and encounters with troublesome knowledge.

The affective dimension of TCs forms a key part of my conceptual framework within the overall theoretical framework of the TCF. In this section I have also discussed the nature of concepts and category learning, and the constructivist tradition, relating these to key literature in the TCF. The following section describes both my own and others' criticisms of TCs, within which further aspects of my conceptual framework are presented, concerned with how TCs can be identified according to their characteristics. These elements are identified in the text and a full summary of the conceptual framework is provided at the conclusion of this chapter.

2.4 Criticisms of threshold concepts

Despite the acceptance of TCs by a growing number of academics, key questions are still to be addressed within the literature. Largely, these derive from issues with the definition of the characteristics and inconsistent application of such to empirical study. Although criticism of TCs is not extensive (Rowbottom, 1997; O'Donnell, 2009, 2010; Delany, 2012; Barradell, 2013, 2016; Walker, 2013, 2015), the arguments put forward are credible, and unsurprising in their direction of argument considering the issues alluded to above. Of more concern, perhaps, is the apparent paucity of engagement with these critiques by the wider community involved with TC research and publication. The following discourse therefore aims to critically address some of these concerns to provide a degree of clarity for the reader with regard to perceived limitations of the TC approach, namely:

- Definitional issues
- Inconsistency in nomenclature
- Methodological issues
- Agent-dependence
- Teacher/student perceptions

2.4.1 Definitional issues

As noted previously, in their early published work on TCs, Meyer and Land (2003, 2005) did not explain their own interpretation of what constitutes a concept, or how concepts are acquired. This omission was highlighted by Rowbottom (2007) and cited as a source of potential ambiguity in Meyer and Land's subsequent definition of the term 'threshold concept'. Despite this criticism having been levelled, few authors have addressed this in their own work, with Walker (2013) being an exception. Meyer did respond to this critique more recently (Meyer, 2016), citing a description of concepts by Perkins (2006, p.41):

Most fundamentally, concepts function as categorisers. They carve up the world we already see and often posit the unseen or even the unseeable.

The nature of concepts and concept learning forms an essential part of the theoretical framework of TCs, and has been included as such in this thesis. One of the other key issues still to be resolved in the literature is an epistemological one: how a TC can be identified empirically using the definitions in the framework, as there is still no consistent approach to identification or verification (Batzli, et. al., 2016).

Rowbottom (2007) argued that TCs were impossible to empirically isolate, even in principle, using the definition proposed by Meyer and Land (2003). He asserted that they failed to specify the properties of a TC, positing by way of example that '...it is necessary to understand what the essential properties of X's are, in order to be able to determine if there are any Xs' (Rowbottom, 2007, p.264). Rowbottom's (2007) argument assumed a positivist stance supported by philosophical, logical reasoning and the use of metaphorical analogy. His position assumed the classificatory pursuit of TCs, which is at odds with the aims of the interpretivist

tradition that TC research draws from. There is seemingly very little in terms of rebuttal within the literature, although Rountree and Rountree (2009, p.141) argued that the lack of a precise definition did not disprove the existence of TCs. Additionally, Meyer (2016, p.467) argued that ‘...all students will vary in their experiences of comprehending a TC because of individual differences in, for example, relevant prior knowledge of that concept, the proximal subject domain in which it is located, or a habit of mind that resonates with the epistemic function of that concept’. He proposed an approach which embraced ‘inter-individual variation’, rather than searching for a fixed rate of ‘inter-individual transformation’ within learning episodes (2016, p.467). Within whichever paradigm research is positioned, an overly constrictive definition may not be achievable (or desirable) and does not preclude TCs from being clearly described.

Another inconsistency in the literature is the set of defining characteristics used in empirical work. Some authors (e.g. Haji Bungsu, 2014; Hofer, Townsend & Brunetti, 2012; Slinger, 2011) have based their research almost solely on the list of five characteristics proposed by Meyer and Land (2003), referred to hereon as ‘original’ characteristics for clarity. As previously mentioned, these were tentative and generative in nature, offering an imprecise set of ‘probable’ rather than ‘defining characteristics’ (O’Donnell, 2010, p.3) or ‘accidental’ rather than ‘essential properties’ (Rowbottom, 2007, p.264). The eight features proposed by Meyer and Land (2003, 2005), and referred to hereon as the ‘TCF characteristics’, are now widely accepted in the TC community (see Flanagan, 2017; Baillie, Bowden & Meyer, 2012), however, there is little evidence of the TCF characteristic set being applied widely to empirical work as a set of identifying features, with many authors relying on the original five characteristics. This brings us back to the consideration of unresolved questions relating to the identification of TCs, highlighted by Barradell (2013, p. 267) thus (*italics added*):

- a) how many of the five (*or eight?*) characteristics should a TC possess to be regarded as a TC?
- b) are some characteristics more important than others *in the identification of TCs?* e.g. is troublesome more important than bounded?

- c) if a concept is transformative and integrative, but not troublesome, is it a TC?

In a statistical analysis of keyword frequency across the titles of over a thousand published papers on TCs (Flanagan, 2017) words relating to troublesome (n=84), transformative (n=82) and liminality (n=70) featured strongly, whilst integrative (n=42) and discursive (n=11) were less prevalent, with irreversible (n=1) and bounded (n=0) being notable by their lack of inclusion. Whilst this rudimentary analysis does not take into account the application of the characteristics to identification of TCs, examination of the literature involving empirical work would suggest that there is an underlying hierarchy within the criteria. Certainly, the *transformative* characteristic appears frequently in the literature and often features, whether explicitly or implicitly, in the identification of TCs. It has been referred to as a compulsory feature (Male, Guzzomi & Baillie, 2012); non-negotiable (Barradell, 2013; Land, 2013, 2016); superordinate (Land, 2011; Walker, 2013); a principal feature (Atherton, Hadfield & Meyers, 2008); necessary (Davies & Mangan, 2007) and essential (Rountree, Robins & Rountree, 2013). According to Cousin (2010, p.2), 'grasping a threshold *is* transformative', suggesting that this characteristic holds more weight than others. This position was reinforced by Land's assertion that 'the superordinate and non-negotiable characteristic of a TC is its transformative capacity' (Land, 2016, p.16). Flanagan's website also states under the definition of each of the eight TCF characteristics that:

Examples of the threshold concept must be transformative and involve a traverse through a liminal space. They are likely to be characterised by many of, but not necessarily all of, the other features listed above. (Flanagan, 2017, p.1)

Whilst the *integrative* feature has been identified as 'indispensable' (Park & Light, 2010, p. 260) and of 'prime importance' (Higgs, 2014, p.17) in navigating the route for students, it appears to have been applied infrequently by many authors as an identifying feature in empirical fieldwork.

Meyer and Land's early description of TCs (Meyer & Land, 2005, p.373) stated that the *transformative* and *troublesome* characteristics 'define critical moments of

irreversible conceptual transformation', suggesting that these two characteristics are crucial to definition. Some studies have relied only on these two characteristics, such as one by Male, Guzzomi and Baillie (2012), who used *troublesome* and *transformative* as 'compulsory' criteria to identify the TCs in their Australian study of foundation level engineering, arguing that the other criteria were not intended to be compulsory features, citing a personal communication from Jan Meyer in support of this assertion. However, in more recent work, Land, Meyer and Baillie (2010, p.ix) suggested that the *transformative* and *integrative* features are definitive, with *troublesome* and *irreversible* seen respectively as 'likely and frequent'. Park and Light (2010) referred to the integrative and transformative characteristics as 'indispensable' (p.ix) and were cited by Meyer (2016, p.464) in his own description of TC characteristics.

Akkaraju and Wolf (2016) applied the transformative and troublesome characteristics, whilst Lucas and Mladonovic (2007) used *troublesomeness* alone to identify TCs in accounting. One issue with only relying on this one feature is that it then suggests that anything conceptually challenging could be a TC (Barradell, 2013; O'Donnell, 2010). Rodger and Turpin (2011) suggested that identifying troublesome knowledge was an effective starting point for considering TCs in occupational therapy. Having discovered elements of the curriculum that students found troublesome, they then matched their data against all 5 'original' characteristics of TCs in compiling the results of their three-stage action research project. So, should empirical research into TCs be designed to include all characteristics? In a review of TC literature, Birchmore, Irvine and Carmichael (2008) found very few TCs where all five 'original' characteristics were present. The current state of the field shows much the same picture and rarely do the features integrative, irreversible or bounded appear as strongly determinant characteristics in empirical work. For example, Haji Bungsu (2016) presented the original five characteristics but then used only troublesome, transformative, and integrative in the identification of TCs. Wilson et al. (2010) even found that participants in their study discarded 'bounded' as a characteristic due to the difficulty they experienced with its interpretation.

The question of whether a TC can have all characteristics simultaneously may depend at what point the data is collected. To illustrate this, we can return to the idea of the modes of variation in a relational view of the characteristics (see section 2.2.9). If concepts are scrutinised in the preliminal or liminal stages, it may be too early to elicit evidence of all characteristics, whilst Davies (2006, pp.75-76) suggested that all five 'original' characteristics are present at the end of the learning process (the postliminal stage). This perspective might, therefore, suggest that fieldwork could be designed to identify TCs after successful mastery if all characteristics are to be identified. However, there are problems with this: once a learner has mastered a TC and has reached a postliminal state, the concept would ostensibly no longer be troublesome. If this were the case, O'Donnell (2010, p.4) argued that troublesome cannot therefore be a defining characteristic if it is capable of disappearing. As an argument in deductive logic this seems straightforward, but it does suggest that there is a point at which a TC suddenly ceases to cause problems for the learner and does not take into account the complexities of individual variation in the experience of troublesome knowledge in the learning process, which will be different for each individual. A researcher would find it almost impossible to design fieldwork to capture data at precisely the right moment to overcome these barriers. It has also been argued that thinking about a single point in time as representing understanding of a TC, simultaneous to the resultant epistemic and ontological shifts, is unhelpful (Meyer, 2016, p.467). So it would appear that aiming to identify a TC at a specific single point in the learner's journey to mastery would prove highly troublesome in itself, particularly if the aim were to find a point where all characteristics were evident simultaneously. This line of argument suggests that a longitudinal approach with multiple points of empirical investigation is worthy of consideration, as advanced in this study.

There is also the question of whether a TC needs to have all characteristics simultaneously. Hofer et al. (2012) compared all five 'original' characteristics to potential TCs in their study of information literacy conducted in the USA. However, their approach has been criticised by Morgan (2015, p.20) who suggested that their 'delineation of threshold concept attributes is nearly mathematical in its exactitude, an unusual characteristic for a fundamentally contingent phenomenon'.

Rather than criticising the use of all characteristics, Morgan questioned the application of these as a process of 'discovery or identification rather than a process of interpretation or argumentation'. In this circumstance, the question of how many characteristics are needed is less important than how they are applied and an interpretative approach that takes account of the variation of learner experiences is advocated in this thesis.

It is argued here, as part of my own conceptual framework, that it is worthwhile to move away from the view of the TCF as a 'tick list' of characteristics, with ensuing conflict over which are more important or whether all need to be present, and instead embrace a more pragmatic standpoint which allows for practical application in a professional context. The relational view of TCs proposed by Land, Meyer and Baillie (2010) presents the *troublesome* feature as instigative, and therefore a good starting point for identifying potential TCs, with *transformative* and *integrative* seen as defining features (Land, Meyer & Baillie, 2010; Meyer, 2016). I therefore propose to take an approach to inquiry where certain characteristics serve to highlight potential TC candidates, with the other characteristics helping to strengthen and add confidence to the identification. This approach also draws from the principle of the prototype view of concept acquisition from cognitive psychology (Murphy, 2016; Eysenck & Keane, 2005, p.297), allowing for the TCF characteristics to be applied across a range of concepts and contexts. This model is developed further and exemplified in the discussion in Chapter 6.

2.4.2 Inconsistency in nomenclature

Throughout the literature authors have referred to Meyer and Land's (2003) notion of TCs as a theory (Davies & Mangan, 2007); a model (Trafford & Leshem, 2009); an analytical framework (Osmond, Turner & Land, 2008) a form of enquiry (Cousin, 2008) a theoretical framework (Lucas & Mladenovic, 2007), and a conceptual framework (Shanahan, Foster & Meyer, 2008). In the editors' preface to the volume *Threshold Concepts and Transformational Learning*, Land, Meyer and Baillie (2010, pp.ix-xii) refer to the 'threshold concepts approach', 'threshold concepts framework', 'thresholds framework', 'thresholds approach', 'thresholds

theory', and frequently just 'thresholds'. In an informal setting, the use of 'thresholds' may be acceptable, such as in the 2014 NAIRTL conference twitter feed (#thresholds2014), where delegates regularly referred to the 'thresholds conference' in verbal communication. However, in academic writing, this imprecision is unhelpful and O'Donnell (2010, p.7) noted a worrying trend towards papers which dropped the word 'concept', referring to 'threshold theory', 'thresholds approach' and 'thresholds theory'. He criticised a lack of consistency in terminology, but ironically then introduced another term, 'Threshold Concept Hypothesis' that he referred to throughout his paper. A decade on from the inception of TCs, the term Threshold Concept Framework (TCF) was introduced (Land, 2013, p.1) to describe the overall approach and emerging theoretical framework within which TC research is situated. If other authors continue to adopt it, this clarity and consistency of nomenclature is welcome.

2.4.3 Methodological issues in the threshold concept literature

A wide variety of methods are employed in TC identification (Barradell & Peseta, 2014; Batzli et. al., 2016). Early published research in the field often exhibited limited methodological explanation. The seminal paper by Meyer and Land (2003) referred only to identifying TCs through informal discussions with academic colleagues who had been provided with the criteria of a TC. Whilst this approach may be a good starting point to identification of TCs (Eckerdal, et al., 2006), it does not consider other factors, such as the learner's experience.

Criticism has also been levelled at the TC literature for a lack of empirical evidence (Walker, 2013) and for claims which are not grounded in such evidence (Batzli et. al., 2016). Morgan (2015) presented a critique from within the field of information literacy in higher education. Far from rejecting TCs, he presented an argument concerned with the application of the framework by Hofer, et al. (2012) in a study outlining TCs for information literacy instruction. Based on short descriptions of potential stumbling blocks for students, provided by fifty-nine librarians via an on-line survey tool, the authors presented seven TCs. However, Morgan (2015) argued that their findings were oversimplified and based on clichéd assumptions of student attitudes with no requirement for supporting evidence from

the participants. It is worth noting that Hofer et al. (2012) were self-critical of their own research, highlighting several limitations including the self-selecting nature of the sample and the lack of opportunity to follow up ambiguous responses due to the static nature of the data collection methods. Morgan (2015) further argued that their analysis of these responses against Meyer and Land's (2003) original set of criteria was founded on the notion that TCs are entities to be discovered rather than contingent phenomena, resulting in a restrictive methodology. This critique is important to my thesis as it supports the argument previously posited as part of my conceptual framework that the TCF characteristics cannot be applied merely as a tick list of criteria to be searched for, but rather they need to form part of an interpretative and holistic approach to identification, which also takes contextual factors into account.

2.4.3 Agent-dependence

A defined curriculum within a subject, devised by teachers and professionals is made up of fundamental concepts that will be referred to here as 'core concepts', defined earlier in this chapter. These core concepts exist within specific curricula in relation to each other. In contrast, O'Donnell (2010) argued that demonstrating the existence of TCs is epistemologically difficult due to their reliance on the subjective effects on the learner. He referred to this as agent-dependence (p.7). From a positivist perspective, the argument is valid, where the aim is to identify and generalise concepts that exist as domain-dependent phenomenon; O'Donnell provided *gravity* as an example. Gravity has also been cited as a TC (Meyer & Land, 2003), and in this case, would be subject to the affective dimension experienced by the learner, would be context-specific and non-generalisable, but nonetheless valid from an interpretative perspective. What is transformative for one student may not be for another, as this will depend on their prior learning and the conceptual schema already in place (Rowbottom, 2007).

What is seen as a limitation when viewed from within one paradigm (normative) can help to shape the theoretical framework of TCs when viewed from another (interpretative). In light of this discussion, it is argued here as part of my own conceptual framework that it is useful to view the TCF characteristics as being

situated as 'agent-dependent' or 'domain-dependent'. Core concepts are defined and constrained within curricula by professionals and these are therefore domain-dependent. Some of these core concepts may also be considered TCs by professionals, but not necessarily by the learners themselves (Walker, 2013; Taylor, 2008), who will bring with them prior knowledge in the form of existing schema and misconceptions. Thus, as with the schema theory of learning, many aspects of the TCF can be thought of as agent-dependent, relying on the subjective effects on, and being internal to, the individual. Figure 4 offers my own visual representation of this notion, which resonates with the argument proposed by Park and Light (2010), that 'the two indispensable characteristics of a threshold concept – that it is integrative of the domain and that it is transformative for the student – suggest two distinct units or components of analysis: a conceptual component and an experiential component' (p. 260).

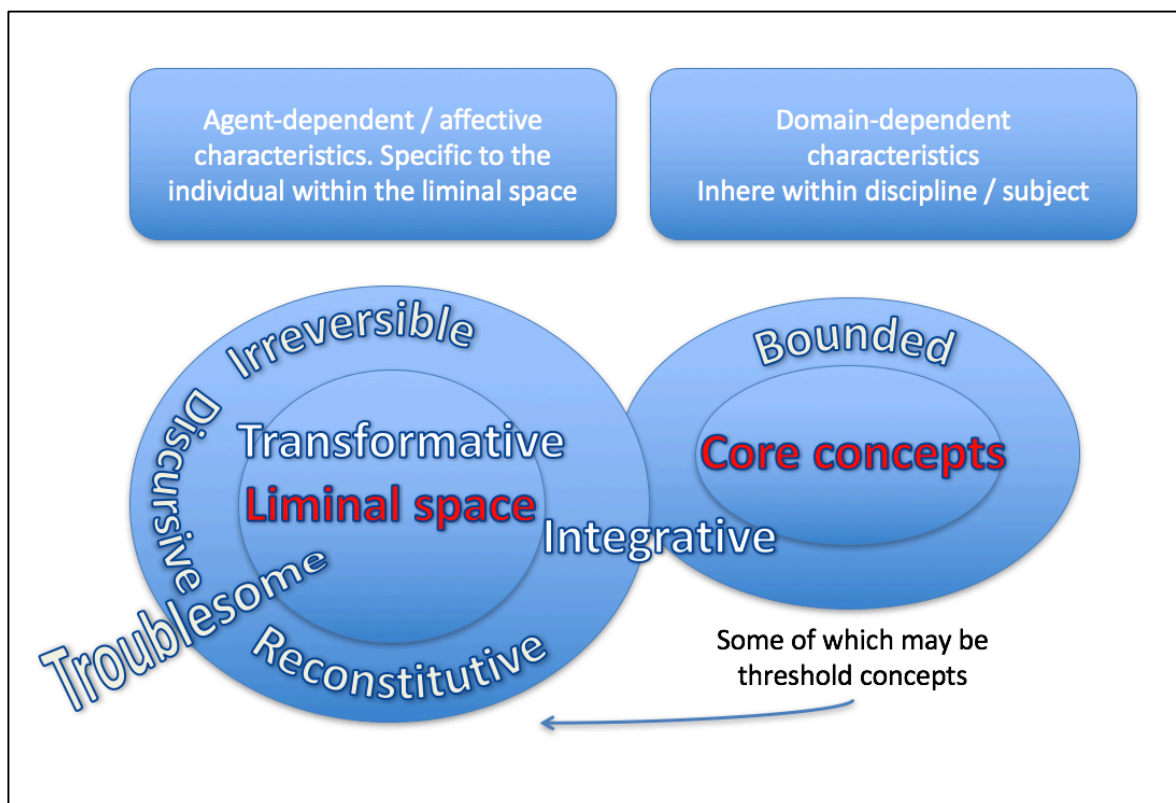


Figure 4 - Agent-dependent versus domain-dependent characteristics of a threshold concept

Some have suggested that the bounded nature of a TC is linked to transformation within a learner in such that the linkage is 'representative of behaviour that defines and demarcates one discipline or field from another' (Barradell & Peseta, 2014,

p.263). However, I argue here that core concepts are bounded by their relationship to other concepts and are not inherently dependent on the learner for their existence. Therefore, the bounded characteristic is identified here as purely domain-specific and stands alone as such.

Whilst the integrative characteristic may be considered to inhabit both spaces as shown on the diagram, with concepts being structurally integrated through relationships to other concepts within a discipline, this integration is also dependent on the existing (and potentially new) schema within the individual learner, and it is therefore included as agent-dependent. The troublesome characteristic is shown as straddling the diagram to represent the notion that a TC does not necessarily need to be troublesome to be a TC, but it is likely to appear as an instigative feature of TC acquisition at the preliminal phase. The intention of the above argument is not to disparage or bring into question the theoretical framework of the TCF characteristics, but rather to clarify the conceptual framework which underpins my research design and which also forms part of the analytical framework upon which the findings of this study, and an exploratory model of identification, are based.

2.4.5 Teacher / student perceptions

One further issue with empirical investigation into TCs relates to who identifies them. A number of studies have relied on the opinions of lecturers or professionals alone to identify TC candidates, without taking into account the views of students (see Meyer & Land, 2006 and Morgan, 2015 for examples). One of the limitations of this approach is that teachers and lecturers may be so far removed from their own experiences of studying that they may consider potential TCs as ‘tacit knowledge’ (Meyer and Land, 2003, p.7) which they have long ago internalised and have since become part of ‘the natural world they inhabit’ (Osmond, et al. 2008, p.253). If we accept that TCs are agent-dependent as previously posited, then the involvement of students in the discussion becomes fundamental to empirical investigations. Furthermore, I argue here that one of the strengths of TCs research is where there is co-inquiry involving subject experts, students and educational researchers, an approach which Cousin (2008) titled ‘transactional

curriculum inquiry'. Investigating from these very different viewpoints helps to address the limitations of a purely 'top-down' or 'bottom-up' approach (O'Donnell, 2010, p.10). The point at which investigations take place is also worthy of consideration. If students are asked about TCs early in the learning process, then they are unlikely to be able to identify whether a concept is, for example, transformative or irreversible. However, if they are asked at the end of a course they may find it difficult to remember their experiences, as the knowledge may have become embedded and tacit in a similar way to teachers and lecturers. The longitudinal approach adopted in this thesis therefore aims to address these limitations.

2.5 Threshold concept research relating to secondary schools and biology

The following section now considers two more tightly focused areas within the TC literature relating directly to the context of this study: a) research in the discipline of biology and b) research within the secondary school sector.

2.5.1 Threshold concepts in biology

Investigations into TCs within the discipline of biology have been conducted by authors in the UK (Kinchin, 2010, 2011; Jordan, Tracy & Johnstone, 2011; Chandler-Grevatt, 2015), North America (Johnson, Middendorf, Rehrey, Dalkilic & Cassidy, 2014; Batzli et al., 2014, 2016; Wolf & Akkaraju, 2014), Germany (Daems, Erkens, Malzahn & Hoppe, 2014) and Australia (Kennedy, 2014). Additionally, the Australian Learning and Teaching Council project, *Thresholds in biology* (ALTC, 2015), was tasked with conducting novel research into the definition of a TC in biology. This project was a collaboration between biologists at the universities of Sydney, New South Wales and Western Sydney focusing on improving teaching and learning in undergraduate biology courses. Publications by the team between 2006 and 2014 reported on the identification of TCs in the discipline (Taylor, 2006, 2008), the evaluation of intervention strategies to help address difficulties with the learning of TCs (Ross & Tronson, 2007), how students respond to tasks involving specific TCs (Taylor & Cope, 2007; Taylor & Meyer, 2010; Taylor, Tzioumis, Meyer, & Ross, 2014; Zimbardi et al., 2014) and have generated a matrix of TCs for biology (Ross et al., 2010a). The following section

aims to review the key themes in this influential body of work, interwoven with research from other authors.

The first of the ALTC papers (Taylor, 2006) involved exploratory interviews with seven biology academics across four universities in Australia and the UK. The study purported to have identified TCs in the discipline: scale, language, biological processes, variability, hypothesis creation and osmosis. Whilst not always troublesome, photosynthesis was also seen as a TC due to its potential to transform understanding in the discipline. Taylor's study also highlighted that biology in a university context is highly diversified, with sub-fields such as human biology, environmental biology, ecology, marine studies and biochemistry to name but a selection (Taylor, 2006, p.88). This level of specialisation is notably absent from secondary school biology, a fact worth noting for when comparisons are drawn later in this thesis. However, Taylor highlighted a common ancestry that is revealed at the basic level once field-specific concepts are unpacked. By way of example, she posited that nerve impulses in human biology (neurobiology), photosynthesis in plants (biophysics), and water uptake in crops (agricultural botany) all rely on an understanding of *osmosis*, the movement of water across a membrane (Taylor, 2006, p.88).

Further work explored students' perceptions of TCs (Taylor, 2008). In this study, postgraduate students were asked to consider examples of TCs identified by teachers (from Taylor, 2006), or provide their own using Meyer and Land's (2003) original definition of a TC. Many of the respondents identified the sheer mass of theory covered in the first year as being troublesome, alongside difficulties with disciplinary language. They also highlighted specific concepts as counter-intuitive, such as *osmosis*. However, students were less able to identify abstract concepts other than *scale*, for example, in relation to species and population. Broadly though, students involved in this study felt that those concepts identified as troublesome by academics had not particularly caused them difficulty, findings which support my argument for a focus on student experiences in this thesis.

A later study situated in the sub-discipline of plant sciences (Jordan, Tracy & Johnstone, 2011) identified several biological TCs through semi-structured

interviews with 13 teachers at the University of Cambridge, UK. The interviews were designed to explore TCs through questions raised by students in tutorial sessions, surfacing those most commonly causing difficulty before these were mapped against the original TC definitions (Meyer and Land, 2003). The study identified *photoprotection*, *water potential*, *electrical potential*, *circadian rhythm* and *species area curves* as TCs. Whilst the focus in this study was on troublesomeness, the authors noted the importance of context in identifying TCs. For example, whilst *water potential* was grasped relatively easily as an isolated concept by students, the 'threshold [sic] identified was to realise its full implications at the whole plant level' (Jordan et al., 2011, p.4).

2.5.2 Scale as a threshold concept

Two members of the ALTC team (Ross & Tronson, 2007) set out to evaluate the effectiveness of utilising creative activities, such as dissecting 3-dimensional playdoh cells to visualise the 2-dimensional view of cells as seen under a microscope, to teach the concepts of photosynthesis, glycolysis and the Krebs cycle. These were suggested as TCs although no explicit rationale was offered for their choice other than identification by academics. Students' responses indicated that the intervention activities helped them to connect the abstract biological concepts with the everyday world, or in other words, to relate the 'sub-microscopic' to the 'macroscopic' (Ross and Tronson, 2007, p.92).

Scale has been posited as a TC not only in terms of physical size, but also time. A study conducted by Taylor and Cope (2007) investigated students' initial encounters with the concept of *evolution*. First year students on an undergraduate biology course in Australia (n=50) were asked to complete a questionnaire on *adaptation*. Phenomenographic analysis of the responses identified four dimensions of variation: time, scale, the process of change, and the genetic underpinning of natural selection. Two separate studies carried out in the United States also highlighted *scale* as a TC in relation to 'evolution through natural selection' (Wolf and Akkaraju, 2014) and 'geological time' (Johnson et al., 2014). Both studies focused on the implementation of strategies or interventions for improving teaching and learning of difficult concepts. Online quizzes, reflective

writing and examination questions were utilised by Wolf and Akkaraju (2014) to assess the effectiveness of a student-centred approach to the delivery of evolution, concluding that the use of SMART objectives demonstrated observable benefits to learners. However, the validity of evolution as a TC was not clearly established, relying on previous work by Taylor (2006). Whilst the study by Johnson et al. (2014) focused on geological time rather than biology, it is included here as the authors asserted that associating geological time with biological time was an issue for students in the context of evolutionary trees: Whilst students could relate to hundreds and thousands of years, the researchers found that time became incomprehensible once into the millions and billions. They further extrapolated their argument to suggest that scaling issues may present as problematic in a range of other academic disciplines such as medicine (epidemiology) and sociology and philosophy (social-ecological systems).

A third study in the United States (Batzli et al., 2014) focused on using TCs as a heuristic to improve teaching and learning of biological concepts in genetics. The authors drew from previous work that had identified TCs within genetics and evolution (Taylor, 2006, Ross et al., 2010) to propose *variation over evolutionary time* as the focus TC. The validity of this as a TC was not addressed and the research instead concentrated on the development of student mental frameworks using free word association. Responses of 209 undergraduate students enrolled on introductory ecology, genetics and evolution courses were analysed two weeks prior to and two weeks following formal tuition designed to provide an integrated introduction to genetics and evolution. Findings indicated that the integrated approach was successful in generating improved word association post-tuition. Due to the importance of the integrative nature of TCs within a subject, further consideration is now given to this aspect within biology.

2.5.3 A biological web of concepts

As noted earlier in this chapter, it has been argued that it is helpful to view TCs within a discipline as a web of interrelated concepts (Davies & Mangan, 2007). Early observations by Taylor (2006, 2008) emphasised the complexity of biology as a discipline, proposing that many of the more difficult concepts to teach in

biology stand alone as 'isolated islands of knowledge'. These concepts remain as such until students are encouraged to make links to a more complex 'web of composite knowledge and understanding' (Taylor, 2006, p.89). Another study in the UK (Kinchin, 2011) found concept mapping to be an effective tool for students to consider knowledge structures in biology. Empowering students to process and synthesise curriculum content through concept mapping enabled them to visualise the interrelated nature of concepts within the discipline.

