The Identification of Threshold Concepts and Their Application in Curriculum Development:

Exploring Threshold Concepts Through the Context of Engineering Education

A thesis

submitted partial fulfilment

of the requirements for the degree

of

Master of Education

at

The University of Waikato

by

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THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

2019

Abstract

Threshold Concept (TC) theory was introduced by Erik Meyer and Ray Land in 2003 and states that every discipline of study contains troublesome concepts that transform the learner when they come to be understood. This transformation will concern either the learner's thinking about the discipline and/or their perception of the discipline. Five characteristics were originally proposed that can help to signalise TCs, which are, *troublesome*, *transformative*, *irreversible*, *integrative* and *bounded*.

This thesis explores both, the in-depth ways in which TCs have sought to be identified, and to what extent the role of TCs in curriculum development has been studied. This was done by exploring researchers' thinking in regard to the importance of each of the five TC characteristics, the data collection methods and participants that were included in their studies, and the extent to which they attempted to study TCs in relation to the development of curricula. Engineering education TC studies formed the context through which I attempted to answer the research questions. The first method I used to obtain my data was to carry out a systematic quantitative literature review (SQLR) of peer-reviewed TC research articles that were published between 2003 and the present day. From the relevant 147 papers that resulted from my database searching, I narrowed this down to the 15 articles that related directly to engineering education. The SQLR data was then used to inform the semi-structured interviews that I conducted with three TC researchers in the field of engineering education.

The findings suggested *troublesome* and *transformative* to be the TC characteristics that are the most essential of the five to consider when seeking to identify TCs. This finding was based on the fact that they were the two characteristics most highly referenced in the SQLR literature and were the ones thought most important by two of three of my interviewees. The inclusion of

multiple types of participants and data collection methods were found to be common and effective practices amongst TC researchers. Again, this finding was supported with the SQLR data and by all three interviewees. Lastly, it was discovered that, despite TCs being considered the potential centrepieces of a curriculum, there is a lack of TC studies focussing on the role of TCs in curriculum development. There existed no studies within the SQLR literature that held this aspect as a sole focus.

Acknowledgments

I wish to acknowledge my supervisor Bronwen Cowie for the amazing support in all aspects in the creation of this thesis. I would like to acknowledge my family and friends for their constant support and encouragement. Furthermore, I care to thank my interviewees who were each courteous and enthusiastic to participate. Lastly, I wish to acknowledge the staff members of Omokoroa Point School and their support throughout the writing of the thesis.

This thesis was funded by the University of Waikato Research Masters Scholarship.

And so he that had received five talents came and brought other five talents, saying, Lord, thou deliveredst unto me five talents: behold, I have gained beside them five talents more.

Matthew 25:20 (King James Version)

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Chapter 1: Introduction

This thesis is based around threshold concept theory. In the introduction threshold concept (TC) theory will be outlined beginning with an analysis of the seminal paper for the theory authored by Erik Meyer and Ray Land (2003). Several other aspects will be touched on including an analysis of a more recent paper on TC theory by Timmermans and Meyer (2017), a discussion on several related theories, and an argument regarding the relevance of this study.

1.1 Introducing the Characteristics of Threshold Concepts: The Seminal Threshold Concept Paper

The most fitting way to begin this thesis is to provide a comprehensive discussion of the seminal paper on TCs: *Threshold Concepts and Troublesome Knowledge: Linkages to Ways of Thinking and Practising within the Disciplines* authored by Erik (also known as Jan) Meyer and Ray Land. This paper was published as an occasional report for the *Enhancing Teaching-Learning Environments in Undergraduate Courses* (ETL) project in May of 2003. The ETL project was based in the United Kingdom (UK), and was carried out between January 2001 and June 2005. It explored the teaching-learning environments within 25 higher education departments throughout the UK (Economic and Social Research Council, n.d.; Hounsell et al., 2005). Two key aims of the ETL project were to identify which factors lead to quality teaching and discovering which interventions may be made to best enhance teaching-learning environments (Hounsell et al., 2005). Meyer and Land, as part of the economics team of the ETL project, published their paper on TCs arguing that these concepts are important to consider when designing curricula and have the potential to increase the effectiveness of teaching-learning environments.

1.1.1 Threshold Concept Definition

Meyer and Land (2003) reasoned that every discipline contains a number of concepts that represent critical aspects of understanding for that discipline. To present this idea, they provided it in the form of a metaphor that compares the learning of TCs to a stepping through a portal. Before entering into the portal to grasp the TC, a student will be at a stage of limited understanding in terms of thinking and/or perception concerning their discipline of study. After stepping through the portal and experiencing a time of troublesome learning, the learner will emerge with either, a transformed way of thinking about (or within) the discipline, or a transformed perception of the discipline; they will have a more advanced level of understanding (see Figure 1).

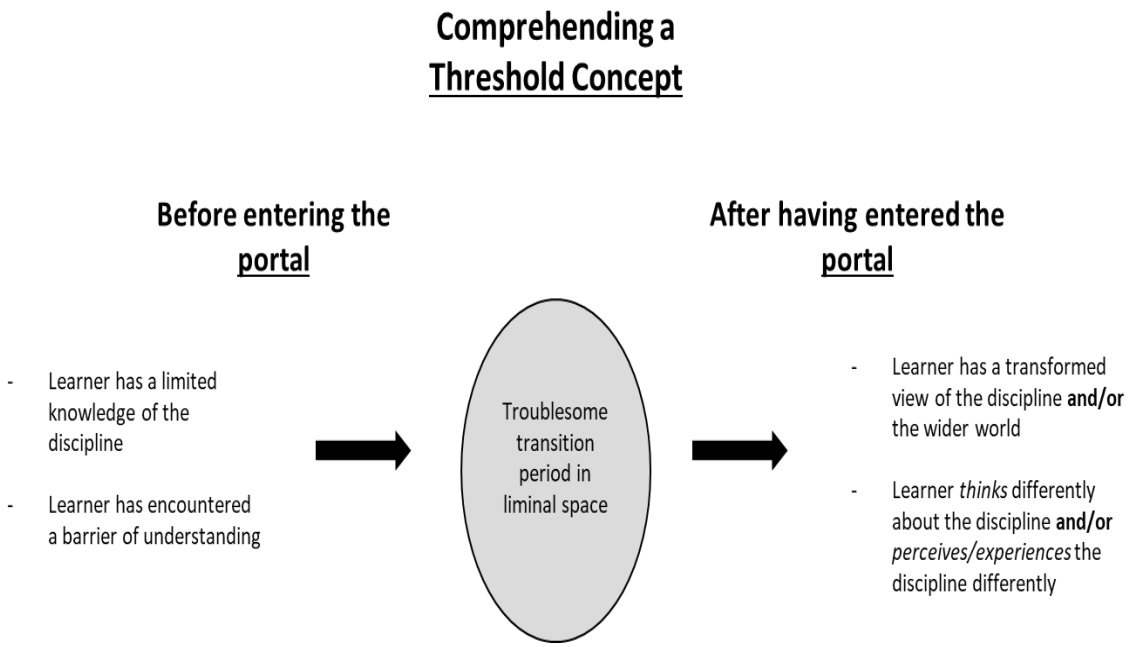

Figure 1. The portal metaphor for the comprehension of threshold concepts based on the work of Meyer and Land (2003)

To illustrate their theory, Meyer and Land provided the example of 'heat transfer' as a TC within the discipline of cookery:

Imagine that you have just poured two identical hot cups of tea (i.e. they are the same temperature) and you have milk to add… You add the milk to the first cup immediately, wait a few minutes and then add an equal quantity of milk to the second cup. At this point which cup will be cooler, and why? (The answer is the second cup, because in the initial stages of cooling it is hotter than the first cup with the milk in it and it therefore loses more heat because of the steeper temperature gradient.) (p. 1)

The reason that this notion may be considered a TC is that, once grasped, it alters the way in which an individual thinks and acts. Specifically, the transformative nature of the idea leads people to carry out activities (specifically cooking) in a different light, even altering the tools they use, based on the newfound knowledge.

1.1.2 Threshold Concept Characteristics

Meyer and Land (2003) explicitly stated that the TCs differ from the core concepts within any discipline. Core concepts are those that enable an individual to progress in understanding, whilst TCs are those concepts that enable progression and/or alter the individual's view of the discipline. In relation to this, the authors provided five specific characteristics that that may be attributed specifically to TCs. One important aspect that can be inferred from their discussion of the characteristics is that any given TC may not exhibit each of the five characteristics they identified. The characteristics are outlined below.

Transformative

The *transformative* nature of TCs has been repeatedly mentioned prior and is the only one of the five characteristics that can be considered absolutely essential. Aside from an individual experiencing a transformation in their understanding of a discipline upon comprehending a TC, they may also experience a change in

personal identity due to the altered perspective. A further transformation may also occur in the actions or behaviour of an individual if a TC relates directly to the actions of individuals. One example of this form of transformation may be seen in the aforementioned ‘heat transfer’ TC in which an individual may alter their cooking technique as a result of their understanding of this concept.

Irreversible

The characteristic *irreversible* refers to the fact that TCs, once comprehended, are almost impossible to be unlearned. In other words, an individual will have difficulty attempting to adopt their original frame of mind after having achieved their new, transformed perspective. This characteristic was argued to have important implications for educators seeing that a teacher, having already comprehended the TCs that they are attempting to teach, will struggle to understand the trouble that their students are experiencing prior to comprehending these TCs. This characteristic was described as “probably” (p. 4) a component of TCs by Meyer and Land, which may be taken to mean that the majority of TCs will hold this characteristic.

Integrative

The *integrative* nature of TCs was another characteristic discussed yet one which, again, may not be applicable to all TCs. This term refers to the way in which an individual begins to see new relationships and connections between the ideas within a discipline as they come to understand the discipline TCs. Meyer and Land highlighted that only so much integration is possible and so connections may not be able to be made between every concept within a discipline.

Bounded

The *boundedness* of a TC alludes to the way in which it can help define the boundaries that exist between one discipline and another. Just like the above

notion that any one TC can integrate so much, the similarities that may lie between disciplines only exist to a certain point. To explain it in other words, the epistemological and ontological beliefs that belong to those from one discipline may cause a TC to be relevant, yet the beliefs that are inherent to those in another discipline may cause that TC to be non-applicable within their discipline. Again, this characteristic is described as "often" (p. 5) associated with TCs, meaning that it is not an essential feature of every TC.

Troublesome

Lastly, *troublesome* was pinpointed as a characteristic that was stated as "possibly inherenetly" (p. 6) related to TCs. It was made explicitly clear within the paper that this troublesome characteristic was based on Perkins' (1999) discussion of four differing forms of troublesome knowledge. These four are outlined below but it is important to first state that any one piece of knowledge has the potential to exist under multiple troublesome knowledge forms. Each of these forms represents a way in which a TC may be troublesome for a learner.

The first of the four forms of troublesome knowledge is inert knowledge, which is that which is learnt by an individual yet is not actively utilised (Perkins, 1999). Thus, a mathematics concept that is taught to a student with no explained connections to either, the student's real life, or other mathematics concepts, will most likely be inert knowledge. Meyer and Land (2003) discussed how certain TCs have the potential to become inert knowledge if they, either, are unable to be easily connected to other concepts within a discipline or are difficult to connect with the physical world.

Ritual knowledge is a second form of troublesome knowledge and refers to that knowledge which is used in a ritualistic way and carries little meaning. An example may be the use of an algorithm to produce an answer for a mathematics

problem. Although the algorithm may be utilised ritualistically by an individual, they may struggle to explain how and why it works.

A third example of troublesome knowledge comes in the form of conceptually difficult knowledge. If a concept is prone to misconceptions by students and appears to be strange or complex to them then this is an indication that it is a conceptually difficult concept. Although existing in all disciplines, conceptually difficult knowledge is most commonly found within mathematics and the sciences with one example being the fact that heavy objects will fall with the same rate as lighter objects. Comprehension of this concept most likely will involve a student altering their initial conception, that the heavy object will fall at a faster rate, and the explanation may appear strange and complex to them (Perkins, 1999).

Perkins' final form of troublesome knowledge, although he acknowledged that are potentially other forms that exist, was foreign knowledge. This is knowledge that originates from a perspective that differs from that of the student. For example, a student may struggle to see the motivations behind the actions of a historical figure without studying the historical perspective of that person (Perkins, 1999).

Aside from discussing Perkins' four forms of troublesome knowledge, Meyer and Land provided two forms of troublesome knowledge of their own: tacit knowledge and troublesome language. Tacit knowledge refers to knowledge within any discipline which is implied and may not be explicitly articulated by practitioners. Meyer and Land provided the example of 'tuning' within the discipline of music. Whilst students might view the tuning of their instruments as common sense, it is not until they learn that other tuning structures exist that they may begin to question how and why they carry out the process in the way that they do. Troublesome language is the last aspect the authors touched on and refers to the jargon that is utilised within each discipline that can be difficult for students to initially understand. This troubles may be further heightened when teachers of

the discipline attempt to explain complex concepts with the use of the unfamiliar jargon that students are yet to understand.

1.1.3 Ways of Thinking and Practicing

Meyer and Land (2003) dedicated a section towards the end of their paper to discussing *ways of thinking and practising.* Within this section it was reasoned that TCs may be more easily identified within disciplines that have a widely established body of knowledge (e.g. the sciences and medicine), whereas within less established disciplines, the *ways of thinking and practising* that are required of students "...constitutes a crucial threshold function in leading to transformed understanding." (p. 9). *Ways of thinking and practising* as a concept originated and was defined by several of Meyer and Land's colleagues working on the ETL project: they are the ways in which a learner of a specific discipline begin to think and act based on the values, language, practices and norms established by that discipline (Hounsell & McCune, 2002). It is interesting to note that Meyer and Land state *ways of thinking and practising* as a "...threshold function… " (p. 9) not as a threshold *concept*. The reason for this alteration of wording was not explained yet it may be inferred that, as thinking and practising are processes and behaviours, then *function* is a more appropriate descriptor than *concept*, which refers to a single idea. A discussion of the essence of the term *concept* is included in a later section of the introduction.

1.1.4 Liminality

A final aspect discussed by Meyer and Land (2003) was the liminality that may be experienced by a learner as they attempt to comprehend a TC. In essence, liminality is a "... suspended state in which understanding approximates to a kind of mimicry or lack of authenticity." (p. 10). The authors pointed to the origin of the term liminality by expressing that limen is the Latin word for 'threshold'. Liminality, along with the notion that learners mimic others before entering into full understanding, are both ideas that are expanded on in later sections of the introduction.

1.2 Further Examining the Metaphor *Threshold Concept*

The term *threshold concept* in and of itself holds strong significance and through the examination of this metaphor much can be garnered. This section is dedicated to exploring the words *threshold* and *concept* in order to highlight why they were chosen to represent those concepts that transform the thinking of learners (Meyer & Land, 2003). For each of the two words a discussion of their meaning is provided before a note on their relevance to TC theory.

1.2.1 The Meaning of Threshold

The word origin of *threshold* can be traced to the English word 'thresh' which refers to step or trample (Oxford English Dictionary, n.d.-c). Moreover, *threshold* is a term that is given to a piece of wood or stone that lies below the front door of a building; it must be stepped over in order to enter a structure (Oxford English Dictionary, n.d.-c). Several other uses of *threshold* include, describing the point in which conditions must be met to initiate an event or reaction (e.g. the 100℃ temperature threshold that must be met, or exceeded, in order for water to boil), to reference a starting point (e.g. 'on the threshold of a new era') or to refer to a difficulty or obstacle that is encountered (though this use is presently obsolete) (Merriam-Webster, n.d.-c; Oxford English Dictionary, n.d.-c).

