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Emergent learning and threshold concepts in tertiary education

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Mastering threshold concepts in tertiary education: "I know exactly what you are saying and I can understand it but I've got nowhere to hook it."

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Abstract

International interest is growing in the hypothesis that a focus on teaching threshold concepts can engender transformation in the epistemological and ontological dimensions of learning. According to threshold concept theory (Meyer & Land, 2003) concepts that are troublesome to learn are also transformative when mastered: the acquisition of threshold concepts is conducive to the change in the student's understanding of a discipline, and what it means to be a disciplinary expert, engendering in the student deep knowledge and learning throughout the student's life span. Our project explored how threshold concept-focused pedagogies and assessments can afford opportunities for student learning of hard-to-grasp concepts. The impact of a threshold concept-informed curriculum was examined through two cycles of collaborative action-research, in doctoral writing, leadership, a Bachelor of Arts foundation course and an electronics engineering course. Results revealed that although the direct impact of changed teaching practice on students' short-term learning could not always be uniquely identified, results from student surveys confirmed that their learning experience had been enhanced. Results also suggest that by focusing teaching on identified threshold concepts, lecturers can attend to what they consider the keys to deep learning and ways to best enable it. The explicit teaching of these integrative troublesome concepts offers students somewhere to hook their disciplinary understandings as they continue to learn new concepts.

Keywords

Threshold concepts, cross-disciplinary, student learning

Introduction

According to threshold concept theory (TCT), in each academic discipline there exist concepts that once grasped allow new and previously inaccessible ways of perceiving and thinking about the subject being studied to emerge (Meyer & Land, 2003). This transformative shift in thinking and the emergence of a higher level of understanding distinguish threshold concepts (TCs) from the so-called key concepts. However, students often find TCs troublesome and this is where they often 'get stuck' (Harlow, Peter, Scott, & Cowie, 2011).

The starting point in our project was the findings from New Zealand and overseas that first year undergraduate students, across disciplines, have great difficulty learning certain concepts and progressing in their tertiary studies (Buntting, 2006; Meyer, Land, & Baillie, 2010; Rountree & Rountree, 2009; Scott, Harlow, Peter, & Cowie, 2010). The project also built on overseas studies that have examined factors related to pedagogy and knowledge acquisition (i.e., the acquisition of TCs) in tertiary education as an alternative solution to the problem of troublesome learning (Baillie, Goodhew, & Skryabina, 2006; Cowart, 2010; Eckerdale, McCartney, Moström, Sanders, Thomas, & Zander, 2007; Meyer, Land, & Baillie, 2010).

Since the inception of TCT many researchers in the field have focused on identifying TCs using the attributes identified by Meyer and Land (2003), TCs are *transformative* (they change the learner's whole way of thinking), *irreversible* (they are hard to unlearn, as riding a bicycle), *integrative* (they connect into many diverse niches of a discipline), *bounded* (they mark the edge of a discipline), and they are potentially '*troublesome*' (difficult to grasp; counter-intuitive). Our research capitalised on the impact that TCs have in focusing lecturers on pedagogy and student learning (Beaty, 2006; Cousin, 2006). Emerging evidence from investigating the curriculum and pedagogical implications of TCT (Irvine & Carmichael, 2009; Land, Meyer, & Smith, 2008; Meyer & Flanagan, 2010; Rowbottom, 2007) suggests that TCs provide a theoretical framework that encourages lecturers to deal with current concerns within the curriculum in a creative and fruitful way (Lucas & Mladenovic, 2007).

Background

Internationally there is an interest in how TCT can transform tertiary teaching and learning—what changes do lecturers make to curriculum and pedagogy when they focus on TCs and how do tertiary students respond to threshold concept-informed curriculum? In contrast to the situation overseas, very little research in New Zealand has been conducted within a threshold concept theory framework.