Applying the theoretical definitions of Davies and Mangan (2007) discussed earlier in this chapter to previous work in biology (Taylor, 2006, 2008; Ross & Tronson, 2007; Taylor & Cope, 2007), researchers from the ALTC project team (Ross et al., 2010b) identified a range of concepts that fit within the definition of *basic*, *discipline* and *procedural* concepts. They further added the category of *pre-basic* concepts to distinguish the type of conceptual change that occurs through life experience prior to formal tuition, whereas *basic* then begins to integrate ideas from the discipline. The ALTC model titled the Biology Thresholds Matrix (Ross et al. 2010b, p.169) posits that TCs within biology occur where there is 'integration of discipline concepts and the emergence of a commonality or web of conceptual change' extrapolated from the procedural concepts. An extract of the matrix is shown in Figure 5, running throughout which is the notion of language acquisition as a critical feature of development in the subject. Students often confuse biological language with everyday meanings (Ross et al., 2010b), for example confusing cell respiration with breathing, a phenomenon associated with TCs (Meyer and Land, 2003; 2005). Language may also present as a barrier due to the volume of new and unfamiliar words, particularly those derived from Latin.

The model proposed in the Biology Thresholds Matrix (Figure 5) contends that whilst there are specific TCs relating to areas of content knowledge, these also feed into a more generalised web of concepts that encompass the entire discipline of biology and occur throughout each area of knowledge. This proposed web of concepts may be considered transferable: particular concepts such as *scale* (Johnson et al., 2014) and *hypothesis creation*, are found in other sciences such as chemistry and physics (Ross et al., 2010b) or even in other fields such as medicine and sociology (Johnson et al., 2014). They may not therefore be

considered as *bounded* within the discipline as defined by Meyer and Land (2003). Thus, it was argued by Ross (et. al., 2010, p.173) that the process for identification of a TC in biology centres around it being considered transformative, irreversible and integrative coupled with consideration of the journey from novice to expert in the context of ways of thinking and practising. This view echoes my own conceptual framework in respect of the approach to identification of a TC focusing on the transformative and integrative characteristics. The notion that transferable concepts may not be considered bounded may be at odds with my proposal that bounded is a domain-dependent characteristic as discussed earlier in this chapter. However, my analytical framework relies on an approach to identification centred predominantly around the agent-dependent characteristics of a TC which is not fundamentally undermined by this argument.

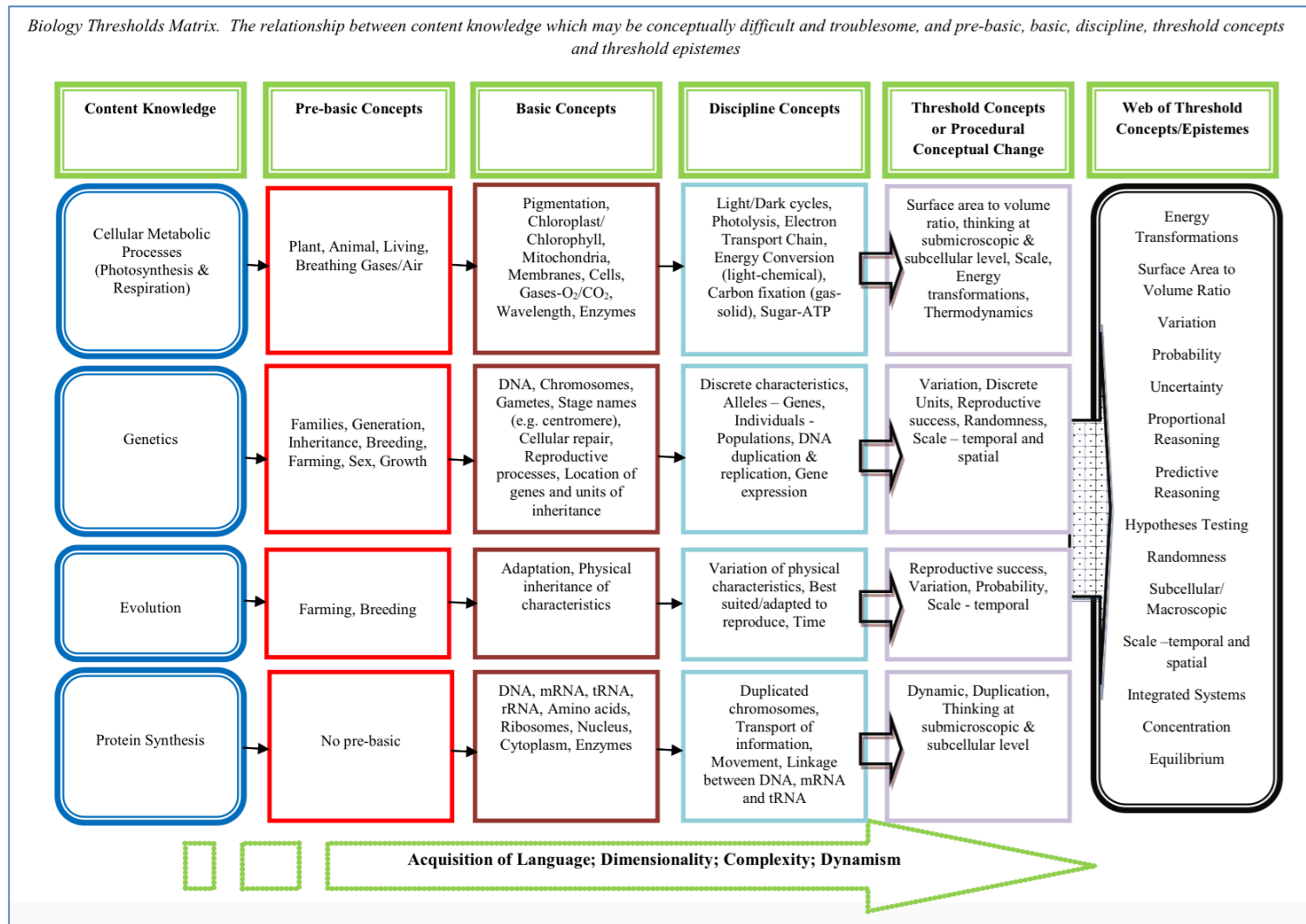


Figure 5 - Biology Thresholds Matrix (Ross et al., 2010b, p.171-172) page one of two.

2.5.4 Threshold concepts in secondary education

The biology specific research in the previous section was situated in higher education, featuring brief references to students' encounters with TCs in primary and secondary education prior to embarking on undergraduate study (Taylor & Meyer, 2010; Taylor et al., 2014). Although research into TCs in the secondary education sector is limited, some studies have been conducted with secondary age students. These studies focused on agriculture in Brunei (Haji Bungsu, 2014); geography in the UK (Slinger, 2011; Renshaw & Wood, 2011), economics in the UK (Ashwin, 2008) and Hong Kong (Pang & Meyer, 2010); chemistry in Ireland (Sheehan, 2010) and the UK (Chandler-Grevatt, 2015); and biology in the USA (Wolf & Akkaraju, 2014). Despite covering a range of subjects in different cultural contexts there are similarities in approach when seeking to address problems with learning 'difficult' topics at school and to consider alternative curriculum or teaching approaches to help.

The exception to this is the study by Pang and Meyer (2010), which aimed to develop the evidence base in higher education (HE) by exploring pupils' initial apprehension of a TC prior to any formal tuition in the subject. Located in a school in Hong Kong, this study involved 40 'Secondary 3' students aged 13-14 (equivalent to year 9 pre-GCSE in the UK) focusing on 'opportunity cost', considered to be a TC in HE (Shanahan & Meyer, 2006; Reimann & Jackson, 2006; Davies & Mangan, 2007). Through semi-structured interviews conducted in Cantonese and later translated into English, participants were asked to respond to questions relating to scenarios in which the concept of 'opportunity cost' was embedded. Pang and Meyer (2010) referred to these scenarios as 'proxies', proposing that this method allowed understanding of the TC to be brought into view despite the lack of formal tuition. Phenomenographical analysis was used to investigate the dimensionality of 'subliminal' variation (existing tacit knowledge, prior to formal tuition) and 'preliminal' variation (how a TC comes into view), terms established by Meyer, Land and Davies (2008) as discussed earlier in section 2.2.

The study found that whilst many pupils demonstrated little or no economic understanding of 'opportunity cost', a small number were judged to have reached

the 'pre-liminal' stage, despite their lack of specific tuition. In doing so, Pang and Meyer (2010) argued that those pupils seemed to oscillate between adopting a layperson's view and 'thinking like an economist' in their answers, being able to articulate a joined-up view of the various elements whilst lacking in the specific technical language. These findings are relevant to this thesis particularly in that Pang and Meyer highlighted the need to identify misconceptions to understand 'how pupils initially perceive, apprehend, conceptualise or experience the threshold concept' (2010, p.380). This in turn, they argued, allowed teachers to understand where and why learners may find themselves in 'stuck places' and help them to progress through the preliminal and subliminal modes to subsequent acquisition of a TC.

Ashwin (2008) also focused on discovering how students encountered cost-related TCs in Economics prior to undergraduate study. Working with GCSE pupils aged 14-16 in the UK, he employed examination-style questions to assess their understanding against a structured classification called the SOLO (Structure of Observed Learning Outcomes) taxonomy. The study was designed to assess pupils' level of understanding of cost-related concepts identified through other studies at undergraduate level in economics. Although it is unclear from the paper how many pupils were involved in the research, Ashwin (2008) argued that the consideration of TCs is as relevant to secondary education as it is to HE, particularly in identifying examples where learners have 'passed through the portal' with a view to influencing curriculum design.

The taxonomy-based approach to externalising TCs from student responses has also been used in the United States high school system by Wolf and Akkaraju (2014). In this study, 57 freshmen (UK Year 9, age 14-15) and 26 sophomores (UK Year 10, age 15-16) enrolled on an introductory biology course were taught a specific TC and assessed against taxonomic levels, namely knowledge, comprehension and application. The TC selected for Wolf and Akkaraju's (2014) research was 'evolution through natural selection'. This was derived from previous work in biology conducted by Taylor (2006), who identified this as a TC through her own research in HE. Students in Wolf and Akkaraju's (2014) study were taught using a variety of methods and assessed using an online quiz, reflective writing

and a written examination. Whilst the focus of the study was to assess the impact of a pupil-centred approach to teaching, the authors also concluded that their observations supported the view that evolution through natural selection is a TC in biology.

An exploratory case study in the UK (Renshaw & Wood, 2011) employed the TCF to develop an approach to learning in geography based on holistic understanding underpinned by central concepts which are considered essential but may be difficult to understand. The project ran over four years in an 11-16 school in the Midlands, involving 13 mixed-ability groups of Year 9 (age 13-14) pupils. Teachers used mapping with students to explore a range of planetary level physical systems such as *atmosphere*, *oceans*, *glaciers* and *volcanoes*. Pupil perceptions of this approach, and their own learning, were then evaluated by the researchers through focus group interviews, along with interviews with the class teacher. Findings led the authors to suggest 'interdependence' as a TC that played a significant role in transforming pupil understanding. Using concept maps, pupils were able to see the integrative nature of global physical processes and the underlying interdependence involved. Renshaw and Wood argued that this also helped students to work through some of the troublesome knowledge identified by the research team (2011, p.374).

Another piece of research relating to the secondary school sector is the PhD thesis of Maria Sheehan (2010), who employed questionnaires and written tests with Junior and Senior 'Irish Second Level' chemistry students (equating to GCSE and A level study in the UK). Despite only limited reference to TC literature, this study is included as it aimed to identify areas and topics causing difficulty for secondary level science students with the aim of developing supportive teaching strategies. The study refers to the science misconceptions literature, highlighting the intrinsic difficulties presented to students in chemistry through operating at both the macro and micro level, an observation which resonates with those discussed earlier in this chapter in relation to biology (Ross & Tronson, 2007). Sheehan's (2010) study also serves to highlight the need for caution where the term 'threshold concept' is used without sufficient thoroughness: She claimed that 'the Particulate Nature of Matter and the Mole in Chemistry' [capitalisation in

original] are seen as TCs, but does not state by whom and on what basis, other than that 'failure to grasp either concept prevents true and correct understanding of other topics' (Sheehan, 2010, p.101).

Haji Bungsu (2014) investigated the learning of agriculture education in a secondary school in Brunei Darussalam, although this choice of setting was a compromise, as there were no students taking agriculture at university level (p. 115). The study involved questionnaires with students (n=19) and teachers (n=14), although most of the data was gathered from interviews with students (n=7), each of whom were interviewed twice. Haji Bungsu described their research as a phenomenological case study, aiming to find TCs in agriculture education as well as identifying progression in the understanding of these TCs. The findings listed five potential TCs: *planting and planting techniques*, *plant science*, *agribusiness*, *agriculture research method*, and *farm management*. In identifying these Haji Bungsu referred to the original five TC characteristics (Meyer, 2003) in the literature review, applying only transformative, troublesome and integrative in the analysis and identification of these five TCs, meaning that the other characteristics were not considered. Despite referring to the study as a 'synchronised' use of case study and IPA, some of the research questions adopted a distinctly different epistemological position to those in my own thesis, phrased as 'What are...?' and 'Is there...?' (Haji Bungsu, 2014, p. 4), taking a phenomenological stance to identify common experience. Conversely, the questions in my study focus on personal meaning and sense making and are phrased in an IPA style to surface the affective dimension of participants' experiences, for example 'How do students make sense of the transition from GCSE to A level study?' Whilst my study bears some similarities to Haji Bungsu's research design, there are significant differences in the application of IPA within the two approaches, with my own taking a more integrated approach to designing a hybrid blend of case study and IPA throughout all aspects of the methodology.

The final study included in this section was conducted in a sixth form college in England (Chandler-Grevatt, 2015) and involved students (n=70) in their first year of A level study following AS courses in sciences, although the report only

discusses findings in chemistry. Whilst the setting is similar to that of this thesis, the stimulus for Chandler-Grevatt's research originated in HE where, he argued, university lecturers are commonly concerned that undergraduates have limited recall and understanding of 'key concepts' from A level chemistry. His research therefore intended to engage students with more difficult concepts at A level with the aim of alleviating this perceived problem in HE, based on 'the notion that threshold concepts can be mastered' (Chandler-Grevatt, 2015, p.2). Teachers of A level sciences were tasked with identifying potential TCs from course specifications in their subjects, using their experience and examination reports to identify those concepts which 'most students find troublesome' (p.3). There is little further detail explaining to what extent the teachers were briefed on TCs, and the selection appears to have been based only on those concepts students have found difficult in the past. Following the identification process, the teachers and researcher developed what they called Threshold Concept Mastery tasks (TCM) which students were asked to carry out towards the end of a unit containing an identified TC and were then marked by the teacher and feedback provided to students. Following each TCM task, students were interviewed in a series of 18 group interviews and teachers were also interviewed. The findings presented focused on the usefulness of the TCM tasks in engaging students with more challenging topics. Little evidence is offered with respect to the TCs identified or why students found them difficult and there is no explicit reference to any of the TC characteristics other than troublesomeness. The addition of TC terminology in this particular study appears to add little to the aims of the research which were essentially to identify difficult concepts and design tasks to engage students with them.

This section has presented studies from within the academic discipline of biology, and also at the level of secondary education, that make reference to TCs. It is clear from consideration of these latter studies that there is still much work to be done in migrating TC research into secondary education for the specific purpose of improving teaching and learning in that sector. Furthermore, two examples presented (Sheehan, 2010 and Chandler-Grevatt, 2015) raise concerns over the superficial use of the term threshold concepts.

Finally in this section, I include research by Hernandez-Martinez et al. (2011) who studied the transition from GCSE to A level in mathematics. Whilst not involving TCs, it is worthy of inclusion as the findings offer insights into the affective impact of students' experiences of transition. Interviews were conducted with students in four secondary schools (n=25) and five colleges (n=47) in the UK. The results presented describe troubled and problematic experiences, balanced by stories of positive changes in identity as students overcame these barriers, even if this meant realigning their future aspirations. The authors argued that transition should be viewed more positively despite the difficulties experienced and transition should be seen as growth of identity (p.119). What this work brings to my own study is a comparison set of findings from within the secondary sector which support my argument that the transition from GCSE to A level can present as troublesome for students. However, I argue that encounters with TCs provide additional layers of difficulty which can be more effectively explored through applying the TCF as a theoretical framework.

2.6 Point of departure, aims and research questions

Following this review of literature, the originality and contribution of this study can be evidenced in several ways. The first of these is the specific application of TCs to learning within a secondary school setting. As this review of literature has demonstrated, the few studies of TCs that have been conducted in the secondary sector have mostly focused on informing HE, or have been undertaken without sufficient rigour or methodological explanation. There is also a gap in the research regarding difficulties experienced by students transitioning from GCSE to A levels.

This study aims to engage the theoretical framework of TCs in focusing specifically on secondary school students' experiences of learning in a secondary setting in biology as they move from Key Stage 4 to 5. In the academic literature, the need for further research into students' experiences of encounters with TCs has also been suggested, particularly regarding detailed consideration of the 'affective dimension' of TCs (Felten, 2016; Rattray, 2016) and my thesis makes a contribution to this area by exploring the learning experiences of students as they transition from GCSEs to A levels, illuminating that stage in students' educational

journeys through detailed consideration of the affective dimension of participants' lived experiences. An argument is advanced that encounters with TCs at A level are significant for students, thereby exacerbating an already challenging transition point.

The conceptual framework outlined throughout this chapter explicates how this research is positioned within the theoretical framework of TCs, which in summary comprises:

- a) A definition of a concept drawn from cognitive psychology and a definition of both a TC and the individual characteristics, which are presented as being agent-dependent or domain-dependent.
- b) The underlying framework for a longitudinal inquiry model of TC identification, based on the prototype theory of concept learning from cognitive psychology, coupled with the notion of TC characteristics forming an interrelated web rather than a hierarchical list.
- c) Positioning this approach within the context of constructivist learning theories and the literature on children's learning in science, including the importance of misconceptions, prior knowledge and schema. Also the role that conceptual change approaches may play in creating cognitive conflict at the instigative stage of TC learning.
- d) The affective dimension of TCs and the importance of student experiences, which are inherently and purposefully linked with the chosen hybrid approach of IPA and case study. Consideration of the agent-dependent nature of certain TC characteristics and how these relate to the affective dimension.

This study sets out to achieve the aims outlined above within the theoretical and conceptual frameworks presented, through the application of an original hybrid methodological approach drawing from the case study tradition and Interpretative Phenomenological Analysis (IPA). This approach enables the cognitive and affective nature of students' encounters with TCs to be surfaced through their lived experiences, whilst also illuminating potential TCs in the A level Biology programme of study. The research design, explained in the following chapter, aims to answer the following questions:

Research Questions

- How do students make sense of the transition from GCSE to A level study?
- How do students experience TCs in A level Biology?
- How is the affective dimension of TCs represented in students' experiences?
- How do the theory and definitions of TCs fit in this local context, and can TCs be identified in secondary biology?

Chapter 3 - Research Design

This chapter begins by presenting an overview of the methodological landscape within which TC research resides. From this overview, a range of methods and approaches are discussed to explain the evolution of the hybrid research design developed for this thesis. Two pilot studies are analysed, the research design is communicated in detail and the analytical framework is also explained. Finally, ethical considerations, sampling and issues of reflexivity are discussed.

3.1 Methodology in threshold concept research

As noted in the critique in Chapter 2, early published research in the field exhibited a lack of detailed methodological explanation. However, Meyer and Land's initial explorations, coupled with those who took a similar approach (Cousin, 2006b; Davies & Mangan, 2005) paved the way for others to experiment with a much wider range of methods and subsequent literature has largely provided greater explanation, highlighting an eclectic mix of methods.

Interviews have been used to elicit responses from teachers and students (Savin-Baden, 2006; Cousin, 2006b; Taylor, 2006, 2008; Baillie & Johnson, 2008; Cove et al., 2008; Zander, et al., 2008; Cheek, 2010; Kabo & Baillie, 2010; Orsini-Jones, 2010; Osmond & Turner, 2010; Weil & McGuigan, 2010; Haji Bungsu, 2014), as well as from research supervisors, alongside written responses (Kiley & Wisker, 2009). Surveys have been used in isolation (Zander, et al., 2008; Hofer et al., 2012), and together with a range of other methods, such as analysis of student posters (Batzli et al., 2014) and the construction of concept maps with both lecturers and learners (Park & Light, 2010). Both qualitative and quantitative analysis of examination questions have been employed to externalise the troublesome aspects of curricula (Flanagan & Smith, 2008; Shanahan, et al., 2008; Ashwin, 2008), and examination questions have also been utilised to assess the effectiveness of intervention strategies aimed at supporting the learning of difficult TCs (Johnson, et al., 2014).

Whilst some studies have identified potential TCs from examples of students' work (Ashwin, 2008; Carstensen & Bernhard, 2008; Shanahan et al., 2008; Cowart, 2010; Davies & Mangan, 2010; Pang & Meyer, 2010; Park & Light, 2010;), a number of studies have analysed student responses to specific tasks designed by the researchers (Shanahan & Meyer, 2006; Reimann & Jackson, 2006; Lucas & Mladenovic, 2006; Orsini-Jones, 2008; Pang & Meyer, 2010, Taylor & Meyer, 2010), in some cases combining these with interviews (Osmond & Turner, 2010) or quizzes and reflective writing (Wolf & Akkaraju, 2014). Mixed-methods analysis of student responses to questions and scenarios have also been employed (Taylor, Tzioumis, Meyer & Ross, 2014) and the use of information technology has been applied to TC research, for example through face-to-face workshops involving the creation and sharing of videos (Daems, et al., 2014) as well as online teacher discussions (Higgs & Cronin, 2013), blogs (Akkaraju & Wolf, 2016), and online surveys (Hofer et al., 2012). More complex approaches have also emerged, such as the combination of student questionnaires, in-depth interviews, course evaluations, and focus groups together with in-depth lecturer interviews and analysis of course artefacts (Baillie & Johnson, 2008) alongside the use of existing methodological approaches from other fields, such as Nominal Group Technique (Barradell & Peseta, 2014).

Despite the range of research methods exemplified above, and the relative clarity in communication of these methods, the literature on TCs is still quite remarkable for a lack of detailed methodological explanation. Although this may be due to the necessity for brevity in research papers in general, it is not helpful when attempting to draw together the methodological traditions and analytical structure that underpin their application. I therefore decided to look outside of TC literature when developing a suitable methodological approach that was fit for purpose. The following section provides an overview of the reasoning and decision making that took place when constructing the hybrid approach presented in this thesis.

3.2 Developing a suitable methodological approach

As this study aimed to explore students' experiences of the transition between specific phases in secondary education, an approach was needed which would

reconcile a focus on the (broadly predefined) theory of TCs with a more open consideration of individual lived experiences, requiring a suitably flexible analytical framework. A number of methodological traditions and methods were considered and some of these methods were trialled through a series of pilot studies. The journey to reach the final research design was not a linear one. Indeed, a number of existing traditions initially presented themselves as potential candidates, selected both from the TC literature and from the wide array of qualitative approaches in the methodological literature (Creswell, 2013, p7). Initial considerations included phenomenology, case study, grounded theory and, phenomenography. This section is structured to illuminate the analytical and developmental journey undertaken to arrive at the final choice of methodology and research tools. Interwoven with this thought process are the pilot studies which were employed to provide some practical testing. Figure 6 shows the chronological timeline of the pilot studies leading up to the full data collection for this thesis.

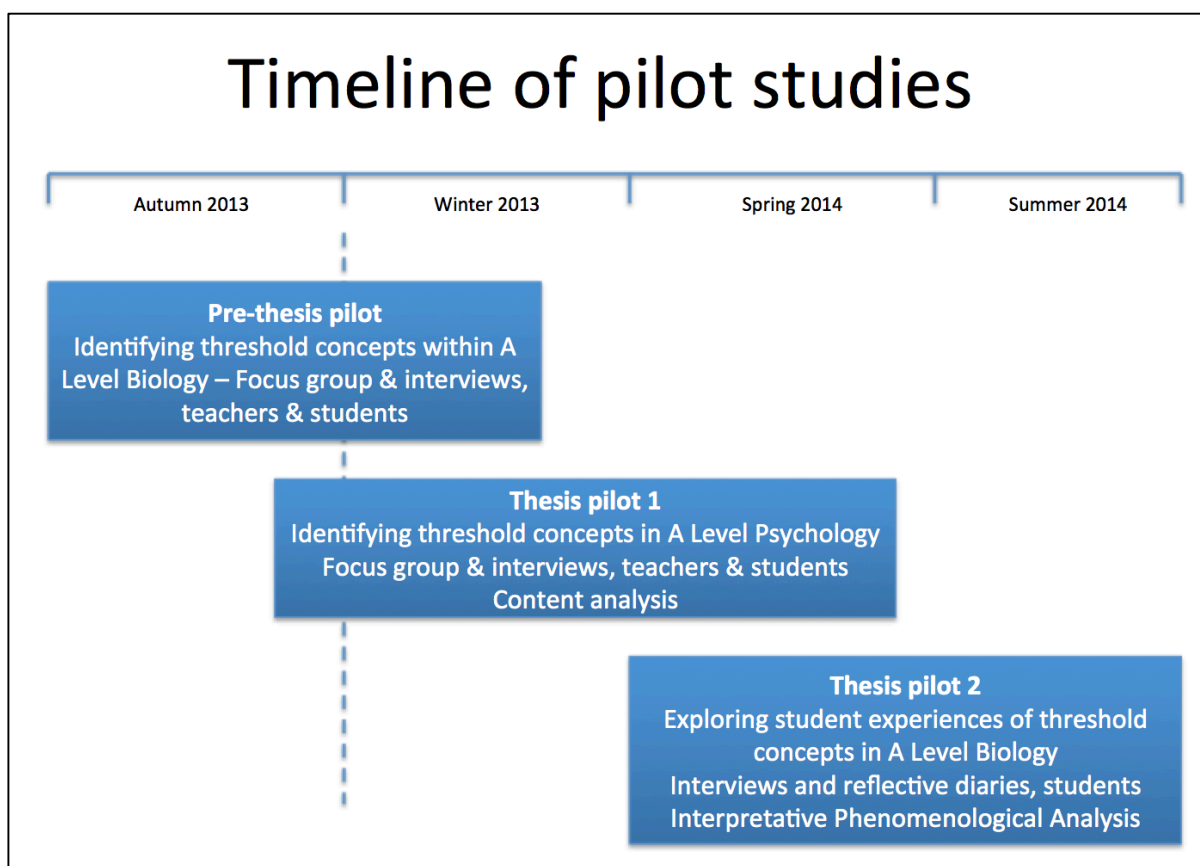


Figure 6 - Timeline of Pilot Studies

3.2.1 Pre-thesis pilot

Prior to beginning the thesis stage, a small-scale pilot was undertaken, with the purpose of assessing the potential of identifying TCs in A level Biology. Eight students at the end of their two-year biology A level course were consulted on their thoughts on potential TCs. The students were presented with a briefing paper on TCs, including a full definition of the TC characteristics and were then asked to think back over the previous two years and consider which areas of study they had found difficult and which concepts may be considered TCs. They identified four concepts: *cell specialisation*; *the heart and lungs*; *natural selection*; and *biochemistry* as fitting with the notions of being troublesome.

One issue was that the students did not fully grasp the other features of a TC and were unable to see past the difficult nature of the course. They also found it extremely hard to remember back to when these topics were studied to recall how they felt at the time. Alongside this, the three teachers of A level Biology were also presented with the briefing paper and definition and asked to identify TCs in the A level Biology course over the course of a two-hour semi-structured focus group discussion. The teachers identified *active transport* and *evolution through natural selection* as being potential TCs. Two main limitations of this pilot became evident: a) the teachers and students did not necessarily agree on which concepts may be considered TCs and b) the method chosen did not capture the lived experience of the students, partly due to the design of the methods, but also due to the point in time at which the research was conducted: the students were too far removed from the learning experience.

3.2.2 Thesis pilot one

To address the limitations of the initial pilot, an alternative approach was sought. One notable trend in the TC literature focuses on examining variation between student experience of TCs, in particular through the application of phenomenographic principles (Davies and Mangan, 2007; Meyer, Land & Davies, 2008; Åkerlind et al., 2010; Pang & Meyer, 2010; Baillie et al., 2012). First proposed in published form by Ference Marton (1981), phenomenography emerged from educational research conducted in Sweden in the 1970s (Marton,

1994) concerned with the experience of learning (e.g. Marton & Saljo, 1976). This research found that ‘...phenomena, aspects of reality are experienced (or conceptualised) in a relatively limited number of qualitatively different ways’ (Marton, 1981, p.181). Phenomenography carries with it epistemological assumptions about how knowledge can be gained from the experiences of others. From a constructivist viewpoint that we construct meanings of phenomena from a variety of influences, phenomenography considers the way in which different people understand the same phenomena and takes a fundamentally different angle of approach from other qualitative traditions (Cousin, 2009). For example, phenomenology adopts what Marton called a ‘first-order’ perspective (Marton, 1981, p.1). Such an approach aims to identify and describe particular aspects or features of the world as it is. In contrast, phenomenography is concerned with describing peoples’ experience of those aspects: a ‘second-order perspective’ or the world as it is understood. Whilst different, the two approaches can be seen as complementary, examining the same phenomena, but from a different viewpoint.

The first full pilot combined a focus group with twelve students, followed by individual interviews with questions structured around the TC definition based on phenomenographic principles. Rather than being provided with a briefing sheet, the idea was to remove any difficulty with interpretation and ask participants direct questions relating to their learning experiences, as well as gaining a broader narrative of students’ experiences. To provide a fresh group of participants, this pilot was conducted with an A level Psychology group, comprising of seven students, some of whom were at the end of the Year 12 course, whilst others were in Year 12, halfway through the course. The focus group was intended to be an interactive process and students were asked to work together to group the key concepts studied in order of difficulty (see figure 7).

Analysis of the interview transcripts for this pilot was conducted using phenomenographic principles and methods. Although students could identify the difficult concepts as a group in the focus group session, at interview they identified quite different concepts individually. A strong theme which came through from all participants at interview was that there were few individual concepts that were particularly troublesome (*validity, reliability and usefulness*), but rather it is the application of the concepts to examination questions that was troublesome to them. This was made particularly acute alongside the requirement to learn 50 case studies by the end of the two-year course, which must then be used to provide context and exemplification in the application of the key concepts. This appears to be a feature of the psychology A level course and limits the comparison to the other pilots.