As discussed, TCs are those concepts which are troublesome for learners which result in transformed understanding (and potentially identity) as a result of becoming understood (Meyer & Land, 2003). For this reason it makes sense that the word *threshold* (in the sense of a piece of stone or wood at an entrance that is stepped over) is utilised as the metaphor for such concepts as this transformation is akin to stepping from one area (an area of limited understanding) into a new one (an area of heighted, transformed understanding) (Oxford English Dictionary, n.d.-c). Additionally, this meaning of *threshold* is reflected strongly in the portal metaphor introduced by Meyer and Land (2003); TC learning is similar to *stepping through* a portal into new understanding (see Figure 1). It would be interesting to see whether this portal metaphor was conceived by the authors prior

to their selection of the word *threshold* or vice versa as they obviously link very closely to one another. As a last note, the obsolete use of *threshold* (to reference an obstacle or barrier) is also relevant when regarding TCs. TCs are notably troublesome for learners and thus act as obstacle to be overcome before fuller understanding may be reached (Oxford English Dictionary, n.d.-c).

1.2.2 The Meaning of Concept

In one view, a *concept* is a memorised grouping of knowledge which is utilised by a person to aid such cognitive processes as understanding language, categorisation and the forming of analogies (Machery, 2005). Machery furthers this definition by providing the example of *dog* as a concept. A person will have a grouping of knowledge stored within their long term memory relating to *dog* and will utilise this knowledge for such processes as to classify animals as dogs (or not, if the case may be), and to understand and make sense of the term *dog* when it is brought up in conversation.

In a similar vein, the etymology of *concept* relates specifically to mental processes. The word originated from both the word conceptum (classical Latin), meaning an idea that is conceived within the mind, and the word conceit, in the sense of anything that is conceived within one's mind (e.g. thought, conception, notion, idea) (Oxford English Dictionary, n.d.-a; Oxford English Dictionary, n.d.-b). A differing view of concept was discussed by Fisher (1916) who expanded on the thoughts of Betz (1911, cited in Fisher, 1916); concepts may materialise in a more motorary sense in the form of attitudes, rather than through mental images. For example, when hearing, or seeing, the word *red* (in relation to the colour), an individual may feel the emotions indicative of that colour (e.g. anger or passion) initially before reproducing a mental image of the colour. This view of concepts and idea conception is more multi-dimensional as it acknowledges emotive responses alongside cognitive processes.

Meyer and Land (2003) refer to TCs as part of the content of any select discipline. Taking into account that *concept* refers to the result of a mental process (e.g. the

production of a thought, notion or idea), or in Fisher's sense an emotional reaction that aids the understanding of an idea, it is clear that TCs are limited to only those discipline aspects that can be understood mentally (Fisher, 1916; Oxford English Dictionary, n.d.-a; Oxford English Dictionary, n.d.-b). On a personal note, this was a very useful discovery as I was previously under the impression that physical skills required for a discipline may hold the potential to be TCs. The importance of the mind and mental processes in the meaning of *concept* helps to refute the idea that physical skills can be counted as TCs.

1.3 Data Collection Methods in the Researching of Threshold Concepts: A Recent Publication

A recent paper titled *A Framework for Working with University Teachers to Create and Embed 'Integrated Threshold Concept Knowledge' (ITCK) in Their Practice* was authored by Julie Timmermans and Jan Meyer (one of the two founding authors of TCs) in 2017. The intended audience for this paper was educational developers and the purpose of the text was to aid these developers to work with university teachers to integrate TCs into their teaching programmes. The authors developed the term *integrated threshold concept knowledge* (ITCK) to describe the multi-step process of identifying TCs, and incorporating pedagogical strategies that are contextually relevant to support students' acquisition of the identified TCs. The relevance of this particular paper (especially in the sections regarding both, the identification of TCs, and the utilisation of TCs in curriculum development) have led me to include this analysis of the paper.

1.3.1 Timmermans and Meyer's ITCK Framework

Timmermans and Meyer (2017) decided to create the ITCK framework to aid educational developers as they work to help university teachers to incorporate TCs into their course programmes. They did so by providing seven teaching and learning principles, followed by seven 'clusters' of activities that should be carried out by educational developers throughout the ITCK process. The

principles and the framework were both based on a synthesis of TC research literature that was said to be inclusive of a range of countries, disciplines and institutional contexts. To give a brief description, the seven teaching and learning principles were:

1. Placing the students first with the use of a student-centred teaching approach.
2. All discussions related to TC acquisition should include a focus on the *transformative* nature of TCs; this being an important characteristic of the original five provided by Meyer and Land (2003).
3. Acknowledging the importance of emotion and motivation in relation to learning. This is most relevant when considering the *transformative* and *troublesome* nature of TCs which may potentially impede motivation and affect learners emotionally.
4. Care should be taken by educational developers and university teachers because of the importance of TC understanding and the inherent student *transformation*. They must show care to one another, the students, and the discipline in general.
5. Students may each have a differing experience within the liminal space before coming to comprehend a TC and so difference must be celebrated rather than dismissed in order to maximise students' chances of fighting through the liminal space into fuller understanding.
6. Educational developers and university teachers must practice reflexivity so that learning can be contextualised for each cohort of students to maximise the chances of students' successful comprehension of TCs.
7. Lastly, educational developers should encourage university teachers to communicate with colleagues about TCs and teaching pedagogy. These conversations should then be used to inform course programmes and/or teaching practice.

The next subsection will detail the seven activity 'clusters' introduced by Timmermans and Meyer (2017) that rest on the seven foundational principles listed above.

The Seven Activity Clusters

The first activity cluster given by Timmermans and Meyer (2017) for educational developers as seek to help educators embed TCs into their courses is identifying and analysing TCs. In order to identify TCs, the authors recommended that information be gathered from multiple sources which will help to inform whether or not a particular concept can be considered a TC. These sources include: existing literature, teachers (through methods such as focus groups, interviews and concept mapping), students (through methods such as interviews, surveys and focus groups) and discipline experts.

The second activity cluster revolved around ensuring the experts (i.e. the course teachers) can make their understanding of TCs explicit. This can be achieved in ways such as interviewing experts multiple times about the nature of specific TCs; asking them to form a rubric for each TC which breaks each into a series of components (including the required *ways of thinking and practising* needed to understand the concept); creating metaphors for each concept that tie the abstract ideas to concrete, real-world scenarios; and asking experts to provide a meaningful name to represent the TC (which could exist in the form of a phrase, equation or image) (Timmermans & Meyer, 2017). Similarly, activity cluster three required the TCs to be situated into a discipline. The authors note that teachers can have transformational mind-shifts when asked to consider and situate TCs within their discipline, specifically in an epistemological sense. They may come into fuller understanding surrounding how knowledge is attained within their specific discipline which can aid them in their teaching practice. Activity clusters one, two and three are foundational and lead on to cluster four, five and six which hold their focus specifically around teacher pedagogy.

Cluster four regarded designing student outcomes for a course once the relevant TCs have been identified. The authors discussed that there are differing learning domains (e.g. cognitive and psychomotor) and levels of comprehension (e.g. novice understanding and expert understanding), and that educational developers and teachers must discuss what realistic student outcomes should exist considering the length of the course and the TCs being taught. During this cluster, stakeholders should consider such aspects as how TCs should be distributed across a course and whether or not TCs should be continually revisited. A note of critique I would raise on this section of the paper is that Timmermans and Meyer (2017) seem to be alluding to the fact that TCs may involve psychomotor learning. As a result of my analysis of the term *threshold concept*, I came to the resolution that *concept* refers only to something that originates in the mind (e.g. thought or notion) and thus cannot be used to refer to physical actions. I am wary, therefore, of this allusion to the psychomotor elements of TCs.

Cluster five was deemed highly important and surrounded the assessment of students to gauge their understanding of the TCs being taught. A heavy focus on the *transformative* nature of TCs was apparent within this cluster, the authors calling educators to assess students in such a way as to capture evidence of students' transformation of thought whilst also accepting that much variation may exist amongst students because of the *troublesome, transformational* nature of the learning. Closely linked to this is cluster six which encompassed teaching and learning activities. Suggested teaching and learning activities to aid TC acquisition included; activities that blatantly introduce students to the troublesome nature of the TC with the aim of leading them into the liminal space; times within which students can display their current understanding of a TC and receive targeted feedback; and a modelling approach whereby an appropriate analogy is shared to introduce the TC, followed by a discipline-specific example and concluded with a discussion of the TC and its components.

The final activity cluster concerned the fact that teachers who aim to make TC theory a part of their pedagogy can make use of this in a scholarly fashion. It is

suggested that both quantitative and qualitative data should be collected by teachers to investigate aspects such as learners' experience of TCs and the effectiveness of certain teaching methods when teaching TCs. It was said that educational developers may then disseminate this knowledge through avenues such as conferences and symposiums. In this way Timmermans and Meyer position the study of TCs as a collaborative enterprise of knowledge building around TC identification and curriculum development, something that that this thesis aims to contribute to.

In the next section I will further discuss the nature of TCs by discussing two key ideas.

1.4 Ideas Relevant to Threshold Concepts

Several existing ideas can be associated with, or which apply, when considering TCs. In the following subsections, two such theories will be succinctly summarised and then coupled with TC theory. These two were specifically chosen on the basis that they are relevant to the focuses of my thesis.

1.4.1 Expanding the Idea of Liminality

The concept of liminality was originated by Arnold van Gennep in 1960. Victor Turner built on the concept in his paper in 1969. Both authors discussed this in the context of cultural rites of passage and rituals. Briefly, from their eyes, liminality, which arises from the Latin word *limen* (threshold), refers to the transformational period of time in which the rites and rituals take place. Meyer and Land published a paper in 2005 that linked liminality to TC theory. They proposed liminality to be an appropriate notion to apply to TCs based on the liminal rites of passage phases described by van Gennep (1960) and Turner (1969). This proposition was argued in three respects; these phases are *transformational*, in that an individual or group shifts into a new state of being; new knowledge is obtained by those transitioning

which results in a new identity within the community; and the process is often *troublesome* for participants, occurring sometimes over long periods of time with potential oscillation between states transpiring.

1.4.2 Mimicry

In their seminal paper, Meyer and Land (2003) mentioned that the learning in the liminal space before a TC is fully understood can take the form of mimicry. They stated that students will mimic what is expressed by teachers and what is written within the literature until, ideally, the TC will become fully understood in their minds. Cousin (2006) expanded on the notion of student mimicry by stating that students will fall into the practice of mimicry when learning a TC in order to feel a higher level of safety and comfort whilst traversing the troublesome journey into full understanding. The phenomenon was left with several questions by Cousin as she pondered whether or not this should be encouraged amongst students and whether it acts more of an aid or hindrance to TC learning. Interestingly, Zepke (2013) cast his opinion on this very issue voicing that the deep level of learning that is achieved when TCs are understood, through the *transformation* of the students, may be cause for teachers to discourage the practice of mimicry amongst their students. He felt that students should be doing their own thinking, questioning and connection-making to reach full understanding as opposed to mimicking the understanding of others.

The next section discusses the term *curriculum* and the role that TCs hold in the development of curricula.

1.5 Curriculum Development with the Aid of Threshold Concepts

The role of TCs in curriculum development is one of the focuses for this thesis. It is necessary, therefore, to provide a discussion of what is meant by the term *curriculum*. I have done this by comparing this term with the term *pedagogy* as

there are strong links that exist between them. Following from this discussion is an account of how TC researchers view TCs in relation to curriculum development. This last account provides the thoughts of researchers other than Timmermans and Meyer (2017), as their paper was analysed in Chapter 1.3.

1.5.1 Curriculum vs Pedagogy

The word *curriculum* was originally a Latin word that meant either 'running' or the 'course of a race' (Merriam-Webster, n.d.-a). From there the meaning of the term changed to, firstly, refer to academic endeavours and then, secondly, to the time constraints within which academic understandings should be taught and learned (Egan, 1978). More recently, Su (2012) claimed that the modern day definition of *curriculum* is not universally agreed upon, one of the reasons being the large number of stakeholders that exist who bring their own view to the term (e.g. educators, students, parents, researchers). Su provided five current conceptions of what is meant by curriculum; a compilation of educational goals or objectives to be met; the way in which courses of study and the content for these courses are selected; a plan or blueprint for the content and the teaching and learning (though the teaching and learning itself is not considered as part of *curriculum*); a physical document that officially outlines a course programme; and as a programme for different learning *experiences*. The definition of *curriculum* that I have chosen to adopt for this thesis, informed by these definitions, is the arrangement of content, goals, objectives and experiences that are compiled by the developers that may, or may not have, been printed into a formal document.

Pedagogy originated from the Greek word *pedagogue* which means 'teacher' (Merriam-Webster n.d.-b). Like the term *curriculum*, pedagogy has several perceptions, one of which being anything that a teacher does to influence learning for students (Child Australia, 2017). The Ministry of Education (2007) expanded on this definition in *The New Zealand Curriculum* by providing seven elements that comprise a teacher's pedagogy; establishing an environment in which students feel comfortable in and within which are supported; nurturing students to

be able to individually reflect and turn these reflections into actions; making learning relatable and manageable for students; aiding students in connecting new learning to what has been learned prior; providing an appropriate amount of time and opportunities for students to learn; and teaching through inquiry by constantly asking questions and trialling new techniques in the hope of bettering their practice.

Simplistically put, curriculum and pedagogy are different in that a *curriculum* refers to the content that is taught whilst *pedagogy* pertains to the techniques that are used by an educator to deliver the curriculum content (Standing Committee on Education and Training, 2002). There are however multiple definitions for each term. I will be focussing on curriculum development as a part of the thesis and not considering how different pedagogical approaches might be employed to implement or enact the curriculum. As pedagogy is not a focus of the thesis, therefore, I feel no need to provide a concrete definition of the term.

1.5.2 Threshold Concepts and Curriculum Development

Several researchers have attempted to explore the role of TCs in the design, or redesign, of a curriculum. Indeed, the seminal TC theory authors Land and Meyer, along with Cousin and Davies (2005), devoted a paper to the role of TCs in curriculum development. In this paper those authors described TCs as the 'jewels in the curriculum'. This metaphor was used in two instances, as a reference to TCs being the valuable parts of a course that teachers may want to focus on and provide learning opportunities for in order for these concepts to be fully understood by students; and, secondly, that TCs can be diagnostic 'jewels' useful for teachers as they attempt to identify sections of a course that will prove *troublesome* for students. At this point it is important to point out how easily the lines between *curriculum* and *pedagogy* can be crossed. In the above example, the authors described TCs as 'jewels' in the *curriculum* but then went on to discuss how these can be used to inform teachers at which points learning experiences should be provided. The physical act of providing learning experiences relates to

teacher *pedagogy* and not *curriculum* as this is an action from the teacher to influence student learning.

As a more recent example, McGowan (2016) profiled an attempt of a history professor as he attempted to use TC theory as a basis for his redesign of a history course at his university. His intent was to introduce students to core TCs in the discipline of history and his particular study led him to conclude teacher assistants to be invaluable in the teaching of these TCs. Interestingly, this finding, similar to the point above, was related to *pedagogy* and the conveyance of course content rather than the *curriculum* itself.

1.6 My Study

My academic background has been in the discipline of education and I have, at this stage, completed a Bachelor of Teaching (Primary) and have completed a Summer Scholarship project through the University of Waikato. This project saw me analysing assignments from pre-service teaching students in Australia for evidence of potential TCs. I first encountered TC theory when completing a masters level paper that focused on life transitions. I saw wonderful potential with TC theory as a way to take a fresh look at the New Zealand primary school curriculum and I was very enthusiastic about using this thesis as an opportunity to attempt to identify potential TCs at a primary school level. This was my initial thought as, up to this point, TC theory had been very much been based on tertiary courses with very few researchers focussing on the preceding levels of education. I came to the realisation very soon, however, that I had so many unanswered questions about the best way to design a study that sought to identify potential TCs, especially since so little TC research had been conducted on students below university age. In light of this, I felt it necessary to conduct an in depth study on the most common and effective data collection methods to use when conducting a TC identification study and which are most effective in a study that utilises TCs in the curriculum development process. I felt that the conclusions drawn from one

such study would make my initial study idea much stronger seeing that I will have chosen my data collection methods based on the ones that have proven to be the most successful and effective in the past. That is why this current thesis holds the focus that it does.

1.6.1 Gaps in the Literature That Aim to be Addressed

As is evident is both Meyer and Land's (2003) seminal paper and Timmermans and Meyer's (2017) framework, TC theory is mainly applied to tertiary education. This was true of Meyer and Land's paper as it was grounded in a project that was exploring *undergraduate* learning-teaching environments. It was true of Timmermans and Meyer's framework as it was aimed at educational developers to aid *university teachers* to incorporate TCs into their teaching programmes. I hope to provide findings that are of a more general nature that may more easily be applied to a wider range of educational levels.