One of the questions that our project addressed was how the introduction of TCs into *teacher-student discourse* and teaching practice impacts *student learning* at the tertiary level? This question focused on how *changes* in lecturers' pedagogy as they teach TCs impacts students' perceptions and understanding of threshold concepts, as gauged through course assessment and surveys. The expectation was that the results would provide an indicator of the merit of different pedagogical practices and signal potential places for further pedagogical change.

In our project two characteristics of TCs that were of special interest were *troublesome* and *transformative*. Meyer & Flanagan (2010) suggest that learning may be troublesome because students must suspend their beliefs, they must almost 'forget' certain knowledge in order to cope with the new TC and integrate it with pre-existing knowledge. Depending on discipline and context, knowledge might be troublesome because it is ritualised, inert, conceptually difficult, alien or tacit, because it requires unfamiliar discourse, or because the learners do not wish to change their customary way of seeing things. This means that it is important to pay attention to the discomforts of troublesome knowledge. Despite the fact that many researchers have found TCT to be a useful idea (Meyer & Flanagan, 2014), there have been several TCT critics over the years. O'Donnell (2010) argued that the definition of threshold concepts made their identification difficult, arbitrary or impossible. Atherton, Hadfield and Meyers (2008) felt that TCs were more 'articles of faith' to be believed as much as understood while Rowbottom (2007) felt that it was impossible to empirically isolate TCs and that what might be 'threshold' for one person might not be for another.

According to Meyer and Land (2003), after initially encountering a TC, students may spend time in a 'liminal' state'—which is akin to a phase transition observed in dynamical systems and cognitive development (Haken, Kelso, & Bunz, 1985; Stephen, Boncoddo, Magnuson, & Dixon, 2009; Treffner & Peter, 2002)—before crossing the threshold to deep understanding. Until students cross the threshold they are only able to mimic deep understanding and are therefore unable to solve new problems in diverse situations. Thus, it is crucial to uncover why students find it troublesome to master TCs and, once mastered, to verbalise their knowledge.

Threshold concepts have been linked to ontological shifts (Meyer, Land, & Baillie, 2010) thus it is equally important to determine how some students undergo a transformational experience. This change in thinking and practising within a discipline extends the meaning of TCs to 'threshold practices', 'threshold competencies', or 'threshold experiences'. Baillie (2012) suggested that TCs may be reconstitutive and this change usually takes time. Baillie described TCT as an educational tool to "focus learning on concepts most critical to students' progress…." (Baillie, 2012, p. 4).

Our project built on our earlier work in which the lecturer in the first-year electronic engineering course identified TCs in analogue electronics and investigated the impact of a TC-informed curriculum and pedagogy on students' learning (Harlow, Peter, Scott, & Cowie, 2011; Scott, Harlow, Peter, & Cowie, 2010). The current project expanded this focus across four disciplines where researchers and lecturers from a range of disciplines explored TCT with the aim of re-envisioning curriculum and pedagogy in a way that attends to both the epistemological and ontological dimensions of learning (Horn, 2012; McKenzie, Akerlind, & Wilson, 2012; Ó Donnchadha, 2012). Cousin (2006) refers to this type of TC research as a form of transactional curriculum inquiry. In our two-year action-research project, researchers and lecturers identified TCs, developed curriculum interventions focusing on TCS and explored the affordances (opportunities for action; Gibson, 1977; Gibson, 2001) of various disciplinary teaching practices on students' perceptions and learning of TCs.

Theoretical framework

For experts, who have crossed the threshold to deep understanding, TCs are often held as tacit knowledge. Hence, the lecturers, being experts in their fields, may not teach them explicitly, and consequently, students may not realise their importance. TCT suggests that lecturers need to focus their teaching on identified TCs, address troublesome features, and help students become aware of certain critical, distinctive features of these concepts. This idea resembles the principles of perceptual learning (Gibson, 1966; 2001) where learners become aware of distinctive features of things, invariants of events over time, and higher order structures (Gibson, 1966), and can be recognised in education *variation theory* (Marton & Booth, 1997; Marton & Tsui, 2004; Runesson, 2005). Variation theory focuses on the object of learning and is interested in students' experience of, and ways of understanding an object of learning, e.g., a TC. According to variation theory it is the patterns of variation and invariance among examples, instances, cases, illustrations and other aspects of teaching, that are the key to better learning.