Despite evidence of phenomenography being employed in the TC literature, there are limitations to this approach. As phenomenography is largely concerned with conceptual understandings, there may be a tendency to neglect the emotional dimension of learning (Cousin, 2009), through the interview and analysis process, although this can be overcome through careful wording of the research questions with a view to draw out the affective side of students' experiences. Additionally, the prescriptive nature of data analysis, resulting in the reduction to an 'outcome space' (Marton, 1981) did not reconcile with the aims of the project. What was needed was an approach that focused on the lived experiences of students, whilst allowing the TCs to emerge through their narrative. At this point, comparison of the approaches considered so far (see Table 4) generated an overview of their characteristics.

Characteristics	Phenomenography	Case Study	Phenomenology	Grounded theory	Phenomenographic case study	Interpretative Phenomenological Analysis (IPA)
Focus	Identifying the different ways in which people experience, interpret, understand, perceive or conceptualise a phenomenon (Marton, 1981)	Developing an in-depth description and analysis of a case or multiple cases, within a real-life context or setting (Yin, 2009)	Understanding the essence of experience. Describes the essence of a lived phenomenon (Cresswell, 2013)	Developing a theory grounded in data from the field.	Identifying and describing the different ways in which people within a defined case boundary experience and conceptualise a phenomenon	A qualitative research approach committed to the examination of how people make sense of their major life experiences. When everyday life takes on particular significance for people (threshold concepts affective)
Background	Drawing from education, child psychology, constructivism, subjectivism.	Drawing from psychology, law, political science and medicine; constructivism	Drawing from philosophy, psychology and education	Drawing from sociology. Glaser and Strauss (1967)	Drawing from both phenomenography and case study traditions: constructivism, subjectivism.	Phenomenological – concerned with exploring experience in its own terms
Position	Non-dualist ontological position where reality is seen as internal and unique to the participants (Costello, 2008). Object and subject are not independent of each other (Ornek, 2008). Subjectivist.	Qualitative, interpretivism, investigating social phenomenon (Swanborn, 2010). Does not seek to generalise. Can be regarded as a methodology (Cresswell, 2013), or a choice of what is to be studied (Stake, 1995)	Interpretivism (social constructivism). First order	Constructivist, adopting an inductive, comparative, emergent and open-ended approach. (Charmaz, 2014)	Qualitative, interpretive, constructivist, with a non-dualist ontological position. Will not seek to generalise, realising that findings are not absolute truth, but are unique to the participants and context of the study.	Interpretative – hermeneutic – researcher trying to make sense of the participant trying to make sense of what is happening. Therefore second-order as the researcher only has access through the participants' account.
Unit of analysis	Responses combined into one unit of analysis, typical to treat all transcripts as a single text (Cousin, 2009), or separated out into 'pool of meaning' (Marton, 1994)	Studying an event, a program, an activity, or more than one individual.	Studying several individuals who have shared the same experience (Cresswell, 2013)	Studying a process, an action, or an interaction involving mainly individuals.	Responses transcribed and combined into one unit of analysis, then separated out into 'pool of meaning' in order to study the selected case.	Semi-structured interviews, individual responses analysed – what the experience for this person is like, what sense <i>this</i> individual is making of what is happening to them.
Data collection	Predominantly semi-structured, deep interviews (Booth, 1997); focus groups (Cousin, 2009)	Using multiple sources, such as interviews, observations, documents and artefacts (Yin, 2009)	Using primarily interviews with individuals, although documents, observations and art may be considered (Cresswell, 2013)	Primarily interviews with 20-60 individuals.	Multiple sources - focus group; deep semi-structured interviews; student diaries.	Semi-structured interviews, diaries Homogeneous sample, selected to provide convergence and divergence
Data analysis	Categories of description developed from transcription analysis, resulting in an outcome space containing a limited number of qualitatively different and logically interrelated ways in which the phenomenon or the situation is experienced or understood.	Analysing data through description of the case and themes of the case as well as cross-case analysis	Analysing data for significant statements, 'meaning units', textual and structural description and description of the 'essence'. (Cresswell, 2013)	Analysing data through open coding, axial coding and selective coding	Detailed description of the case combined with phenomenographic analysis resulting in an outcome space.	Detailed, case-by-case analysis, then cross-case analysis presented as a narrative account by the researcher. (Use Constant comparative analysis)

Table 4 - Comparison of the characteristics of approaches. Adapted from Cresswell (2013, p104)

The red areas in the table illustrate where particular traditions and methods were not judged preferable for answering the research questions. The main issue here was the constrictive effect of reduction to an 'outcome space' (phenomenography) or 'essence' (phenomenology). It was decided that the initial solution to this was to combine phenomenography with the case study approach (see column six), but this was considered too reductionist due to the perceived analytical constraints. The search for a suitable approach was widened to include fields other than education, which led to the field of healthcare psychology from which others have drawn inspiration for TC research (see Barradell & Peseta, 2014; Flanagan, 2017), and specifically, Interpretative Phenomenological Analysis (IPA) (Hill, 2012; Haji Bungsu, 2014). The yellow columns in Table 4 show a comparison of both Case Study and IPA, which I combined to develop the hybrid research design in this thesis, trialled in the second thesis pilot. A discussion of both traditions is now provided, which leads into the development of the final approach and research design adopted here.

3.2.3 Case Study

Case study research is a popular and flexible research approach with a strong tradition in the social sciences, where it can be considered as one of the principal means of inquiry (Thomas, 2010a, p.511). There are noticeable differences in how case study research is perceived between some of the classic texts such as Glaser and Strauss (1967), Miles and Huberman (1984), Merriam, (1988), Stake (1995, 2005), Denzin and Lincoln (2005) and Yin (2009). Furthermore, conflicting views have been presented in the literature as to the standing of case study as a research methodology. Whilst some authors have presented the case study as a methodology (Creswell, 2013; Merriam, 1998), others have argued that it is not. Stake is well-cited as disabusing the notion of case study as a methodology stating that it '...is not a methodological choice, but a choice of what is to be studied' (2005, p.443), whilst others have presented it as a strategy of inquiry (Denzin & Lincoln, 2005), which enables the researcher to study a case within a real-life, contemporary context or setting (Yin, 2009). Across this debate, however, agreement exists in the common goal of studying clearly defined real-life situations from multiple perspectives (Simons, 2009) and across multiple data

sources (Swanbourn, 2010), with the flexibility to employ a range of appropriate methods of data collection. It is argued here that it is this flexibility that makes case study particularly well suited to innovation and a hybrid research approach, providing a structure within which to locate the methods and an analytical framework suited to answering the research questions in this thesis.

Whilst each author writing about case study offers their own definition, of all the perspectives on case study research, that of Thomas (2010, 2011a, 2011b) aligns most closely with the philosophy and approach taken here. Rather than viewing case study as a method in itself, he argued for 'analytical eclecticism' (Thomas, 2010a, p.512), seeing case study as a design frame that integrates a number of methods. The research design for this thesis draws upon Thomas's work to communicate the interaction of case study with Interpretative Phenomenological Analysis, and the interdependency of the bounded case with TC theory. Figure 8, adapted from Thomas's typology provides a visual explanation of how case study forms the basis of the hybrid methodology, and it is important here to explore some aspects of this typology in more detail.

I have delineated the typology into two sections, illustrated in Figure 8 by the vertical dashed lines, which form a fuzzy demarcation for the purpose of communicating how case study and IPA synthesise. One of the defining features of case study research is that it relies on the identification of a specific case with clear boundaries which may take many forms, whether tangible entities, such as individual students or organisations, or those less concrete, such as programmes of study or a school community. Volumes have been written on how to define a bound case (see Yin, 2009; Stake, 1995; Merriam, 1998; Swanbourn, 2010; Thomas, 2010b), but the key to a good qualitative case study remains in ensuring that it is a 'case of something' (Stake, 1995). In Thomas's typology, the 'of' forms the 'analytical frame' of the study (Thomas, 2010a, p.512). It would not be sufficient in this thesis, for example, to conduct a case study on a group of students learning A level Biology purely by providing a description of their experiences.

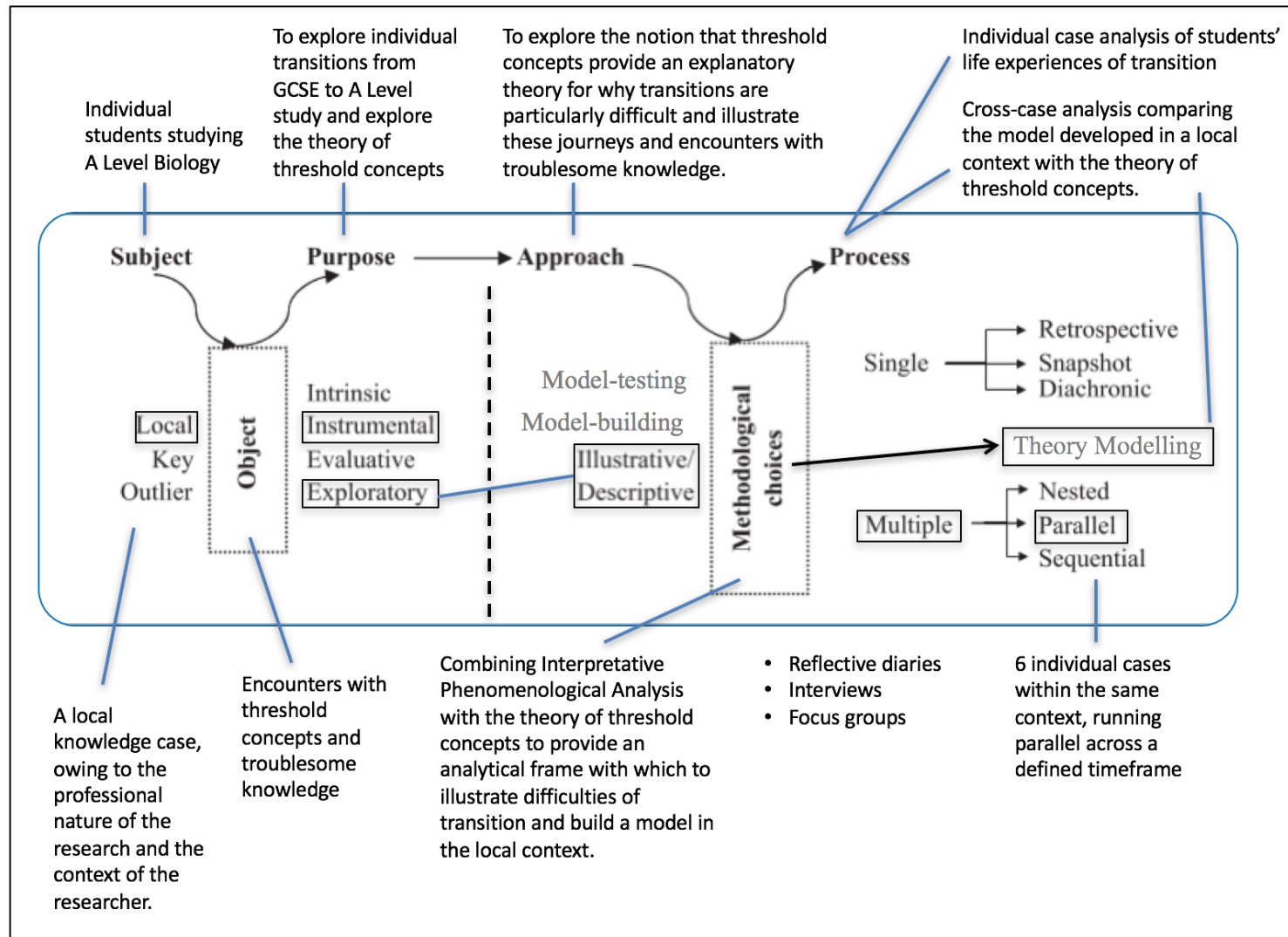


Figure 8 - Case study typology – adapted from Thomas (2010a)

A case study requires a focus, or ‘object’ as Thomas explained:

The case that is the *subject* of the inquiry will be an instance of a class of phenomena that provides an analytical frame - an *object* – within which the study is conducted and which the case illuminates and explicates (Thomas, 2010a, p.511).

So the subject and object are inextricably linked, with each part needing the other. The *object* in this case study gives meaning and an analytical frame to the investigations into the *subject*’s experiences.

Subject	Object (analytical frame)
Individual students studying A level Biology	Threshold Concept Framework – Encounters with TCs

Once this synergy between subject and object has been defined, the purpose of the study can be clarified, which in this instance is to explore individual student’s encounters with TCs through their experiences of transition from GCSE to A level study. At this point, it worth noting that Thomas never intended his typology to represent a linear or sequential process (Thomas, 2010a, p.518), instead recognizing that much decision making will often take place in simultaneous fashion. The second part of the discussion hinges around the methodological choice of IPA and how this choice fits within the case study design frame and has influenced the remaining sections of the typology, to the right of the dashed line in Figure 8.

3.2.4 Shaping the case study

Once the subject and object and their relationship had been defined, the third key element of the design frame was the methodological choice of Interpretative Phenomenological Analysis (IPA), which predicated to an extent the methods and analytical framework employed. Whilst others have combined IPA and case study in researching TCs (Haji Bungsu, 2014), the two traditions were applied as separate parts of the methodology in this earlier study. In contrast, my approach is much more integrated, with case study lending an essential guiding framework, whilst IPA can be seen as the powerhouse that drives the design frame, process and methods of data collection and analysis. The approach delineated in Figure 8 is in one respect illustrative and descriptive of students’ life experiences, whilst also providing a second focus: to explore the notion that TCs provide an

explanatory theory for why transitions are particularly difficult and to illustrate these journeys and encounters with troublesome knowledge. Engaging with theory in case study research, Thomas (2010a, 2010b) suggests, may take the form of ‘theory-testing’ or ‘theory-building’, approaches which can be thought of as being at extreme ends of a continuum (see Figure 9). Whilst theory-building is predominantly intended as an approach where no existing theory exists (Thomas, 2010b, p.112), theory-testing takes the assumption that an existing theory or explanatory framework exists for the focus of the research. As the theory of TCs does exist and has been applied to a wide range of situations and contexts (see Chapter 2), it would have been possible to take a theory-testing approach in this research design.

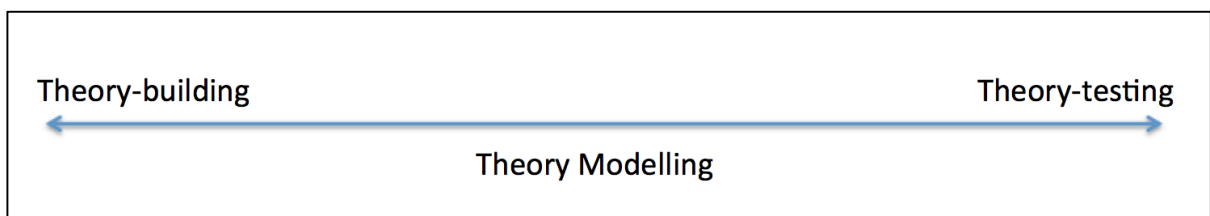


Figure 9 - A continuum of theory approaches to case study.
Adapted from Thomas (2010b, p.112)

However, a third approach to engaging with theory is advanced, adapting both extremes of theory engagement, referred to here as ‘theory modelling’ which may be considered to sit on the same notional continuum but which is positioned at the ‘back end’ of the amended typology in Figure 8. This positioning symbolises the intent to build an exploratory model of identification in the local context, drawing from the existing theory and definitions of TCs alongside the emerging and illustrative data from within- and cross-case analysis, following the collection and analysis of data.

The final part of the typology in Figure 8 concerns the process used in the context of the case study framework, which in this study was ‘multiple’, as the six students involved were viewed as separate cases allowing for cross-case analysis. It was also ‘parallel’, in that each case was considered alongside the other with equal importance, taking a longitudinal approach rather than being nested (Thomas, 2010b) or embedded (Yin, 2009), where the importance lies with the context. However, it is important to note a difference with the process design in this study.

The aim of a multiple, or collective (Stake, 2005) case is inherently to compare manifold cases, focusing on the analysis of the *object* and the individual cases are less important in this respect. For example, in this study, the cross-case analysis of the six individual students' experiences of TCs enabled modelling to be undertaken in a local context. However, the research design in this thesis involved a secondary layer, looking at a case-by-case analysis of the individual student experiences alongside the cross-case analysis. Here, the focus is very much on the *subject*, although still considered through the lens of TCs as the *object*. A simple illustration is shown in Figure 10, but the important point to note here is that both processes stem from the use of IPA as the chosen methodological approach and sit well together because of this methodological underpinning.

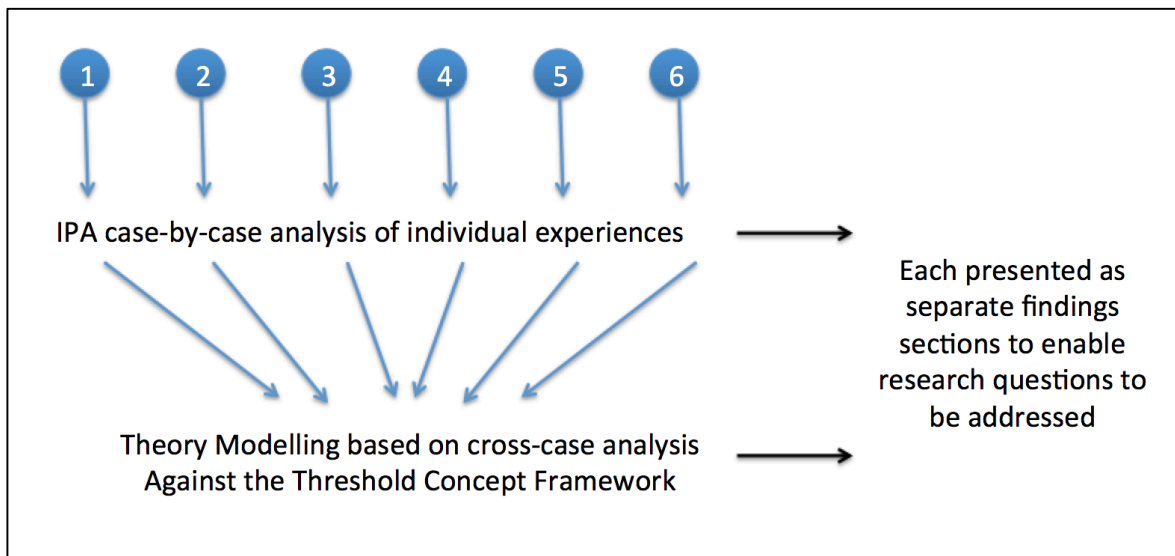


Figure 10 - Cross-case and case-by-case analysis

To explain this further, it is necessary now to look more closely at Interpretative Phenomenological Analysis, its underlying philosophy and methods before moving on to the detail of the research design and methods that were significantly informed by the choice of IPA.

3.2.5 Interpretative Phenomenological Analysis (IPA)

Interpretative Phenomenological Analysis (IPA) is a qualitative research approach originating from healthcare psychology, which demonstrates a commitment to exploring in detail how people make sense of their personal and social world, particularly where something significant has taken place in their lives. IPA was

originally introduced by Jonathan Smith (1996) as an approach to applied psychology that could capture the qualitative and experiential, aimed at 'people concerned with the human predicament' (Smith et al., 2009, p.5). Located predominantly in health psychology, the largest body of literature employing IPA explores an understanding of illness as a major life experience (Smith, 2011), but IPA researchers also commonly look at major *transitions* in people's lives, such as having a child or leaving home (Smith, et al., 2009, p.3), which was what initially captured my interest. Whilst moving from GCSE to A level study may not be a major life transition in the same way as those exemplified above, when coupled with encounters with TCs, I argue that this transition has the potential to be a significant life experience, making IPA a suitable approach.

The introduction of IPA was intended by Smith to be useful to researchers without formal psychological training but with an interest in psychological questions (Smith, et al., 2009, p.5). As such, in recent years the use of IPA is evident in other fields, including education. For example, IPA has been employed in HE to explore undergraduate experiences of stress and coping in their first year of university (Denovan & Macaskill, 2012), how students experienced the learning of qualitative research skills (Cooper, Fleischer & Cotton, 2012), as well as in secondary schools to consider teachers' perceptions (Bailey, 2011). IPA has also been used to research undergraduates' experiences of TCs in the context of prosthetics education (Hill, 2012). To discuss the principles and origins of IPA in more detail, I have provided figure 11, which illustrates my understanding of the various aspects of IPA that informed its development.

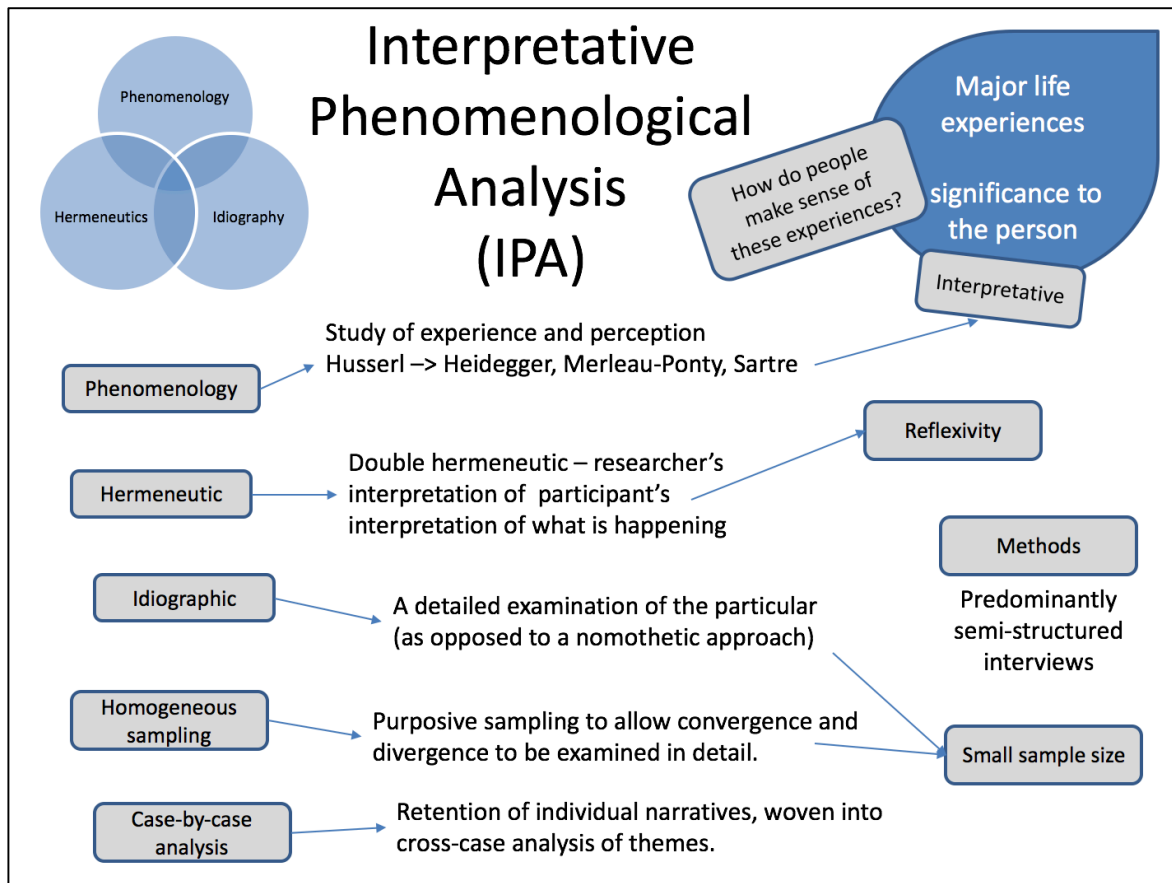


Figure 11 - Interpretative Phenomenological Analysis: an explanatory overview

The roots of IPA lie in phenomenology, hermeneutics and idiography, three areas of philosophy that have long established traditions in the study of knowledge and experience, combined to form the theoretical axes of IPA (Smith, 2004). The ontological assumptions of IPA centre around the belief that multiple realities are constructed through interactions with others based on lived experiences. In terms of how reality is known, the epistemological position of IPA researchers is that co-construction of reality takes place between the researcher and participant, in turn shaped by individual experience. This co-construction takes an axiological stance where values are negotiated between individuals and that individual values are honoured. The combination of an existential view of phenomenology, with ideography and hermeneutics places IPA, and therefore this study, within a broadly interpretivist worldview, where subjective meanings of experience are complex, varied and multiple, whilst acknowledging the position and influence of the researcher. Each of the three theoretical axes that underpin IPA

(phenomenology, hermeneutics and idiography) is now dealt with briefly to position the methodological approach more precisely.

IPA research is phenomenological in nature, and is concerned with the exploration of experience through making sense of people's lived experiences of the world. IPA's perspective on phenomenology was informed by the work of Edmund Husserl in the early 1900s, as well as Heidegger, Merleau-Ponty and Sartre, who later expanded on Husserl's work. Each of these authors agreed on the core purpose and values of phenomenology, whilst also taking the tradition in subtly different directions.

In the 1920s Edmund Husserl outlined a phenomenological approach advocating that experience should be examined in its own terms, in the way it occurs, in the consciousness of the individual (Smith, et al. 2009, p.12). In the phenomenological view, this consciousness will always be consciousness *of* something, much as the experience will be experience *of* something, which Husserl referred to as the 'intentionality' of focusing attention on a particular object or phenomena. Husserl further argued that examination of the object of experience in this way would require the existing world to be 'bracketed', or put to one side in order that attention could be concentrated on the researcher's perception of the world. Using a series of 'eidetic' reductions (Husserl, 1927) to remove distractions, Husserl contended that one could transcend the particular to arrive at the general 'essence' of a phenomenon that lies beneath the surface of individual perceptions.

Whilst Husserl aimed to achieve an abstract, transcendental approach to phenomenology, Heidegger's seminal work, *Being and Time* published in 1927 (Heidegger, 1962), saw a move towards a more existential and hermeneutic approach, acknowledging an interpretative stance grounded in the world of lived experience. His use of the term *Dasein*, meaning 'there-being' explicated his view that humans are 'thrown into a world of objects, relationships and language' (Smith et al., 2009, p.18), to exist always in relation *to* something. This feature of Heidegger's work contributes significantly to the phenomenological aspect of IPA. Merleau-Ponty (1962) shared Heidegger's views on human relationship with being in the world, but placed the emphasis on the 'embodied' nature of that

relationship, seeing the body as 'our means of communication with it' (p.106). In 1943, Sartre (2003) also contributed to the existential development of phenomenology, following on from Heidegger's view that humans exist in the world, but with an interest in the developmental aspect of being, with the notion that the individual consciousness does not pre-exist, waiting to be revealed but is always in the process of developing through engagement with the world.

Interpretation and analysis in IPA is further informed by the notion of the 'hermeneutic circle', in that a part cannot be understood without consideration of the whole, and vice versa. Heidegger's conception of phenomenology was that of a descriptive, but hermeneutic undertaking (Carman, 2006). Smith, et al. (2009) argued that in IPA, if the *whole* is considered as the researcher's biography and preconceptions, and the *part* is the researcher's encounter with a new participant, the hermeneutic circle can be seen to offer a reflexive, circular view of bracketing within the analysis and interpretation of IPA research. The notion of a hermeneutic circle also focuses thinking on the importance of an iterative analytical process within IPA, rather than a linear one, such that the researcher is more likely to move back and forth through the analysis. This links with the notion that case study research requires a similar iterative process as noted earlier regarding Thomas's typology (2010a). The interpretative process of IPA also resonates with Heidegger's notion of phenomena as 'appearances' (Carman, 2006), which require the researcher to uncover and make sense of them. In doing so, the researcher is engaged in a 'double hermeneutic' (Giddens, 1987), whereby they are attempting to make sense of the participant making sense of their experience. In this thesis, the research process involved me as the researcher constructing a 'reality' based on my own interpretations of the data, which in turn were formed from participants' interpretations of their experiences of a phenomenon.

The third theoretical axis of IPA is that of idiography. By committing to a detailed examination of each case, the researcher aims to uncover the lived experience for each individual, in a detailed and rich way. Although cross-case analysis is often involved in IPA research, it is important not to lose the importance of the 'particular' with respect to depth of detailed analysis of the individual experience (Smith, 2004). Consequentially, IPA usually invokes purposive selection of

participants, in relatively small numbers, and samples are also invariably homogeneous and carefully situated (Smith et al., 2009). The detailed and rich approach to analysing data, combined with a hermeneutic focus to the analytical process is well suited to this study, enabling a detailed exploration of individual experiences of transition whilst also generating sufficient depth to consider those same individuals' encounters with TCs. In relation to this latter aim, idiography does not preclude generalisation but, rather than attempting to do so in a nomothetic sense, locates such generalisation in the particular (Smith et al., 2009).

3.2.6 The hybrid approach – fitness for purpose

This section outlines how the combination of case study and Interpretative Phenomenological Analysis were used to build a hybrid design frame, and Figure 12 offers a visual overview of this approach.