There does not exist an examination of TC literature that explores the amount of focus researchers' place on each of Meyer and Land's original five TC characteristics. I feel this is of great importance as these characteristics were described by Meyer and Land as a way to identify potential TCs. There may exist trends between TC studies that indicate which characteristics are of greater or lesser importance (if any difference at all). If trends do exist then this may hold implications for those who intend to carry out future TC identification studies.

On a similar note to the last gap mentioned, there does not exist a systematic quantitative literature review (SQLR) that attempts to quantify the specific data collection methods, or research participants, that TC researchers utilise and include in their studies. I feel that one such literature review would be of value for TC researchers who are intending on planning a future TC study. Ideally, this form of review would point to trends for which methods are used most, those

which are used to least, and which types of participants are included, to help inform researchers' decisions in their own TC study design.

My discussion of the role of TCs in curriculum development (Chapter 1.5.2) mentioned several times the ways authors have discussed *pedagogy* and *curriculum* in tandem. This was of particular note when McGowan (2016) discussed a finding that related to *pedagogy* rather the *curriculum* in his paper. I hope to bring further clarity to this area of TC theory by attempting to produce findings that relate solely to the role of TCs in curriculum development, taking care to not to discuss any aspects that relate to *pedagogy*.

1.7 The Structure of the Thesis

I will begin by outlining the method of my study in Chapter 2, discussing such elements as the paradigm that has been adopted for the study, the data collection methods utilised and the ethical considerations for the research participants. Following this, in Chapter 3, is a SQLR of engineering education TC publications that focuses on aspects such as; the locations the papers were published in; the number and type of data collection methods the researchers utilised; the types of participants the researchers included; and the prominence of each of Meyer and Land's (2003) original five TC characteristics amongst the literature. Chapter 4 provides vignettes for each of the three semi-structured interviews that I conducted with engineering education TC researchers. Lastly, in Chapter 5, is a discussion and implications section where; themes are tied together from the SQLR and the interviews; the emerging themes are then linked with the literature discussed in the introduction; and implications are outlined based on the thesis findings.

Chapter 2: Method

This chapter fully details the way in which my study was conducted. It begins with the list of research questions that this study attempted to answer. Following this is an account of the research paradigm that was adopted, the data collection methods that were utilised, and the ethical considerations for the participants in the study.

2.1 The Three Research Questions

This study is based around three research questions which are provided below. These questions were directly based on my observation of literature gaps (see Chapter 1.6.1). As discussed, I feel the answers to each will be beneficial for those who are interested in carrying out studies based around TCs. A last note of import is that I ended up narrowing my focus to TC researchers in the field of engineering education as the context through which I have attempted to answer these questions (see Chapter 2.3.3).

1. To what extent have TC researchers focused on each of Meyer and Land's original five TC characteristics?

2. Which data collection methods, and participants, are most commonly included when attempting to study TCs?

3. To what extent have studies explored the role of TCs in curriculum development?

2.2 Pragmatism Paradigm

The research paradigm that is adopted by a researcher as they carry out a study is foundational to the whole project. It influences the researcher's conception of

knowledge, whereby influencing the research design chosen and the specific data collection methods that will be utilised (Cohen, Manion, & Morrison, 2018). Several opposing paradigms exist within the realm of social science research, the main two of which being positivism and interpretivism. To give a very brief explanation, positivism holds that a single form of knowledge exists and that standard laws can be created to represent all things including human behaviours (Cohen et al., 2018). Contrarily, interpretivism maintains that knowledge exists through each individual's interpretation of the world and, therefore, no standard laws can be produced to explain social phenomena as there is no one form of knowledge (Cohen et al., 2018). My choice of paradigm, the pragmatism paradigm, allows a researcher to adopt a viewpoint that accepts both, that there is a single world that exists from which knowledge can be discovered, and that individuals can each hold their own interpretation of this world (Morgan, 2007). This paradigm is discussed in the following subsections, including the reasoning behind my choice.

2.2.1 The Pragmatist's Conception of Knowledge

In the pragmatist view, ideas are non-existent without the consideration of the context (i.e. physical environment, historical era, and social environment) in which they were developed (Brinkmann, 2013). Two significant implications arise from this belief: ideas may not develop purely within the mind of an individual as they are directly tied to the context that the individual exists within and, similarly, ideas cannot be studied by themselves because of their ties to their context of origin (Brinkmann, 2013). Furthermore, the adaptability of an idea is the crucial factor of its application, as opposed to the unchangeability of an idea. Adaptability refers to the way an idea can be modified to solve new problems that are faced in society (Brinkmann, 2013).

In a similar vein, pragmatism dictates that ideas hold their meaning in their applications or consequences rather than holding meaning in and of themselves (Brinkmann, 2013; James, 2010). James (2010), a forefather of this paradigm,

points out the futility of carrying out metaphysical debates over issues that bear no significance whether one side is considered true or another; the truths that should be sought are those which bear consequences within society. If an idea is to be considered true then the practical consequences of that idea must be investigated and tested through application. Again, an idea must not be separated from its application/s and consequence/s as its truth is held within its physical application (James, 1907).

2.2.2 Utilising the Pragmatism Paradigm Within Research

At the conclusion of a study that has employed the pragmatism paradigm, the implications from the data are not intended to be fully generalizable. Interestingly, the implications are also not intended to be completely case-specific, relating only to the participants within that study. Instead, the implications are intended to be transferable so that readers may be able to acknowledge that, while the implications cannot be absolutely transferred to another context, they will have at least some level of transferability (Morgan, 2007). This idea links strongly with the conception of knowledge as believed by pragmatists: an idea is only of use if it holds applications and consequences within the wider world. In this sense, allowing a reader to transfer the implications from a study into their own personal context is what gives the study its relevance (Brinkmann, 2013; James, 2010).

Throughout the data collection process, pragmatism requires a researcher to adopt abductive reasoning (Morgan, 2007). This means that the researcher will not think solely inductively by first collecting data and then producing a theory as a result of the data. Nor will the researcher rely solely on deductive reasoning where they first begin within a theory and gather data to test the theory. Abductive reasoning, rather, requires the utilisation of both of these types of reasoning. For example, the researcher may conduct initial observations to develop a potential theory (inductive reasoning) before collecting quantitative data to test this created theory (deductive reasoning) (Morgan, 2007).

As previously mentioned, a pragmatism stance allows a researcher to appreciate that the world holds universal truths that can be uncovered through quantitative means, as well as appreciating that individuals can hold differing interpretations of the world that can be uncovered through qualitative means (Cohen et al., 2018; Morgan, 2007). Therefore, when adopting the pragmatism paradigm, a researcher will be able to opt for those data collection methods that will most effectively enable them to answer their research questions; they are not impeded by having to use solely qualitative or solely quantitative data. In the following subsections I expand on this point by discussing the mixed methods research design, which is the approach I have selected to adopt, and how the aspect of reflexivity is of importance for this form of study.

Mixed Methods Approach

The mixed methods approach is a type of research design based upon the utilisation of quantitative and qualitative data collection methods to most effectively answer the established research questions (Cohen et al., 2018; Creswell, 2003; Johnson, Onwuegbuzie, & Turner, 2007). The nature of my posed research questions required me to obtain both quantitative and qualitative data. I quantified the data collection methods the TC researchers used, the number of times each TC characteristic was mentioned in the literature, and the number of studies focusing on TCs in curriculum development (see research questions one, two and three in Chapter 2.1). I also collected qualitative data by obtaining opinions on TC research from my interviewees to compare with my quantitative data. This was opted for as the research design for my study because of its strong links with the pragmatism paradigm; each allows for qualitative and quantitative data to be collected through a variety of data collection methods.

Reflexivity

As was believed by Dewey (1927), the development of objective laws to explain social and psychological phenomena, the likes of which can be seen in the natural sciences, is an impossibility. His argument is based on the grounds that, as further

social and psychological knowledge is developed, this will influence change on those who are discovering the knowledge. In effect, the obtaining of new knowledge will constantly change the behaviours of those discovering it, making the discovered knowledge obsolete. Brinkmann (2013) agrees that this issue is prevalent within the disciplines associated with the human and social sciences and terms the concept *reflexivity*.

I have included this section on reflexivity because of its importance for researchers conducting a study that utilises the pragmatism paradigm. Reflexivity is most notable in the abductive reasoning approach that is required of the researcher (Morgan, 2007). As an example, a researcher may opt to conduct initial observations to form a hypothesis which they may then test with a quantitative survey. Within this example, the researcher must display reflexivity by analysing the data from their observations and using this to inform what questions are to be asked within the survey. Lastly, that researcher will have another significant period of contemplation time once they have obtained their survey data as they revisit their initial hypothesis and begin to discuss the overall results.

One last example of reflexivity in practice was detailed by Pickering and Byrne (2013) in their paper on SQLRs. They indicated that the results from an SQLR must relate directly to the initial research questions. This means that if the identifiable patterns and gaps within the literature, as determined through the analysis of the data tables (the SQLR process is discussed in more detail in Chapter 2.3), are not directly related to the initial research questions then the researcher must exhibit reflexivity by reviewing and altering the research questions to provide coherence to the project.

2.2.3 The Reasons for Adopting this Paradigm

The significance of identifying TCs, as originally stated by Meyer and Land (2003), lies not within the concepts themselves but how they can be utilised to

develop curricula and improve teaching-learning environments. This aspect of TCs, therefore, falls in very closely with what pragmatism deems to be useful knowledge: that which has applications and consequences as opposed to being facts without applications (Brinkmann, 2013; James, 2010). Adopting the pragmatism paradigm garners an air of cohesiveness throughout my project as the subject matter, TCs, lines up with what is deemed as useful knowledge within the realm of pragmatism.

It was always my intention to interview TC researchers as a part of my study and question them on the studies that they had personally conducted. Giving the matter further thought, I realised how much more effective my study would be if I were able to incorporate an abductive reasoning approach (Morgan, 2007). Specifically, collecting quantitative data to help me identify patterns in the TC field (i.e. collecting data to form hypotheses) which would then be discussed with the interviewees (i.e. testing the created hypotheses by collecting further data). As has been discussed, adopting the pragmatism paradigm requires the researcher to use abductive reasoning within the project (Morgan, 2007) and is, therefore, a suitable choice for this study.

2.3 Systematic Quantitative Literature Review

A SQLR was the first of two data collection methods utilised within my study. A SQLR differs from a traditional narrative literature review in terms of the way the literature is sourced and included, and the ways through which the literature is analysed and discussed. These differences of approach are briefly outlined below.

To determine the literature to be included, the author of a narrative literature review uses their judgement and intuition to identify items of relevance (Pickering, 2013a). The author of an SQLR, however, approaches this inclusion process with a systematic approach, scouring online databases, taking into

consideration every single relevant item of literature and evaluating it against a strict inclusion criteria (Pickering, 2013a; Slavin, 1986). The method by which literature is located and included must be comprehensively detailed by the author to maximise the replicability of the process (Pickering & Byrne, 2013; Pickering, Grignon, Steven, Guitart, & Byrne, 2014).

After having read the literature to be included within the review, the author of a narrative literature review provides a summary of each item of literature, compares and contrasts the literature and, commonly, provides an assessment of the quality of each literary item (Day, 1995; Ferrari, 2015; Pickering et al., 2014). The author of an SQLR, however, approaches the discussion of the literature in a different way. To conduct an SQLR it is required that, as the literature is being read, a spreadsheet is filled in that displays chosen variables extracted from each literary item (e.g. location of origin of the article, research methods adopted) (Pickering, 2013a; Pickering & Byrne, 2013). Upon completion, this spreadsheet is used to produce quantitative tables that display these variables numerically. Thus, the SQLR author bases their discussion on these quantitative tables; discussing not only the identifiable patterns within the reviewed literature, but also any noticeable research gaps (Pickering, 2013a; Pickering & Byrne, 2013).

The following subchapters will comprehensively outline the processes involved, and choices made, for the SQLR that I undertook. I begin by discussing the initial literature inclusion criteria before listing the databases that were used to acquire the literature and the search terms used. I then discuss the process of narrowing the focus of the review and finish by discussing the table formation and analysis.

2.3.1 Literature Inclusion Criteria

The first requirement in the inclusion criteria for my SQLR was that each item of literature had to be a research article. That is, an article detailing original research (Perneger & Hudelson, 2004). The reasoning behind this was that I planned to

uncover the way TC studies had been designed and structured. Therefore, the most effective method of obtaining this knowledge was to direct my focus solely on original research articles that detailed the study methodologies and results. I chose also to include only those research articles that had been peer-reviewed. The reasoning behind this was so that I would only analyse those papers that had been adjudicated and approved by other scholars and, therefore, would be of a high quality with data likely to be reliable (Spier, 2002).

Secondly, all literature was required to have been published between 2003 and present. There is a logical explanation for this seeing that the seminal article on TCs (Meyer & Land, 2003) was published in 2003. No studies on TCs will have been published prior to 2003 as the concept was yet to be introduced.

Thirdly, in order for a research article to be included in the SQLR the topic of the study had to encompass either, an attempt to *identify* a TC or multiple TCs within one or more disciplines, or the implementation of TCs within the development of curricula. Where a study attempted to identify a TC/s, this had to have been a primary focus of the study in order to be included (i.e. not as a secondary goal or as an afterthought). I did not include those papers that involved authors arguing that a concept is a TC based on their own experience. Instead, the papers had to involve the researcher/s collecting data in order to identify potential TCs.

2.3.2 Databases and Search Conditions

The complete list of databases that were used to acquire and compile the literature is listed on the next page. There were nine in total and were selected due to the content they relate to. I favoured those databases that contain literature on a large range of focusses because of the fact that TCs do not relate solely to one discipline but, rather, every discipline.

1. Taylor and Francis
2. Science Direct (Elsevier)
3. Sage
4. Springer Link
5. Emerald Insight
6. Wiley Online Library
7. Proquest Central
8. Ebsco Host
9. Jstor

The search conditions that were used are listed below with explanations for why they were used. I was as consistent as was possible. It is of import to raise that some databases allowed for searches to be conducted to a higher level of specificity with a larger number of search options. Therefore, those search options were used below when possible (depending on whether the database contained the option or not). This did not mean any literature was excluded from those databases with less advance search engines. It just meant there were more search results that appeared.

- The only search term used was 'threshold concept'. This term was chosen as a singular, as opposed to a plural, as I wanted papers to appear no matter the number of TCs that were mentioned. I felt no need to search any synonyms of *threshold concept* because from my initial reading I have found no widely used synonyms to exist.
- The date of publication range that I used was from 2003 to present. This was because the concept was initially conceived in 2003 and, therefore, no papers would exist on the topic before that year.
- I selected the option *peer-reviewed research articles* where possible. This is because I was focussing on researchers accounts of their own studies and reasoned research articles to be the most fruitful source of such accounts. I opted for *peer-reviewed* articles as I wanted the literature that I included to be as valid and trusted as possible.

- *English* was opted for as the language for the articles because it is the only language I can read.

2.3.3 Narrowing the Focus

There was a total of 2 165 search results that were produced from the nine databases. The number of search results for each data base are listed below.

- Taylor and Francis: 411 results
- Science Direct (Elsevier): 514 results
- Sage: 84 results
- Springer Link: 363 results
- Emerald Insight: 56 results
- Wiley Online Library: 299 results
- Proquest Central: 162 results
- Ebsco Host: 123 results
- Jstor: 153 results

Much of this literature was not relevant to this study and did not meet the literature inclusion criteria that I had set. From this number, I ended up with 147 relevant articles. Pickering (2013b) stated that an SQLR should contain between 15 and 300 articles, so this number could have been used in totality. I, however, reasoned that if I could I narrow this list to include studies based around the same context then this would make the analysis and conclusions more cohesive. Therefore, I decided to narrow it down according to the discipline the papers focussed on. I came to the final conclusion of including only those TC articles that related to the discipline of engineering as this was one of the disciplines most highly represented in the list and was the discipline which Erik Meyer, a co-founder of TC theory, was lecturing on (Timmermans and Meyer, 2017). This left me with a final list of 15 papers which are listed on Table 1. These papers are also all included in the reference list at the end of the thesis.