Therefore, in thinking about why some students 'get stuck' in their learning, teachers need to cultivate a "third ear that listens not for what a student knows … but for the terms that shape a student's knowledge" (Land, Cousin, Meyer, & Davies, 2006, p. 200). Land et al. (2006) wrote about learning as an excursion that sets out towards a destination but does not necessarily stick to the expected route or indeed end in that place: "… The eventual destination may be reached, or it may be revised. It may be a surprise. It will certainly be the point of embarkation for further excursion" (p. 206).

Lecturers can acknowledge the uniqueness and complexity of learners by guiding them to become an integral part of learning (Glaserfeld, 1989; Wertsch, 1997). Thus, a curriculum change may be the first step where lecturers can create the conditions that support learning of the TCs.

Methodology

Participants

Two educational researchers facilitated the research conducted by five practitioner researchers from four disciplines. Four academics taught first year courses and the fifth was a facilitator of doctoral writing workshops. In electronics engineering and in Bachelor of Arts foundation courses between 100-120 students enrolled; in leadership courses (first-year and corporate) there were between 15 and

45 students and in the doctoral writing group the number of students varied between 10 and 25 students.

Design

The overall research design in the study was that of two cycles of collaborative action research (McNiff, 2002; Elliot, 2009; Saunders & Somekh, 2009). The first cycle started with identification of points in a curriculum where students got stuck, and cross-disciplinary discussions of TCs. The lecturers reflected on how experts in their discipline think and practise, and considered ways of teaching and rates of learning. This phase was followed by revising the curriculum and pedagogy (teaching to the concept). The development and implementation of new teaching strategies, collection of data on student perceptions, formal measures of achievement and evaluation of the outcomes—individually and within group discussions—informed curriculum and pedagogical changes implemented in the second cycle. The second cycle repeated the process with a new intake of students, which allowed for the analysis of data from two student cohorts.

Data drawn from observations of lectures, workshops, tutorials and laboratory sessions, interviews, student surveys and focus group discussions, achievement results, camera stills, relevant document analysis and recourse to university-based Moodle (open source platform) information collected over the two years were analysed and synthesised.

Data analyses, both quantitative and qualitative, focused on identifying changes in students' understanding of TCs and their perceptions of threshold-concept-centred teaching. Qualitative data analysis employed an inductive grounded theory approach (Charmaz, 2005; Creswell, 2005) and data from lesson observations, and student and lecturer commentary were integrated to develop descriptive case studies of how teaching of TCs played out.

Findings—Students' grasp of threshold concepts

This article offers four 'vignettes of practice', one from each participating discipline, about how TCs were identified and taught, and how students were supported to grasp the TCs in their courses. Three of these vignettes are more extensively covered in other articles in this special edition.

Threshold concepts in the Bachelor of Arts foundation course

The benefits for tertiary teaching and learning in the arts and humanities of focusing on threshold concepts have been explored in a number of recent studies (Adler-Kassner, Majewski & Koshnick, 2012; Kelly, Russell, & Wallace, 2011; McEntee, 2007; O'Brien, 2008; Wisker & Robinson, 2009).

Arts 101 is a course intended to provide students with a background for study within the Bachelor of Arts. This cross-disciplinary course is structured around the metaphor of journey and cultural encounter, focuses on a variety of texts, images and sounds, and promotes understanding of how different ways of interpretation work. Recognition of the subjective character of critical interpretation in literature and the arts (Bleich, 1975; Eaglestone, 2000) led the lecturers to identify *subjective interpretation*—the ability to interpret texts and other media from the different perspectives of characters or from the perspective of different readers—as an important TC in this first-year BA course. A survey conducted at the start of the course confirmed that students found this concept troublesome, thus meeting one of the core requirements of a threshold concept. Throughout this foundation course there was a focus on identifying diverse critical perspectives and students were encouraged to develop and express their own views.