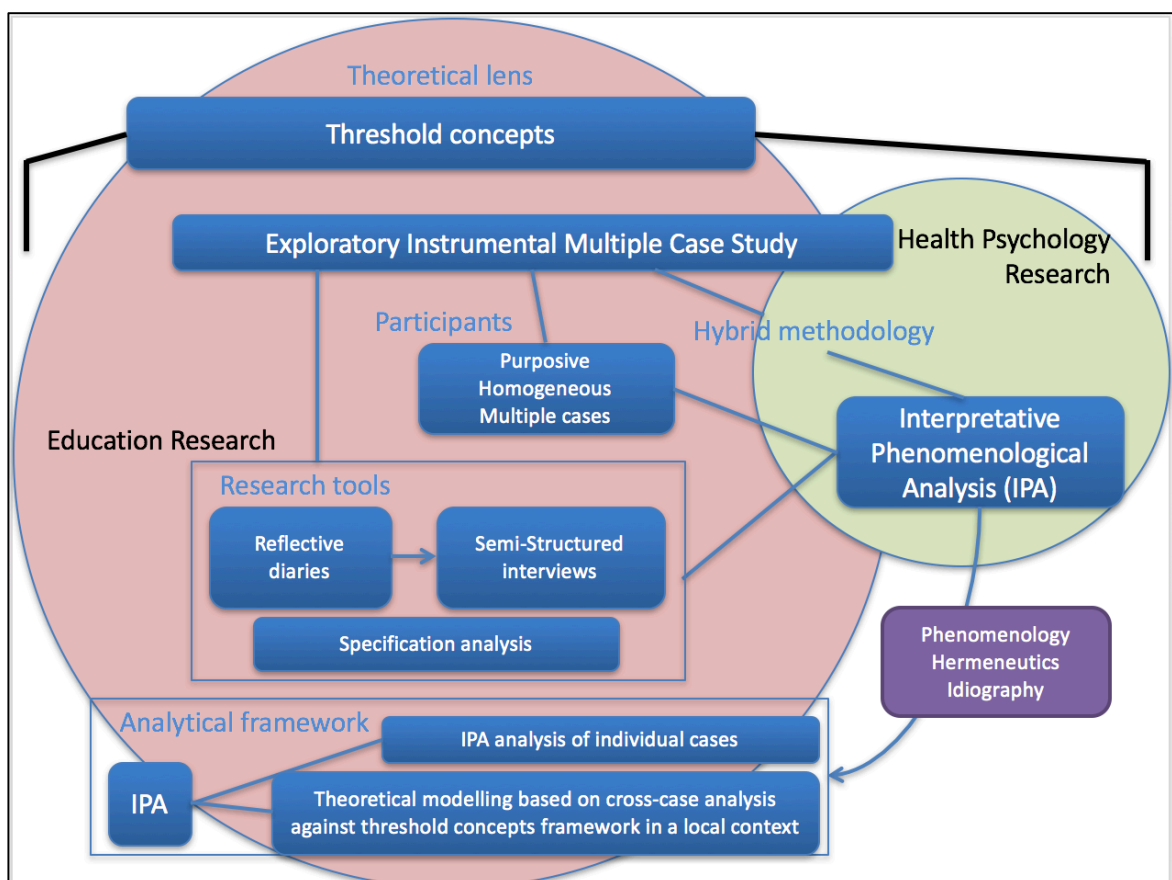


Figure 12 - Methodological overview of the research design

As noted earlier in this section, both IPA and case study share some common philosophical approaches, being compatible in both ontological and epistemological terms. In fact, some guidance on IPA research specifically refers to taking a case study approach:

We have been increasingly advocating the case study in IPA and hope to see increasing numbers of case studies conducted. However, most IPA is, and is likely to continue to be, idiographic in focus, but with a sample size larger than one (Smith et al., 2009, p.38).

However, the term case study in this context appears to be related to the selection of participants rather than as an explicit methodological link. In Smith, Jarmon and Osborn (1999, p.220), an example is provided of an 'idiographic, case-study approach', and the authors suggest that IPA projects may 'take the form of a single-case design or involve a larger group of participants'. However, there appears to be little further in the way of detailed explanation with regard to the case study aspect of the research and how it is applied to IPA. Smith et al., (2009, p.38) discuss the analytical process of IPA, proposing that it begins 'with the detailed examination of each case, but then cautiously moves on to an examination of similarities and differences across the *cases*' [italics added]. This infers that each individual is a 'case', which supports the commitment to an idiographic approach, focusing on the particular, before making comparisons across individuals. It is argued here then that whilst the term 'case study' is used in the field of IPA, which confers precedent and compatibility, this study offers originality through a clearly-defined design frame positioning the use of 'case study' within its own body of literature. In doing so, the research design makes clear the interaction between the case study tradition and IPA as a compatible and integrated analytical framework with which to answer the research questions.

3.3 Ethical considerations

Great care has been taken to ensure that this project has been designed with consideration for social acceptability and research ethics throughout, with respect for the individuals and institutions involved and the integrity of knowledge. This research follows the guidelines of The Bishop Grosseteste University Research Ethics Policy (2014) and the British Educational Research Association (BERA)

Ethical Guidelines for Educational Research (2011). The following parties were considered as requiring ethical consideration within this project:

- The student participants
- The teacher participants
- The principal researcher
- Bishop Grosseteste University
- The school within which research was undertaken

3.3.1 Reflexivity

When developing the research design for this thesis, I was aware of the dangers of making assumption that researchers can remove their own influence completely from the research (Orgill, 2008). All researchers will bring their own backgrounds, experience and beliefs to the process, and must therefore make their backgrounds and beliefs explicit (Webb, 1997) to ensure that the reader is aware, as far as possible, of all variables that may have affected the results. Clarifying reflexivity in research reports is vital to countering (or rather embracing) this limitation (Cousin, 2009), which might otherwise render the findings opaque to the reader. As an insider-researcher, immersed in the context of this case study as my own place of work, it is therefore vital that my position is made clear in relation to the data collection and analysis, thus allowing the reader and participants an insight into the lens through which my interpretations have developed. This important feature of qualitative research is often omitted from methodological accounts in academic writing (Clegg & Stevenson, 2013), but here I attempt to offer some explanation of my position, not to bracket this, but to offer some clarity around my background and relationships, and the associated perspective, for the reader.

A simple definition of the 'insider-researcher' does not capture the complexities of my position to the participants, and so I use the notion of a continuum (Mercer, 2007) with insider and outsider at either end to present my position. Whilst as an employee of the school I am very much an insider, I would argue that to the student participants in the biology group I am an outsider in many respects. I have not taught any of them directly, with interactions on an individual level being limited to handing out reports or brief corridor conversations. Whilst I am

established enough to be considered a long-serving member of teaching staff, with regard to the subject of biology I am more likely to be seen to inhabit a space outside their 'community of practice' (Wenger, 2009), as a non-biologist. I would therefore argue that my position lies more towards the 'outsider' end of Mercer's (2007) continuum. However, when considering difficulties with the transition from GCSE, my own experiences bring me closer to the students, despite these being in the past.

It should also be noted that I have been reading literature on TCs over a period of eight years and this must also be taken into consideration reflexively. Every effort has been made to explain the application of the TCF in this thesis, including detailed examination of the characteristics and analytical approach. My embedded knowledge (Clegg & Stevenson, 2013) therefore forms an integral part of the data collection and analysis and this has been embraced rather than making attempts to bracket it out. This embedded knowledge inherently impacted on the data analysis process, particularly when identifying and interpreting students' responses to issues surrounding TCs, where my own knowledge and experience will have led me to make certain assumptions. For example, whilst generating emergent themes, I was conscious that I was internally comparing each response to my existing knowledge of the TCF and this would have led to a biased interpretation.

As a senior leader, I realise that my position in the school may impact upon students' responses, although discussions were largely focused on learning-related issues and students were reassured that their specific responses would remain confidential. At the outset of the research process I have included the biology teachers in discussions on changes to the research design and I have communicated clearly my aims to the participants. Specifically, I spoke with the group of students about the research forming the main data collection for my thesis, explaining to them the professional and academic reasons for my choice of focus as well as my own personal reasons for wishing to undertake the study.

3.3.2 Access and safeguarding

The project was located within my place of work and authorisation to conduct the research in the school was granted in writing by the Headteacher of the school and by the Bishop Grosseteste University ethics committee. I had enhanced CRB clearance and had attended safeguarding training within twelve months of conducting the interviews, ensuring compliance with legal requirements for working with children (BERA, 2011, p.7). As an employee of the research site and a qualified teacher, I was also conversant with the school policies and procedures for working with children and ensuring adequate health and safety.

3.3.3 Selection, inclusion and exclusion

All students within the biology teaching group (n=7) were offered the opportunity to take part in the project, and the class teacher was present during the initial presentation to the group. Only one student chose not to take part as they were on a foreign exchange programme and would not be present for the whole year. Interview sessions were arranged at the convenience of the individual to ensure that no students were excluded due to unavailability.

3.3.4 Voluntary informed consent

Informed consent was obtained from all participants to engage in the research as well as for future use of the data for inclusion in this thesis and for potential publication (BERA, 2011, p.5). An initial meeting was conducted during a biology lesson, where I explained the aims of the project to the class. As I held a senior post in the school, it was important that participation was clearly identified as being voluntary, so that no unintended coercion was involved. This was further accomplished through provision of a 'cooling-off period' between the initial briefing and commencement of the interviews. Students were reminded at the initial interview that they were not compelled to participate and that there would be no negative consequences for not taking part.

3.3.5 Right to withdraw

All participants were apprised of the right to withdraw from the research at any time either verbally or via email. I also ensured that participants were reminded of this right at the commencement of each session. Participants were told that should

they chose to withdraw they would be able to do so without consequence and that they would be involved in any group discussions to ensure they did not feel excluded. However, it should be noted that none of the participants chose to exercise their right to withdraw.

3.3.6 Attention to vulnerable groups and other sensitivity issues

Although the research was not designed to be sensitive in nature, it was considered a potential risk that some students may feel uncomfortable when talking about difficulties with their work. Where any signs of stress were evident, I ensured that students were reminded that they had the right to withdraw or take a break. Prior to the interviews, I also sought information from the class teacher regarding any potential issues of this kind.

As the project involved exploration of areas of the curriculum where students were likely to be experiencing difficulty, I recognised that potential criticism of the methods of delivery or teaching style of one or more of the class teachers involved may arise, presenting an ethical dilemma. This was especially sensitive due to my position in the school as a senior leader and the professional power relationship with the class teacher. I decided that, should any criticism occur, I would deal with it sensitively with consideration for both the students and teachers and refocus on the individual narrative. As the professional aim of the project was to improve pedagogy, information was to be presented back to teachers, and students were reminded of this at the outset. Although this may have potentially reduced the openness of student responses, ethical considerations and the transparency of the process were judged to take priority in this regard.

3.3.7 Data protection and security

Data collected from the interviews was in the form of digital audio recordings, which were then transcribed onto Microsoft Word. Students were asked whether they consented to being recorded at the start of each session. A semi-professional digital recorder was used to record conversations and files were transferred across to a secure area of the school network immediately following each session. The secure storage area is only accessible by the researcher through network log

on and is therefore password protected. The files were then immediately deleted from the recorder. A backup copy was made on Dropbox (cloud storage service) and encrypted. These measures also applied to transcriptions, which were also anonymised using pseudonyms. As I was an employee of the school concerned, which is a public-sector organisation, any requests from participants to access the data relating to them would be handled according to the Freedom of Information Act, 2000.

3.3.8 Confidentiality and anonymity

The identity of the school, teachers and students has been protected as far as is practicable in the process of thesis write-up and publication. However, as the researcher works at the school concerned, it would be impossible to fully conceal the identity of the biology teaching staff or students to any employee of the school. Although groups could be potentially identified, individual anonymity has been preserved using pseudonyms such that comments will not be directly attributable to any specific individual. All data has been stored securely, such that individuals cannot be identified from sound files.

Participants were advised that the confidentiality and anonymity covered above may be overridden in the case of the need for disclosure (BERA, 2011, p.8). The school has a clear policy on safeguarding and 'whistleblowing', which outlines where issues should be reported to the designated safeguarding lead or senior member of staff in the case of illegal or potentially illegal behaviour coming to light.

3.3.9 Integrity of knowledge, publication and dissemination

Participants were informed of the intended use of the data with regard to inclusion in the written thesis and future publication and this formed an integral part of the informed consent requested. I was mindful of the University policy on plagiarism and accurate referencing as set out in the Bishop Grosseteste University Handbook for Written Coursework (2015). I have also ensured that research findings are not distorted or falsified.

3.3.10 Participants and setting - defining the case

The participants for this study were selected on a basis consistent with IPA, that is, a homogenous sample selected purposively (Smith et al., 2009) on the basis that they might provide a perspective on the particular phenomena being studied. As the focus for this research was that of encountering TCs and troublesome knowledge through the study of advanced level courses, a group of students studying A level Biology was selected. The thought process leading to this specific subject comprised two key elements: a) biology is relatively well-documented in the TC literature, allowing for comparison with previous research in HE, and b) the subject is not one taught by the principal researcher, thereby contributing to a degree of reflexivity in the research design. From a professional perspective, science teachers in the school were also keen to engage with facilitating the research to illuminate perceived difficulties with the subject resulting in less than satisfactory results for some students.

In IPA studies a sample size of between five and ten is common (Smith, 2004) and single cases are also studied. Hefferon and Gil-Rodriguez (2011) recommended four to ten data points for professional doctorates, suggesting that 'fewer participants examined at a greater depth is always preferable to a broader, shallow and simply descriptive analysis of many individuals.' (p.756). In total, six students took part in the project from a class of seven, all of whom were from a White British background and one of which was male. One student chose not to take part as they were on a foreign exchange programme and due to leave the school during the research cycle. Each of the six participants thereby formed an individual case in relation to the IPA-based analysis (see Figure 13), seen within the local context of their class.

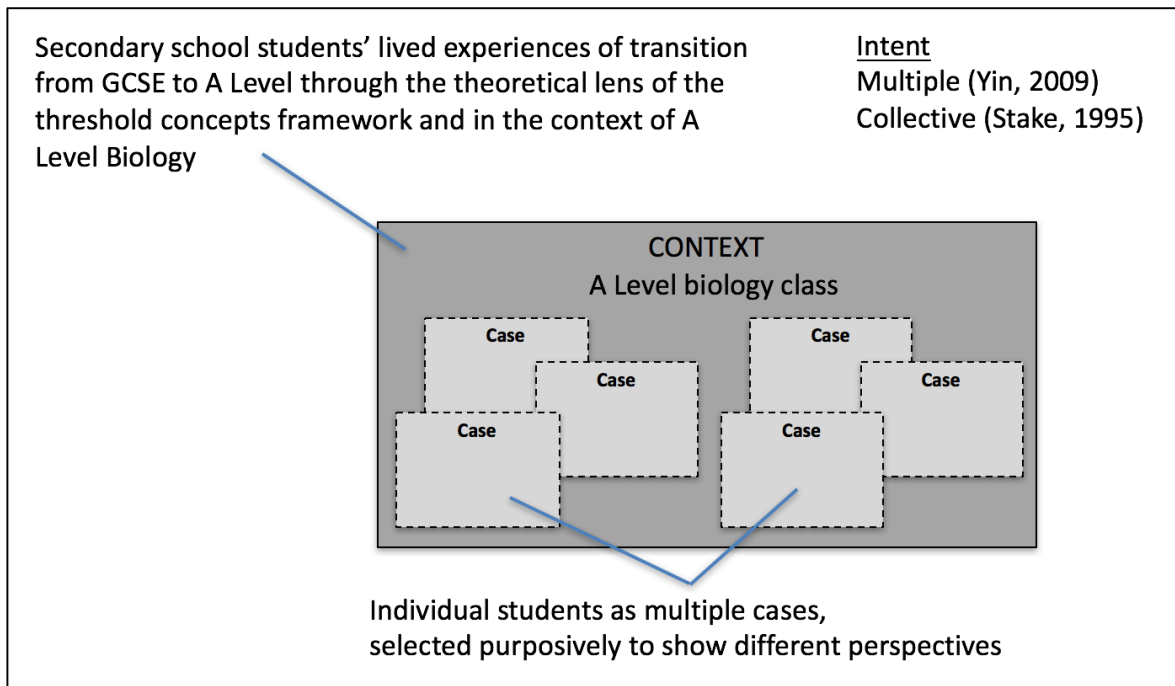


Figure 13 - Visual representation of the defined case

3.4 Data collection – an overview of the process

A brief overview of the process is provided here to provide a sense of time and purpose. At the commencement of the project, I spoke to the group of students to expand on the purpose of the research study from both professional and academic perspectives. Each student was then issued with a reflective diary and the process for completion of these was explained and discussed. Brief, individual follow-up meetings were arranged a week later to ensure that individual students understood the process, providing opportunity for any questions to be raised. Students were encouraged to record any thoughts relating to their work and prompts in the diaries supported this reflection. See Figure 14 for an illustration of the process.

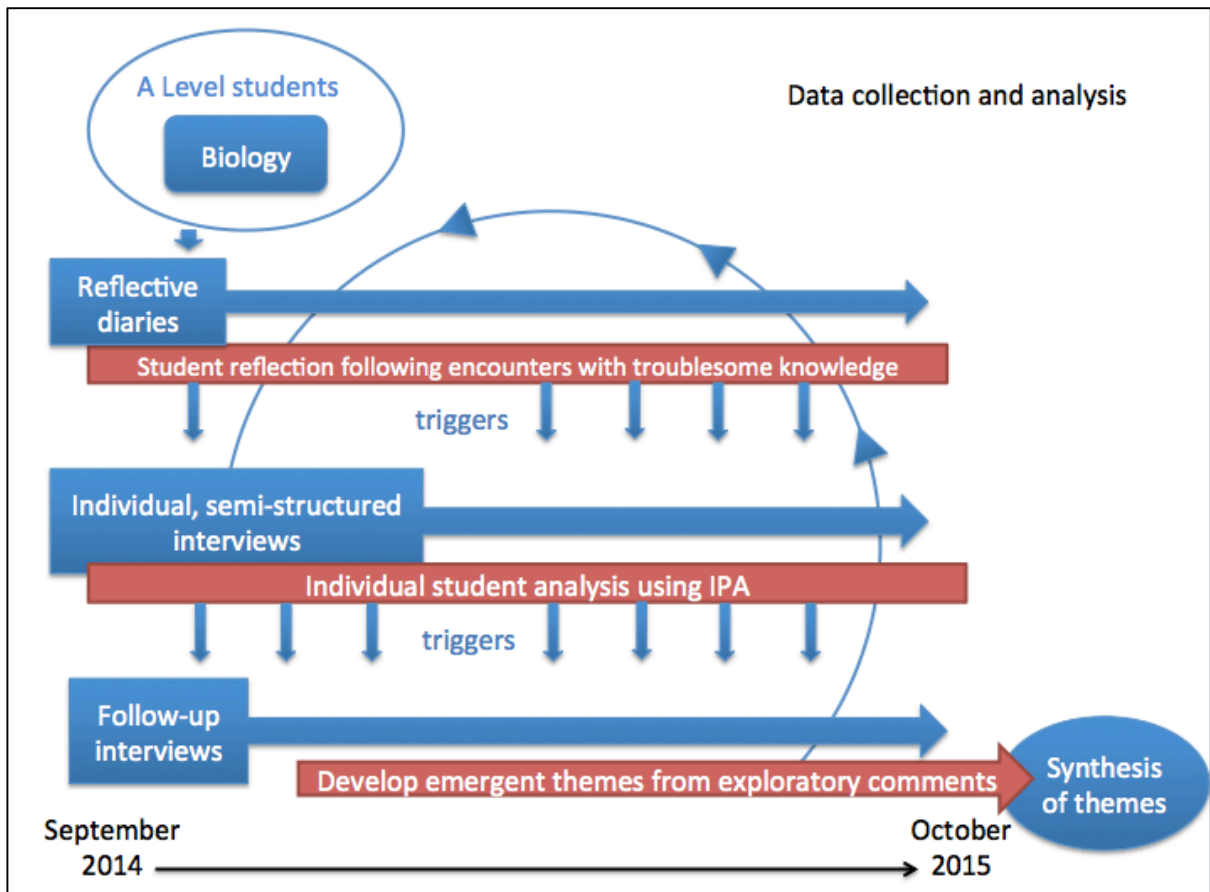


Figure 14 - Data collection and analysis timeline

Initial semi-structured interviews were then arranged with individual students starting in the first term (between September 2014 and October 2014) to capture students' initial perceptions of transition to A level study, with a final interview at the end of the academic year (between June and July 2015) around the time of examinations. In between these periods, students were encouraged to undertake further short open-ended interviews to discuss any particular issues relating to their studies, triggered by reflections in their diaries. In the final term (July 2015), the group undertook a specification analysis designed to consider aspects of the TCF. The class teacher conducted this analysis, with support from myself. One further interview was conducted in September 2015, following the examination results to give the students an opportunity to reflect on the year. Figure 14 gives a visual representation of the interaction between reflective diaries and interviews. The following sections now provide details and critique of each of the research tools in turn, starting with the central data collection method: interviews.

3.4.1 Semi-structured interviews

In-depth, semi-structured interviews with individuals are commonly used in IPA (Smith, 2004), due to the need for a medium that allows for a two-way idiographic dialogue. This involves an open-ended interview maintaining a careful balance between guiding and being led (Hefferon & Gil-Rodriguez, 2011, p.757). I decided that semi-structured interviews allowed for a flexible approach, and this method of data collection has been used by others in IPA-based research into TCs (Hill, 2012). For my study, the design of the interview questions was considered central to the incorporation of specific aspects of the TCF into the discussions. For this reason, the interview questions were developed, cross-referenced against the TCF and trialled over the course of the three pilots, being adapted after each pilot interview following reflection and partial analysis. The questions were not necessarily asked in order, but were used as a checklist of themes to ensure sufficient opportunity for coverage of the TCF and the affective dimension interwoven with discussion about students' transitional journeys.

One of the most important aspects of the interview protocol was ensuring that I took a reflexive approach to reviewing and amending the process where necessary. In the first few pilot interviews I found myself leading the discussion and responding to the students' answers in too much detail. I recognised that I needed to become more focused on listening, utilising long periods of silence to encourage the students to continue on their own track. As one of the main objectives with my research design was to draw out discussion of feelings I adopted an approach that was designed to encourage students to feel confident to speak up by offering brief examples from my own experiences to attempt making a connection (Smith et al., 2009), as well as giving them opportunity to tell their story through more effective listening. This was an important change to my interview technique, one that Cousin refers to as 'the art of hearing data' (Cousin, 2009, p.75), and which helped in allowing me to avoid dominating the interview.

3.4.2 Reflective diaries

Reflective diaries were introduced to the research process as a result of lessons learned in the first and second pilots. When interviewed, most students found it

difficult to recall their experiences of particular concepts and, in particular, how they felt at the time. Whilst this was due in part to conducting the interviews only at the end of the academic year, I felt that encouraging students to keep diaries would help them to keep an on-going record commensurate with the longitudinal design of the interview process. It has been documented that the use of diaries can help to address potential inaccuracies in participants' recall of situations that may change over time (Alasewski, 2006, p.113) and are recognised as a suitable method of data collection in IPA:

Data need not be confined to interviews. It is also possible to use multiple sources such as diaries where the researcher has asked people to keep a journal documenting their thoughts and experiences. Other useful sources include personal accounts, letters, or returns from questionnaires. (Biggerstaff & Thompson, 2008, p.9)

Diaries also provided further opportunities to delve into the emotional aspect of student experience. Students were asked to record their thoughts after each lesson or whenever they encountered difficulty in their learning, referring each time to the prompt questions located at the bottom of each diary page. At interview, each student was asked to bring their diaries along and was given time at the start of the interview to reflect on their experiences prior to and during the interview process. Figure 15 shows a sample page from a student reflective diary.

Date of journal entry:
Please give a brief description of the topics or concepts covered for this entry
<p>How difficult did you find it learning this topic or concept?</p> <div> <div>Extremely difficult</div> <div>OK</div> <div>Extremely easy</div> </div>
<p>Describe your experience of learning this topic or concept below.</p> <p><i>To help you reflect, you could consider some of the following prompts:</i></p> <ul style="list-style-type: none"> • <i>Did you find anything hard? Why? How did it make you feel?</i> • <i>Did you have any light bulb moments when you suddenly realised you had 'got it'?</i> • <i>Maybe you thought you understood something previously but later realised that you didn't.</i> • <i>Do you remember feeling any different towards the subject as a result of this week's lessons? If so, how?</i> • <i>Did any of the things you learned this week help you make sense of previous learning?</i> • <i>Was there anything that particularly helped you in your learning? If so, what was it?</i> • <i>Were there any barriers to your learning?</i>

Figure 15 - Extract from student reflective diary

3.4.3 Course specification analysis

The specification analysis was conducted in a single lesson toward the end of the year, prior to the final interviews. To undertake the analysis, the class teacher for the A level Biology class provided each of the students with a copy of the course specification. This material listed each of the concepts covered arranged by topic and sub-topic. Students were then asked to read through the course specification and indicate in the margin which concepts they recalled finding particularly difficult, and which they felt were central to understanding the topic, or to understanding concepts in other areas of the course. This particular research tool was introduced to provide another reflective opportunity for students to pinpoint areas of troublesome learning and concepts of an integrative nature as they looked back over the year. Individual student analyses were then discussed in the final interviews, acting as a prompt.

3.5 Analytical framework

The analytical framework for this thesis, along with the methods of transcription, coding and categorising, was informed by IPA literature, including guidance from Smith et al. (2009) on how to undertake and analyse IPA research. However, these authors make it quite clear that there is no single prescribed method (p.79) and that innovation in IPA research is welcome, suggesting that following the underlying philosophy of IPA matters more than the procedure (p.4). Drawing from its idiographic roots, analysis in IPA involves a detailed examination of each participant's responses, with a strong focus on the individuality of each, only then attempting to identify emergent themes across the group (Smith, 2004). One of the initial attractions of IPA to me as a methodological approach was this idiographic focus, enabling a detailed individual narrative whilst not precluding the consideration of overall themes and patterns within the group. In a good quality IPA study, shared themes and distinctive variations and individual voices should come through (Hefferon & Gil-Rodriguez, 2011).

Transcripts were set out using a three-column table (see Table 5) and initial analysis involved a line-by-line consideration of the experiential dialogue of each participant's responses in turn, through an exploratory examination of semantic content and language use. There are no hard rules in the IPA literature about how this analysis is conducted, which is close to a free textual analysis (Smith et al., 2009). Emergent themes were then identified, attempting to reduce the volume of data whilst retaining complexity. This was achieved by analysing the exploratory comments across the individual transcript. Whilst this process seems at first to 'fragment' the experiences of the participant (Smith et al., 2009, p.91), breaking up the narrative flow, it plays an important role in the iterative and inductive cycle.

<p>Descriptive comments in plain text Linguistic comments underlined Conceptual / interpretative comments in italics</p>		
Emergent themes	Original transcript	Exploratory comments
Shock	Since our last discussion, is there anything you want to talk about with regard to your journey from GCSE to A Level?	
workload	Well, it was a big shock at first, for GCSE Science for example, my book was the size of my biology book now and I had biology, chemistry and physics. And I feel like I have just got used to the workload and now it's about to end. So I feel like I have just got the hang of it and I can do it now, but it's gonna get harder and they are upping the stakes next year in A2. And I just feel a bit left behind.	<u>It was a big shock</u>
increased difficulty		<u>Upping the stakes</u>
Feeling left behind		<i>She has found the transition difficult and is now concerned about the jump next year to A2</i>
Adjustment time	Really, in what way? Yeah...erm, I don't know how other people feel if they have kept up but I feel like I needed more adjustment time to it and I thought maybe resit the year and then I would be able to keep on track from the very start. I don't know if that is such a good idea...?	<i>She is unsure as to how others have coped and is comparing herself to them, thinking that she needed more adjustment time. She was top of the pile at GCSE and achieved the best grades in her year group. Now her confidence has been affected by the difficulty she is experiencing, even to the point of considering sitting the year. Questioning whether to resit the year, as if asking the interviewer.</i>
Time management		
Pragmatic	So are there any of the four subjects that you are thinking of not carrying on with to A2? I don't think I would be able to drop out of any of my subjects, simply because I have started it now and I want to	Determination, not wanting to quit

Table 5 - Example of initial analysis through notation of individual transcript

The next stage involved searching for connections across emergent themes, identifying superordinate themes through a process of abstraction, such as to group similar themes under one heading, or subsumption, which occurs where an emergent theme itself acquires a superordinate status (Smith et. al., 2009, p.97). Once this process had been conducted for each of the six participants, patterns were identified across the cases (see Table 6). This process involved moving from the particular to the shared (Reid et al., 2005), identifying those common themes which emerged from detailed reading and rereading of transcripts. I felt that it was important at this stage to continue to refine the dataset to avoid ‘too large a number of descriptive superordinate and subordinate themes with insufficient data extracts presented to support each theme’ (Hefferon & Gil-Rodriguez, 2011, p.757).

Superordinate theme	<u>Troublesome transitions and transformative journeys</u>
Category theme	Transition from GCSE to A level (troublesome)
Component themes	The jump to A Level Perception that A levels would be like GCSE Increased workload and pace Pressure intensity and stress
Category theme	Acclimatisation and the liminality of transition (liminality)
Component themes	Adapting and adjusting: a messy journey Questioning self: wobbly confidence Coping, pragmatism and resilience Organisation and time management Experiencing success - liminality Coasting versus struggling
Category theme	Identity and social comparisons (communities of practice)
Component themes	Becoming an A level student Frustrated at others / intimidated Isolation vs fitting in: feeling left behind Immersion in language Becoming a scientist Aspiration and motivation - competition Planning for the jump to degree Questioning identity - the unknown future

Table 6 - Partial initial cross-case analysis and identification of superordinate themes

The final list arrived at is presented at the start of the next chapter, and details the themes which represent my interpretation of the individual responses and those identified by the group.

Chapter 4 – Findings: Troublesome transitions and transformative journeys

In this and the subsequent two chapters, the findings and analysis of results are presented and discussed. Whilst it is acceptable in IPA to relate themes to the literature throughout the analytical write-up (Smith et al., 2009, p.113), it is more common that findings and discussion are presented separately, which is the approach taken in this thesis. The structure for the following sections has been chosen to provide a logical and accessible narrative for the reader which illuminates all four research questions through the process of data analysis and interpretation.

Research Questions

- How do students make sense of the transition from GCSE to A level study?
- How do students experience TCs in A level Biology?
- How is the affective dimension of TCs represented in students' experiences?
- How do the theory and definitions of TCs fit in this local context, and can TCs be identified in secondary biology?

Analysis of transcripts and the subsequent themes which emerged resulted in two main superordinate themes being identified. These are presented as separate chapters: Chapter 4, 'Troublesome transitions and transformative journeys' narrates the process of moving from GCSE to A level study and how this was experienced by the six participant students, offering insights into the first and third research questions. Chapter 5, 'Threshold concepts, troublesome language and previous knowledge' provides a detailed insight into how this group of students experienced TCs in A level Biology, illuminating the second and fourth research questions. It must be made clear that, despite this intended signposting, these two chapters do not neatly fit each of the research questions in what is an inherently messy and complex interpretative discourse. There are many overlaps between the two sections, the four research questions and, indeed, other component themes which have emerged through the data analysis.