Table 1. The Final List of Papers for the Systematic Quantitative Literature Review

Article name	Author/s and Year
Identifying Threshold Concepts: Case Study of an Open Catchment Hydraulics Course	D.B. Knight, D.P. Callaghan, T.E. Baldock & J.H.F. Meyer (2013)
Threshold Concept Theory as an Enabling Constraint: A Facilitated Practitioner Action Research Study	A. Harlow, B. Cowie, D. McKie & M. Peter (2017)
'Getting stuck' in Analogue Electronics: Threshold Concepts as an Explanatory Model	A. Harlow , J. Scott , M. Peter & B. Cowie (2011)
Heuristic for Learning Common Emitter Amplification with Bipolar Transistors	K. Staffas (2017)
Threshold Concepts in Undergraduate Engineering: Exploring Engineering Roles and Value of Learning	S.A. Male & D. Bennett (2015)
Identification of Threshold Concepts Involved in Early Electronics: Some New Methods and Results	J. Scott & A. Harlow (2012)
Threshold Concepts in Engineering Education: Exploring Potential Blocks in Student Understanding	C. Baillie, P. Goodhew & E. Skryabina (2006)
Results From a Study with Threshold Concepts in Two Chemical Engineering Undergraduate Courses	K.R. Davey (2012)
Application of Threshold Concepts to Improve a Design-Focused Course in Transportation Engineering	D. Cernusca & G.H. Bham (2011)
Threshold Concepts: A Point of Focus for Practitioner Research	N. Irvine & P. Carmichael (2009)
A Cognitive Approach to Threshold Concepts	G. Walker (2013)
Inquiry Based-Computational Experiment, Acquisition of Threshold Concepts and Argumentation in Science and Mathematics Education	S. Psycharis (2016)
Identifying Threshold Concepts and Proposing Strategies to Support Doctoral Candidates	M. Kiley (2009)
Intensive Mode Teaching of a Humanitarian Engineering Course to Enhance Service-Learning	J. Smith, P. Compston, S. Male, C. Baillie & J. Turner (2016)
Seeing Through the Lens of Social Justice: A Threshold for Engineering	J. Kabo & C. Baillie (2009)

2.3.4 Spreadsheet

I compiled all 15 articles into a spreadsheet and then began to analyse them in relation to specific categories. These categories were chosen to both, help me to observe the difference in contexts between the articles (e.g. location of study), and to gather data to answer the three research questions. Each category (e.g. which data collection methods were used to identify TCs) held its own column in the spreadsheet and I wrote the correct information in this column for each article. The list of categories is listed below:

- Geographic region the study was conducted in
- Year of publication
- Subdiscipline of engineering that is focussed on
- Was there a focus on TC identification?
- Was there a focus on TCs in relation to curriculum development?

- Data collection methods used to identify TCs
- Data collection methods used to explore TCs in curriculum development
- Total number of data collection methods used
- Participant types included
- Number of times *transformative* was mentioned
- Number of times *troublesome* was mentioned
- Number of times *integrative* was mentioned
- Number of times *irreversible* was mentioned
- Number of times *bounded* was mentioned

2.3.5 Table Formation and Analysis

The last step in completing the SQLR was to gather the quantitative data from the spreadsheet and place it into tables to be analysed for themes. These tables and themes are discussed in Chapter 3. Instead of including a discussion of the literature gaps from the SQLR at the end of Chapter 3 I have provided this information in the discussion of future research recommendations in Chapter 5.2.4.

2.4 Semi-structured Interviews

Semi-structured interviews of four TC researchers were the second data collection method utilised within this study. Semi-structured interviews were opted for as they require the researcher to plan the topics and questions to be covered prior to the interview, yet award the researcher a certain amount of freedom when conducting the interviews (Cohen et al., 2018). One such freedom is the option to rephrase questions for interviewees in order to maximise clarity. In doing so, the researcher ensures that the interviewee has correctly comprehended the question and maximises the potential for lucrative answers (Barriball & While, 1994). A second area of freedom awarded by the method is the ability for the researcher to probe interviewees for further information in response to specific answers. This allows the researcher a chance not only to gain clarity about an answer, but also to

find out more information when a topic of interest is raised (i.e. a topic that the researcher had not considered prior to the interview) (Adams, 2015; Bishop, 1997; Rabionet, 2011; Wilson, 2014).

The semi-structured interviews were conducted after the completion of the SQLR. The findings from the review aided in the shaping of the interview script (see Appendix 4). For example, my identification of a specific pattern (e.g. similar focuses between the studies) from the literature allowed me to formulate a question surrounding this pattern and hence gain each interviewee's perspective of the pattern. This links back to the idea of abductive reasoning (Chapters 2.2.2 and 2.2.3); I used inductive reasoning to create hypotheses from the SQLR data which were then tested deductively through the collection of qualitative interview data (Morgan, 2007).

2.4.1 Specific Details of the Interview Process

Firstly, participants, each of which were supervisor contacts, were sent an email of invitation (Appendix 1) which, if they were willing, they could accept via a return email. They were then sent a second email (Appendix 2), and an informed consent letter to sign (Appendix 3). These outlined further details surrounding the interview process and gave them the option of either a *Skype* or face-to-face interview (depending on their personal preference and location). The second email also asked them for dates and times that would suit them best for the interview.

The interviews lasted between 45 and 90 minutes. Each interview was audio recorded for analysis purposes. Once the interviews were transcribed, participants were emailed either a full transcription of their interview, or a summary of the interview. For the summary I succinctly outlined what was covered throughout the interview and embedded key quotes (participants had the choice of either option). Participants were given the option of a final 45 minute *Skype* or face-to-face meeting that would allow them the chance to provide further comments on the

topic. This meeting was not opted for by the any of the four participants on the basis that they had conveyed their full thoughts within the initial interview.

2.4.2 Coding

Coding is a data analysis strategy that allows researchers to organise and condense their interview data, and begin to identify patterns and themes within transcripts (Ary, Jacobs, & Razavieh, 2002; Cohen et al., 2018; Gorden, 1992; Westbrook, 1994). In order to code, the researcher reads the transcripts to identify any recurring concepts or themes. Each of these concepts or themes is then classified as a category and assigned a unique phrase, symbol or colour (i.e. the code for each category). These categories may be altered upon reflection as the researcher continues to study the transcripts (Westbrook, 1994). To conclude the process, the researcher re-reads the transcripts as many times as necessary to finalise the assignment of codes. The categories for the coding process may, alternatively, be decided upon prior to interviews if the researcher has a firm idea of what kinds of responses they will receive from the interviewees.

In the case of this thesis, I had the three research questions at the fore of my mind before the interviews and so I used these as my three broad coding categories. Each interview transcript was coded with the categories *discussion of TC characteristics*, *discussion of data collection methods,* and *discussion of TCs in relation to curriculum development.* I left these very broad as I was not sure of the themes that would emerge and did not want to miss anything crucial by making my categories any more specific.

2.4.3 NVivo 12

NVivo 12 is a digital tool developed by the company QSR International and is the tool through which I coded my interview transcripts. I first uploaded all of the interview transcripts to NVivo 12. I then created my coding categories by creating a series of nodes within the tool (nodes are synonymous term for categories).

After completing these first steps I coded the transcripts by highlighting sections and assigning these to the relevant node (Silver & Lewins, 2014; University of Hull, 2017).

2.4.4 Vignettes

The method through which the interview data is presented within Chapter 4 is individual vignettes. Vignettes allow interviews to be summarised succinctly for the benefit of the reader, highlighting only the most notable points that arise from the interviews (Miller et al., 1997). I chose to combine two different vignette styles to create these individual vignettes. I first presented summaries of the interviews within which I embedded relevant quotations and occasionally had to make inferences to the meaning of some comments. This followed the deductive vignette format. I then used the thematic vignette style by looking at each interview, as a whole, and identifying apparent themes. Following on from the individual vignettes, a section is provided that compares and contrasts the themes from each of the interviews.

2.4.5 Ethical Considerations in Regard to the Participants

Several ethical considerations are discussed below. These were carefully considered before the beginning of the interview process. The interview process was reviewed and sanctioned by the University of Waikato Human Research Ethics Committee.

Participant Confidentiality

For confidentiality purposes, I provided all participants with pseudonyms when sorting the data and throughout the writing of this thesis (although they did have the option to have their true names published (Appendix 3)). Each transcript was only seen by the participant, my supervisor and myself. The only people who I discussed the interview details with were the individual participants and my

supervisor. I did explain to participants that their anonymity may not be possible because of their profile within the field of TC theory.

Potential Harm to Participants

I outlined the participants' rights in my second email (Appendix 2) and the consent form (Appendix 3). This ensured that they were informed of such aspects as their right to question the way the study was being conducted and their right to withdraw themselves and their data up until the point their transcripts (or summaries) were approved.

The time requirement was kept to a minimum. I endeavoured to be as efficient as possible in communication and during the interviews to ensure that participant time was respected. I did not publish any data that participants told me was private information.

Participant Withdrawal of Data

Each participant had access to the data they had provided. The participants were able to contact me via email if they wished to withdraw themselves and their data up until the point their transcripts (or summaries) had been approved. However, this did not occur with any of my participants.

Participant Access to Information

I emailed through each participant's interview transcription (or summary) when I had completed them. The participants were then asked to read them and use return emails to inform me of changes/queries/alterations. Aside from this, participants were informed that they had access to their data at any point. I intend to send them a copy of the completed thesis if they have requested this.

Chapter 3: Systematic Quantitative Literature Review

This chapter contains the data that was collected from the SQLR as well as an account of the themes that emerged. The method of conducting the SQLR was outlined in Chapter 2.3. For the ease of the reader I have inserted the quantitative tables one by one with a succinct analysis of the data and themes directly above each corresponding table.

There are three points of note regarding the SQLR data and the structure of this chapter:

1. The percentages have each be rounded to one decimal place (where applicable). This will account for any totals that add to slightly over or under 100%.

2. Within the SQLR literature, the data collection methods were so closely woven together with the types of participants that I felt it inappropriate to separate them both when discussing the specific methods used. For example, this accounts for methods being described as *teacher interviews* and *student interviews* as opposed to solely *interviews* (see Tables 9 and 10).

3. I have structured many parts of the thesis into the three sections *Threshold Concept Characteristics*, *Threshold Concept Study Data Collection Methods* and *Threshold Concepts in Relation to Curriculum Development.* The last section mentioned has no subchapter of its own in this chapter as there was no specific data that I could attribute solely to the role of TCs in curriculum integration. Instead, data that relates to studies with that focus is discussed in Table 4, Table 7 and Table 10.

3.1 Study Context

Table 2 displays the geographic region/s where the research was conducted for all 15 articles. Each study, except one (Kiley, 2009), was conducted in only one region. The most highly represented region was Australasia which accounted for 8 of the 17 instances (47.1%). The second most represented region was Europe with 6 of the 17 instances (35.3%). There was a significant difference between Europe and the next mostly highly represented region which was North America with a total of 2 out of 17 (11.8%). The region that was least represented was Asia with a total of 1 out of 17 (5.9%). The distinguishable theme from this data is that the majority of studies were conducted in Australasia and Europe, a total of 82.4% when combined.

Table 2. Research Locations of Each Study

Author/s and Year	**Geographic Region/s**
Baillie, Goodhew & Skryabina (2006)	Europe
Cernusca & Bham (2011)	North America
Davey (2012)	Australasia
Harlow, Cowie, McKie & Peter (2017)	Australasia
Harlow, Scott, Peter & Cowie, (2011)	Australasia
Irvine & Carmichael (2009)	Europe
Jeremy Smith, Compston, Male, Baillie & Turner (2016)	Australasia
Kabo & Baillie (2009)	North America
Kiley (2009)	Australasia, Europe & Asia
Knight, Callaghan, Baldock & Meyer (2013)	Australasia
Male & Bennett (2015)	Australasia
Psycharis (2016)	Europe
Scott & Harlow (2012)	Australasia

Staffas (2016)	Europe
Walker (2013)	Europe

Table 3 displays the target discipline or subdiscipline that each study focused on. I have labelled *Engineering in General* as a discipline and labelled every other category (e.g. *Analogue Electronics*) as a subdiscipline. This is because each of the 'subdisciplines' is a specific field within the discipline of engineering. *Engineering in General* was the most highly exhibited with a total of 5 instances out of 15 (33.3%). The only subdiscipline that exhibited more than 1 instance was *analogue electronics* with a total of 4 out of 15 instances (26.7%). The remaining 6 subdisciplines were each represented by 1 study.

Table 3. Target Discipline/Subdisciplines of the Studies

Target Discipline/Subdiscipline	**Number of Studies**
Engineering in General (discipline)	5
Analogue Electronics (subdiscipline)	4
Chemical Engineering (subdiscipline)	1
Materials Science and Engineering (subdiscipline)	1
Humanitarian Engineering (subdiscipline)	1
Civil Engineering (subdiscipline)	1
Transportation Engineering (subdiscipline)	1
Open Catchment Hydraulics (subdiscipline)	1

Table 4 displays the research focus of the studies, whether it be identifying TCs, structuring a curriculum with TCs, or both. The vast majority of papers focussed on identifying TCs as their sole goal with a total of 12 instances out of 15 (80%). The remaining 3 papers focussed both on identifying TCs and utilising them in curriculum development (20%). None of the papers focussed solely on using TCs in the development of a curriculum. The outstanding theme is that TC

identification is a more popular focus for researchers in engineering than a dual focus of TC identification and using TCs in curriculum development, and a sole focus on TCs in curriculum development.

Table 4. Research Focus of the Studies

Focus of Study	**Number of Studies**
Identifying TCs	12
TCs in Curriculum Development	0
Both Identifying TCs and TCs in Curriculum Development	3

3.2 Threshold Concept Characteristics

Table 5 shows the number of times each of the five TC characteristics (Meyer & Land, 2003) was referenced, by name, throughout the 15 studies. Out of the five TC characteristics, *troublesome* was the one discussed most with 119 mentions out of a total of 260 characteristic mentions (45.8%). The second most mentioned characteristic was *transformative* with 79 out of 260 mentions (30.4%). The third most mentioned characteristic was *integrative* with 33 out of 260 mentions (12.7%). Bounded was the next most mentioned characteristic with 17 out of 260 mentions (6.5%), followed by integrative with 16 mentions. The least mentioned characteristic was irreversible with 12 out of 260 mentions (4.6%). The conclusion to be drawn from this data is that *troublesome* has been the most commonly referenced TC characteristic followed by *transformative* which was also highly referenced. The remaining three integrative, irreversible and bounded were mentioned significantly fewer times than these two.

Table 5. Number of Times TC Characteristics Were Mentioned Within the 15 Studies

TC Characteristic	**Number of Times Mentioned**
Troublesome	119
Transformative	79
Integrative	33
Bounded	17
Irreversible	12

3.3 Research Participants

Table 6 shows which type/s of participants were included in the research studies. The vast majority of studies had both students and teachers as participants with a total of 11 instances out of 15 (73.3%). Three studies involved *students only* (20%). The category *teachers only* held one instance (6.7%). The clear theme from this data is that the inclusion of both students and teachers as participants is the most popular choice for researchers in engineering education. If one sole type of participant were to be opted for *students only* was the more popular choice than *teachers only*.

Table 6. Participant Type/s Within the Studies

Type/s of Participants	**Number of Articles**
Students and Teachers	11
Students Only	3
Teachers Only	1

Table 7 is similar to Table 6 in that it displays the types of participants included in the studies. However, it further refines this to consider what the topic of study was in the papers. Analysing the studies that focussed solely on TC identification, the participant type *students and teachers* was the most common with nine out of a total of 12 instances (75%). There were two studies with *students only* (16.7%), and one with *teachers only* (8.3%). A clearly detectable theme from this data is that studies that focus solely on TC identification usually include students as participants (91.7%), with *students and teachers* being involved in 75% of the studies.

The most popular type of participant in the studies that focussed on TC identification and TCs in curriculum development was *students and teachers* with two out of a total of three studies. The other study was *students only*. It appears that students are always included in studies that have a focus on TCs in curriculum development, however I am wary of drawing any definite conclusions because of the small sample size.