A variety of teaching, learning and assessment methods was used to communicate this TC throughout the course. These included an initial lecture on subjective interpretation; regularly invoking the concept in lectures and tutorials, and explicitly relating it to the works encountered on the course,

question-and-answer sessions, invited student participation in lectures, role-playing, and specific assignment and final examination questions on subjective interpretation.

Analysis of student survey and focus group data revealed that identifying the TC, subjective interpretation, and related concepts was valuable in terms of unlocking and validating students' voices and perspectives, and in helping them to identify connections between a wide variety of texts and other media. Students expressed their appreciation for being introduced to a threshold concept that they could then apply both to learning other university subjects and to their own creative endeavours, for example, dancing, music, and creative writing.

> I think you simply can't advance in the humanities without the ability to subjectively analyse something…. In one or two papers, like anthropology, you can use subjective interpretation to interpret other things, like the cultural use of rituals…. (Arts 101 student)

Students found the lecturers' various pedagogical approaches to threshold concepts helped their learning and their ability to situate their voice within a variety of perspectives. Participation in a collective exercise involving role-playing, movement and vocalisation and taking part in a performance helped students to grasp the concept of subjective interpretation and recognise its importance; it also promoted transformative shifts in their understanding:

> You got to see different interpretations of the idea. In *The Tempest*, when they changed the characters around and they acted like melodramatic characters and changed their personalities completely, and then we kind of sided with one of the characters. (Arts 101 student)

In Arts 101, students' grasp of TCs was examined in their first assignment in 2012 and 2013, a compulsory exam question in 2012, and an essay question and a test in 2013. As can be seen from Figures 1 and 2, in both years of the project, students grasped the identified threshold concepts to a greater degree at the end of the course than at the start. This indicates that changes in the pedagogy focusing on threshold concepts enhanced students' understanding of these concepts.

In the first year of the project there was a 100% pass rate on the compulsory TC question on subjective interpretation in the final exam. The positive correlation between students' answers on the TC question and the total year grade was positive and strong, $r = 0.7$. When asked what had helped their understanding of subjective interpretation, more than 80% of students identified the different assignments, lectures, and group discussions that had been developed during the study. The majority of students stated that they best understood perspective (87%) and subjective interpretation (73%). Unexpectedly, 45% of students found the concept *unreliable narrator* to be the most troublesome concept to understand. Following these findings, the lecturers focused on this additional threshold concept in the second year of the project.

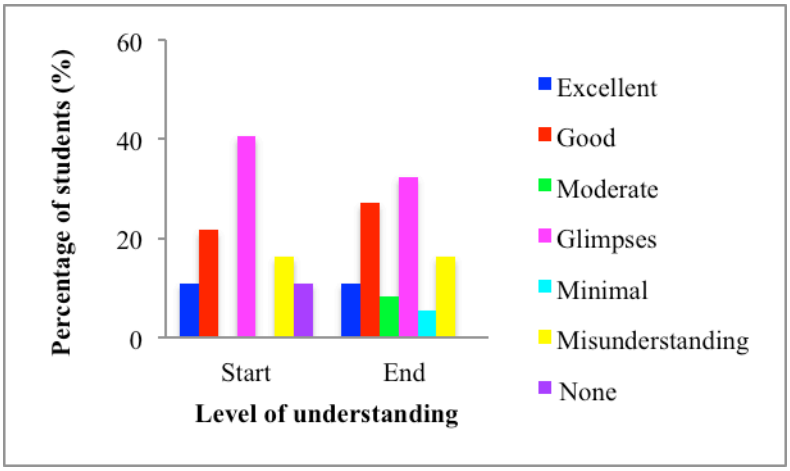

Figure 1. Bachelor of Arts foundation students' understanding of *subjective interpretation* at the start and at the end of the course in 2012

Comparison of Figure 1 and Figure 2 shows that the student achievement in 2013 was comparable to 2012. The graph does not show this. In both years there was a 100% pass rate on the threshold concept question on subjective interpretation in assignment 1; of 85 students who submitted an essay (23.5%) achieved A/A+ grade, and 80% of students passed the final exam.