The discussion in Chapter 6 draws together these findings alongside the extant literature and responds to all four research questions in detail. Table 7 provides an overview of themes along with chapter designators to allow for easier navigation.

Superordinate theme	Category theme		Component themes	
4. Troublesome transitions and transformative journeys	4.1	Transition from GCSE to A Level	4.1.1	The 'jump' to A Level
			4.1.2	Expectation and realisation
			4.1.3	Increased workload and pace
	4.2	Acclimatisation	4.2.1	Adapting and adjusting
			4.2.2	Questioning self
			4.2.3	Experiencing success
	4.3	Identity and communities	4.3.1	Becoming an A level student
			4.3.2	Becoming a scientist
			4.3.3	Transformed identity
5. Threshold concepts, troublesome language and previous knowledge	5.1	Encounters with threshold concepts	5.1.1	Thresholds coming into view
			5.1.2	Integrative awakenings
	5.2	Troublesome language	5.2.1	Language as a barrier
			5.2.2	Alien language and ridiculous words
			5.2.3	Specificity, precision and keywords
	5.3	Previous knowledge	5.3.1	Simplified knowledge
			5.3.2	Letting go and slipping back
	5.4	Threshold concepts in A Level Biology	5.4.1	Scale

Table 7 - Overview of findings emerging from data analysis

Additionally, one theme forms an integral part of the research aims and is suffused throughout participants' responses and the subsequent analysis: that of the affective dimension of TCs. As stated in earlier chapters, this theme is an underdeveloped area in the field of TC research and largely inspired the choice of IPA as an approach to exploring student experiences of transition as a major life experience. The affective dimension is integrated into the discourse and whilst it is addressed through the third research question, it also emerges as this chapter unfolds, with students talking quite openly of the 'stress', 'anxiety', 'panic', 'awe', 'wonder', 'worry', 'fascination', 'struggle', 'shock' and 'terror' in their journeys through what is argued in this thesis to be a significant life experience. The discussion in Chapter 6 explores this in the context of the overall findings.

Key of notations

... participant pause or hesitation

[...] material omitted

[sighs and looks down] explanatory information added by the researcher

“It was ridiculous” underlined words show emphasis within participant response

4.1 Transition from GCSE to A level

This category theme is concerned with these six students' lived experiences of their transition to A level study and provides an introduction to them as characters in this interpretative account through their own observations and recollections. Throughout the interviews conducted, one of the clearest and most consistent themes to emerge was the significant difference between the participants' experiences of study at GCSE compared to their new programmes of study at A level. Whilst individuals expounded this in different ways, all made clear reference to the increase in demand placed upon them, particularly the workload and the accompanying stress and pressure. This category theme also illuminates students' perceptions and expectations of what A level study would be like, and the strong feelings experienced as they came to terms with the contrast of their lived experiences.

4.1.1 The 'jump' to A level

All six students referred at some point to the 'jump' they experienced upon starting their A level courses, a term which emerged through students' own responses rather than being explicitly prompted by the interview questions. The component theme explored in this section provides the opportunity for the reader to be introduced to each of the students through their recollections of the transition as a 'jump'.

Liam tells us how he came into his A level studies expecting little change, but was surprised by just how much he had underestimated the increase in demand:

I thought that GCSEs were relatively easy for me. I thought, oh it can't be that much harder, I can maybe carry on as I was but it's really not...[laughs]...there's a big jump. It really did take me by surprise when I look back at it now. (Liam, interview 2)

There was a sense throughout the discussions with Liam that, whilst he was finding it challenging to adapt to the difficulty of the work and the increased workload, it was the appreciation of just how striking the jump was that really shocked him, demonstrated here by his repeated and emphatic use of the term 'full-on' when recalling his previous approach to study at GCSE.

It's a lot more full-on, like especially with GCSE I thought I could just coast along I didn't have to make an effort with my homework, didn't have to make a large effort in class, whereas now...yeah, full-on. (Liam, interview 2)

Liam appears to have spent much of his GCSE years coasting and allowing his natural intelligence to carry him through. He carried this approach through into Year 12 and found that he struggled as a result, failing all four subjects at the end of the year and subsequently having to retake the first year of his A levels.

Throughout the early interviews with Liam there was a sense of nonchalance, as if he were almost an observer of his own learning. It was only later in the year, following his mock examinations that he appeared to accept that he would have to change his approach and take control.

In contrast to Liam, Gemma started the year expecting to find her A levels hard, based on what she had been told by students and teachers, but initially seemed surprised to find things fairly easy. However, looking back part way through the year, she acknowledged that it was much harder in some subjects than others:

Yeah, it is...everyone used to say that it is a really big jump and to start with...in, especially in geography...I didn't think, I still don't think it was that big a jump in geography, but it is in biology. (Gemma, interview 2)

Although she took a while to appreciate it, Gemma found the jump in biology to be significant for her and, towards the end of the year, she had come to realise that she was not really enjoying her A levels and wished that she had taken an alternative educational route. As the interviews developed it became clear that a large part of Gemma's problems with her learning stemmed from the realisation that A levels were so much harder than she expected, causing her to 'switch off'.

Such was the significance of her journey that she tried to pass this knowledge on to younger students to prepare them for what is to come and avoid making the same mistakes.

I have said to GCSE students that I know now...like, don't just think it is like GCSE, you've got to try a lot harder, you can't just sit back and not do any work, it is a huge jump. (Gemma, interview 3)

This awareness of the 'jump' that students refer to is passed on by word of mouth as Gemma suggests, but this received wisdom seems to have been hard to believe initially for some students in this study, as Anna explains:

I think it's that really you don't...at the start of Year 12 people tell you all the things that you are going to need to do and you don't believe it and it is only when you get to the stage of...oh my God I have got so much work to do...you don't understand the pressure until you get there. So six months ago I would have said oh I will be fine [...] but really...it's hard [laughs]. (Anna, interview 2)

Anna's laughter signalled a release of tension, emphasising just how hard she found the transition. So significant was the jump for Anna that she described it as a 'leap of faith' (Anna, interview 3), suggesting that she had stepped into the unknown, relying on her faith in education or maybe even her own resilience to guide her through.

Reflecting back over Year 12 allowed Yasmin to gain the perspective to see the 'jump' in terms of how quickly the year had passed, and how she had to adjust in such a short space of time. Here she recalls her astonishment at the step up from GCSE to A level.

It's been a really big shock and I have only just got used to it and I feel that now I can do it, but now it's ended. [...] I can't believe how easy the old GCSE exams were only a year ago...I thought it was so difficult at the time and it was so clever, but now I just think it's so...it's so scratching the surface...from what we are doing now, it's such a huge jump. (Yasmin, interview 3)

There is a sense of disappointment as Yasmin explains how she has finally come to terms with the shock of her first year of A levels and also trepidation as she embarks on the second year. It is clear that she is concerned that the difficulty will ratchet up again although she has only just come to terms with the initial shock and having to reassess her expectations.

All of the students were affected by the transition to A level study in one way or another, but none so significantly as Erin. Towards the end of the first year of A level study, she reflected on the difference between her GCSE years compared with her recent experiences of the previous 10 months.

It's insane, absolutely insane...obviously for me because I did triple science I probably had, like, three science lessons a week when I was in Year 11...a biology lesson, a physics lesson and a chemistry lesson...and I did exams but...oh my god, now they're...it's...it's a ridiculous jump...it's an absolutely ridiculous jump. (Erin, interview 3)

As Erin was talking there was a sense of urgency and amazement as she described her journey. Alongside this, the repeated and emphatic use of terms such as 'insane' and 'ridiculous' conveyed a feeling of awe with her experience, as if it were somehow surreal. Erin described her transition as a major life experience that affected her both physically and mentally, to such an extent that she sought medical intervention:

After my exams I got diagnosed with anxiety and depression [...] and that is mainly due to the stress of my A levels. Not all of it, but the jump from GCSE to A level, I have experienced first-hand how that can be a really bad thing. (Erin, interview 2)

Erin attributes much of her resulting illness to her troublesome transitional experience, which exacerbated personal issues she was having at around the same time. She goes on to describe the point in time when she realised the effect that the struggle with her studies was having on her, and that she could not carry on without changing something:

I went...I went to the doctors the day after my 17th birthday, because...basically I woke up one day and sobbed. I couldn't...it was like...I can't do it anymore. So this was between the exams and getting my results, it would have been the 2nd June, the day after my birthday, I just woke up and sobbed...broken...said I can't do it...can't do it anymore. I actually, physically can't do this anymore; I have to stop. (Erin, interview 2)

There was a real sense of anguish from Erin throughout her recollection of the point where it all became too much. The emphasis on certain words, particularly 'can't' signify her realisation that she was at the end and had given all that she could. For Erin, the transition to A level ended with serious repercussions and the 'jump' was just too great for her to cope with. As a result of her experience, Erin

left the school at the end of the year and took up an alternative programme of study elsewhere.

Other students, such as Anna, appeared to come to terms with the transition despite finding it a huge challenge, and were able to adapt as time progressed:

It is so...hard...that jump is huge and you don't realise. After a couple of months doing A level I really struggled...I didn't think I was going to do very well. But then over time it starts to become easier, 'cause you are picking up the different bits. Now I just can't imagine doing GCSE, it just seems really easy. (Anna, interview 3)

Even though Anna did find that things became easier for her, the experience of the transition to A level had such a profound impact on her that she would not want to go through that shock again unprepared. Here, she reflects on the year, repeatedly referring to the jump as 'huge' whilst thinking ahead about how she is already considering and preparing for the next 'jump':

So like, me now...I am already preparing myself for degree. Because I know it's going to be a huge jump because when you go from GCSE to A level it is huge...you don't actually feel it as you are going through it but when you look back retrospectively it is huge. The amount of work, the quality of work you have to produce, it all changes. So I am preparing myself for degree because I don't want it to be like it was for me going from Year 11 to Year 12. Because if I am on my own I don't think I will be able to cope [laughs]. (Anna, interview 3)

In many ways, more striking than Anna's fear of the next transition is her concern about facing it alone. The fact that she struggled with the transition from GCSEs to A levels has clearly affected her confidence going forward, but she covers her concern with laughter at the end of this account, and appears to take a pragmatic approach to preparing for the prospect of going through it all again, demonstrating resilience and growing awareness of her own learning journey. Anna also highlights a feature that emerged across all students' accounts within this category theme of transition, which is how their perceptions changed throughout the year and how they were unable to see the extent of the 'jump' in difficulty until they looked back. Despite being warned in advance by siblings, parents, older students and teachers, of the potential increase in difficulty, workload and pressure, none of the students' experiences in Year 12 matched their beliefs of what was to come.

The variation between their expectations and eventual realisation is illuminated through the next component theme.

4.1.2 Expectation and realisation

For Liam, who suggested that he coasted through his GCSEs unscathed, coming to terms with the expectations at A level was a relatively slow process. He didn't really begin to accept that he was finding it difficult until the end of the mock examinations in the January of Year 12: 'we got all the grades back from our mock exams and it was kinda like all laid out on the table and they said look this isn't acceptable, you will not pass if you carry on like this' (Liam, 2nd interview). Reflecting on that experience and the dawning appreciation that he was struggling with his work, Liam's shock was apparent when he recalled thinking 'whoa, I wasn't expecting A level to be anything like this' (Liam, 2nd interview). One of the possible reasons for Liam's shock is that he hadn't really considered what the transition would involve, expecting his studies to be a continuation of GCSE, but with a more tightly focused range of subjects. Another student who admits coasting through her GCSEs and found the jump significant in comparison was Erin. She readily admits here that she expected no change from her previous approach to learning:

I didn't really do any work at home when I did my GCSEs. I was one of those kids who thought yeah I can do this and I don't need to do anything [...] I thought it would be the same this year but... [laughs] ...it's really not. (Erin, 1st interview)

This realisation dawned quite early on in the year and came as quite a surprise to Erin, who, like Liam, expected that she would be able to continue to rely on natural intelligence to see her through. The notion that things would not change may explain why they both found the transition such a shock.

Ivy also started her A levels expecting to change little in terms of her approach. Two months into Year 12 she felt that she had little reason to alter this opinion:

I think it's quite similar to be honest [...] it's pretty much the same way that we did it and it's similar the way we are doing it this year. So in all subjects it's just pretty much similar. (Ivy, 1st interview)

However, further probing during this first interview uncovered a flaw in Ivy's perception that work was no more difficult when she was asked to explain a concept that she felt she had confidently learnt. She chose to explain the difference between validity and reliability:

[long pause] reliability would be, like, if it can be repeated so, like, if you gave your research to somebody else would they be able to repeat it and err...get the same results...I think...and validity would be...I can't remember. (Ivy, 1st interview)

It was clear at the time of this exchange that Ivy did not fully appreciate that she needed to change her approach to her A level studies and when the application of her knowledge was tested in earnest in the mock examinations, she realised how she had underestimated the jump to A level.

When we got to the exams I sort of...I did realise that it was really hard, definitely, much harder than I first thought. And obviously...my grades reflected that [...] It was not a very nice feeling when you open the paper and realise you can't do the first question, [I felt] quite panicky really (Ivy, 2nd interview)

As a result of her examination performance, Ivy changed her career aims and, whilst she did continue with her studies, she dropped biology as she had come to realise that it was much harder than she initially thought.

Other students were quicker to appreciate that a more independent approach was required for A level study if they were going to survive the experience:

At GCSE it's given to you...things are handed to you on a plate..."you need this to do this", whereas at A level [...] it's down to you, you've got the pressure on you a lot more...to go away and find out bits if you don't understand it. It's about you working out bits that you don't get, to then research and find out why. (Anna, 2nd interview)

Anna realised early on that she would have to change the way she worked, taking a much more independent approach to solving her own problems with learning. In her final sentence she refers not only to identifying 'bits that you don't get' but goes on to suggest that A levels required her to explore why she didn't get them. Her resilient and pragmatic approach enabled Anna to come to terms with these changes and whilst she identified the need to adapt her way of working quite early on, other students took considerably longer to fully appreciate the step up. For

most, it was not until they first tried to apply their knowledge in examinations that realisation really hit home.

Two other students who were shocked by their skewed perception of what was to come at A level were Gemma and Yasmin, but to some extent this was as a result of having joined from other schools. Gemma expected to find things easier having come from a grammar school and in recounting her thoughts appears to suggest that she expected to be top of the class due to her grammar school education.

It sounds awful but I thought because I came from a grammar school I would understand things easier than other people but now I realise that everyone is just as...like everyone knows just as much as me [...] in biology...I don't know...I am not like the highest of the class or anything like that. (Gemma, 1st interview)

However, she came to realise early in the year that she was actually on a level playing field, and that others were even finding the work easier. She appeared to be struggling to come to terms with this and there was a sense in talking to her that she was questioning her identity and status within this new community of practice, which was new both from an institutional perspective as well as that of domain-specific, advanced level study. In a similar way to Gemma, Yasmin was also surprised by just how difficult she found the transition. Whilst she did not attend a grammar school, she was the highest achiever in Year 11 at her previous school and was accustomed to finding learning straightforward.

I got 8 A*s and a B at GCSE [...] I thought I would just go through this quite easily and come out with some A's because of my GCSEs, but I didn't. And I am not used to...I don't want to sound arrogant or anything...but I'm not used to not understanding it. So when I got the point where I wasn't understanding it I just panicked and shut it off and I left that bit and tried to do something else. But then when it got to doing things in detail I couldn't understand anything, I was just panicking about it (Yasmin, 2nd interview)

This statement clearly shows the struggle that Yasmin went through in coming to terms with the feeling of not understanding her work at A level and she conveyed a sense of losing control and shutting down upon encountering this unfamiliar situation. The panic she referred to was also palpable when talking to her and had clearly caused her to question her own ability and preconceptions of A level study.

4.1.3 Increased workload and pace

This section now explores a significant component theme to emerge from the student interviews and which appeared to be one of the main causal factors for the troublesome nature of their experiences: that of increased workload and pace. Despite studying fewer subjects at A level, the workload greatly increased for all of the students, which Anna attempted to quantify at the culmination of the first year of study:

So GCSE is like a quarter of the size, well that's how it feels anyway, the amount that you cover feels like a quarter of what you cover at A level, and then when you get this huge bombard of a load of work and you are like...oh!...I have got all of this to learn and it becomes, like, a struggle trying to cope with the amount of things you've got to try and remember (Anna, 3rd interview)

The 'struggle' to cope with the sudden increase in quantity was a common theme across all of the interviews, and for some students added another layer of challenge to increasingly difficult level of work:

It's not the work is erm difficult most of the time, it's just...if I had more time, I could get it done, it's not that the work is too hard and I don't understand it it's just that I don't have enough time to do all of it. (Yasmin, 2nd interview)

I think it's more...the amount we get given, especially in biology. biology is not only the difficulty of work is going up but there's a lot more of it and there's a lot more to remember. (Anna, 1st interview)

Yasmin and Anna's accounts are representative of the general feeling of all of the students, for whom the increased workload presented significant issues, one of which being the ability to retain the huge volume of information coming at them:

it's like as soon as one thing goes in one thing goes back out again and then you have to learn it...you just have a constant cycle of learning and trying to keep it all until the end of the year. (Liam, 1st interview)

This notion of a cyclical approach to learning, forgetting and relearning certainly appeared to be troublesome for the students, and there is a sense of having insufficient time to get to grips with new information before it is time to move on. Anna talked of struggling to 'keep it in your head for long enough' (Anna, 3rd interview), linking workload with the relentless pace that other students reported as, result from significant amount of work being covered in the year.

Err, at GCSE I just did my work at school in lunch or breaks, I didn't really do much at home but now I have to go home and like, literally work until about half past nine at night and do a bit of every subject. Because it's really detailed. (Yasmin, 1st interview)

This combination of workload and pace had a profound effect on the participants and suggests another link to the affective dimension of threshold concepts, demonstrated through some of the strong, emotive language used:

Well...on a Monday when I have a full day it gets quite daunting. By period 5, I sort of want to cry a little bit...it's a bit stressful. (Liam, 1st interview)

I would come to school on a Monday, and I would do a couple of hours of biology, then physics, chemistry, physics, then go straight to piano and do a 45-minute piano lesson. And then just go home and just...die [laughs]. This is why I am so full of stress and anxiety basically [...] The level of stress that you're under, the amount of work [...] as soon as you start your A levels it's like...slam! Do these exam questions, do this, read this, copy that, and I was like, 'no!...I have a job actually, and a hobby and...other stuff...' (Erin, 2nd interview)

The way that Erin explained the link between workload and pace highlighted both the emotional impact on her and the potential for transformation in her personal and social identity. She spoke quickly and forcefully in the interview, describing the stress and, towards the end of this extract, a sense of loss around the other parts of her life that were starting to take a backseat. The sudden and sustained increase in workload and pace triggered a number of affective responses, notably as a result of increased stress and pressure, which is explored further in the next section.

4.1.4 Pressure, intensity and stress

The intensity of feelings caused students to feel out of their depth, offering further evidence to support the existence of a strong affective dimension around encounters with TCs. What is certainly apparent from the accounts of these six students is that the transition from GCSE to A level presents both cognitive and emotional issues, further strengthening the assertion that this particular educational transition was a major life experience for them, resulting in high levels of stress and anxiety, as Anna highlights in her recollection of the impact that stress had on her self-efficacy.

When I get stressed I get really stressed and...that's why I have to keep on top of my work, because when I stress I don't do, like, any work because I am so stressed with thinking about all of the things I have got to do I don't actually get anything done [...] To be honest I get more stressed about being stressed [laughs]...than anything else. (Anna, 3rd interview)

The pressure that students reported also arose from the fear of failure, and Liam became quite emotional in relaying his account, particularly in the faltering final sentence as he relayed the overwhelming feeling of this pressure.

It's such a lot to take in, it can certainly get in your head and...put you down pretty quickly, when you start thinking too much about it. There is a lot of pressure...on you cos it's your future...it's just quite overwhelming really and you just want to ...well you have to do well...or...it's...you know...all hanging on it to be honest... (Liam, 2nd interview)

Grappling with troublesome knowledge also caused issues for students throughout the year, resulting in frustration and significant emotional impact.

I was getting frustrated with myself because [at GCSE] I would always understand it, or if I didn't understand it I would be able to go home and understand it and do it that way, whereas now [...] I am trying my best and I am trying to understand it and it just doesn't go in...which...really frustrates me...it really stresses me out. (Anna, 1st interview)

Table 8 illustrates range of emotionally affective terms used by students throughout this research.

Yasmin		Anna	Erin	Gemma	Liam
amazed	shock	angry	I am horrible	annoyed	Panic
angry	silly	annoyed	went mental	disappointed	shock
annoyed	self-esteem	aspiration	excitement	enjoyment	struggle
arrogant	struggling	bombarded	amazement	frustration	overwhelming
commitment	stunned	challenged	anger	nervous	baffled
confidence	surprise	confidence	anxiety	pressure	confusion
determination	trepidation	confused	feeling cheated	self-efficacy	confidence
dread	trust	coping	confidence	Stressed	disappointment
empathy	uncertainty	disappointment	coping	confusing	scared
frustration	upset	emotional	depression	Not happy	surprise
getting upset		frustrated	disappointed	self-efficacy	enjoyment
guilt		grown up	drained	uncomfortable	flustered
hated doing it	Ivy	head fuzzled	feeling clever	undecided	Frustration
self-esteem	anxious	leap of faith	frustration	Frustration	Intensity
inferior	can't do it	maturing	highly strung	regret	lack of control
intolerant	heart not in it	motivation	isolation	Stressful	nervous
irate	Intimidated	panic	just die	Unsure	Reflection
self-confidence	matured	upset	lost	wishing	
low self-esteem	not a nice feeling	pressure	overconfidence		
optimistic	out of depth	realisation	panic		
panic	panic	resilience	pressure		
pressure	relief	self esteem	self-confidence		
relief	worried	stressed	stress		
scary		struggling	terrified		

Table 8 - The affective dimension of participants' lived experiences

The emotional impact of the stress caused by cognitive challenge and increased workload caused many issues for students, and the response to getting stressed was a new experience for some, which exacerbated the emotional impact. Getting used to these changes and feelings took time for many, as they sought to acclimatise. The next section explores this process further.

4.2 Acclimatisation

Having illuminated the perceived jump from GCSE to A level and the increase in difficulty, workload and stress that this brought with it, this second category theme explores how the participants in this study reported coming to terms with the transition, and how they experienced the setbacks and success of that journey. Links are made with the TC literature, particularly in relation to the transformative and affective nature of acclimatising to A level study.

4.2.1 Adapting and adjusting

It was quite clear from the interviews that all of the students found the increase in difficulty and workload a shock, and coming to terms with this was the first step they needed to take in order to start the process of acclimatising and adapting to new ways of working.

Adapting to it was really slow at first, cos I was just quite panicked and worried and I wasn't getting everything straight away and I was shocked at how hard it was so I was just sort of stunned so I didn't really do much (Yasmin, 2nd interview)

Adapting was slow for Yasmin, whose account here is representative of the group with regard to the emotional impact caused by the shock of the difficulty of work. However, whilst the shock was difficult to cope with at the start, each of the students found ways of adapting and coping over time, most coming to the realisation that they would need to be more active learners, changing their previous work ethic of passivity and reliance on the teacher.

At GCSE you got spoon-fed a little bit because most people wouldn't go home and do it themselves, but like now they expect you to do your own independent research and homework [...] I think it's more just getting used to the type of studying it is. (Yasmin, 1st interview)

Even at this early stage in the year, Yasmin had realised that she would need to change her approach and addressed this quite early on. However, others took longer to acclimatise, needing time to adapt and appreciate the need for change.

Well, at the start I found it really quite difficult to cope with...the amount of work, the... difficulty of the work. But as I have gone on, I don't really know why but I have got into that mind frame of...right, okay, if I don't get it I need to do something about it, I can't just wait until next lesson, I need to go and check what I am doing (Anna, 2nd interview)

This gradual acclimatisation resonates with the notion of a messy liminal journey referred to in the TC literature, where students do not suddenly 'get it', but rather adapt at their own pace, even at times slipping back to old ways of working, whilst trying to come to terms with the significant changes they are experiencing. The affective domain is also prominent again throughout students' accounts of their experience, highlighting a range of emotions.

But I have been in loads of stages, like I have been going...frustration mainly...then I have been getting angry with myself for not understanding...but then I have been thinking maybe it's not me, maybe it's just I don't get it and I just need to look over it and see if I can get it again and then...if I don't get it again then I get upset or whatever...but loads of different...different emotions at different times (Anna, 2nd interview)

Anna explains how she has been questioning herself throughout the year, getting angry and frustrated, but there were signs in this interview that she had started to find ways of adapting and acclimatising, by becoming more resilient in her approach to dealing with setbacks. The strength of emotions students recalled feeling again resonate with the affective dimension, which comes through from all of the students' accounts whilst they were trying to acclimatise to the transition to A levels.

Well I am ridiculously high maintenance so just stress and...anger. I just get mad and walk away. [Anger towards yourself?] Yeah, everything, honestly I am horrible. I just get really angry. (Erin, 1st interview)

But...feelings...I have gone through loads of...pfff...like the other week when I had so much work...when I get frustrated it comes out as me being upset...and so I just get really emotional that I am not doing things and...that just makes you not do it even more. (Anna, 2nd interview)

As students started to acclimatise, they reported a change in their approach to difficulty with learning, suggesting that a transformation had taken place for them in terms of their own outlook to coping with troublesome knowledge and higher levels of workload:

I am much better this year, because last year I was just panicking that it was hard and getting upset about stuff. But now I know what I have got to do I am trying from the start to do better. I have adjusted to knowing that it will be harder but also what I need to do to cope with it. And because I know the depth that I have to go into I am better prepared for it. (Yasmin, 3rd interview)

This signals another link with the TC literature, that of a transformative element to the transitional journey. Whilst finding ways of coping was personal to each individual, one of the common changes students reported was in managing their time and personal organisation, even early in the year.

It's just like trying to get that effort into going home and doing it as well which I struggled with initially I kind of struggled with getting the enthusiasm to go home and think I've got to get this work done. And I need to get it done and learnt. (Liam, 1st interview)

Although Liam recalled 'struggling' with motivating himself to work at home, he also recognised the need for resilience. For those students who stuck at it and adopted this pragmatic mindset, the personal transformation achieved through navigating the troublesome and affective liminal journey of transition resulted in transformed self-efficacy and self-esteem:

The amount of work makes you feel...challenged...but it's sort of scary because you think how am I going to learn all of this and if I don't I am not going to do very well and I will fail. But you get through it because you don't have a choice. And I know now, at the end of this year, that I can pretty much get through anything. (Anna, 3rd interview)

However, to arrive at this point required exposure to very difficult experiences for students, which resulted in their self-esteem and identity being questioned.

4.2.2 Questioning self

As the previous component theme highlighted, self-critique was a common affective feature of students' reflections on their journey, and all reported questioning their ability or suitability for A level study at some point. Even for

Yasmin, who excelled in her GCSEs, the transition was much harder than she thought it would be.

It feels like I've just been fooling myself a little bit and...sometimes when it's going well it's okay but it makes you feel like I don't know if I should be doing this anymore, like I have put too much on myself. (Yasmin, 1st interview)

I was just shocked at first and thought I should understand it because I never really experienced that at GCSE [...] I thought I was just being an idiot and I shouldn't be on the course... (Yasmin, 3rd interview)

This feeling of isolation and self-doubt seemed to be common across all students, resulting in the questioning of self-efficacy resulting in reduced self-esteem early in the year.

At the start of the year I thought I was the only one going through it and not understanding things. And I thought that I was being really thick. (Anna, 3rd interview)

I get...annoyed with myself because I want...I really want to do well but...I don't know...I just...disappointed really...sometimes I think I have done okay but when I get the results back it's like...I haven't.... (Gemma, 1st interview)

The hesitant way that Gemma reflected on her first few months of A levels emphasised the disappointment and frustration typical of all the students in the group. Whilst most of them did come to terms with the increase in difficulty and learned to adapt, the messy nature of the journey through liminal space kept their confidence in a state of flux as they could sense further conflict around the corner, as this extract exemplifies:

I think I am doing okay at the minute but over time there's going to be more and more and more and whether my memory is going to get mixed up and I am going to get kind of head fuzzled about everything... (Anna, 2nd interview)

For others, such as Ivy, the feeling of self-doubt hardly relented once realisation had set in. She continued to question herself even towards the end of the year, doubting her capacity to continue into the second year of study.

I don't think I realised, like...everybody said how hard biology was but I don't think I realised until I was actually doing it, how difficult it actually is. And I think, at A2 it's just going to be worse...and I just don't feel like I can...I can do it (Ivy, 2nd interview)

As this section has demonstrated, coming to terms with the difficulty of their experience and questioning their self-efficacy had significant emotional impact for the participants in this study, who reported strong feelings throughout the journey. The sense of dealing with problems in isolation may have contributed to the intensity of these feelings, which Yasmin felt could have been avoided if she had been better prepared.

If someone had said this is normal and that would have been...cos I thought it was really abnormal and I should have just understood it, and I couldn't cope with but it wasn't...I was just shocked. (Yasmin, 3rd interview)

4.2.3 Experiencing success

Whilst students reported many learning barriers relating to troublesome knowledge and adapting to A level workload and pace, they also experienced success throughout the year. In much the same way as the barriers triggered affective responses, the successes also surfaced strong feelings and emotions and further links with the TC literature on liminality and the affective dimension emerged from this component theme. Understandably, experiencing success brought relief to students, particularly those who had questioned their ability to learn, as Yasmin demonstrates in this account of feeling able to move forward having grasped an aspect of troublesome knowledge:

Well I had this one question that I had been struggling on for six months and I always went back to doing it and I never got the answer at the back of the book and then one day I had been taught earlier and I went home and I saw that I had got it right and I was just really relieved and felt I could go on now. (Yasmin, 2nd interview)

Illuminating students' experiences of success through adversity strikes a chord with the notion of oscillation through a messy journey towards mastery and here, Anna describes how she moved back and forth between feelings of certainty and uncertainty in her understanding.