Table 7. Types of Participants Arranged by Study Focus

Study Focus	**Types of Participants**	**Number of Articles**
TC Identification	Students and Teachers	9
	Students Only	2
	Teachers Only	1
Both Identifying TCs and TCs in Curriculum Development	Students and Teachers	2
	Students Only	1
	Teachers Only	0

3.4 Data Collection Methods

Table 8 displays the number of data collection methods utilised within each study. A large majority of the studies, 12 out of 15 (80%), made use of more than one data collection method. The most common number of data collection methods utilised was two. Five out of the 15 studies used two data collection methods (33.3%). Three studies made use of four data collection methods (20%). There were two studies that made use of three data collection methods (13.3%). One study made use of just one data collection method (6.7%). Similarly, there was only one example of both five data collections being used and six data collection methods being used (6.7% respectively). To conclude, 13 of the 15 studies used between one and four data collection methods, with two studies using over four methods.

Table 8. Number of Research Methods Within the Studies

Number of Data Collection Methods	**Number of Studies**
1	3
2	5
3	2
4	3
5	1
6	1

Table 9 displays the number of times each specific data collection method was utilised for the studies that focussed on TC identification (a study with multiple identification methods is counted under multiple categories). These methods are from those studies that focused solely on TC identification and also the TC identification methods used within those studies that shared a dual focus of TC

identification and TCs in curriculum development. The total number of data collection methods used in TC identification studies was 36. These 36 instances are compiled into 16 specific data collection methods. Out of the data collection methods, six of the 16 (37.5%) related to gathering data from teaching staff. These were teacher's individual informed opinion, teacher interviews, teacher questionnaires, teacher concept mapping, teacher discussion and teacher surveys. Seven of the 16 data collection methods (43.8%) related to gathering data from students. These were student written reflections, student interviews, student questionnaires, student concept mapping, student surveys, student group presentations and student observations. One of the 16 data collection methods (6.3%) related to analysing students' performance from a course, which was grade distribution. The remaining two out of 16 data collection methods (12.5%) related to analysing known information/texts to pinpoint TCs. These were textbook/programme analysis and concept inventory. The theme that arises from this data is that a slightly larger number of data collection methods in TC identification studies were based around gaining data from students (43.8%) than gaining data from teachers (37.5%), with very few based around gaining data from analysing known information/texts (12.5%) or from analysing student's performance (6.3%).

The largest amount of times that any one of these 16 methods was utilised was four out of 36 (11.1%), (36 was the total combined number of all times the methods were used). There were four data collection methods that had this total of four out of 36 instances (11.1 % respectively). These were teacher's individual informed opinion, teacher interviews, student questionnaires and textbook/programme analysis. Student written reflections and student interviews had three instances of use out of 36 (8.3%). Four of the methods had two instances of use out of 36 (5.6% respectively). These were teacher questionnaires, teacher concept mapping, teacher discussion and grade distribution. The remaining six methods each had one instance of use out of 36 (2.8% respectively). These were teacher surveys, student concept mapping, student surveys, student group presentations, student observations and concept inventory. There is no clear cut theme to present from this data other than the fact that the popularity of the

data collection method does not appear to be based on the source of the data. This is evident in the fact that, of the joint most popular methods, data was collected from teachers in two of them (teacher's individual informed opinion and teacher interviews), one gathered data from students (student questionnaires), and one gathered data from known information/texts (textbook/programme analysis).

Table 9. Threshold Concept Identification Methods Used in the Studies

TC Identification Method	**Number of Times Utilised**
Teacher's Individual Informed Opinion	4
Teacher Interviews	4
Teacher Questionnaires	2
Teacher Concept Mapping	2
Teacher Discussion	2
Teacher Surveys	1
Student Written Reflections	3
Student Interviews	3
Student Questionnaires	4
Student Concept Mapping	1
Student Surveys	1
Student Group Presentations	1
Student Observations	1
Grade Distribution	2
Textbook/Programme Analysis	4
Concept Inventory	1

Table 10 displays the methods that researchers used when studying the effects of using TCs to structure a curriculum. There was a total of seven instances of use

for data collection methods focusing on using TCs in curriculum development. These seven instances of use are compiled into 5 different data collection methods. The most highly utilised data collection method used when studying TCs in curriculum development was *student reflections* with three instances of use out of a total of seven (42.9%). Only one instance of use out of seven (14.3% respectively) existed for each of the remaining four methods. These were *student surveys*, *student observations*, *student interviews* and *grade distribution*. Four of the five methods (80%) related to gathering data from students. These were *student reflections*, *student surveys*, *student observations* and *student interviews*. *Grade distribution*, the remaining method making up the final 20%, related to gathering data from students' performance in a course. There were no data collection methods (0%) used when exploring the role of TCs in curriculum development that relate to gathering data from teachers.

I will not make any conclusions based on the participant types that were included in these methods based on my lack of conclusions from Table 7 (see discussion in Chapter 3.3). It is of note, however, to mention that each of the three studies (100%) that held a focus of the use of TCs in curriculum development utilised *student reflections* as a method. I will cautiously state, because of the low population size, that student reflections may be considered an effective method to use when exploring the use of TCs in curriculum development because of the 100% adoption rate of the method.

Table 10. Threshold Concepts Within Curriculum Development Data Collection Methods Used in the Studies

TCs in Curriculum Development Methods	**Number of Times Utilised**
Student Reflections	3
Student Surveys	1
Student Observations	1
Student Interviews	1
Grade Distribution	1

One last theme concerns information in Table 9 and Table 10. If interviews were combined into a general category that included both student and teacher interviews from both TC identification and curriculum development studies (Tables 9 and 10), then they would be the most commonly used method, with eight of 43 instances overall (18.6% of all instances).

Chapter 4: Semi-structured Interviews

In order to succinctly summarise the views of the three engineering education researchers I interviewed, I have written a vignette for each person. These vignettes are provided below, ordered by the sequence in which the interviews were conducted. Each vignette begins with a brief introduction to the interviewee. I have described how the specific details of the interview process in Chapter 2.4. Each interview is summarised first in a descriptive fashion before being analysed for emerging themes. A final section discusses the common themes between the vignettes. As a point of clarification, I did interview four participants but the fourth holds her expertise in pre-service teacher education, not engineering education. I have discussed her interview separately in Chapter 5.3.2.

4.1 Vignette One: Sharon

Sharon is an engineering lecturer currently working in an Australian University. She studied electrical engineering before stepping into her role. She has conducted several TC studies based on engineering.

4.1.1 Comments on Threshold Concept Characteristics

Sharon's description of a TC revolved heavily around the characteristics *transformative* and *troublesome*:

Sharon: *A threshold concept is a concept that's extremely transformative, in other words it change, totally changes, how you see the world and, and, probably even how you see yourself in the world. … there are things that you can do that once you understand the threshold concept that you didn't, wouldn't be able to do before understanding it.*

Sharon then went on to present a solid link between *transformative* and *troublesome*:

Sharon: Threshold concepts are concepts…are especially transformative, they open up new ways of thinking and seeing the world. They also open up new capabilities and those capabilities are critical to your progress in the discipline... And because they're extremely transformative they're almost always challenging in some ways. Or troublesome in the, in the language of threshold concepts.

Sharon did not believe that a concept has to have evidence of each of Meyer and Land's (2003) original characteristics to be considered a TC. In fact, she felt that attempting to assess a potential TC against each of the characteristics is not a "...particularly valuable thing to do". She listed several useful applications of the five characteristics other than their function as a criteria for judging potential TCs, including, informing us of the nature of TCs, helping us understand how we might help students overcome TCs, and using them as a general guide when asking students and staff to identify potential TCs in their areas.

Transformative was described as an imperative characteristic of TCs with *troublesome* acting almost as a side effect of a TC's *transformative* nature. *Integrative* and *irreversible* were also thought to be "useful" although Sharon had an interesting stance on the *irreversible* nature of TCs. She thought that details could be forgotten by learners if a TC is not in use, leading to that person forgetting the TC:

Sharon: The only thing with irreversible... I think if you're not using them [threshold concepts] all the time you, you do actually, it's not forget them but you forget the detail… And using the discipline all the time then you forget large parts of the discipline, including, and I think you can even forget the threshold concept.

Bounded was the characteristic Sharon thought was least relevant. She did not seem convinced of the nature of *boundedness* and appeared confused as to its

meaning. She argued against (her perception of) the characteristic by voicing that the same TC can exist in multiple disciplines making *boundedness* non-applicable to TCs:

Sharon: Bounded is one I don't actually like at all...The idea that it's something that is unique, oh, it's specific to the discipline and only applies in the discipline. I think there are threshold concepts that are actually broader than a discipline and why does that make them not threshold concepts? I don't really get that...Unless it's that he's declaring that they're gateways to the discipline and, and, that makes it… they have to be specific to the discipline? But I think there can be concepts that are absolutely critical to progress in a discipline that don't only exist in that discipline.

4.1.2 Comments on Data Collection Methods in Threshold Concept Studies

When we discussed Sharon's research around TCs, I brought up the fact that she had used both student questionnaires and student workshops as research methods in one of her TC studies. Her first response was that it was usually useful to use more than one method:

Sharon: Okay, so. In any case, in any circumstance it's useful if you can have more than one way to identify, to reach any conclusion.

She then expressed that the student workshop had worked well as an exploratory method with findings used to inform the questions asked in the questionnaire:

Sharon: ...so workshops, interviews, focus groups - they give you depth and help you to explore people's understanding of something in a way… if you, if you don't know how they understand it and you don't know what you're looking for, how could you write a questionnaire that's going to be very valuable?

Sharon went on to say that the questionnaires were then used to find out how far the conclusions from the workshop generalised over a wider population. This is a

research design method that she had used repeatedly. She then pointed out that it can work the other way with general questionnaires informing the discussion and activities for focus groups. She moved on to discuss these two approaches in terms of their respective qualitative and quantitative natures:

Sharon: ...sometimes you use, you know, sometimes you use the quantitative to confirm something in the exploratory stage, sometimes you, you use the exploratory stage to design the quantitative stage... we usually use a, an exploratory stage which is to find out what sorts of things are suggesting to us might be threshold concepts and then quantitative approaches to, to generalise to find out how, how much the perspectives generalise.

We then transitioned into talking about which research methods had been more or less effective in her experience. She brought up another of her studies that involved both student and staff participants and stated that the staff interviews were useful:

Sharon: ...the teaching staff help me to understand the, the concepts the students were talking about but also - especially if it's a discipline that's not my discipline… they also help me to just clarify, you know, "they were talking about those assessments" or "they were talking about those workshops we held or that game we played in class". And I can ask them the detail bits - "what is that game and why do you…?"

Sharon brought up that in-class questionnaires should bring about a bigger response rate than asking students to complete an online survey in their own time. Yet, she argued that an online survey has the potential to reach a larger group of participants.

4.1.3 Comments on Threshold Concepts in Relation to Curriculum Development

Sharon discussed her various experiences of attempting to structure curricula with the aid of TCs. These focussed heavily around how TC theory has altered the way she and her teaching colleagues have shifted in their discussions of curricula. She conveyed this as a positive change that aided with curriculum-based discussions:

Sharon: Even now where we're restructuring those units considerably, and still everybody just talks as if it's normal language. Everyone in the faculty, the academics, talk about threshold concepts… So in fact it's changed how they think about curriculum development. Um, and they even, you know, "so what should we be making sure? We… Obviously there are, we need to assess things that aren't threshold concepts as well but we need to make sure that we've assessed the threshold concepts."

Similarly, Sharon felt discussing TCs with staff is useful because it helps everyone to know, and remember, what the curriculum requires students to know and why it has been structured in the way it has. She holds the same opinion for students, which is why she is inclined to announce and explain the TCs in a course to students that she teaches:

Sharon: Something that I keep trying to improve is making sure that the students understand why you've defined the curriculum, designed the curriculum how you have.

4.1.4 Themes from Sharon's Interview

Based on the comments discussed in the vignette above, themes will be identified under the subheadings *Threshold Concept Characteristics*, *Threshold Concept Study Data Collection Methods* and *Threshold Concepts in Relation to Curriculum Development.*

Threshold Concept Characteristics

It was very clear that Sharon placed *transformative* and *troublesome* as having the highest importance out of the five characteristics. *Transformative* was thought to be essential for TCs with *troublesome* resulting from the transformation that learners experience. Sharon regarded the characteristics *integrative* and *irreversible* as slightly less essential, describing them as "useful". Bounded was of considerably less importance to Sharon with her expressing confusion at the meaning of the term in regard to TCs.

Clearly Sharon held a hierarchy of importance towards the five TC characteristics. This indicated that she did not believe each needs to be present in order to label a concept as a TC, as she explicitly expressed. In addition to believing that each characteristic did not need to be identifiable within a TC, Sharon pondered the level of value of using the characteristics as a criterion for identifying TCs. Instead, she voiced that the characteristics are of more use when attempting to do such things as comprehending the general nature of TCs, and using them as a foundation when questioning teachers and students about potential TCs.

Threshold Concept Study Data Collection Methods

Sharon structured part of her discussion of data collection methods around the use of both, quantitative data collection phases and qualitative data collection phases. She stated that she usually designs her studies to incorporate a qualitative, exploratory data collection phase at the beginning. In this phase she mentioned the use of data collection methods such as workshops, interviews and focus groups. Sharon said she would then carry out a quantitative data collection phase, informed by the initial qualitative phase, utilising data collection methods such as questionnaires and surveys. Totalling the number of these methods, Sharon mentioned five in all. The unequivocal theme that emerged from her interview was the effectiveness of more than one data collection method. Sharon expressed the importance of multiple data collection methods in multiple stages. The first

state informed successive phases and which, although she did not explicitly state this, worked to increase the validity and reliability of the overall findings.

In terms of the types of participants that data should be collected from when researching TCs, Sharon expressed the value of including both teacher and student participants. Here again, I am inferring that she viewed that having multiple participant types increased the reliability and validity of the data collected. She expressed the value of having both student and teacher participants so that students could be questioned about their learning whilst teachers could be asked to clarify any aspects that students brought up in their interviews (e.g. clarify the content and how it is taught).

Threshold Concepts in Relation to Curriculum Development

The clear theme brought up by Sharon in relation to TCs and their role in curriculum development was that TCs can be a useful platform, for both teachers and students, to discuss the curriculum and what students should be required to know. She expressed that this was the reason she explicitly announces and discusses, with students, TCs in the courses she teaches. It is interesting that Sharon focused most on how the curriculum can be *discussed* using TCs, as opposed to focussing on *altering* a curriculum with the use of TCs. This may be an indication that Sharon sees more value in TCs as a foundation for curriculum-based conversations, rather than the act of attempting to embedding TCs into a curriculum.

4.2 Vignette Two: Michelle

Michelle was a senior researcher at a New Zealand University before moving into her role in the New Zealand Ministry of Education. She has co-authored several TC papers in the Engineering field.

4.2.1 Comments on Threshold Concept Characteristics

Michelle's description of TCs focussed largely on their characteristics. She stated that each of Meyer and Land's (2003) initial characteristics may not necessarily be evident within every TC, yet emphasised *troublesome* and *irreversible* as compulsory characteristics.

Michelle: So, although there are different characteristics that are tied to the threshold concepts it seems to me that some of them may or may not hold most of the time. Or some of the time. But there are two characteristics of concepts, that in any discipline that learners of a concept actually have to have right. Either they're troublesome and they're, um, irreversible.

When asked about whether a TC has to have evidence of the five foundational characteristics, Michelle reasoned *transformative* and *troublesome* to be compulsory characteristics of TCs. *Irreversible* was thought to be quite important, and *bounded* and *integrative* were thought of as not necessarily required. It was interesting that *transformative* was mentioned as compulsory to her at this point and yet not during her opening statement. She also mentioned liminality to be a prominent feature associated with TCs.

Michelle: I would think that it has to be transformative. It has to be troublesome. Ah, it has to have a pretty good high level of irreversibility. And liminality should go into play.

Below is another instance of the point raised above.