I can't remember what it was, probably in GCSE when someone explained something to me and I have gone...oh yeah I get that...and then you try to do it and you're like...no...I'm not...I got it when they said it but I'm not actually understanding what they are doing. So then you have to ask again and you are like...no I am still not quite sure and it just takes a bit of time. So yeah I think you have

to go back and forth a bit to get where you want to go in like, the journey (Anna, 2nd interview)

Interestingly, Anna perceives that her experience differs from others, who she sees as having 'lightbulb moments' where they appear to suddenly grasp a concept. However, she also suggests here that when she finally feels that she has achieved understanding after navigating the troublesome journey that the knowledge is permanent, suggestive of the irreversible nature of a TC.

It's kind of gradual for me...I have never particularly had those sorts of moments, but I know there has been obviously people that do because they suddenly understand it and you're like...oh okay...but it always takes me a while just to get my head around it...but when I do understand it, it doesn't leave my head, it will stay in there. And as long as I keep...going back to it I can link bits together and different bits of modules I can say ooh that links to this... (Anna)

The final part of this account from Anna is indicative of the integrative characteristic of a TC, where she recalls going back to a concept and linking it with other aspects of knowledge. Her account is fascinating in surfacing the excitement she experienced as she recalled discovering that she can link concepts together as part of a fluctuating and messy journey.

4.3 Identity and communities

This category explores the themes that emerged from the interviews regarding students' growing awareness of changes to their identity, by which I mean how these individuals regard themselves subjectively in relation to contexts, for example within, or outside of, particular communities or groups. This definition draws from a sociocultural approach, concerned with students' experiences of being a learner and becoming a member of particular communities of practice, such as becoming a scientist.

4.3.1 Becoming an A level student

The transition from GCSE to A level brought with it many challenges for the students in this research, and led to some of them describing at the start of the year that they were shifting their identity, becoming part of a Sixth Form community. Within this community, the notion of disciplinary micro-communities of

practice emerged from discussions. This response from Liam, talking about the biology class, suggests a feeling of collaborative working:

We work quite well together as a group. We are quite a small class and we have to help each other out. I would like to say we are kind of doing the A levels as a team instead of just doing them yourself and then going home and doing it. I will kind of be at home and then be on the phone to my friend going how did you do this, oh I did it this way and then kind of working through it. (Liam, 2nd interview)

When asked about what makes such strong bonds between members of the biology group, students identified language as a key feature which defined the boundaries of membership and created a feeling of belonging that other students could not achieve:

Yeah, you couldn't talk to people not doing A level Biology. If you had a problem, you would just have to talk to the teacher or somebody else doing A level Biology. (Erin, 2nd interview)

Other people would start walking off because they didn't know what we were saying. It sort of makes you realise you are part of that group and you all have something in common that they don't have or...understand. (Liam, 1st interview)

This resonates with the discursive nature of TC acquisition and the development of transformed language use. Along with a shared disciplinary focus, this certainly appeared to define the community, rather than social bonding, which was an issue for some students, as these two extracts suggest:

I am not really too close to the people...my friends they don't do it and I am not really close to them in my class and I feel like...sometimes I hear them saying wrong stuff and I want to chip in but...I feel like they will think I am condescending so I just don't. I prefer to work on my own anyway (Yasmin, 1st interview)

I think it got a little bit easier as the year went on, and I felt a little more confident but still a little bit out of my depth because there are people in the group who are quite intimidating because they seem to know everything and get it really easily (Ivy, 3rd interview)

The feeling of isolation was a common phenomenon across all the interviewees, albeit for different reasons. A strong affective dimension to this social aspect of community membership brought with it many strong emotions. As well as internal isolation, some students reported becoming more isolated from others outside this community of practice. Here, Erin provides a neat summary of her experience of talking to her friend about biological processes.

For her it was really just like a foreign language where you know some of the words but a lot of them just mean absolutely nothing [laughs]. And it makes you feel really...clever I guess 'cause you understand it and they don't. But then it can be a bit isolated when you need to talk to someone about it. (Erin, 2nd interview)

She alludes to a feeling of superiority and satisfaction at realising she has knowledge that others do not possess, but then in the same paragraph reports how isolating this can be, limiting the social network available to her and reducing her support network. In this context, membership of a community of practice can both empower but also alienate from others who are not part of that community of practice.

4.3.2 Becoming a scientist

At the start of the year, students struggled to come to terms with the transition to A levels, but later in the year, it was apparent that they were not only adapting to the change but were starting to look ahead, considering their futures and the transition to university and careers. When asked specifically about how far along they saw themselves in this journey, it began to emerge that there were clear links with the literature on communities of practice and, specifically, becoming a scientist.

It is starting to come together. Now my brain is kind of catching up with it all everything is becoming easier to understand, so I could see myself becoming a scientist really. (Liam, 1st interview)

For some students, like Liam, the prospect of evolving into this new identity was a clear possibility. However, for others, even at the end of the year, the thought of specialisation was a step too far at that stage, as Anna explained:

I still see myself as a student. I don't think I will ever see myself as anything else until I have got to that level of 'now I am a teacher' or 'now I am in a job'. Like, I want to do maths but I don't see myself as a mathematician because I studying more than one subject. I think maybe when I get to degree I might start to see myself as something in particular. (Anna, 3rd interview)

Anna offered the breadth of subjects being studied as one factor why seeing herself as 'becoming a scientist' was not really feasible. However, some students in the group were following a programme of study made up almost entirely of sciences. Yasmin's response to rating her progress towards becoming a scientist (out of ten) highlighted the perceived distance from this goal:

Right now I feel about a 4, but when I have finished my A levels maybe I would be a lot closer...about 8...I would just feel a lot closer to it, but it seems like...all this work, it just makes it seem like really far away and like it's never going to happen. (Yasmin, 1st interview)

However, despite a feeling from the group that they were a long way from entering a scientific community of practice, there was a distinct feeling that they were starting to think like scientists.

And sometimes I will look at trees and think...I know how you work and especially when I was learning human biology and I couldn't get over the fact that it was going on while I was reading it. It's like, I was reading about it and it's happening right now [in my body]. It terrifies me, but in a good way. (Erin, 2nd interview)

This transformed way of thinking also started to affect the students' self-esteem and confidence that they would eventually be able to achieve their goals and move on to university or careers in their chosen fields, as typified by Anna's response:

I was watching the telly the other day and something came on some programme and it was about biology...something about myoglobin ...and I just thought...I know about that...and I'm like...but they are doing degree, and it just gives you that...buzz of...oh, I know that and that's a lot harder than my level so maybe I am good enough to do that. (Anna, 2nd interview)

4.3.3 Transformed identity

Along with the notion of entering and transitioning between communities of practice, it also emerged from the interviews that students had developed skills and ways of thinking and practising that had instigated a perceived transformation in their identity, such as becoming a scientist and starting to think like a scientist.

A scientist is someone who is always looking always looking for something new, they are trying to find something that has never been found before and I am starting to develop certain things that have changed the way I look at things, like...ways of thinking (Liam, 3rd interview)

Liam's experience was not unique in the group, and other students also highlighted changes in ways of thinking and practising, but whilst for some this was described as a positive outcome, for others it brought about changes which were not necessarily welcome.

I think my way of thinking has changed...a lot [...] I haven't written an essay for about a year now and I feel like I have lost like...I went to write a letter the other day and I didn't know where to start...and I forget how to spell words and stuff, so I have sort of lost that skill (Yasmin, 2nd interview)

Yasmin's reflections on her first year of A levels conveyed a distinct sense of loss and this was a common theme for others in the group also. The focus on science-specific skills led to Yasmin perceiving that other skills and knowledge had begun to degenerate, leading to a transformation in her way of thinking. It was clear from talking with her that she felt quite uncomfortable about the changes she had experienced, and here she relates the group's use of more specific terminology to her increasing intolerance for waffle and imprecision:

It's made my attitude just...I don't know...not pleasant sometimes...because it...I don't know...I am not used to...[pause]...everyone in the class really is quite specific now...so...I am a bit intolerant to just waffling and using stuff in the wrong way. (Yasmin, 2nd interview)

Both accounts from Yasmin are indicative of transformed identity, accompanied by a strong affective dimension and she is not alone in this experience. Erin emerged from the first year of A level study as a different person, from her perspective. She recalls a feeling of anticipation and excitement prior to starting her studies but ultimately felt drained by the experience.

This time last year I would have been quite excited about it, I was actually looking forward to the year ahead of me and that I had the opportunity to study science and now I am...drained and not...not the same person at all [...] I am definitely not the same person that I was...definitely not. And I don't know how much school contributed to that but...it's...yeah, it was definitely not...not good...at all (Erin, interview 2)

Although she cannot specifically pinpoint how much school contributed to her transformation, she was clear that she has changed significantly. She explained forcefully in this interview about her certainty of this change in her identity, with repeated use of the word 'definitely' conveying her perception of just how much impact the transition had on her as a person.

Another change to identity reported by students centred around feelings of growing up and maturing in different ways through having encountered the

challenges of transition. The need to adapt and take a more independent and proactive approach to dealing with the challenges encountered seemed to be the main driver for these transformations.

This year I have realised that doing A levels you have to do a lot of growing up [...] You change a lot as a person and become more mature because you just have to. If you don't...adapt, it's just not going to happen. (Liam, 2nd interview)

I do feel more mature after this last year. I feel like I have grown up a lot since GCSEs, a lot has changed since then, just the way I look at things, like...my mind-set on things...generally. (Ivy, 2nd interview)

Changing as a person generally emerged as a theme from the interviews conducted but students also explained how their way of thinking and viewing the world had developed. Despite the difficult journey, most of the students reported feeling more confident and more capable of dealing with difficult situations and encounters with troublesome knowledge, developing transformed skills and increased learning capacity, as demonstrated in this extract from Anna:

Yeah, I think I have grown up a lot since before...and because of the fact that I think I have grown up...I am getting to the stage where I can handle my work, I can understand things better and quicker than I would have been able to at the start of the year. (Anna, 3rd interview)

Chapter 5 – Findings: Threshold concepts, troublesome language and previous knowledge

5.1 Encounters with threshold concepts

This chapter continues the presentation of findings, exploring students' experiences of TCs, from their initial encounters with troublesome knowledge to more complex observations of how participants saw concepts interlinking and integrating across the subject. Students' experiences of troublesome language and the impact of previous knowledge are also presented as component themes. This chapter provides insight into how TCs are experienced in this local context for these students, and aims to illuminate all four research questions, whilst also presenting concepts identified by students as demonstrating features characteristic of a TC. The findings in this chapter support the argument that difficulties with transition are exacerbated by encounters with TCs.

5.1.1 Thresholds coming into view

The first component theme in this chapter emerged from students' experiences of their initial encounters with troublesome knowledge and uncovers the variation in how the notional 'portal' is initially perceived or apprehended. The following section explores participants' experiences of their encounters with TCs and the resultant affective impact, illuminating how they made sense of the difficulties they were experiencing.

For the students in this research, coping with the transition to A level study raised several issues, causing discomfort and surprise as they wrestled with adapting to new ways of working and increased demands, as noted in Chapter 4. The increase in difficulty of work also emerged as a major conceptual and affective hurdle for students.

I am trying my best and I am trying to understand it and it just doesn't go in...which...really frustrates me...it really stresses me out. (Anna, 1st interview)

Initial encounters with new conceptual knowledge in biology did cause problems for most of the students, and Liam exemplifies the feelings of confusion and dawning awareness that the work had stepped up in difficulty:

It was hard when I first tried explaining gaseous exchange, I kind of ended up talking gibberish (Liam, 1st interview)

Well, nucleophilic substitution, I got that down okay in the exam, but we learnt another mechanism...electrophilic addition...that wasn't fun! That was hard...yeah...there was all sorts going on. (Liam, 1st interview)

Liam described this particular concept as being uncomfortable for him, and in discussion there was a sense of him feeling out of his depth and overloaded from "all sorts going on". Each of the six participants relayed similar examples of topics and concepts and knowledge that they had found difficult to grasp, for different reasons. In this example, Erin related to a way of working that was counterintuitive for her, that she recalls as presenting conflict:

Well you sort of look at a picture of the heart and, if you are looking at a piece of paper and you have a picture of the heart...on the left hand side of the paper will be the right ventricle and the right atrium. So that immediately is like...no...my brain goes no! [laughs]. The teacher is saying you label it as if it's like your own body...I'm thinking...I can't compute that at all. (Erin, 1st interview)

This observation is particularly interesting as it was relayed at a point in time where Erin's encounter with this learning episode was fresh in her mind. Capturing experiences in this way also uncovered dynamic instances of students struggling to come to terms with particular knowledge, evidenced by their difficulty in explaining the concept itself when asked to describe examples of troublesome knowledge.

It is something that we have done really recently but I can't remember what it's called...it's about the movement of sucrose in the phloem of plants...about how sucrose moves in and out of the phloem at a source and a sink. That's pretty confusing because there's lots of things about active transport and that brings in things we learned about cells so there's a connection...erm...but basically it's...I don't know (Erin, 1st interview)

These snapshots provide an insight into students' experiences as they sought to acquire troublesome knowledge, highlighting the fluid and messy nature of concept acquisition.

Throughout the interviews, the difficulties caused by the sheer volume of knowledge encountered at such an early stage in the year was often compounded by the 'alien' terminology, which students reported feeling bombarded with. The following account from Erin shows this clearly, giving a sense of her struggle to cope with the sudden appearance of so many complicated and previously unknown scientific terms, which linked to her previous knowledge at GCSE, but built on the layers of complexity.

If you look at a diagram of a cell at GCSE work it will be like you've got the nucleus, the cytoplasm, the plasma membrane round the outside, but then at A level, suddenly there's lysosomes and vesicles and the Golgi apparatus in cells and stuff like that...and then you've got smooth endoplasmic reticulum, rough endoplasmic reticulum and you're supposed to know all their functions and how they work together and about the centrioles and the...like, cytoskeleton and...everything about this cell and you're just like...oh...okay then...err...[laughs] (Erin, 1st interview)

When talking to Erin at the time of this interview, she was somewhat overwhelmed by her early encounters with new conceptual knowledge in biology, which was troublesome for her largely due to the volume and complexity of such a range of key terms and how each of these interrelate with each other. The integrative nature of links between aspects of knowledge within and across disciplinary boundaries thus started to become apparent and this is explored as a separate component theme in the next section.

5.1.2 Integrative awakenings

The interviews with students uncovered interesting insights into the relationships between concepts and how students made sense of them. The following extract from a discussion with Yasmin, looking back over Year 12, suggests that understanding cell structure and function was a central concept in biology that was of particular significance to her:

The cells and things like...the cell membranes...everything can relate back to cell structure, in fact everything does. So a lot of stuff in cell membranes was really important because even now when we learn new things you have to learn about stuff going over membranes and you have to use all of that. (Yasmin, 3rd interview)

This account presents the importance of cell structure in empowering Yasmin to learn other aspects of biology and this feeling was shared by the other students,

who also highlighted cells as being central to their understanding of a range of other topics. There was also some evidence of the integrative nature of cross-disciplinary concepts, particularly with chemistry. Those students who studied chemistry alongside biology reported finding these specific concepts as playing a key role in helping them to make sense of new biological knowledge.

The cohesion tension theory is about like...you have got massive trees in the rainforest...how does the water get to the leaves? Obviously you have got root pressure, so when the water goes from the root hair cells into the stem that can push the water up the stem but only a couple of metres...so that might be fine for like a sunflower, but it's about how does it get that far in a huge tree. And that again is to do with the bonds between water molecules. Knowing that about water from chemistry helps to apply that. (Erin, 1st interview)

Erin recognised here just how important an understanding of chemical bonds was to allow her to more easily grasp the concept of cohesion tension theory. She was keen to explain this particular example and explain how she had come to realise the importance of the integration of knowledge across subject divides. For those who did not study chemistry as well as biology, this awareness was not evident in the interviews, but those who did study both subjects were able to explain how that integrative prior knowledge had allowed them to generate a deeper understanding, rather than just accepting it at face value:

We did stuff in chemistry about hydrogen bonding and when we were looking at the protein structures and there were hydrogen structures in them and stuff no-one else seemed to know it and they just seemed to accept it was there, but because I actually knew why they did it, it made more sense to me and I was relieved that I knew it otherwise I would have struggled. (Yasmin, 1st interview)

One of the tensions to emerge from the discussions was that between viewing concepts in biology as a series of linear, or hierarchical 'building blocks' versus a messier, interconnected network. The following explanation from Yasmin illustrates how she perceives the concepts to act in an integrative way:

I think it would be more of a web because it doesn't build on each other exactly but there is overlap in some areas. More than one thing will help you understand...like quite a few of the concepts will help you understand another one. They are interlinked but it's not like one thing helps you with that, which helps you with that. It's more like two

or three concepts help you with one hard topic and they overlap
(Yasmin, 3rd interview)

Yasmin explained her rationalisation of the 'web' description by interlinking her fingers whilst talking, illustrating how more than one concept link together. She further explained that, for her, there was no logical progression as such and that these links 'suddenly appeared' (Yasmin, 3rd interview). This view of concepts in biology as an integrative web was shared by others in the group, and Anna described the relationships between them in a very interesting way.

So I guess it's more messy like a load of things all stirred up together. But I think that's just the nature of this course, having like the mess, the way everything links into each other I think that's just most sciences. But If it was maths, that is sort of a building blocks approach I would say. (Anna, 3rd interview)

Anna's visualisation of the relationships between concepts as messy conjures up images of a bowl of spaghetti, all stirred up and messy, with links being made which are hidden from view until they become uncovered by digging into them. She also referred to the integrative nature of this notional mess being specific to the sciences, with the concepts forming a web across, and within, scientific subjects.

Anna's experience of studying maths was very different from biology, appearing to her as more of a linear and logical progression through knowledge, each step building on the next in a logical sequence. Other students also showed growing metacognitive awareness, and Liam explained his own experience of coping with the integrative nature of concepts within biology.

It was almost like a three-dimensional jigsaw...I was just putting bits together and I just realised actually that bit can go there it goes better and I will move that bit somewhere else. It is all just like...one big jigsaw in my mind that I am putting together bit by bit and moving bits around to see where they fit. (Liam, 1st interview)

Liam's account is particularly enlightening, as he alludes to an initial mess, much like the web analogy, but explained how he could find order in the mess by moving concepts in his mind to make links within a three-dimensional jigsaw, thus suggesting a degree of control over the organisation of the web to suit his learning journey and previous knowledge schema.

5.2 Troublesome language

One of the consistent themes to emerge from the interviews and reflective diaries was that of difficulties with language in biology. This section explores students' engagement with troublesome language, initially highlighting their early encounters before moving on to specific themes which emerged from the data.

5.2.1 Language as a barrier

Language emerged as a significant cause of difficulty for the participants in this study, who all found the specific biology language to be a barrier to learning in a range of different ways, causing strong emotions in some students.

At the beginning of the year the big words scared me or put me off a bit because we weren't used to them...they [teachers] use quite complicated words and that scares me and I feel like I shouldn't be doing it because it's too hard. (Yasmin, 1st interview)

Yasmin's account of her early encounters with scientific language in biology were typical of the group, who all recalled feeling daunted by unfamiliar terminology at some point in the first few months. The resultant affective impact was significant and students reported feeling stressed and shocked by the volume of large words they needed to grapple with and remember. The following account from Anna exemplifies this:

There's bit in the transport systems of plants there's like the xylem and the phloem and the xylem is for the water and water soluble things and then the phloem is for your...err...your glucose, but it's sucrose and erm...it's learning things like that and it's learning the fact like...mass flow theorem for the phloem and the...I can't even remember the other one...err...cohesion tension theory for water. (Anna, 1st interview)

As she was talking, it was clear that Anna had struggled with remembering all the key terms in this topic, but she also conveyed a sense that she was coming to terms with this and that she would be able to cope with it with enough time.

Part of the issue with acclimatising to a new vocabulary at A level was the difference in detail when compared to GCSE. Gemma explained this but also acknowledged how important it is to develop a deeper knowledge of definitions is at A level compared to GCSE.

Erm...there's a lot more words to learn and, yeah, they are more difficult and you have got to learn them all in detail and the definitions and stuff...cos you can't just make up like...in GCSE you could...it was more common sense, you could make the answer up but at A level you have to get it like...all the words right otherwise you won't get the marks (Gemma, 1st interview)

Gemma alluded to having been able to 'make the answer up' at GCSE, implying that a general prosaic approach would suffice. However, at A level, all students realised that they needed to know and understand the specific language, no matter how difficult it was to learn. Anna explained her approach to dealing with this, and the implications for her time management.

The description used words that I didn't know what they meant so I was then having to go to the back of the book to find those descriptions to go back and carry on reading that and to kind of like fill in the bits that I don't know. I have also found words that I have looked up but still don't know what they mean. (Anna, 1st interview)

Making the time to research words whilst learning was a skill that most of the students learned to develop. Another barrier that they had to contend with and which came across strongly in their early encounters with troublesome language was that of the close similarity of many related words, which caused confusion and difficulty.

When you do about the pancreas and you learn about...erm...glycogenolysis...glycolysis... glycogenesis ...gluconeogenesis, and all of these different things and you have got to know each of the different ones, what all of them do, not get them confused, know how to spell them all. And it just...they are all so similar, you have no idea what is going on in your head [laughs]. (Anna, 1st interview)

The resemblance of these words made it particularly difficult for students to remember and Anna recalled here feeling confused and overwhelmed by the task of remembering them. However, these words were made even more troublesome for students due to their unfamiliar nature, seemingly incoherent to the participants upon first encounter, and the next section explores this in more detail.

5.2.2 Alien language and 'ridiculous' words

For all the participants in this study, initial encounters with biological discipline-specific language were rendered particularly troublesome by words which seemed

far removed from students' own previous knowledge and therefore presented as incoherent to them, conveying a sense of remoteness between previously established vocabulary and the new biological language.

I had to learn how to spell a lot of ridiculous words. I have always been quite good at spelling because I am quite articulate but...I don't know...things like haemoglobin, which is 'h, a, e, m', which is just a bit unexpected. (Erin, 1st interview)

What we are doing at the minute is the Bohr Shift and there's quite a lot of carbamino hemoglobin and things like that...that are quite difficult to get your head around, 'cause they are just so different and so long. (Ivy, 1st interview)

These accounts convey just how challenging some of the terminology was for the students to 'get their heads around'. As Ivy pointed out, the length and unusual nature of the words present the main barrier, whilst Yasmin suggested that the actual concepts themselves are nothing too challenging once you can get past the initial shock of the language:

Err well, when we did erm biochemistry, words like oxyhaemoglobin and stuff came up and it's only like, it's nothing complicated, the idea, but it's this massive long word... (Yasmin, 1st interview)

As well as the length of the words, and unusual spellings, students also reported feeling that some of the terms presented in a similar way to learning a foreign language, in that they were so unfamiliar and alien, difficult to spell and remember, but what made them troublesome for Liam was that some were difficult to articulate as well:

Well I guess there were a few words that didn't really seem English like Phylogeny and Phylogenetic. They are difficult to pronounce and they are the ones that are really hard to learn. (Liam, 3rd interview)

Discussions suggest that disciplinary language in biology acts as troublesome knowledge in that it provides barriers to understanding of topics which may otherwise be less difficult for students. In the early stages of their A level studies, it took a while for students to become accustomed to troublesome language, but once they did, some even began to embrace the complexity of the words:

Yeah...yeah and like atrioventricular and stuff like that, you can shorten that to AV valve if you want but I don't, it's crazy but quite...cool at the same time...to know them and what they mean. (Erin, 1st interview)

Erin showed throughout the interviews that she is in awe of scientific knowledge and was highly motivated to find ways to learn it no matter how difficult. In contrast, Anna took a more pragmatic approach:

And you have got to try to do it from the structure of the word. So like...glycogenesis...genesis is creation, glyco is glycogen, therefore...creation of glycogen. You've got to try and work it out by the word. So if you don't understand what they are by just remembering it you can kind of get it by working out by what the word is saying (Anna, 3rd interview)

Whilst discussions with all of the students suggest that troublesome language was a significant issue for them early on in the year and a barrier to learning, over time they found ways to adapt and ultimately recognised just how important these words are to communication within the subject.

If you do about oxygen disassociation and how carbon dioxide affects the blood, there's words like carbaminohaemoglobin...when you have to speak about affinity for oxygen you can't exactly define that word itself so you just have to use it and there is no other way of saying it apart from that...I couldn't explain quickly and easily to you what that meant but I could use it to answer a question. (Erin, 1st interview)

Erin showed her awareness of the need to use specific key terms and could recognise their importance as there is no substitute, but was also frustrated by the length and complexity of them. Liam rationalised this by viewing specific language and key terms as objects:

At GCSE if you didn't know the key term you could explain what it was but in A level it kind of seems you can't explain the key terms because they are something to do with it. They are more of an object rather than a way of describing something (Liam, 1st interview)

In offering this perspective, Liam suggests that he has raised the status of specific terms and their importance to him in succeeding at A level. Over time, most students found that once they accepted the difficult aspects of language in biology they were able to cope more easily with its troublesome nature and came to realise that the best way to survive was to embrace it, and to acclimatise through immersion in the subject language.

I've been like walking round in my lessons randomly blurting out words like carbaminohaemoglobin (Liam, 1st interview)

I just thought if I use them enough and read enough and listen to the teacher saying them enough then I will gradually pick it up [...] I have heard the words so many times now that it's second nature to talk about them and use them and they don't seem very scary anymore. (Yasmin, 2nd interview)

As the year progressed it appeared that students were becoming accustomed to encounters with incoherent and alien words, particularly once they accepted that there are no shortcuts. Further through the year, however, once they started to apply their knowledge and understanding through exam questions they soon began to see the need for specific terms.

5.2.3 Specificity, precision and keywords

One of the most common themes to emerge from the data was the challenge for students of using biological language in a correct and precise way when applying their knowledge and understanding. This was particularly apparent with regard to answering examination questions and aligning their responses with the requirements of examiners' mark schemes.

There's like...specific words to get the marks and if you don't get them in then you won't get the marks, so they form the basis for all the answers (Ivy, 2nd interview)

It took time for students to adapt to this new way of working, despite acknowledging the importance of key words compared to the approaches they would have used at GCSE where less specific language was acceptable, as Yasmin explained:

At GCSE it was very predictable, you'd just do a few past papers and you would know exactly what you were getting marks for. I learnt pretty quickly that I had to become more analytical and start applying things a lot more [...] I didn't find the theory hard, it was just applying it that I found hard. (Yasmin, 3rd interview)

The need for specificity in responses added an extra dimension of difficulty for students and the first attempts at examination questions came at a time in the year when they were only just starting to acclimatise to the troublesome language. This added to the affective dimension of their experiences, causing surprise and the realisation that they would have to adapt their approach to studying.

And then biology was probably the biggest shock for me [sigh]... instead of the rough endoplasmic reticulum processing and

synthesising protein, I would say it would adapt the protein...I would use less specific keywords and that is where I would lose my marks...it still makes sense to explain it but...the exam mark schemes they...they are very specific on the keywords you have to use (Liam, 3rd interview)

The requirement to use precise keywords came across as a challenge for all the students in this study, but caused significant frustration for some more than others. Erin explained quite forcefully how things had changed for her:

You have to use the right word...you can't say, erm...water travels through a membrane by diffusion, you have to say osmosis, because that is the name for transport of water via diffusion. It's got its own scientific name so you have to use it. Otherwise you just don't get the marks. (Erin, 2nd interview)

Erin became quite agitated as she explained this, and had clearly felt the stress of adapting to a new way of working, as did others. Gemma became quite frustrated about her poor performance in practice questions:

I have tried really hard but I haven't really got the marks because I have not been putting in the keywords and things like that, or explaining it well enough. I try really hard but then I don't get all the marks and I do understand why but it's just hard to know exactly what to put and expand it more (Gemma, 1st interview)

Further prompting of students at interview indicated that students believed that the need to use precise and specific terminology was not enough to secure good performance in the exam questions. The need to have a deep and secure understanding of the detail of each term and concept was vital to be able to explain it and to use it in the right context, using the correct syntax, as a biologist.

Especially with biology as well...the language that you have to use...you have to speak in proper biologist terms otherwise you don't get the marks (Erin, 1st interview)

Over the year, as students acclimatised to troublesome language in biology and the need to gain a deeper understanding of their meaning and correct usage, they became more aware of changes in their own use of language. For some, the change was transformational, in respect of their use of language within the subject, but also outside of the classroom. Yasmin was particularly affected by this

transformation and could recall how much she had changed in terms of disciplinary language use in only six months:

Yeah...It's funny because I looked at one of my GCSE papers the other day that I just found and I just couldn't believe some of the things I was writing...how like just how much of a simpleton I sounded at some points [laughs]. At GCSE I was a bit, erm...fleeting over stuff I just used to talk. I didn't really...I could throw a few words about but I didn't know what they mean. But now it's a lot more specific. I don't say anything without meaning it, or just to waffle on. just...put the answers down for the marks and I use the words and I know what they mean. (Yasmin, 2nd interview)

Yasmin felt that her ability to answer questions had become more integrated into her way of thinking and practising, that she was able to use the words without forcing it, suggesting a changed use of language for her as a person. This assertion is further illuminated by Yasmin's thoughts on changes to her own use of language and how she had undergone a transformation in her daily language use.

Well, I use more scientific words now, but I am not as articulate anymore. I am more brief I think. There is no beating around the bush or flowery language, it is just straight to the point now [...] I think my scientific language is getting a lot better but then my language I am using every day is getting worse because I am not using it very much. (Yasmin, 3rd interview)

5.3 Previous knowledge

Whilst many of the terms and concepts covered in the year were new to students, a large proportion also built on their previous experience from GCSE and their wider life experience. Some of the most challenging and affective situations that students reported resulted from learning which challenged their previous understandings.