Alan: Yip. So, so you're saying that… that transformative, irreversible, troublesome and liminality, ah, they're, they're more compulsory than the other two I mentioned? Integrative and bounded.

Michelle: Yes that's correct. Yes. That's, that's how I see it. Yes

When asked about her reasoning regarding *bounded* and *integrative* being less integral to TCs she mentioned that it is because they are less prominent in the literature.

Michelle: Because sometimes in the, at least in the literature that I've read they're present and then sometimes they're not. And even Meyer and Land in their original 2003, 2005 papers, they're talking in terms of "potentially, possibly, mostly, sometimes". Even they're not definite about them.

4.2.2 Comments on Data Collection Methods in Threshold Concept Studies

Michelle had included teachers and students as participants in one of her studies. This choice was based on her need to triangulate the data. She wanted students' perspective of what concepts they were struggling with. She was also interested in teachers' views on TCs and TC acquisition, even though teachers may have forgotten what it was like to acquire those concepts themselves.

Michelle: The research was based on the lecturer's [one teacher] *observations of what's happening to students. The lecturers themselves have forgotten what it meant to learn those concepts. All they do is students' grades and how they do when they do their lab work and whatever, tutorials etcetera. So they can see the students are struggling. Now whether that is really a threshold or not we don't know. So it is a matter of triangulation. It was the only other thing that we can do really is to ask students themselves apart from looking at their exams grades. Ah, is to ask students how they feel, how they learn, what helps them learn, where do they feel they are stuck and things like that. It's just a really the only decent methodological thing that one can do.*

Michelle had been pleased with the way students were able to voice how they thought they learnt best which, in turn, she shared with the lecturers to inform their teaching practice. It can be inferred from Michelle's comments that this input from students helped with TC identification as students were able to voice at which points they felt stuck.

Unpacking the above quote further, Michelle mentioned teacher observations as one of the data collection methods she utilised. Whilst not specifically stated, teacher interviews were also conducted to discuss the teacher observations. The two data collection methods that were used to gather data from students were interviews and analysis of student grades. I infer from this quote that these three were each thought of as effective methods by Michelle, due to the fact they were embedded in her argument of data triangulation to produce the most reliable and valid data possible.

4.2.3 Comments on Threshold Concepts in Relation to Curriculum Development

When asked her opinion on using TCs to develop curricula, Michelle said she was, "...*all for it*". She argued that they should be the centrepiece of a curriculum due to the fact that they are the hardest concepts to learn and, therefore, the highest focus should be on them. In her view, other concepts are easier to learn and can be taught through other mediums such as general conversation, books, and on the internet.

Michelle: I think that, I think that, um, when it comes to … curriculum … the focus should be on them, um, because a lot of other things it's easy to learn and you can find it on internet and books and talking to other people. But the thresholdy bits are really important.

On the topic of why more research has been conducted on the identification of TCs than their incorporation within curricula, Michelle was disappointed in the lack of curricula-based studies. She was unsure as to why this is the case but reasoned that it may be because the process is complex and may be hard to achieve with no effective approach readily apparent.

Michelle: I don't have a really good, um, idea why that is so. Except for the thought that it, it's a complex matter and that people maybe don't know how to go

about it and instead of spending a little bit more time trying to figure out how to, you know, understand how these concepts work and, and how do humans, animals actually learn them.

4.2.4 Themes from Michelle's Interview

Based on the comments discussed in the vignette above, themes will be identified under the subheadings *Threshold Concept Characteristics*, *Threshold Concept Study Data Collection Methods* and *Threshold Concepts in Relation to Curriculum Development.*

Threshold Concept Characteristics

Michelle held a hierarchy of importance toward the five TC characteristics. She believed *troublesome* and *transformative* to be essential, *irreversible* to be important, and *integrative* and *bounded* to be the least important. These last two concepts were thought to be less important on the grounds of the inconsistent mentioning of them within the literature (e.g. sometimes they are mentioned and sometimes not) and how they were initially introduced by Meyer and Land (2003). These authors had not described either of them as essential. These points support Michelle's belief that not all five characteristics need be identified when claiming a concept to be a TC.

Threshold Concept Study Data Collection Methods

Michelle advocated for, from experience, the inclusion of both teachers and students as participants to triangulate data, which, I infer, she considered would maximise the data's level of reliability and validity. Students' grades were useful to, I believe she was saying, find out which parts of a course were difficult for students based on their performance in the assessments. Interviews with students were useful to gain a sense of their feelings towards the course, whilst teacher interview data was useful for their thoughts about potential TCs and TC acquisition. A key theme from Michelle's interviews, therefore, was that student

and teacher views together contribute to insightful research on TCs because they allow the researcher to triangulate the data.

There were three overall data collection methods that Michelle named in her discussion of data triangulation that I have inferred to be effective in her mind. These were teacher observations, interviews (with both teachers and students) and grade analysis (grade distribution). I can confidently conclude that Michelle is an advocate for the use of multiple data collection methods when researching TCs as an effective technique. This is based on her strong argument for data triangulation to increase the reliability and validity of data.

Threshold Concepts in Relation to Curriculum Development

Michelle advocated for the active use of TCs in the development of curricula based on the fact that these are the most *troublesome* concepts and, therefore, they are the ones that require the highest amount of attention. Michelle argued that the reason that TC studies are less commonly focussed on TCs in curriculum development than on TC identification is because curriculum development is a complicated process that researchers are cautious in approaching. From Michelle's comments I will consider that she firmly believes in the use of TCs in curriculum development, and that the lack of research in this area due to the apparent difficulty and unfamiliarity associated with it.

4.3 Vignette Three: Jim

Jim works in a New Zealand university and his interests lie in electronics and engineering education. He has authored several TC papers focused on electronics and engineering.

4.3.1 Comments on Threshold Concept Characteristics

Jim, referring to his experience, stated that each of Meyer and Land's (2003) characteristics were present within every TC that he has come across. He alluded to the fact that *troublesome, transformational*, and *irreversible* will be the most easily identifiable, with *bounded* and *integrative* being less easily apparent. He argued that the ease with which the characteristics can be identified does not mean that they are less present than the others, it is just that a deeper level of analysis is required to discern them.

Jim: So when I've dug deep enough there is some kind of connection to all five buckets for every one I've found, although I'm open to the idea that there might not be. I think troublesome, transformational and irreversible are gonna fit all of them. Um, the others y- you have to work a bit harder… But I've got a sneaking suspicion they were originally quite right and you pretty much need all five.

When asked about his thoughts on a potential order of importance for the five TC characteristics, Jim described an order with which he attempts to identify TCs. Again, it is apparent from his comments that the conspicuousness of a characteristic does not influence its presence.

Jim: In terms of identifying a threshold concept, troublesome is the, is the one which is most conspicuous and therefore the one I invariably start with. In terms of ontol- ontology and intellectual impact, the transformative one is clearly the most important. Um, beyond that no, you know, the others are just the others.

4.3.2 Comments on Data Collection Methods in Threshold Concept Studies

In one of his own studies Jim, along which several other researchers, had identified TCs by interviewing a single teacher. His reason for this was that the researchers needed to quickly identify potential TCs and the teacher, who knew their discipline well, was able to express those parts of the curriculum that students often find troublesome.

Jim: Yeah, that's easy. Troublesome, troublesome. You go often in, ah, within the discipline of engineering when, ah, teachers are discussing their classes somebody will go, "Oh and of course such and such: everybody gets that wrong". Right?

Alan: ...Great. Um, so maybe, ah, to put it in other words, and correct me if I'm wrong, ah, you needed to quickly have examples of threshold concepts that you could focus on the main element of the paper so you went to where you could most easily identify them. And that was to go to someone with experience teaching? Okay?

Jim: Mmm. Yeah. I suspect in that paper we actually said, "We quizzed a lecturer" when, in fact, the truth of the matter was we, we quizzed multiple lecturers all of whom went, "Oh yeah, that one".

Jim mentioned three data collection methods that were the most effective TC identification methods in his experience. The first of these was an ambitious, time consuming attempt to video students' behaviour during a lecture to identify at which points students were on the point of arguing with each other about the course content. These animated conversations were, Jim stated, often founded on a course TC.

Jim: ...They would video a three hour laboratory and each camera was essentially focussing on two people.

Jim: ... Well they had this wonderful method of analysing the video recording. And it must of killed them - either financially to pay students to do it or do it themselves - but they essentially went through the video and they classified every activity that each of those people was doing. You know: consulting mobile device, adjusting thing on the bench, exchanging conversation with partner, debating with partner. And remarkably some of those correlated magnificently. When the two students were going, "No but it's…", and they were almost arguing… you could bet they were talking about a threshold concept. And I was blown away with how effective that was.

The second and third TC identification data collection methods that Jim stated as effective, based on his experience, were student interviews and student observations. He alluded to the ease in which data can be quickly and effectively gathered by carrying out these two, especially the interviews. His example questions focussed on gaining the students opinions based on their experiences.

Jim: ...Just watching a class, asking the class, something along those lines. Ah, so, ah, for that example say, someone would come in to the class and go, "Hello, my name is Fred Bloggs and I'm doing a study on this. You've signed the, ah, okay forms. Can you tell me what's hard about this paper?" And they go, "Oooh the analogue bit". It can be more specific, "Oh this bit here. We've no idea what's happening here". And you could, you can nail down just by asking the students: "What essentially scares you the most in the exam? What's giving you the most trouble? What worries you the most?" And they will hone in on the bit that they have not understood. And that will be the threshold concept.

Jim discussed his interest in making a concept map to identify potential TCs when asked about issues he has experienced when researching TCs. He stated he hasn't yet had the dedication to complete one. He also discussed that he would like to further explore grade distribution as a quantitative method for identifying TCs. Specifically, he believes a bimodal grade distribution will be a strong indication that a TC exists in the course or exam. This quantitative data could then be followed up with student interviews to hopefully reflect on the reasons for this distribution in relation to the characteristics. I have included his full description of this method below.

Jim: But when you have a class of say more than fifty people, you can construct a grade distribution which is a little plot where you have marks on the x axis and the number of people that got that mark on the y axis. And you would expect to see a Gaussian type: little hump where the majority of people got about, I don't know, fifty-five or sixty percent, and that the curve rolls down and there's a chunk that were, got almost no marks, ah, and they got a fail, and a bunch out the top who

are geniuses and got nearly everything right...And you expect to see a distribution like that [indicating a bell curve]. *Well you don't. When you get up to more that fifty you will often get this shape goes wrong. And you get a double hump… And we would call this a bimodal distribution and my belief is that when you have a very central threshold concept in the paper that you're teaching, there's 'them what gets it' and 'them won't don't get it', and the 'don't get its' provide the hump on the left. So the bimodal distribution is telling you that you've got a threshold concept in whatever it was you're examining that gave you this grade distribution… It wouldn't tell you what it is* [the threshold concept] *but then you ask the students, "What's giving you the shits? Why did you not pass?" They'll go, "Oh, cos of bloody whatever x it is". And now you've got it.*

4.3.3 Comments on Threshold Concepts in Relation to Curriculum Development

Jim believed TCs to be useful in curriculum development as they provide a gauge as to whether or not a curriculum is "over-stuffed". Based on his experience, he believed that no university paper should cover more than two TCs as this would be too much for students to grapple with. The ideal number in his eyes was one or two, as this will maximise students' ability to manage the content in the required length of time.

Jim: I think university papers should have one or two. I know from experience if you try and teach a paper with three threshold concepts in it you will fail. You will get a bunch of students who are addled, they don't know where they're going, they haven't had time to think things through.

Jim discussed how he mainly assesses students' knowledge of TCs in his assessments. He does this on the basis that the remaining content is easier to comprehend and can be learned through alternative mediums, such as books. He

also discussed the value of mentioning a single TC in multiple papers, if applicable, to reinforce understanding for students.

Jim: The non-threshold stuff you can get out of a book. You didn't need to pay somebody at uni to tell you this. … We also know educationally, certainly in engineering, it, it really pays to mention a threshold concept in two papers. So if every threshold concept was mentioned in two papers and every paper had two threshold concepts in it you might have an ideal degree.

4.3.4 Themes from Jim's Interview

Based on the comments discussed in the vignette above, themes will be identified under the subheadings *Threshold Concept Characteristics*, *Threshold Concept Study Data Collection Methods* and *Threshold Concepts in Relation to Curriculum Development.*

Threshold Concept Characteristics

Jim made it clear that he believed none of the five TC characteristics to be any more or less important or apparent than the others. In saying that, he did state that *troublesome*, *transformational* and *irreversible* were more easily identifiable than *bounded* and *integrative*. He stated that troublesome is the one he begins with when identifying potential TCs due to its conspicuousness. Jim said *bounded* and *integrative* were harder to identify yet equally as present. Overall, Jim believes that, though the characteristics hold differing levels of conspicuousness, each of the five needs to be seen as equally present.

Threshold Concept Study Data Collection Methods

A large array of data collection methods for TC studies were presented by Jim, some utilised by him and some that he hopes to use in future studies. These included the video analysis of students' behaviour (and discussion) in class, interviews (of students and teachers), observations (of students), concept mapping

and grade distribution analysis. So, in all, Jim mentioned five data collection methods. It is clear that Jim is in favour of utilising multiple data collection methods in TC studies, as is reflected in his vast knowledge of applicable methods.

Jim mentioned, in separate instances, that teachers and students are both valuable as participants when researching TCs. Interestingly, he never explicitly mentioned including students and teachers in tandem when conducting a TC study. He alluded to how the approach may be different depending on the participant type. For teachers, he said they could be asked for potential TCs based on their teaching experience and observations. For students, he said they could be asked for potential TCs based on their emotions regarding which concepts feel most *troublesome*. Notwithstanding the fact that Jim did not explicitly state it, I feel assured inferring that Jim is an advocate of involving both students and teachers in the same study. This is because of the large array of data collection methods he discussed that included a variety of participant types.

Threshold Concepts in Relation to Curriculum Development

In regard to curriculum development with the aid of TCs, Jim recommended, from personal experience, that only one to two TCs should be included in any one university paper. These should, if possible, be referenced in more than one paper to reinforce students' understanding. He discussed the apparent futility of focussing too much teaching and assessment time on concepts that are not TCs due to their comparative ease and the fact that, "The non-threshold stuff you can get out of a book". It is evident that Jim, based on opinion and experience, sees value in using TCs to inform curriculum development by having them as the centrepieces of a curriculum.

4.4 Overall themes: Comparing the Interviews

Below is provided a synthesis and comparison of the themes from each interviewee's individual themes. These themes are compared and contrasted under the usual subheadings: *threshold concept characteristics*, *threshold concept study data collection methods* and *threshold concepts in relation to curriculum development.*

4.4.1 Threshold Concept Characteristics

There was some disparity around the level of importance attributed to each of the five TC characteristics by those interviewed. Sharon and Michelle had both constructed a hierarchy of importance between the characteristics, and these hierarchies were very similar to one another. Both of them considered *transformative* and *troublesome* to be the most important with the remaining three, *irreversible*, *integrative*, and *bounded* to be less essential. The most noticeable difference between the two was that Sharon considered *bounded* to be the least important, most likely based on her confusion with it, whilst Michelle grouped it with *integrative* as least important. On the contrary, Jim held no hierarchy of importance, believing each characteristic to be of equal importance and that they should all be present in any TC. He did, however, admit to the characteristics displaying differing levels of conspicuousness making some more or less easy to identify.

4.4.2 Threshold Concept Study Data Collection Methods

All three of the interviewees included both teachers and students as participants in their TC studies and each felt this to be effective. Sharon stressed that it was useful for her, as the researcher, as it allowed her to identify the *troublesome* concepts from the students' perspective. She then appreciated receiving clarification from the teachers about those concepts and how they were being taught. In a similar vein, Michelle was in favour of involving both types of

participants as a way to triangulate the data by being as thorough as possible. She also voiced how sharing the data back to the teachers can be useful to inform their teaching practice. Jim, whilst stating benefits of including both teachers and students as participants, approached the topic in a more disjointed way. He spoke of using teachers as a quick way to gauge the potential TCs in a course and then, later on, discussed how it can be useful to interview students to gather their views on potential TCs. Jim did not marry the two viewpoints as closely as Sharon and Michelle did, with no reference being made to sharing student data with teachers to inform practice.

In terms of which data collection methods were thought to be effective by the participants for TC studies, each mentioned interviewing. Jim described the interviewing of teachers and students to be a time efficient method for gathering a list of potential TCs. Michelle and Sharon advocated for teacher and student interviews in tandem to increase the validity of the data that is gathered and strengthen the generalisations that can be drawn from the data. Sharon was the only one to mention that student workshops and interviews may then be followed up by student questionnaires. She said this was an effective as it allows the researcher to include worthwhile questions in the questionnaires by using the interview and workshop data to inform the questions.

A very obvious theme that links with the interview theme above is that multiple data collection methods, as opposed to a sole method, appear to be favourable to all three interviewees. This is based on the vast number that was discussed by the three participants. Sharon and Jim both mentioned five methods respectively, and Michelle mentioned three. Sharon, in addition to discussing interviews, workshops and questionnaires, was the only one to mention the use of online student surveys to encompass a larger audience. Jim and Michelle, adding to their discussions of data collection methods, both mentioned that examining students' grades is an effective way to identify potential TCs. Jim expanded on this by explaining the use of looking at specific grade distributions as a very reliable method for TC identification. Two more methods of note were discussed solely by

Jim. These were, the videoing and analysis of students' behaviour in class, which was said to be time consuming but highly effective; and concept mapping, which he has not personally attempted but which he believes would be an effective method.

4.4.3 Threshold Concepts in Relation to Curriculum Development

Jim and Michelle both independently voiced the idea that tertiary courses should not place a high teaching focus on aspects that are not TCs. Michelle felt that concepts that are not threshold can be understood relatively easily using the internet, reading books or having discussions. It would, therefore, be beneficial to focus more teaching time on TCs because of their more *troublesome* nature. Jim held similar beliefs but was speaking more in reference to the assessment of courses rather than the teaching. He implied that the teacher's job should not be to teach things that can be understood independently with relative ease (concepts that are not threshold), but those concepts that require purposeful teaching in order for them to be fully understood (TCs). In contrast, Sharon did not discuss the use of TCs in the development of a curriculum as much as the others, yet expressed that much value lies in TCs as a foundation for curriculum-based conversations with teachers and students.

Chapter 5: Discussion and Implications

This chapter begins with a comparison between the themes from the SQLR and the findings from the semi-structured interviews. The similar themes that emerge from this comparison will then be compared to the literature that was presented in the introduction (Chapter 1). This literature connections section (Chapter 5.2) will be fashioned in such a way as to answer, to the best of my ability, the three research questions posed at the beginning of this thesis (Chapter 2.1). Following this will be an implications section where I discuss implications for TC researchers and, more specifically, how the findings would inform the design of a TC study in the field of primary school education. In the implications section I will provide a succinct account of my fourth interviewee's, Karen's, responses and connect them to the discussion. The thesis will end with a limitations section and a brief concluding paragraph.

5.1 Connecting the Themes from the Data Sources

This section will be structured, like many of the other sections, in relation to the three focuses of the thesis. The purpose of the section is to compare and contrast themes from the SQLR and the semi-structured interviews. Themes surrounding TC characteristics will be discussed first followed by themes related to TC study data collection methods. Lastly themes will be presented that relate to TCs and their role in curriculum development.

5.1.1 Threshold Concept Characteristics

In terms of the most commonly referenced of Meyer and Land's (2003) original five TC characteristics, the SQLR showed *transformative* to be the most highly referenced. That characteristic made up 45.8% of all mentions of the characteristics within the SQLR literature and was followed by *transformative* that made up 30.4% of all characteristic references. That led me to conclude,

based on the lower percentages of the other three characteristics, that *transformative* and *troublesome* were the most commonly referenced, with *integrative*, *irreversible* and *bounded* being significantly less commonly referred to. This theme was very consistent with the thoughts of two of my interviewees, Sharon and Michelle. They both held obvious hierarchies of importance in regard to the characteristics which differed only slightly. Upon comparison, both participants saw *transformative* and *troublesome* to be of a higher level of importance than the other three.

Jim's thoughts are the only evidence that brings the above theme into question. He stated that there was no characteristic that is of a higher level of importance, or more essential, than any of the others. This was based on his personal experience in attempting to identify TCs. Jim claimed that when looking at each TC that he had analysed up to that point, at a deep level he was able to see evidence of each of the five characteristics. He did mention, however, that the conspicuousness of each characteristic differs.

5.1.2 Threshold Concept Study Data Collection Methods

A theme that is consistent between my two data sources is the popularity of utilising multiple data collection methods when conducting a TC study. This was evident from the SQLR data in the fact that 80% of the researchers utilised more than one data collection method in their studies. Similarly, each of my three interviewees discussed a multitude of data collection methods for utilisation within TC studies. Jim and Sharon each discussed a total of five data collection methods, and Michelle mentioned three. The most common number of data collection methods to be utilised within the SQLR was two, with one third (33.3%) of the studies utilising this number.

Building on this, a clear theme to arise from the SQLR is that the majority (66.6%) of researchers used both teachers and students as participants in their TC

studies. This theme was reflected unanimously amongst my interviewees. The SQLR is limited as it does not provide information regarding why this was the popular choice, yet the interviews did allow me to hear the benefits of using both of these types of participants. Sharon voiced how the researcher can gain a clearer level of understanding of the implications of students' comments by quizzing lecturers on aspects that students bring up. Michelle stated how this practice can be useful to both, triangulate data, and share student data with teachers to inform their teaching practice. Jim discussed how teachers can be interviewed to quickly gain a sense of potential TCs, and that students may also be questioned to aid TC identification based on their learning experiences.

A last data collection method theme I wish to compare between the two data sources is the use of interviewing as a TC study data collection method. Interviewing was the data collection method utilised most amongst the researchers within the SQLR when the totals of student interviews and teacher interviews were combined (18.6% of all methods used were interviews). Similarly, amongst all three participants, interviewing was thought to be an effective method to use when researching TCs. Michelle and Sharon mentioned student and teacher interviews to be useful in tandem to increase the validity and reliability of the findings, whilst Jim mentioned them to be a time efficient method for identifying TCs. Interviewing, therefore, was a commonly used data collection method that was advocated for as an effective method by my interviewees.

5.1.3 Threshold Concepts in Relation to Curriculum Development

The themes that arose from both of my data sources concerning TCs and curriculum development are difficult to compare as they are of different natures. Therefore, this discussion of themes will be slightly different to the two above (Chapters 5.1.1 and 5.1.2). For this comparison I will, in separate paragraphs, succinctly summarise the theme/s from both of my data sources and then provide a final paragraph that highlights the differences between both of the data sources.

There were three conclusions that I drew from the SQLR data in relation to the aspect of TCs and curriculum integration. The first was that there was a very low number of TC studies that focussed on the use of TCs in curriculum integration compared with those focusing on TC identification. In fact, none of the articles focused solely on the use of TCs in curriculum development and, those that did have a focus on this aspect, also had a shared focus of TC identification (these papers totalling only 20% of the total number of papers). The second conclusion was that, of those papers that had a dual focus, I could draw no strong inference as to which types of participants are favoured by researchers because of the lack of a clear pattern within the data. The last conclusion based on the SQLR data was that student reflections appeared to be the most common data collection method for researchers that had their focus on the use of TCs in curriculum development. As a result, I gingerly proposed this as an effective data collection method for studies of this type.

There was one main conclusion drawn from the interviewees' discussions around the use of TCs in the development of curricula. This was that tertiary courses should place a high curriculum focus on solely TCs. This was argued for on the basis that concepts that are not threshold can be acquired with much less effort through several mediums (e.g. books, general discussion, on the internet). This point was raised by Jim and Michelle. Sharon, on the other hand, mainly discussed how TCs can be useful as a foundation to base curriculum related conversations.

The SQLR themes shed light on how many studies had a focus on TCs in curriculum development, the participants types included in these studies, and the type of data collection methods most commonly used. The main interviews theme, however, concerned not how TCs have been *studied* in relation to the curriculum, but stressed how a curriculum should be *structured* with TCs (by making TCs the centrepieces). In saying this, there is a discrepancy between the SQLR data and the interviewees' comments. Jim and Michelle made strong arguments for the use of TCs to structure a curriculum, stressing how important this can be. One may

assume, based on their argument, that much research would have been conducted to explore and test this phenomenon which, based on small number of papers in the SQLR, is proven to be untrue.

5.2 Connecting the Themes to the Literature

The purpose of this section is to compare the themes that arose in the previous section (Chapter 5.1) from the marrying of the SQLR themes and the interview themes, with the initial literature that was discussed in the introduction (Chapter 1). The subheadings and content in this section will be structured in such a way as to answer the three research questions that this thesis set out to answer (Chapter 2.1). The strength of the themes between the SQLR, interviews and introductory literature will influence the confidence with which I am able to answer each of the three questions.

5.2.1 To What Extent Have TC Researchers Focused on Each of Meyer and Land's Original Five TC Characteristics?

Meyer and Land (2003) clearly stated *transformative* to be the only one of the five TC characteristics to be absolutely essential to any TC. It is interesting, therefore, to observe that *transformative* is not the characteristic that was most commonly mentioned in the SQLR. It was, in fact, second to *troublesome* which was mentioned more often by a large margin, *transformative* having 79 mentions and *troublesome* having 119 mentions. *Troublesome* was, however, slated as 'almost' essential by Meyer and Land. It matches, therefore, that these are the characteristics most highly referenced in the literature. The remaining three characteristics, *integrative*, *bounded*, and *irreversible*, were not considered to be essential to TCs by Meyer and Land and, as expected, are mentioned less times than *transformative* and *troublesome* which are the more necessary characteristics.

In terms of the interviewees' perspective of the five TC characteristics, Sharon and Michelle held very similar beliefs to the Meyer and Land. *Transformative* and *troublesome* were the most important to them which were the two Meyer and Land claimed the most vital of the five. Jim displayed somewhat of a differing opinion to Meyer and Land, however, by stating all five concepts to be equally as present in any TC; they are all thought to be inherent to TCs.

The *transformative* and *troublesome* characteristics was also very evident within Timmermans and Meyer's (2017) paper, especially in both, the second and third of their teaching and learning principles, and in the fifth activity cluster of their ITCK framework (see section 1.3.1). The second teaching and learning principle stated that TC acquisition discussions should always include a focus on the *transformative* nature of TCs, whilst the third principle stated that the *transformative* and *transformational* aspects of TCs have the potential to affect students' emotions and learning motivation. The fifth cluster of the authors' ITCK framework concerned the assessment of students' knowledge of course TCs. The authors discussed how the *troublesome* and *transformational* characteristics of TCs may cause variation in the way that students come to learn TCs and that this should be considered when planning assessments. They also voiced that teachers should assess in such a way as to capture evidence of the *transformation* of thought that learners experience as they come to understand a TC.

The notions of liminality (Chapters 1.1.4 and 1.4.1) and students' mimicry of teachers and literature (Chapter 1.4.2) are both ideas that are relevant to inform this discussion of TC characteristics and their levels of importance. Liminality, the idea that an individual goes through a *transformational* and *troubling* phase during a ritual or rite of passage (Turner, 1969; van Gennep, 1960), was attributed to TCs from the very inception of TC theory (Meyer & Land, 2003). Similarly, mimicry was also attributed to TC theory and concerns the process by which students will mimic, to make themselves feel more secure, what is expressed by their teachers and what is written in the literature until they come in to full

understanding (Cousin, 2006; Meyer & Land, 2003). This process is a way to help students cope with the *transformative* and *troublesome* learning inherent to TC acquisition. Both ideas of liminality and mimicry, therefore, concern the characteristics *transformative* and *troublesome* more prominently than *bounded*, *irreversible*, and *integrative.*

Based on Meyer and Land's seminal 2003 paper, Timmerman and Meyer's (2017) discussion of the fifth cluster of their ITCK framework, the SQLR data, the interviewees' opinions, and the ideas of liminality and mimicry, I am prepared to conclude the characteristics *transformative* and *troublesome* to be of a higher level of importance, and focus, than the other three for TC researchers. These are the two characteristics that must be present within a concept for that concept to be considered a TC. *Integrative*, *bounded*, and *irreversible* were not stated as essential by Meyer and Land, were mentioned the least by the authors within my SQLR, and were the ones Sharon and Michelle thought to be least essential also. On this basis, I am led to conclude that these three, while they may be applicable to many TCs respectively, are not essential when claiming a concept to be TC or not.

5.2.2 Which Data Collection Methods, and Participants, Are Most Commonly Included When Attempting to Study TCs?

Gaining data from both teacher and student participants when completing a TC study appears to be universally considered an effective practice. This was reflected in Timmermans and Meyer's (2017) paper in the first of the activity clusters in their ITCK framework (Chapter 1.3.1). In this cluster they strongly recommended that information be gathered from multiple sources to help inform researchers as they attempt to identify TCs. The sources they stated were teachers and students, as well as existing literature and discipline experts. Similarly, the same theme was reflected in the SQLR with 73.3% (11 out of 15) studies including both students and teachers as participants. Lastly, all three interviewees

advocated for the practice of including both teacher and students as participants based on their personal experiences of the practice.

In addition to the practice of including both students and teachers in TC studies, the utilisation of multiple data collection methods also appears to be effective when researching TCs. Firstly, Timmermans and Meyer (2017) listed four notable data collection methods that could be used to identify TCs, indicating that a combination of these should be used to triangulate the data. The methods suggested by them, based on their literature synthesis, were focus groups, interviews, concept mapping and surveys. This was consistent with the SQLR findings which revealed that 80% of researchers utilised more than one data collection method in their TC studies. Furthermore, the three interviewees each mentioned multiple data collection methods to be used in TC studies; Jim and Sharon mentioning five, and Michelle mentioning three. This consistency amongst the literature and my data findings leads me to conclude that the utilisation of multiple data collection methods in a TC study, in order to triangulate data to make maximise its validity and reliability, is an effective practice.

In terms of the data collection methods that are most highly used when researching TCs, interviewing is the one that is referenced more highly than the rest. Timmermans and Meyer (2017) listed both student and teacher interviews as data collection methods to be utilised when attempting to identify TCs. Similarly, all three interviewees argued interviews to be an effective method to use. They stated that interviews can provide different types of information depending on the type of participant that is interviewed. For example, a teacher may be interviewed around the content in the course curriculum, whilst the students can discuss which parts of their learning they identify as *troublesome*. Interviews were the most frequently utilised data collection method by the researchers in my SQLR, though the margin was not overwhelming (18.6% of all instances). As this was the one method that was very strongly present and advocated for within the literature, the SQLR and the interviews, it is the only one I can confidently state appears to be

an effective, proven, well-practiced data collection method to adopt when studying TCs.

5.2.3 To What Extent Have Studies Explored the Role of TCs in Curriculum Development?

The introductory literature pointed to one valuable application of TC identification being the way in which these TCs can then be used to structure a curriculum. This was evident in Timmermans and Meyer's (2017) paper which recommended, in cluster four of their ITCK framework, that once TCs have been identified in a discipline, educational developers should use their knowledge of the existing TCs to design student outcomes (in regard to the curriculum) alongside teachers. These same authors, in the outline of their seventh teaching and learning principle, voiced that educational developers should encourage discussions about TCs amongst teachers and their colleagues to help inform course curriculum and teaching pedagogy. Similarly, Land et al. (2005) emphasised the use of TCs in informing curriculum development by naming them the 'jewels in the curriculum', saying they should be the centrepieces of a curriculum with the majority of the teaching and learning being focussed on them.

The importance of the role of TCs in curriculum development was discussed also by the three interviewees. Jim and Michelle raised the point that the main teaching focus of tertiary courses should lie mainly with TCs as these are the hardest, and most pivotal, concepts for students to learn. Sharon stated how curriculum-based conversations can be enhanced by using TC theory as a foundation for discussion. The conclusion that I am inclined to come to is that, while TC authors and researchers appear to have differing thoughts on how TCs may best inform curriculum development, the majority highlight this as a crucial application of TCs once they have been identified.