I always used mass and weight as the same thing really, I didn't know the difference between them. But then, they have been really specific with it at A level and you can't write mass and weight as the same thing. You had to know that weight was a force and mass was just a scalar quantity...but it just amazed me because I had just been using them for so long (Yasmin, 1st interview)

Yasmin's amazement at her previous use of scientific terms having been wrong was one of the first signs of this theme emerging, which led to further

investigations of exactly how students were experiencing the integration of their previous knowledge schema with more complex conceptual learning.

5.3.1 Simplified knowledge

One of the consistent themes to emerge regarding previous knowledge was students' realisation that their previous learning at GCSE level was presented as a simplified version which they now had to expand in terms of specifics at a granular level.

At GCSE it was just like, there's a xylem and a phloem in the stem...but there is vascular tissue and all sorts of other stuff as well which I found hard. GCSE is very simplified compared to A level.
(Liam, 1st interview)

In some cases, common sense observations and misconceptions from everyday life were challenged, as with this example from Erin:

If you think what a heart looks like, like a human heart, you've got the bits coming off it but it looks like two halves and that's where the stereotypical image of a heart comes from, it's two human hearts sewn together. That's just something that I assumed...and then you get told that you're wrong and you go...oh that's actually really clever. (Erin, 1st interview)

Erin was impressed by her new found understanding of the heart which challenged and expanded her own layman's understanding generated from everyday experience. However, for the most part, once students started to become aware that their previous learning at GCSE had been simplified, much stronger feelings began to emerge:

Erm, I was quite surprised by it, because at GCSE I didn't realise how much they simplified everything. Like in chemistry, at GCSE they taught us that in the electron configuration, you have 2 in the first shell, and 8 in the next. But when you get to A level it's not that at all and you just feel like you have been lied to. (Yasmin, 1st interview)

There was a real sense when talking to Yasmin about this example that she was quite shocked at how much the work at GCSE was oversimplified and she didn't really see why. She felt very strongly at the time that she had been deliberately 'lied to' and was confused as to why this had happened. When reflecting further on her previous understanding of electron configuration, she highlighted knowledge that had been omitted at GCSE:

It should be, well it's like each sub-shell is two and I didn't know sub-shells existed, I just thought it was 2-8-8 but it isn't. And it's like made up of two and, it's like, there can be three, there can be five, it's just compli...[sic]...that's...made it really hard, because I've got used to thinking of it differently. (Yasmin, 1st interview)

Yasmin found it quite hard to explain her feelings about the situation which had only recently become clear to her when this interview took place. Prior to this realisation, she had even been wondering if the teacher had made a mistake as the information she was being taught conflicted so much with her existing schema:

I found out a lot of it was just lies or oversimplified and when it was explained to me I just didn't understand it because I had learnt something else for so long. And it was different and I just wasn't used to thinking about things in that way because of my previous...understanding of it. I was thinking that can't be right, it doesn't make sense, he has got it wrong (Yasmin, 1st interview)

Yasmin was not alone in feeling lied to and other students were affected by the realisation that work at GCSE had been deliberately simplified. Erin felt quite upset and angry initially and directed her anger towards her teachers:

I felt cheated for a start, I really did...like I can't believe you've been telling me all this for years and now they're telling me that it's actually like this. Why did they not just introduce me to this in the first place and let it stick, rather than mix it up? Unbelievable! (Erin, 1st interview)

Erin couldn't understand why her teachers had apparently been telling her the wrong information for years and she felt cheated by this. The affective impact was clear in talking to her early in the year and she went on to explain how she felt let down by her teachers in this example from biology:

You get taught that there's a nucleus at GCSE, well even at Year 7 you are told that there is a nucleus of a cell...but then at A level you find out that it's got a nucleolus inside it. So it's like...they didn't tell us that! I just felt let down really 'cause I thought I knew that stuff and then...well I had to rethink pretty much all of that and get my head round it. (Erin, 1st interview)

As well as feeling let down, Erin had to grapple with having to rethink her previous understanding and she referred to having to 'get her head round it', implying that she could not simply forget her previous knowledge but would need to work at it.

Later in the year, students were able to accept their difficulties in coping with simplified previous knowledge, to reflect on their experiences of coming to terms with feeling lied to and rationalise the reasoning behind it.

Oh sometimes yeah, you feel lied to...sometimes yeah you are like, well...why?...why did you not explain that before?...but then you start to think well actually I wouldn't have...I wouldn't have understood it. If somebody would have told me some of the stuff that is given to me now...see I would have gone...I don't know what you are talking about [laughs]. (Anna, 2nd interview)

As Anna explained, by the second half of the year, students understood why work had to be simplified for them at GCSE, and she was even able to empathise with the teachers' decision to withhold information from them:

It's not that it is wrong it is just that it is not as complicated. In biology [...] it is like...oh it's not like I have lied to you...I have just not told you the whole story, because at that stage that is all you needed to know. (Anna, 2nd interview)

Despite having an understanding of the reasons behind the simplification, Yasmin's trust of what she was being taught had been severely shaken and it became clear when talking to her that she would no longer take information at face value as she was concerned about being in the same situation again.

I don't...I don't, things just keep being unravelled. I think oh I know it now but another thing will come up and I just wonder like is the same thing happening now, are they lying again? Like...will I get to degree and will it happen again? (Yasmin, 1st interview)

5.3.2 Letting go and slipping back

Part of coming to terms with inconsistencies and misconceptions in previous knowledge involved letting go of previous understandings. There were many examples in the data of this occurring over the year and the affective impact resulting from the challenge of having to do so, suggesting links with Walker's notion of 'cognitive dissonance' (2013. p.250). The process students experienced as they tried to assimilate new information and let go of old ways of thinking manifested as a messy liminal journey, involving instances of slipping back to the use of prior knowledge. One of the ways that letting go was articulated by students was in the context of breaking habits and replacing old knowledge:

It's trying to get out of the knowledge you already knew and putting the new knowledge you had in instead...cos it's kind of like you have old habits and you try to get rid of those habit by putting different language in...it's quite difficult (Liam, 1st interview)

In the following extract, Yasmin talked about breaking the habit of relating back to her previous understanding of electron configurations, and the impact this had on her emotionally:

It's hard to get out of the habit cos I have been doing it that way since Year 10 and I still do it now, so it makes you feel quite bad, like you felt good about yourself at GCSE and thought you could do it and you just start wondering are they teaching me the right stuff now or is it going to get harder? (Yasmin, 1st interview)

There was a real sense of uncertainty when talking to Yasmin. She clearly found it difficult to let go of her prior way of thinking. For other students it was not about the difficulty of the new way the work was presented, but more about having thought of a concept in a particular way for a period of time.

Yeah...it is that you've thought about it in one way for so long...in a very simple way that it's then harder to...it's not even like...it's harder to understand when you are expanding the knowledge because you are so used to the previous...thinking about how it worked before (Erin, 1st interview)

The ingrained nature of previous knowledge made it very difficult for students not to slip back into old habits and the temptation was strong, particularly if new understanding was not yet secure:

Because there is so much to remember you go back to GCSE language because it's a way to describe it. I still can't remember the correct way... (Anna, 2nd interview)

However, once students came to terms with letting go of previous understanding, it soon became clear that they would not be able to return to using it again, suggesting that their new understanding would be irreversible, a characteristic of TCs. Yasmin explained that, whilst she may be tempted to slip back into the habit of using old ways of working, her new understanding is irreversible as she knows that the old way is wrong.

I sometimes do it...sometimes like when I do the electron configuration I still write it as 2-8-8, so it's quite easy to fall back into it because it's easy, but now I know, I won't ever think of it like that again...like, as being true. Well...because it's like habit but now I

know it's more detailed I could never think of it as being simple again. (Yasmin, 3rd interview)

Yasmin's relief at having overcome her habit of slipping back into old ways of working comes across in this account. Whilst some students found it harder to adapt than Yasmin, each of them found their own way of coping. Gemma found it particularly challenging and dealt with the situation by repetition.

I think I just had to try and...forget about what I had already learned and just reread over the new stuff, erm so it gets into my head. It felt a bit strange trying to forget the old stuff but there has been a lot of that in biology this year (Gemma, 2nd interview)

5.4 Threshold concepts in A level Biology

This final section of the findings presents a number of concepts which stood out as demonstrating some of the features of a TC, revealed through analysis of the interviews with students and reflective journals. Table 9 shows an initial list of potential TCs identified by the students themselves through analysis of the biology course specification.

The concepts in Table 9 were identified by students on the basis of having been troublesome to learn, or through the student's perception that they were central to opening up understanding of other concepts, thereby suggesting an integrative aspect. These were the only two criteria explained to students and it is therefore important to state that this list of concepts is in no way offered as a definitive list of TCs in A level Biology. Comparison of the list to the analysis of the interview transcripts and the TCF characteristics identified a number of candidates displaying features of a TC, and 'scale' is provided below as one example, which will then be explored further in the discussion in Chapter 6.

Yasmin	Ivy	Anna	Erin	Gemma	Liam
Biochemistry	Biochemistry	Biochemistry	Biochemistry	Biochemistry	Cell structure/function
Cell cycles	Troublesome language	Cell structures	Carbaminohemoglobin	Lipids and enzymes	Cells - Cytoskeleton
Troublesome language	Specificity and keywords	Fluid mosaic model	Cell structure	Gaseous exchange	Biochemistry
Cell structure	Scale	Haemoglobin	Hydrogen bonding	Specificity	Blood tissue fluid/lymph
Interpreting traces		Specificity	photosynthesis	The heart	Interpret drawings
Quadrats		structure of molecules	Troublesome language	Fluid mosaic model	Troublesome language
Respiration		Plant transport systems	Plants	Cell membranes	Diffusion and osmosis
Scale		Troublesome language	Scale	Troublesome language	Keywords and specificity
Stages of mytosis		The heart	The human heart		Electrophilic addition
The heart					Gaseous exchange
specificity					Nucleophilic substitution
					Xylem and phloem
					Fluid mosaic model
					Scale

Table 9 - Potential threshold concepts identified by students

5.4.1 Scale

One of the aspects of biology that appeared to have a big impact on students was that of scale, not just from the perspective of finding it difficult to master, but due to the strong feelings that it evoked in some, such as Erin, who described feelings of fascination and wonder.

I try to relate a microscopic thing to a massive thing, I would look at a leaf and wonder...oooh, what is happening inside. But that is because I have a really curious mind, I want to know how things work and I like to know what's going on. (Erin, 2nd interview)

Although scale is not taught as an explicit topic, it is so embedded within the biology curriculum that students encountered issues involving scale through a number of different concepts and areas of study. Throughout the interviews, students highlighted scale-related issues, but for many this related to increased levels of complexity at A level compared to GCSE study which is presented in a more simplified way, as Yasmin explained when recounting her experience of learning about cell cycles:

I found the cell cycles quite hard to understand...what goes on inside cells, like respiration and...again we were just told like, we were just given an equation and that was it [at GCSE]. But now it's like a massively complicated process that goes on inside a mitochondria and in a cell, it's quite...I find it hard to believe how this stuff happens and it's just complicated. (Yasmin, 1st interview)

Yasmin came across as feeling very uncomfortable with accepting something on such a small scale that she has been told is happening. This was a particular challenge for Yasmin, who had already expressed concern about feeling 'lied to' regarding simplified knowledge at GCSE (Findings 5.3.1) and was having difficulty accepting everything that her teachers told her as a result. However, she was not alone in getting to grips with believing the micro scale aspects of biology.

With active transport as well...you think okay it's happening...but it's happening on such an unimaginably small scale that it's hard to process the information when you've not really got a lot to compare it to. (Erin, 1st interview)

Erin found that the micro scale made the work particularly troublesome, and she joked about having to trust what teachers and text books told her. There was a sense that she was resigned to having to accept what she is told, but she never really felt totally comfortable with it, needing some sort of proof.

When we started to cover photosynthesis, it was like...here is a diagram...this is one section of a palisade cell inside a leaf...and the leaf is formed of many different types of cells and it's like...this is one tiny little segment of this cell inside one leaf...and it's like...okay, and you're telling me where the electrons are going, which I can't see, and for all I know aren't really there...[laughing]...how did they know this? How did they discover it? Am I supposed to believe a word that they say? They could be telling me anything for all I know. (Erin, 1st interview)

The discomfort experienced by students appeared to be mostly down to lack of tangible evidence for much of the concepts they learned in the first year of biology and they required time to acclimatise to relying on trust.

If I could see it probably, I would probably understand it more but it's just, it's really abstract, you just have to imagine...like you've never seen it before or anything like that. So you just have to trust that it's there and that it's real. (Yasmin, 1st interview)

Yasmin highlighted the abstract nature of studying at such a small scale, relating again back to her trust issues:

Yeah, I just wonder if it's being dumbed down for me again and...I don't know...if they are lying to me again. So that makes it hard to trust and believe it all without seeing it. (Yasmin, 1st interview)

The examples covered so far relate to scale at a micro level, which Liam explained was a feature of A level study he had become aware of when thinking back to his GCSE studies as a comparison:

I have noticed that everything at GCSE is quite big but when you get to A level everything is getting...basically the microscope is getting smaller and smaller (Liam, 1st interview)

As well as size, Erin talked about time at the micro level, when she recounted her experience of learning about the cardiac cycle:

So we did control of the cardiac cycle, about the waves and the impulses that make the heart contract.. And I read that bit and it said like...erm this all occurs in one heartbeat...[long pause]...and I was like...what? I have spent two hours writing pages trying to remember all this stuff and it's like two pages of the text book...like a double page spread, explaining what goes on and then it tells you that it all happens in one heartbeat. And your heart beats at like 80 beats a minute for example, so it's all done in less than a second! It's so difficult to...understand that and...relate to it (Erin, 1st interview)

What is fascinating about this extended account is that Erin conveyed a real sense of discovery as she recounted the journey she went through to learn a very

complex process before discovering with surprise that it all happened in less than a second.

Time also proved troublesome for students at a macro level when studying evolution and the changes taking place over many thousands of years, the results of which can be seen but not the process itself. Macro scale issues also came to light in discussions about biodiversity, where students again found it troublesome due to the huge numbers involved.

Things like, with Simpson's index of biodiversity where you use several different factors, you use an equation to calculate how biodiverse an area is...erm, using data that you have collected from that specific area. I couldn't get my head round it at all, it was like, how...how am I supposed to...like...be able to write about...like...compare the wildlife in different countries, or why is this area more biodiverse than this one? [laughs]. (Erin, 2nd interview)

Sometimes, the combination of micro and macro scales added even more challenge for students. Again, Erin gave a fascinating answer about how she found this particularly troublesome with the interplay between the two extremes of scale:

And also the different scales link together so, like, we studied transmission of disease and how you prevent that, we had to learn about how they were transmitted and cured which was sort of microscopic level and the biology side of that, but then there was the huge side of it which was a bit like biodiversity as in how these things spread around the world. So really it was a bit of both ends of it combined which made it really...yeah...really hard. (Erin, 2nd interview)

5.5 Concluding remarks

The findings presented in the latter two chapters provide an insight into the experience of the six participants, highlighting themes across the group whilst also retaining an individual narrative. These findings will now be analysed and discussed in the following chapter, in the context of the research questions and aims.

Chapter 6 – Discussion of findings

The aim of this study was to explore students' experiences of transition from GCSE to A level through the theoretical lens of the TCF. In doing so, I presented the argument that this transition is often a challenging and emotional experience for students, further exacerbated by encounters with TCs. This chapter now defends this argument, presenting an analysis and discussion of the findings within the wider context of the literature, in response to the research questions:

- How do students make sense of the transition from GCSE to A level study?
- How do students experience TCs in A level Biology?
- How is the affective dimension of TCs represented in students' experiences?
- How do the theory and definitions of TCs fit in this local context, and can TCs be identified in secondary biology?

6.1 Troublesome transitions and transformative journeys

This section predominantly analyses and discusses the first three research questions, of which there is considerable overlap, as they explore students' experiences of a) the transitional journey and b) encounters with TCs. The affective dimension of students' experiences is interwoven throughout the findings.

6.1.1 Transition and transformation - the journey to becoming

Throughout the interviews, there was a sense of students' shifting perception of where they fit within the group, the wider school community, and within their own aspirations for education and future career. In the early days and weeks of study the findings indicated that these students perceived they were becoming A level students (Findings 4.3.1), part of a tightly defined community of practice (Wenger, 2009) within this, creating a micro-community they identified as the biology class itself. As the year progressed, students began to acclimatise at different rates with some adapting more easily to the acquisition of subject knowledge and developing ways of thinking and practising within the subject. However, all students exhibited a transformed way of perceiving their own position in the community as they

progressed (Findings 4.3.1, 4.3.2). This analysis concurs with the view that as students change from student to expert, they also shift from member of one community to another (Davies & Mangan, 2007), or gain membership of multiple communities (for example, A level student, biology student, degree student, scientist or biologist). The changes in identity expounded by students in this study was perceived as arising from changes to ways of thinking and practising within biology, resonating with the assertion of Davies and Mangan (2007. p.712) that these changes shape not only identity in relation to the current academic community, but in relation to past communities and future communities which individuals may aspire to join. Figure 16 illustrates my interpretation of this journey for these students through the notion of nested communities and micro-communities, membership of each forming part of a journey within a journey. This diagram also reflects aspects of Wenger's (2009, p.212) social theory of learning, in terms of identity (learning as becoming), but also community (learning as belonging), which surfaced in the findings in relation to feelings of 'isolation from' and 'belonging to' a group (Findings 4.3.1).

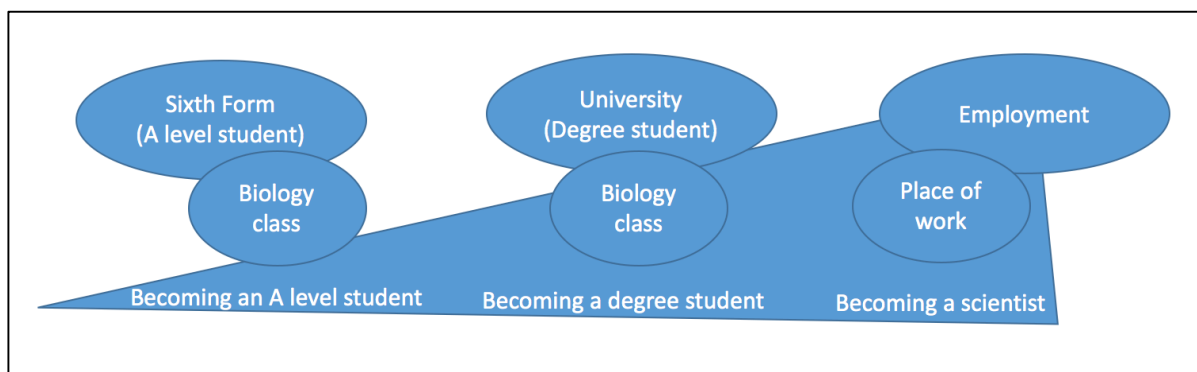


Figure 16 - Nested communities of practice and journeys within a journey

The findings of this research suggest that participants became aware throughout the year that they were on a journey to becoming a scientist, whether explicitly in a future career or more broadly in terms of their subject knowledge (Findings 4.3.2), with university being perceived as the next major transition in this voyage and one which some students were already beginning to prepare for (Findings 4.1.1).

These findings reflect those of Haji Bungsu (2014), in that both sets of participants identified as being on a journey to becoming (scientists or agriculturists). However, whilst the findings of that research suggested students were beginning to 'feel' like

farmers, in my study students mostly reported awareness of becoming scientists with relation to knowledge and language, specifically starting to think like a scientist. This difference may be due in part to the difference in phase, with participants in Haji Bungsu's study being nearer to employment.

Cousin (2010, p.2) argued that the true nature of TCs manifests itself through altered behaviour, and that 'we are what we know'. Barradell and Peseta (2014, p.263) considered the transformative behaviour exhibited by learners inherently linked to the bounded nature of a TC and therefore the subject content and curricula which defines and demarcates a micro-community. Whilst I agree with this assertion in that each micro-community is defined to some extent by the body of knowledge within the subject, I would argue that the agent-dependent aspect of TCs must also be factored in. TC learning involves not only understanding of knowledge, but also an altered way of viewing knowledge in the subject landscape (Meyer, 2016). For students in my study, the realisation of changes in behaviour and identity took hold once they became aware of fluctuations in their own ways of thinking and practising, particularly in starting to think like a scientist as they began to master TCs and subject-specific language (Findings 4.2.3; 4.3.2). However, some suggested that they would continue to see themselves as students, despite developing their subject knowledge, until they reached employment as a scientist, if that were indeed their end goal.

Whilst the perceived shift in identity was welcome for some students, who reported positive improvements in self-efficacy and resilience (Findings 4.2.3), my research suggests that for others this awareness highlighted uncomfortable feelings of loss, particularly of previous skills and ways of thinking. For example, immersion in scientific study causing atrophy of essay writing skills for one student (Findings 4.3.3). Whilst this skill was considered something which could be re-engaged with later in life, other areas of transformation were seen by students as being potentially irreversible, such as altered discourse, needing to communicate like a biologist, and an intolerance for lack of precision and being specific in language usage. These findings resonate with the notion that mastery of TCs may bring with it an uncomfortable ontological shift (Land, 2013) in the learner's view of

the world and potentially their own identity, accompanied by an affective component such as a change in feelings or attitude.

My research also builds on the work of Hernandez-Martinez et al. (2011), who argued that the transition from GCSE to A level was a question of development of social and academic identity. They posited from their findings that students saw difficulties with transition as a challenge to be overcome, allowing them to move on, even if this meant realigning their career aspirations and identity, citing the example of wanting to become an accountant instead of a physicist because of difficulties with the subject matter of their studies. My own research presents similar findings, highlighting social bonds within the micro community (Findings 4.3.1) and transformations in students' academic and social identities (Findings 4.3.3), in some cases leading to a realigning of career goals and aspirations.

The findings discussed in this section support my argument that, for the students in this study, the difficulty of transition is intensified through the affective nature of encounters with TCs and the transformative impact of these encounters on identity regarding belonging to, and becoming part of, micro-communities. The following sections now expand the evidence base from which I have made these assertions.

6.1.2 Expectations and the 'jump'

The notion of journeys within a journey presented in the previous section frames the initial transition from GCSE to A level as the students embarked on the first year of study, and were increasingly aware of 'becoming'. What these findings therefore contribute to the literature is an original body of evidence which explores the experiences of students through this transitional journey in a secondary school at a very personal level. The difficulty students experienced in adapting to A level was clearly articulated throughout the data as they talked in detail about the 'jump' (Findings 4.1.1; 4.1.2), a term which emerged from the interviews and one which is evident in findings of other research into GCSE to A level transition (Hernandez-Martinez et al., 2011, p.125). The findings also support my argument that the transition to A level was a challenging one for these students, highlighting the significant increase in workload and pace (Findings 4.1.3), the increase in difficulty

of work (Findings 4.1.1) and the challenge of subject specific language (5.2.1). My findings display similarities to Taylor's (2008), who reported on undergraduate biology students' reflections on coming to terms with the huge amount of content delivered in the first year and encounters with TCs and disciplinary language. However, my own findings provide additional nuance in that they surfaced much stronger feelings relating to the affective aspect of transition, with students expressing surprise at the 'huge' difference in difficulty and volume of work.

In considering the first research question of how students make sense of their experience, one of the most striking findings was that of the disparity between students' expectations of the transition and their actual experience. Despite having been warned by teachers, siblings and parents, all six of the students underestimated the extent of the increase in challenge they would experience, both in terms of difficulty and through the increase in workload and pace (Findings 4.1.3). Whilst the difficulty of work clearly came through from all students' responses, two of the students needed longer to grasp this, and realisation did not really set in until they were tested under examination conditions, suggesting variation in each student's transitional experience, another interesting feature of the longitudinal approach to data collection, which surfaced the affective dimension over the year, and in different ways.

6.1.3 The affective dimension of transition and threshold concepts

I have argued in this thesis that the transition from GCSE to A level is an emotive one for students, and potentially a major life experience. I have also asserted that there are calls in the literature for further research into the affective dimension of encounters with TCs. The findings in this study offer valuable insights into both aspects of students' experiences, as already seen in this chapter. The emotional and personal dimension of participants' learning experiences were evident throughout the research process, particularly when students discussed adapting to change (Findings 4.2.1). The research design based on IPA philosophies and practices elicited a range of affective phrases, summarised in table 8 (Findings 4.1.4). These provide evidence of the strong feelings generated throughout the transitional process and through encounters with TCs, building on previous work

in HE which surfaced the use of emotive terms by student participants (Felten, 2016; MacIntosh Edwards, 2010), although in these studies this aspect emerged as part of the research findings rather than being sought by design.

The findings of this study provide evidence that students' initial encounters with TCs were emotionally charged and troublesome (Findings 5.1.1). The impact of transition, coupled with these encounters with TCs emerged as causing major issues for some of the students, resulting in medical advice and treatment being sought in one case (Findings 4.1.1). These difficulties ultimately led to half of the group of participants deciding to change programs of study and restart the year, and one of these also changed schools. Whilst I acknowledge that there are inevitably other factors involved, these findings suggest that the increase in workload, the difficulty of work and encounters with TCs were the major contributing factors to these decisions (Findings 4.1.1; 4.1.4). Letting go of prior knowledge and dealing with misconceptions also led to considerable emotional difficulty for students (Findings 5.3.3), aligned with Walker's (2013, p.250) notion of 'cognitive dissonance', in such that students persevered with existing misconceptions or previous knowledge from GCSE to reduce the uncomfortable feeling of uncertainty they were experiencing. This perseverance emerged as a coping strategy on the surface, but also illuminated one of the causal factors inherent in the liminal journey, that of oscillation between old and new understandings (Cousin, 2006a, p.4). Hence, the overlap between the second and third research questions becomes apparent, where students' affective experiences are more acutely represented through encounters with TCs.

Participants also recalled questioning their ability and self-efficacy (Findings 4.2.2), some feeling disappointed with themselves, others using derogatory terms about themselves, whilst one even reported feeling abnormal due to being unable to cope (Findings 4.1.2). Students explained how they were unprepared for the extent of the emotional impact of transition and that it would have helped if they had been advised of this at the start of the year. The changes in identity discussed earlier in this section generated uncomfortable feelings for participants, resulting in feelings of isolation from other 'communities of practice' (Wenger, 2009) through altered discourse and the perceived language barrier of scientific terminology in

biology (Findings 4.3.1). Liminality has become central to representing the journey of 'becoming' that learners experience through various stages of TC acquisition within a subject (Meyer, 2016, p.465). These findings add to the body of knowledge regarding the affective impact of troublesome language and how this language forms part of the liminal journey students experienced as they wrestle with uncomfortable transformations.

Students in Felten's study (2016) articulated their experiences of engaging with increasingly difficult work as troublesome, but their descriptions did not fit the categories of troublesome knowledge in the TCF, as presented by Perkins (2006). Felten (2016, p.6) referred to what he called 'troublesome affect', noting that students described their experiences of engaging with TCs, often emotively, rather than focusing on characteristics of the knowledge that made them difficult. Commentary on engagement with TCs was evident in my thesis, and students were also able to pinpoint specific concepts and the aspects of these that made them troublesome (Findings 5.1.1) and integrative (Findings 5.1.2). I argue that this was enabled by the longitudinal approach to data collection, where students were interviewed throughout the year, and shortly after their troublesome learning experience, rather than at the end of the course. This meant that students were closer to the event and more attuned to recall key features of encounters with TCs, demonstrating a worthy development to methodological approaches previously taken and thus a valuable contribution to knowledge about ways of exploring the affective dimension of TCs. These findings also support my argument that difficulties with transition are exacerbated by encounters with TCs.

The transition to A level, combined with increased pressure, intensity and encounters with troublesome knowledge caused a great deal of stress for students, along with a heightened fear of failure for many (Findings 4.1.4). However, throughout the interviews, a strong sense of resilience and pragmatism came across (Findings sections 4.1; 4.2; 5.2; 5.3). These findings resonate with and extend those of MacIntosh Edwards (2013, p.194), who discovered a strong sense of belief in the students in her study to get themselves through their struggles. Although this resilience varied across students in this study, all experienced success at some point in the year (Findings 4.2.3), which impacted

positively on their confidence. Students in Felten's research (2016) reported feeling comfortable with knowledge once mastered, and the findings in my thesis evidenced this, whilst also illuminating links to the liminal journey leading to mastery through integrative awakenings (Findings 4.2.3) and the irreversibility of successful acquisition of a TC from students' perspectives.

Hernandez-Martinez et al. (2011, p.127) reported that, whilst participants in their study also recounted challenge in the increase in difficulty and amount of work, they largely told stories of *overcoming* problems, which was interpreted as a positive process of identity change by the authors. My own findings extend this work, illustrating that the positive sense of experiencing success (Findings 4.2.3) through developing mastery of subject knowledge and 'becoming' an A level student (Findings 4.3.1) appear to be inherently linked. Rather than contradicting my argument that the transition is a challenging and emotional experience, these findings of success and relief serve to support it by demonstrating how those students who were resilient enough to get through the experience underwent personal transformation.

This section may, at first glance, appear to have presented a negatively biased picture of students' experiences, but the findings also surfaced evidence of positive emotional impact, from experiencing success and increased confidence, to feelings of awe and wonder at scientific awakening. Whilst the singular term 'affective dimension' is used throughout the TC literature, there is certainly some indication that there are multiple dimensions to the affective nature of TCs, which teachers and academics should be encouraged by and which are worthy of further investigation.

6.2 Threshold concepts in the local context

This section considers the fourth research question, exploring how the theory and definitions of TCs fit in this local context, whilst also illuminating the second research question with respect to how students experience TCs. In doing so, I also strengthen my argument that TCs exacerbate the challenge and emotional impact of transition. Meyer and Land posited that a TC can be seen as a '...portal,

opening up a new and previously inaccessible way of thinking about something.’ (2003, p.1). Some consideration has been given in the literature to the theoretical notion of students’ initial perceptions and apprehension of this portal (Pang & Meyer, 2010), as well as variation in the starting points of students’ knowledge (Kiley & Wisker, 2009; Land & Meyer, 2010). However, less has been written about students’ lived experiences in real-time as they approach the ‘portal’ and reflect on how previous knowledge and misconceptions have contributed to their apprehension of a TC. My findings develop this area of research, demonstrating not only variation in students’ previous knowledge, but also affective impact once they realised that previously embedded understandings were in fact misconceptions, or simplified (Findings 5.3.1). This latter realisation came through in the interviews with some students reporting feeling ‘cheated’ and ‘lied to’, raising issues of trust with their teachers and affecting their confidence in future teaching.