The last connection between my data themes and the literature concerns the lack of studies that focus on TCs in curriculum development compared with the identification of TCs. In the above paragraph I concluded that, based on the introductory literature and the interview data, there is a consensus surrounding the vital importance of using TCs to inform curriculum development. It is of potential concern, therefore, that my SQLR revealed only 3 out of 15 of the studies to have a dual focus on TC identification and the role of TCs in curriculum development. Furthermore, there were no studies that focussed solely on TCs in relation to curriculum development. I conclude, based on this information, that there exists a discrepancy between what is considered important by TC researchers (i.e. the application of TCs in curriculum development), and what the majority of the TC studies hold as their focus.

5.2.4 Gap in the Literature

The one major gap that exists in the literature concerns studies that hold the role of TCs in curriculum development as a focus. The lack of studies in this area was discussed earlier (Chapter 5.2.3). As stated, this is an area that I would strongly recommend researchers to focus on because of the high level of importance that is placed on it. This importance was apparent in the introductory literature (Land et al., 2005; Timmermans & Meyer, 2017) and in the interview data.

5.3 Implications of the Findings

In order to structure the implications section, I have first discussed the implications for TC researchers, teachers and curriculum developers. Following this I have provided a section that details how these implications would be applied to the design of a TC identification study in my personal field of primary school education. This is pre-empted by a brief discussion of an interview that I conducted with a pre-service teacher educator. Her interview was not analysed in prior chapters, because of my focus on engineering education, but her comments are applicable in this context.

5.3.1 Implications for Threshold Concept Researchers

I have provided implications for TC researchers in a succinct bullet-pointed list. These do not require thorough explanation as they are based on the findings that were provided in Chapter 5.2.

- Researchers focusing on the identification of potential TCs would be advised to look first for concepts with evidence of the *transformative* and *troublesome* characteristics. The other three, *irreversible*, *integrated* and *bounded*, may also be found to be present but they are not required.

- Researchers that are planning to carry out a study focussed on TC identification or the role of TCs in curriculum development would be advised to include both students and teachers as participants in their study. The utilisation of multiple data collection methods would also be ideal to triangulate the data in order maximise its validity and reliability. Interviews is a strongly recommended data collection method for studies that hold either of these focusses.

- Researchers who hold an interest in both TCs and curriculum development are encouraged to conduct a study with the sole aim of exploring the role of TCs in curriculum development. This was a large gap in the literature and is an area that has a lot of importance placed on it.

5.3.2 Implications for Teachers

As above, I have provided implications for teachers in a succinct bullet-pointed list. These do not require thorough explanation as they are based on the findings that were provided in Chapter 5.2.

- The process of understanding a TC may lead students to mimic their teachers or the literature until they come into full understanding. This fact may be an indication, to teachers that are observing this behaviour amongst their students, that a TC exists within the course of study.

- Teachers are encouraged to prioritise the teaching of TCs within their classes and leave concepts that are non-threshold to be learned by students through other mediums (e.g. books, on the internet).

5.3.3 Implications for Curriculum Developers

As with the other two groups, I have provided implications for curriculum developers in a succinct bullet-pointed list. These do not require thorough explanation as they are based on the findings that were provided in Chapter 5.2.

- Curriculum developers are encouraged to make TCs the centrepieces within the curriculum they are developing. The other concepts of relevance should be structured around the TCs, leaving the TCs as the focal points.

- Curriculum developers may like to consider limiting the number of TCs in a tertiary education course to one or two. This would ideally make the amount of learning manageable for students. Focussing on the same TC in multiple courses that students are enrolled in is another point of consideration.

I will now discuss the implications of the findings for the design of a TC study in education. This will begin with a brief recount of the interview I conducted with my fourth participant.

Interview with a Teacher Educator

The fourth interviewee (Karen) is a pre-service primary school teacher educator that works in an Australian University. She was interviewed using the same process as was used with the other three participants (Chapter 2.4). Her comments were not included with the others due to the fact that she works in the field of education and not engineering. The main themes that emerged from her interview are provided below along with appropriate quotations. I have favoured only those themes that relate to her perspective from the field of education.

Karen thought that, as my findings suggested, interviews are an effective data collection method to use when researching TCs. She voiced three ways that interviews are useful; researchers can use interviews to probe for understanding of potential TCs; researchers can gauge how well those concepts are understood by interviewees; and, researchers can learn how those people came to understand the concepts.

Karen: But actually when you're looking for people's understanding of a concept then having a conversation with them is a really good way of, of getting, ah, to understand what those concepts are and whether people understand them and, more importantly, how they come to understand them. So there's a richness in interview data that you can't actually get in, um, in other forms of data collection I would argue.

Karen stressed that, once identified, TCs need to hold an application. She mentioned that identified TCs should be examined to, I infer, understand exactly what makes them a TC. She voiced that these identified TCs should also be examined to determine pedagogical implications (e.g. how the TCs should best be taught).

Karen: … well it's all well and good to know what they [TCs] *are but what do they look like and how do they work? And, not only that, how do you teach them? So just because we, we might know them, you know, that gives us, gives us a name*

but then what? There's kind of the forwards and the backwards: how did we get here and what do we do now with them?

In terms of curriculum development, Karen considered TCs to be only one factor that should be considered when structuring a curriculum. She mentioned that student objectives should be included in a curriculum and that TCs should be used to inform these objectives. Her reason for not having TCs as the sole focus when structuring curricula is, I infer, that they do not account for skills and behaviours that students should be taught. As TCs only refer to notions within the mind and not skills (Chapter 1.2), they cannot be used to inform the skills and behaviours that are taught to students.

Karen: … I think threshold concepts can be a part of the story on how you get there, um, but I don't think threshold concepts in and of themselves are the destination. Ah, so at the end of the year, you know, we might want kids to understand their ABC, um, and we might know that, ah, understanding the sounds of letters is a really key part of being able to get there. So the threshold concepts could use, could be used throughout the year to structure material in the learning journey but, um, you still have the objectives at the end, um, so, you know you, you know. That gives you the destination.

Designing a TC Study in Education Based on The Findings

In the design of a study that sought to identify potential TCs for primary school students (in a particular subject that they are taught), I would make sure to identify concepts that exhibit *troublesome* and *transformative* as characteristics. This is based on the finding that these are the two characteristics that are inherent within any TC.

In terms of data collection methods for the study, I would utilise a variety as this was found to be an effective way to triangulate data to ensure validity and reliability. I would make sure to include interviews as one of these methods as this

was thought to be effective both, in my findings, but also from Karen's perspective. The inclusion of students and their teachers would be vital to the study as a further way to triangulate the data.

Karen stressed highly, speaking from an educational perspective, that TCs should be applied for practical purposes once they have been identified (e.g. exploring how the TCs should best be taught). Taking this into account, I would examine the current curriculum that teachers are basing their teaching from to assess whether any potential TCs that I may have discovered hold a prominent place within that curriculum. Depending on the results, trialling a redesign of the curriculum may be a useful way to put the findings into practice.

5.4 Study Limitations

The main limitation of this study was the small number of participants that were interviewed (Chapter 4). I used supervisor contacts as a way to gather my participants as I needed to interview engineering education researchers that had had experience in researching TCs. These were very specific requirements. The utilisation of a larger sample size would have given me a larger range of data to increase the validity and reliability of my overall findings (Cohen et al., 2018).

The second limitation was that I could have increased the number of papers in my SQLR by including all 147 papers that focussed on either/or TC identification or TCs in relation to curriculum development (Chapter 2.3.3). I chose not to do this, however, as I thought it would give my findings greater coherence if I could narrow my focus to a single discipline, as opposed to the studies occurring in a large range of disciplines. I recognise that including all 147 papers, however, would have a given me a larger source of data with which to draw findings that could, potentially, have been of a greater level of validity and reliability.

My first introduction to TC theory instantly captured my interest and I was intrigued to apply it, in some way, to my profession of primary school education. At the conclusion of this thesis, I still hold the same the level of interest in the theory and look forward utilising my findings to inform a future research study.

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Appendices

Appendix 1. Letter of Introduction to Potential Participants

Dear (name),

My name is Alan Morgan and I am a student studying towards a Master of Education through the University of Waikato in New Zealand. This is a letter of introduction and an invitation to you to be a participant in my research study.

I have chosen to base my thesis around threshold concepts (TCs). Specifically, I have been exploring which aspects constitute threshold concepts (eg. which elements, perceptions and identification factors are associated with TCs), which methods have been used to research TCs, and how TCs have, or could, be used for curriculum development. To this end, I have completed a systematic quantitative literature review to uncover the existing patterns and gaps within the literature concerning these aspects.

I have now reached the stage where I would like to interview researchers who have completed studies involving TCs, such as yourself. My aim in asking to talk with you is to discover how researchers of threshold concepts conceptualise TCs, why they chose to use the research methods they did, and their view of TCs as an tool for the development of curricula. I consider that talking to researchers will complement and extend the understandings and insights I have been able to develop from reading their work. Additionally, I would like to share and discuss the patterns and gaps I have uncovered from the literature review and gather your thoughts and opinions of them.

If you agree to be part of the study the interview would take place via *Skype* or face-to-face, whichever is prefered by you. I anticipate that the interview would last from 60 to 90 minutes. With your consent I would like to audio record the interview, and take digital notes during the interview. You can decline to answer any particular question and withdraw from the interview at any time. I will provide you with a full transcript or extend summary of your interview (whichever you prefer) for comment and approval. I would appreciate the opportunity to talk with you about your thoughts on the transcript/ summary. The time for this would be up to you but no more than forty-five minutes. You will be able to withdraw yourself, and your data, from the study completely up until the point the time you have approved your transcription/ summary.

Your data will be kept confidential and stored on a password protected computer (which will be erased after five years). You may either opt for confidentiality or not. If so, I will use a pseudonym when sorting your data and within the thesis. Please respect that your confidentiality may not be fully possible, however, because of your profile within the field of TC theory.

If you are interested in being a participant of my study, please reply to me at this email address: aahm1@students.waikato.ac.nz

Thanks for your time,

Alan Morgan

Appendix 2. Secondary Letter Outlining Further Details

Dear (name),

Thanks very much for agreeing to be a participant in my study. This letter will provide you with further details of your rights as a participant, and the process from this point forward. To restate, I have been exploring which aspects constitute threshold concepts (eg. which elements, perceptions and identification factors are associated with TCs), which methods have been used to research TCs, and how TCs have, or could, be used for curriculum development. Below is a list of rights that you have as a participant in the study:

- You may opt for confidentiality - this is anonymity so that the data, when published, is not connected to you personally.
- You may access any data collected from or about you.
- You may withdraw yourself, and your data, from the study up until the point you have read and approved your interview transcript or summary (whichever you have opted for).
- You may decline to participate in any activities that I present to you.
- You may access and correct any personal information throughout the study.
- You may ask me questions about the conduct of the research and any related activities. If I do not answer these to your satisfaction you may raise these via an email to my supervisor, Bronwen Cowie. Bronwen's email address is: bronwen.cowie@waikato.ac.nz

I will now outline a few more logistical details of the study:

- The data that you provide will be published in a written thesis and, upon completion, will be uploaded to the *Research Commons* on the University of Waikato website. I also expect to produce at least one paper for publication and hope to present the findings at a conference.
- Your raw data (e.g. transcript) will be stored on a password-locked computer for five years after which point it will be deleted.
- If you decide to withdraw yourself and your data from the study you will need to inform me via email. I will then be able to carry out the required steps to grant your request.
- I am more than happy to send you a copy of the completed thesis at the conclusion of the project if you are interested in having one.

With those details out of the way, I now wish to discuss the interview process. I would predict the interview lasting no longer than 90 minutes. You have the option of either a *Skype* interview (with or without video) or a face-to-face interview. After the interview I will provide you with either a transcription or report that provides a summary of the interview (whichever suits your preference) for you to read and approve. Once you have had a chance to read and approve the transcript (or summary), I intend to have a final discussion with you (through *Skype* or face-to-face) that will allow me to clear up anything that arises and hear any of your further thoughts.

What potential date/s and time/s would suit you for the initial interview?

Thanks for your time,

Alan Morgan

Appendix 3. Participant Consent Form

I _____ hereby agree to be a participant in Alan Morgan's research project. I have read, and am comfortable, with the following conditions:

- I may opt for confidentiality so that the data, when published, is not connected to me personally. Please indicate your preference: YES/NO
- I may access any data collected from or about me.
- Please indicate if you would prefer to view your full interview transcript or a thorough summary of the interview: TRANSCRIPT/SUMMARY
- I may withdraw myself, and my data, from the study up until the point I have read and approved my interview transcript (or summary).
- I may decline to participate in any activities that Alan presents to me.
- I may access and correct any personal information throughout the study.
- I may complain about the conduct of the research and any related activities. This may be raised through an email to Alan or to his supervisor, Bronwen Cowie. Bronwen's email address is: bronwen.cowie@waikato.ac.nz
- The data that I provide will be published in a written thesis and, upon completion, will be uploaded to the *Research Commons* on the University of Waikato website. I also acknowledge that my data may be included in at least one paper for publication and within a conference presentation.
- My raw data (e.g. transcript) will be stored on a password-locked computer for five years after which point it will be deleted.
- If I decide to withdraw myself and my data from the study I will need to inform Alan via email. Alan will then be able to carry out the required steps to grant my request.
- Please indicate if you would like a copy of the completed thesis when it is finished: YES/NO

Signed: _____ Date: _____

Appendix 4. Interview Script

Questions:

1. In your own words how would you describe the idea of a *threshold concept*?
2. Which authors would you describe as most influential in the field of threshold concept theory? Why?
3. Ray Land and Jan Meyer offered five threshold concept characteristics in their seminal TC paper in 2003 - transformative, irreversible, integrative, bounded and troublesome. Do you feel that a concept must have evidence of each of these characteristics to be considered a TC? Are any of the characteristics more or less important than the others? Why? Why not?
4. I see that you used the research method/s of _____ in your TC study/ies? Why was this/these chosen?
5. Did you find your chosen research method/s effective for identifying TCs? Would there have been any changes that you think would have improved the effectiveness of the method/s?
6. I have come across several issues that have the potential to make the researching of TCs troublesome. To give a common example, authors have pondered what sorts of knowledge are able to be classified as a TC. Several authors have given the impression that physical skills may be counted as TCs, yet from my analysis of the term concept it appears that only things occuring within the mind (e.g. notions, thoughts, ideas) can be considered concepts. What issues, if any, have you experienced when researching TCs?
7. I am completing a systematic quantitative literature review with the aim of quantifying such elements as the TC characteristics that are focussed on most within the literature, research methods used when identifying TCs and methods used to embed TCs within curricula. I have narrowed my scope down to engineering TC studies. One emerging theme is that many more TC studies focus on the identification of TCs than the use of TCs within curriculum development. What are your thoughts of this?
8. I have found Australasia and Europe to be the geographic regions within which the largest number of TC studies are completed. What are your thoughts on this?
9. What are your general thoughts on the use of TCs to structure a curriculum?
10. I have been completing a side project for the University which involves me studying university students' assignments to pinpoint potential TCs (the discipline being diversity and equity within teaching practice). A strong theme to emerge is that the potential TCs within this discipline revolve heavily around the change of thinking in regard to self, others, and the surrounding world. For example, for a student to understand how the self is reflected within their pedagogy, they must reflect about their deep-rooted values and beliefs and how these are enacted in their teaching. I feel that the nature of these TCs would differ strongly to those present within the physical sciences where the TCs would be more conceptual (based on course content) than these which require students to reflect on themselves and their positioning in the world. What are your thoughts?
11. A last theme I am interested to discuss with you is the timelessness of TCs. Among the students' assignments many convey that it is useful and easy for them to incorporate technology into their pedagogy as a teaching aid (e.g. iPad apps, Youtube videos). I feel that this may very well have been a TC for teachers in the past when the idea of utilising technology within the classroom first came about. If it was in the past, it certainly does not seem to be a TC today for teachers entering the field, indicating that some TCs may not be timeless and may become obsolete. What are your thoughts of this? Are there any potential TCs from your field that have, or that you think might someday, become obsolete?
12. Any concluding thoughts about TCs?

Potential Prompts:

1. I found that point interesting. Would you mind expanding on it?
2. Would you mind clarifying your point about _____?
3. I had not previously considered your point about _____. Can we discuss this point some more?