The simplified previous knowledge students had been taught successfully in GCSE study acted as a barrier for them, as found in other research (Flanagan et al., 2010; Kabo & Baillie, 2010; Orsini-Jones, 2010). This was particularly noticeable where previous knowledge was ingrained and secure, with some students finding it hard to let go and accept the new learning, which presented as conceptually difficult (Perkins, 1999) or where troublesome language (Meyer & Land, 2003) was involved (Findings 5.2.2). The findings of my study offer valuable insights into students’ experiences of grappling with the reconstitutive nature of TCs, as proposed by Land, Meyer and Baillie (2010) in the relational model of TC features, discussed in chapter 2 and reproduced here in Figure 17.

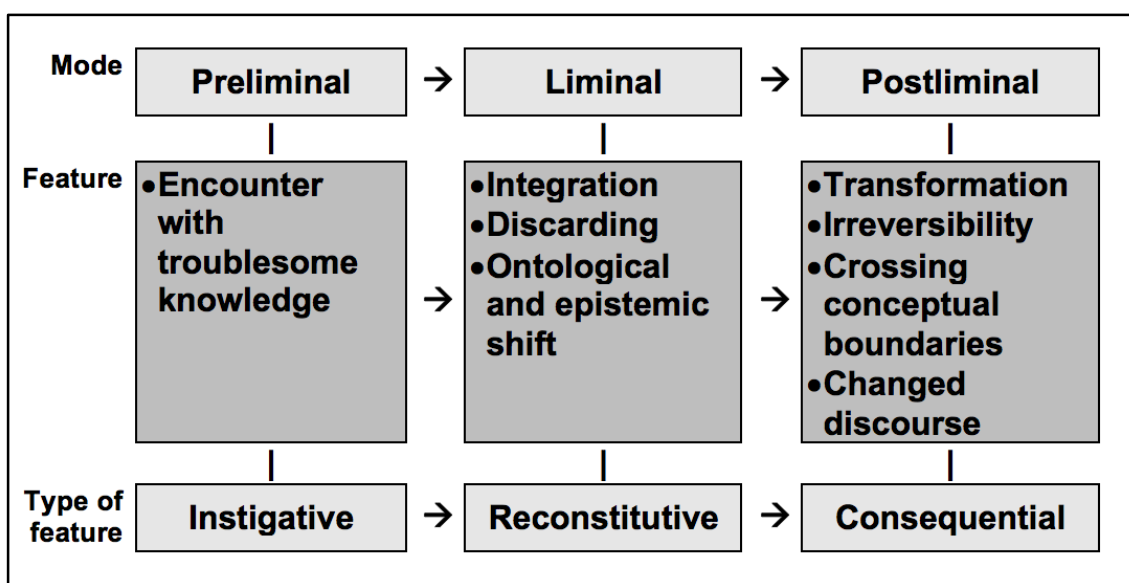


Figure 17 - A relational view of the features of threshold concepts.
(from Land, Meyer and Baillie, 2010, p.xii)

In this model, the initial encounters with TCs (Findings 5.1.1) take place in the 'preliminal' mode where new knowledge is compared with existing schema and misconceptions. Unsettling prior knowledge then renders it fluid (Land et al., 2010), acting as an enabler (Ross et al., 2010) to reconstitution, before discarding of previous knowledge takes place in the liminal mode, illuminated in the research in this study through students' experiences (Findings 5.3.1, 5.3.2) and how they integrated new knowledge. Despite initially emerging as a barrier to learning in early interviews, as students became more aware of how previous understandings needed to be reshaped or discarded, they were more accepting of this resulting in epistemological transformation and a reduction in the uncertainty felt early in the year. This offers insights for teachers of A level Biology to establish dissatisfaction or 'cognitive dissonance' (Walker, 2013, p.250) with these previously taught simplified concepts to establish a reconstitutive liminal state which might then bring about conceptual change.

Davies and Mangan (2007) argued that a concept integrating a range of prior knowledge is more likely to be irreversible as it holds together an individual's way of thinking about phenomena (p.712). The findings in this study support this assertion through evidence of students' struggles with troublesome knowledge and cognitive dissonance, eventually resulting in success (Findings 4.2.3),

transformation and a realisation that they cannot go back to previous ways of thinking about a concept (Findings 5.3.2). The resulting changes in self-efficacy evident in the findings through experiencing mastery (Findings 4.2.3) resonate with Bandura's (1993) social-cognitive theory, with the liminal journey leading to this success being evident as both a messy process (Cousin, 2009) and one which provoked considerable affective impact. These factors combined provide evidence to support the argument set out in this thesis that TCs exacerbate what is already a challenging and emotional experience for students.

6.2.1 Identifying threshold concepts in A level Biology

Examining students' encounters with disciplinary knowledge throughout this research provided opportunities to consider whether any such concepts emerged as being potential candidates for TCs, and allowed for exploration into the possibility of an original model for the identification of TCs in this local context. Following a detailed critique of the definition of a TC in Chapter 2, I argued for a model built on the prototype view of concept acquisition drawn from the field of cognitive psychology, which I have named and refer to hereon as the Longitudinal Concept Inquiry Model (LCIM). In this model, troublesome or affective learning experiences are likely to act as an instigative feature for identification at the preliminal stage of knowledge acquisition, highlighting potential TC candidates, with the other TCF characteristics being applied to add confidence to the identification (see Figure 18). This approach is not dissimilar to that of Rodger and Turpin (2011), who identified troublesome knowledge and then matched these only against the other four 'original' TC criteria (Meyer & Land, 2003). However, in the LCIM proposed here, opportunities to evaluate potential TCs are enabled through a longitudinal research design, allowing for identification through comparison against characteristics at, or close to, the point of occurrence. This latter aspect of the model is argued here to be crucial due to the changing profile of many of the characteristics over the course of the liminal journey, particularly regarding their significance to the individual. The LCIM also provides a more comprehensive approach than that of Rodger and Turpin (2011), by considering all seven of the agent-dependent TC characteristics.

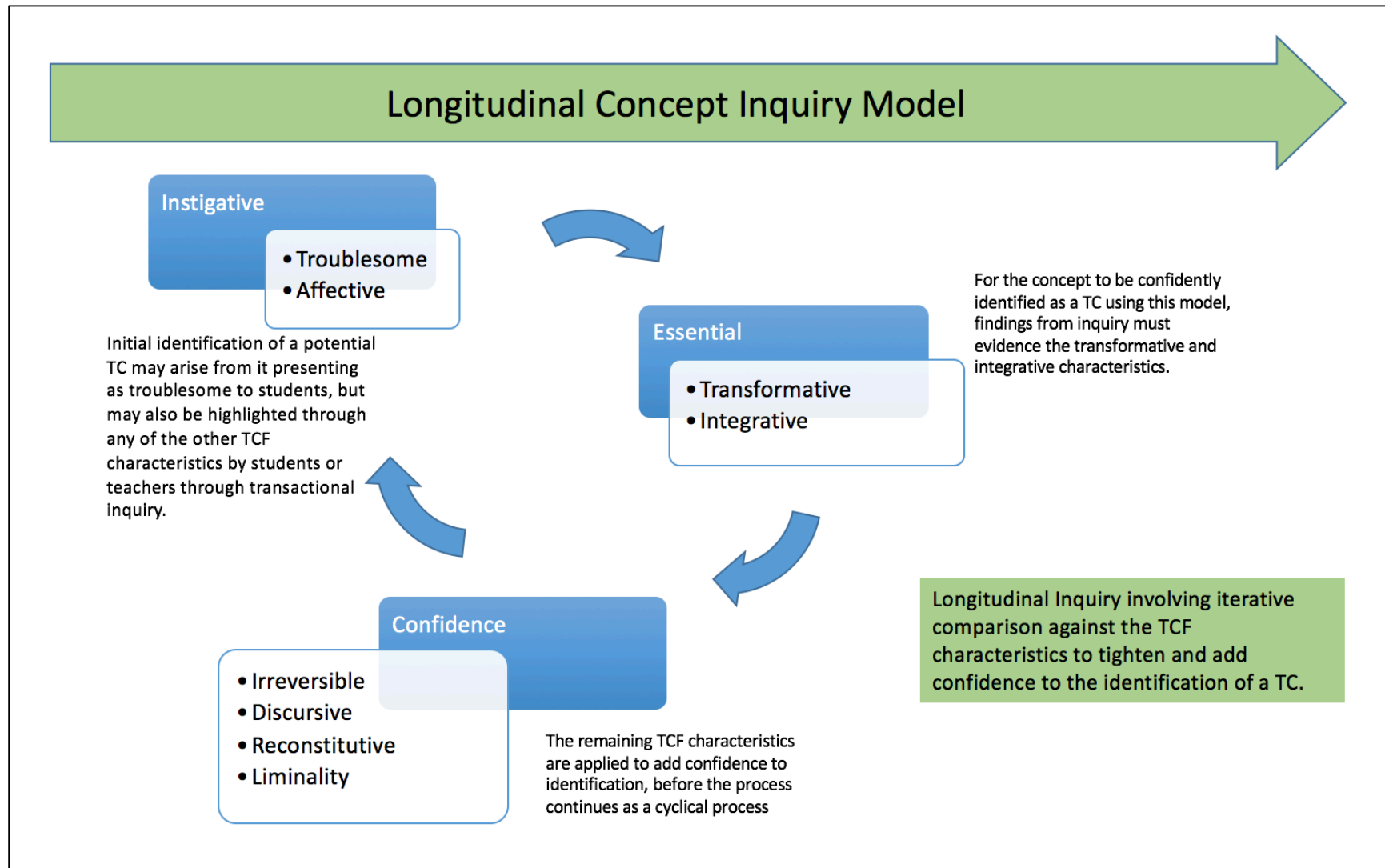


Figure 18 – The Longitudinal Concept Inquiry Model (LCIM)

For each of the TC characteristics I argued to be 'agent-dependent' in Chapter 2.4.3 the significance of each to the individual changed over time. Based on the findings in this study, the troublesome characteristic was most noticeable for participants early on, with direct links to the affective dimension of their experiences, again strengthening the argument for this aspect being particularly important in TC research (Felten, 2014). As a starting point, therefore, troublesome knowledge allowed for initial identification of concepts against which to consider the other characteristics. Towards the end of the year, once many students had mastered individual concepts, they no longer identified these as troublesome, although some could recall them having been so. By viewing the troublesome characteristic as an initial, instigative feature for identification, but not in isolation, the LCIM therefore acknowledges O'Donnell's (2010, p.4) argument that if the troublesome characteristic is capable of disappearing, it cannot be a defining feature. Equally, I argue that a TC may still be identified using this model in a local context, even if it does not present as troublesome to the individual at all, by taking a holistic view of the TCF characteristics to arrive at an identification. Indeed, some concepts emerged from the findings of this research as being potential TCs due to their integrative nature rather than being troublesome.

Some inherent integration with other concepts was noted in the findings at an early stage, although this aspect became more significant for most participants (Findings 5.1.2) as they experienced a wider range of subject content and began to make links. The change in language use increased rapidly early in the year for participants (Findings 5.2), as they developed their awareness and confidence with subject language and the discursive facet of TCs noticeably linked with the troublesome aspect of learning, as troublesome language contributed to difficulty for most students (Findings 5.2.1). However, the transformative aspect of concepts emerged more slowly, although for many students the link between discourse and transformation was noticeable (Findings 4.3.3).

I argue that identification through a longitudinal approach takes into account variation and fluctuation in individual participants' experiences, capturing a broad and balanced view of how TCs have impacted on them in this local context. This provides a useable and flexible model which takes into account how students

adapt to the process of discarding or modifying previous schema and misconceptions at differing rates, reconstituting new knowledge and schema whilst grappling with changes to their identity and the affective dimension of the liminal journey. Applying the LCIM to the findings of this study identified a number of candidate TCs in A level Biology (Table 9, Findings 5.4), and once they had been identified by the participants and considered using the LCIM, five emerged as being strong candidates:

- Scale
- Cell structures
- Biochemistry
- Troublesome language
- Specificity relating to application of language

I now provide a worked example of one TC identified in this research through application of the LCIM.

6.2.2 Scale as a threshold concept

In Chapter 2.5.2, a range of investigations into TCs in biology at HE level were presented from the literature. Several of these studies cited *scale* as a TC (Taylor & Cope, 2007; Johnson, et al., 2014; Wolf & Akkaraju, 2014; Batzli, et al., 2014), based on initial identification by academics in an earlier study (Taylor, 2006), where the spatial and temporal features of scale surfaced. It is useful to consider these papers as a backdrop to the findings of this thesis, which identified scale as a TC based on students' perspectives in A level Biology in secondary education rather than through identification by teachers or academics.

Scale presented initially as a potential TC in this study as it proved troublesome for students across a range of topics and concepts covered in the first part of the year. The fact that students reported encountering issues with scale in different contexts also made it stand out as inherently integrative from the outset, but increasingly so for students as the year progressed. In Findings 5.4.1, specific examples were presented which highlighted the troublesome nature of scale as a barrier to learning. For example, in relation to physical size, difficulties were noted

by students across a range of concepts linked to cell structure, such as cell cycles and respiration. Students referred to these areas of study as ‘unimaginable’ (Erin, 2nd interview) and ‘massively complicated’ (Yasmin, 2nd interview) because of issues relating to scale. This resonates with the findings of Ross and Tronson (2007, p.92) who identified that undergraduate students had difficulty relating the sub-microscopic to the macroscopic, due to the abstract nature of the former in relation to their known, visible world. Wherever students in my study reported finding scale-related issues troublesome, this was often accompanied by affective impact.

One of the most significant factors in the affective dimension of scale arose where the reconstitutive feature of TCs surfaced as students were told to let go of prior learning from GCSE and work at the sub-microscopic level with concepts such as active transport and water potential. However, previous difficulties with trust caused conflict here as students, having to rely on the teacher and text books to understand physical aspects of a biological organism they could not see, already reported feeling ‘lied to’ (Findings 5.3.1) due to knowledge having been simplified at GCSE. Thus, accepting abstract concepts without physical proof was challenging for some participants. This highlights implications for raising awareness with teachers of A level Biology of the importance of how they communicate with students about why previous knowledge has been simplified, to ensure that students are not negatively affected and are aware of the reasons for previous learning and why it needs to be reconfigured.

Towards the end of the year, the transformative nature of scale surfaced in the findings, coupled with transformed language use. However, the most striking example of transformation and irreversibility emerged from an understanding of the big picture articulated by one student. Comparing study at GCSE and A level in biology, Liam (3rd interview) noted that at A level, ‘the microscope is getting smaller’ in comparison to GCSE work, and study is taking place at a more granular and focused cellular and subcellular level. This awareness manifested as *irreversible* for Liam and others, not just in relation to physical size, but also with regard to time. In the review of literature in Chapter 2.5.2, I noted that several studies had highlighted time as troublesome knowledge in the context of scale as

a potential TC, relating to evolution (Taylor & Cope, 2007; Wolf & Akkaraju, 2014; Batzli et.al., 2014), and geological time (Johnson et.al., 2014). Each of these studies illustrated how undergraduate students struggled with relating to time on a large scale, particularly over millions and billions of years (Johnson et. al., 2014, p.125), where time became an abstraction. Whilst adding to the empirical evidence of temporal aspects of scale as a TC, the findings in my research differ from these studies, presenting evidence at the opposite end of the continuum, with time in fractions of seconds. Students found that studying the cardiac cycle in detail was relatively straightforward until they realised that it all happens in less than a second. Having studied for hours to learn about such a complex series of interconnected systems, with troublesome subject-specific language, the awareness that this occurred on such a micro scale was particularly transformative for some students (Findings 5.4.4). The significant reference to troublesome language within these topics seems also to have been exacerbated by a lack of physical evidence, suggesting that scale is also discursive and integrative in terms of students having to grasp a range of highly troublesome terminology across a range of integrated concepts.

As noted earlier, scale as a concept is inherently integrative within the discipline of biology, as much of the topics studied are conducted at an extreme micro or macro level. However, at times these two extremes overlap, as in the example of disease transmission (Findings 5.4.4), where one student (Erin, 3rd interview) pointed out that she had to grapple with the microscopic detail of disease action in the body, and how they are transmitted and cured. When this was then linked to the macro scale topic of biodiversity and the spread of disease around the world, she found it particularly troublesome working across extremes of sub-microscopic and macro scales. However, once she had grasped it, Erin reported seeing the integrative power of being able to deal with multiple scales across topics.

Applying the LCIM to these findings has provided empirical evidence to support scale as a TC. All agent-dependent characteristics were evident, with the transformative and integrative facets surfacing strongly, and I would therefore argue that scale can be considered as a TC in A level Biology. This analysis adds to the body of knowledge concerning TCs in biology in a different setting and

context from existing literature, providing supporting evidence whilst highlighting nuances in the way that scale presents as a TC. The implications for students and teachers lie in how this information is used to improve teaching and learning of biology at A level. Scale is highlighted through this research as playing an important role in enabling students to form integrative links between concepts across the subject. Teaching this transferrable TC to students early in the year, I argue, would provide clarity around the importance of understanding the complexities of micro and macro scale in unlocking conceptual knowledge. The benefits to students of seeing the subject as a web of integrated knowledge would also help learning, providing the big picture and enable them to see how TCs such as scale relate to other concepts and TCs, for example cell structure.

I also argue that there is potential for improving teaching and learning through involving students in discussions with teachers regarding the identification of TCs in A level Biology, using the LCIM. Rather than just informing students that they need to forget previous learning, engaging in joint inquiry around the potentially troublesome and cognitively challenging aspects of the curriculum would provide greater transparency between students and teachers, addressing issues of trust highlighted earlier in this chapter. Within that process, opportunities could be provided to discuss previous understanding and misconceptions and how new learning contributes to a student's mastery of the subject and their journey to becoming a scientist.

Chapter 7 - Conclusions

7.1 Summary of key findings relating to the research questions

As the title of this thesis conveys, the primary aim of this research was to explore students' experiences of transition from GCSE to A level, and their encounters with TCs throughout their first year of study. In doing so, the findings presented here offer insights into the troublesome and affective nature of that transitional liminal journey, whilst also allowing the reader to experience some of the fascinating encounters with troublesome knowledge experienced along the way, through the lens of the TCF. As such, Chapters 4 and 5 responded to the research questions posed:

- How do students make sense of the transition from GCSE to A level study?
- How do students experience TCs in A level Biology?
- How is the affective dimension of TCs represented in students' experiences?
- How do the theory and definitions of TCs fit in this local context, and can TCs be identified in secondary biology?

In summary, the analysis of findings presented several themes which emerged from discussion with the students, one of which being their growing awareness that the journey between educational phases is not a straightforward one. The notion of micro-communities of practice that I presented in chapter 6 highlights the recursive nature of the student to expert transition expounded by the discourse which unfolded throughout the year. There was a growing awareness within participants that mastery of biology as a subject, and as an academic discipline was a long way off, and that the road to mastery would be punctuated by uncomfortable realisations that previous knowledge could not always be relied on and may have to be modified or even discarded. The trust issues awakened by this realisation, coupled with the troublesome nature of the work were almost too much for some, raising considerable affective issues and, for others, a cessation of that journey. The ontological and cognitive transformations students experienced were also demonstrated through perceived changes in identity, with

some students noting the considerable affective impact that these changes had on them in both positive and negative terms.

The 'jump' to A levels provided by the troublesome nature and the increased amount and pace of work also surfaced strongly from the findings. When juxtaposed with students' prior expectations the difference was significant, and this raises issues for professionals in the secondary sector, as this participant group had varied ideas of what to expect and how to develop coping strategies for dealing with the jump. However, exploring the affective dimension of student experiences of transition was both enlightening and encouraging for future research. This study has provided evidence that students in this study experienced a wide and varied range of emotional responses to the process of transition, ranging from strong feelings of failure, panic and frustration, to a sense of achievement, pragmatism and perseverance. There are powerful messages here for teachers and school leaders regarding the feelings and internal struggles students experience throughout the transitional journey and potential methods for surfacing these feelings to address them effectively.

I assert that the findings of this research support my argument that viewing students' experiences through the lens of the TCF has illuminated specific encounters with TCs which have exacerbated the difficulties experienced in transition from GCSE to A level. A range of emotionally-charged interviews have captured encounters with TCs, highlighting changes in identity and a sense of 'becoming' during the longitudinal data collection process. The findings proposed five candidate TCs, some of which (*italicised*) have been identified in previous research in HE:

- *Scale*
- *Cell structures*
- Biochemistry
- *Troublesome language*
- Specificity relating to application of language

The Longitudinal Concept Inquiry Model (LCIM) developed and applied to the identification of TCs in this research is derived from evidence and applied to practice. This study offers much to encourage practitioners and academics to explore further practical methods of engaging with TCs in secondary schools and using this to improve teaching and learning, curriculum design and transitional support for students.

7.2 Strengths and limitations of the research process

I argue that the use of Interpretative Phenomenological Analysis (IPA) combined with case study proved to be an appropriate choice for this research. The hybrid methodology and research methods employed allowed students to analyse the concepts within the course through the specification analysis and reflect on their experiences through the reflective diaries they completed. The interviews then gave them the chance to explore their own journeys in a very personal way, whilst providing a flexible analytical structure which allowed multiple aims to be addressed. The longitudinal approach proved to be effective in gaining a real-time perspective and allowed for follow-up discussions whilst experiences were fresh in students' minds. Students found the process positive and looked forward to their sessions, and many spoke to me informally about how being involved in the study helped them as they felt listened to and had someone to discuss their concerns with.

One limitation is the small sample size of six students, although this is consistent with IPA studies (Smith et al., 2009), and the longitudinal design of the study allowed for several points of data collection throughout the year. Having completed the research, I would have also liked to have had the capacity to explore a range of other subjects, particularly from within each of the students' programmes of study. However, the choice of biology fitted within the science-situated theoretical framework allowing for comparison with previous research in HE, for example in relation to 'scale' as a TC.

The research process was time consuming due to the duration of interviews and the practical implications of arranging these around students' lessons, and may

therefore be difficult to implement for an individual professional in practice within a school setting without some support. However, if the aim was to identify potential TCs within a subject collaboratively with students, rather than to undertake the whole range of professional and academic aims in this study, then shorter interviews or discussions in lessons and a specification analysis may be sufficient to allow for a similar analytical framework to be applied.

7.3 Implications for knowledge

This study has contributed to extending the body of knowledge around the transition from GCSE to A level, as well as the affective dimension of TCs within this context. This has been achieved both through the findings themselves, and in the development of a hybrid research design based on Interpretative Phenomenological Analysis. The longitudinal research design and choice of methods enabled the affective nature of this transition point and encounters with TCs to be captured in real time. Whilst small in scope, the methods and analytical framework employed throughout this research demonstrate promise for surfacing the affective dimension through further refinement and use in secondary education or other settings.

I also argue that this thesis makes a small but significant contribution in reflecting on the use of the TCF characteristics in empirical work across the field. It has been noted earlier in Chapter 2 that application of the framework is varied and that there is often a sense of ambiguity surrounding the definitions in published research. This variation has been challenged here, as has the assumption that academics possess a shared understanding of the definitions of these characteristics (Barradell & Peseta, 2014). Clarity has been provided through a critical examination of the literature leading to a rigorously defined definition which underpins a transparent methodological approach.

Furthermore, I argue that the method for the identification of TCs presented in this thesis offers a practical, evidence-based exploratory model which can be further refined and stress-tested. Whilst much of the existing literature relies on exploring TCs identified by academics, this model is based on the principle of highlighting

potential TCs through learners' experiences before strengthening the identification through the exploration of agent-dependent characteristics. TCs have been identified in A level Biology in a local context and, whilst no claims are made that the LCIM offers a fixed set of definitions that can be generalised, that was never the intention. I would, however, argue that it offers an original approach which could be used in context across a range of subjects and sectors, providing clarity and a shared understanding upon which researchers can engage in a dialogue on the level of confidence in their identification using a common approach.

7.4 Implications for practice

This thesis contributes to the body of knowledge concerned with transition from GCSE to A level study in secondary education. It is my hope that the research will act as a catalyst for further investigation into this area. With changes to linear courses now in place for most subjects at A level, opportunities for students to have a 'second chance' through re-sits are gone. It is therefore even more important that students are supported in such a way as to maximise their A level results. I would argue that this study provides evidence that the TCF can be applied to identifying and addressing key areas of affective and cognitive difficulty that students experience. Whilst teachers and senior leaders in schools are unlikely to be familiar with TCs, professional development designed to develop knowledge of the TCF and its implications for practice could be productive in informing improvements to teaching and learning.

The LCIM developed here as a model for the identification of TCs had an academic audience in mind, but this could be adapted in such a way as to be practical for use by teachers within schools. Subject teachers could employ the hybrid research design developed for this study individually or collaboratively, engaging with students to undertake curriculum analysis, interviews and reflective diaries. The LCIM could then be used to focus on key areas of a subject through the lens of the TCF, to inform targeted improvements to teaching and learning in a local context. Subject leaders could also engage with redesigning curriculum delivery to focus on 'stuck-points' (Barradell & Peseta, 2014, p.263) and TCs,

levering an integrative approach to the order of delivery and the importance placed on individual concepts within schemes of work.

Set within the context of a journey between micro-communities, forewarning students of the affective nature of transition may also help to address some of the uncomfortable emotional issues experienced through the first year and to inform the development of appropriate support systems. Making teachers aware of the affective dimension of students' experiences of transition may also encourage changes to practice and it would be worthwhile raising awareness of the trust issues which may arise from students feel lied to when informed of previous knowledge having been simplified.

7.5 Recommendations for future research

It has been noted throughout this thesis that there is a paucity of literature around the affective dimension of TCs, which this research has contributed to addressing. I argue that the methodological approach presented here could be employed across a wider range of secondary settings and subjects to provide a broader picture of students' affective learning experiences and encounters with TCs. I plan to extend this study by conducting a wider range of investigations into full programmes of study at A level, as opposed to a single subject, as several themes emerged across subjects during the interviews with students. I would also call on colleagues in HE to explore the use of the IPA-based hybrid methodology used here to explore the affective dimension of TCs, either in relation to transition in undergraduate studies, or as a standalone undertaking.

I feel that the LCIM warrants further exploration and stress-testing through application across a range of subjects and settings, with comparison to other approaches to identification. I would also argue that there is a need for researchers in the field of TC research to revisit their approaches to bringing clarity and shared understanding to identification. Collaborative research involving a wider range of stakeholders could also lead to the development of a common approach to defining and identifying potential TCs suitable for application in specific settings and sectors, such as secondary education.

7.6 Concluding reflections

As I stated in the introductory chapter, the first academic papers I read concerning TCs related to doctoral learning (Trafford & Leshem, 2009; Kiley & Wisker, 2009). These two papers investigated the difficulties that postgraduate students encounter on their doctoral journey towards realising what Trafford and Leshem refer to as 'doctorateness' (2009, p.305). The period between my first encounter with TCs and presenting this thesis for defence represents a liminal journey through which I have personally encountered all the TCF characteristics. In addition, there is no surprise that I reflect now on the noticeable affective dimension running throughout my studies.

Kiley and Wisker (2009) argued that one of the main reasons for high drop-out rates in doctoral study was a result of encountering troublesome knowledge in the liminal journey, resulting in being 'stuck'. I recall several times where I considered terminating my studies, having reached a seemingly insurmountable conceptual obstacle. For example, in the early days of the thesis phase I grappled with seeing the 'big picture' and how the different elements of my research fit together. Trafford and Leshem (2009, p.308) argued that the notion of synergy is inherent to doctorateness, and achieving an understanding of the linkages between the various element of this thesis required an ontological and conceptual shift affecting change in my identity both personally and professionally. I have always been well-organised and, as such, developing a structured approach to my studies was not difficult. However, to achieve doctorateness I had to learn to channel this structure in order to develop a coherent line of argument, which has been previously identified as a TC in research study (Kiley & Wisker, 2009). Although this had been explained to me through supervisors and texts, understanding of this truly developed through attending conferences and talking with international colleagues about my own research and how it fit with the perceptions of others interested in TCs. On reflection, I believe that my own misconceptions of the threshold concept of argument presented me with significant cognitive dissonance, requiring conceptual change and the reframing of my existing schema to make progress.

This brings me to one of the key features of doctorateness that Kiley and Wisker (2009) advanced: the ability to explain the significance of the research, or the ‘so what?’ factor (p.435). I have endeavoured to explain in this chapter the contribution to knowledge and practice that my thesis makes, in both the academic and professional worlds. What remains is to outline what I hope to achieve through undertaking this work. From a personal perspective, I have undergone significant transformation in terms of ‘criticality’, and this has had a major positive impact on my professional skills and practice at a senior leadership level. Transformation is also evidenced through the change in my use of language and perspective as I have joined a new community of practice, bringing with it a growing desire to pursue further research and develop my new skills and understanding. Furthermore, I intend to employ these skills and the output of this research to make a positive impact on my practice and the practice of others, whilst continuing to engage with the academic research community.

In this thesis, I have explored students’ experiences of transition from GCSE to A level through the theoretical lens of the Threshold Concepts Framework, in order to extend the professional and academic knowledge surrounding this transitional journey. I have also contributed to the academic research around TCs, particularly to gaps in empirical evidence exploring their affective nature whilst also extending the secondary school literature in the field. Whilst contextually situated in secondary education, the findings and discussion are inherently rooted in the existing TC literature in HE, and therefore contribute to and extend this body of work in biology and more broadly. I also argue that this thesis offers a much-needed critical examination of the original, and current, definition of TCs, as well as contributing an original and effective methodological approach for further research, with a practical exploratory model for the identification of threshold concepts.

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