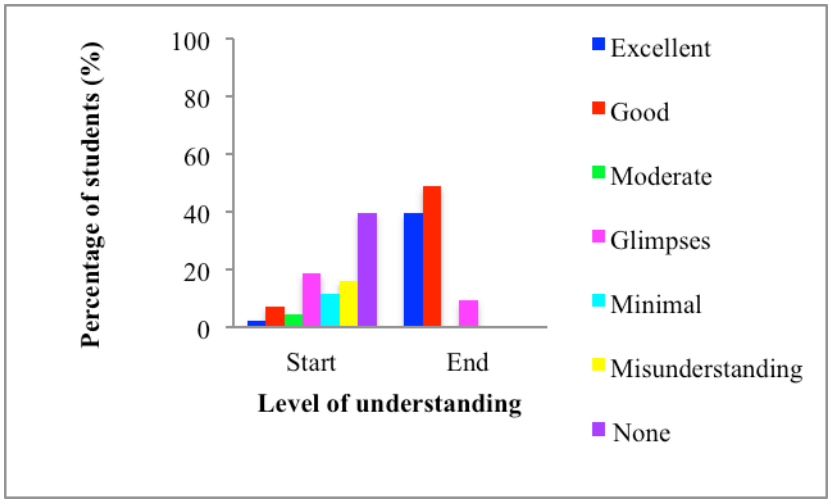

Figure 2. Bachelor of Arts foundation students' understanding of *subjective interpretation* at the start and at the end of the course in 2013

In sum, through a variety of teaching techniques, including role-playing and participation in a collective exercise, students were enabled to grasp the concept of subjective interpretation and experience transformative shifts in understanding through active learning. This was evident in students' application of concepts via repeated references to subjective interpretation, limited point of view, and unreliable narrator in exam scripts—even when questions did not explicitly invite this—thus demonstrating critical thinking, awareness of subjective points of view, and the role of critical evaluation.

Threshold concepts and threshold crossings in Leadership courses

The idea of threshold concepts both excited and humbled the leadership lecturer. He was excited because the concepts offered new ways out of the impasse that leadership theory and pedagogy had reached; he was humbled to discover that he had not explicitly identified the core concepts of leadership in general. To explain the ambiguity, it is necessary to look briefly at Nohria and Khurana's (2010) influential summation of the state of leadership at the end of the first decade of the 21st century: "we discovered how far leadership research now lagged the espoused mission of most business schools – to educate leaders—and how urgent the need was to spur leadership on the topic" (p. xii). Given this situation, TCs seemed to hold the promise of a secure foundation for future pedagogy and research.

Accordingly, the lecturer undertook a form of what Schein (2013) calls "*Humble Inquiry: The Gentle Art of Asking Instead of Telling*" by asking leaders and students for their ideas and also by rereading the literature to identify TCs in leadership. The first main pedagogic outcome was a pre-course student survey that made a provisional list of what the lecturer viewed as potential candidates for leadership TCs: "leaders are made not born;" "leadership is not about creating more followers but about creating more leaders;" and "the job of leaders is growing leaders."

Additionally, the lecturer asked students to rate the importance of such activities as; "being inspiring," "being honest," and "creating a shared vision" and to rate their own capabilities on those activities. The aim in those two sections was to find out how the students felt about, and assessed, their own leadership.

Initially, the questionnaire was designed for students but it proved invaluable for the lecturer to undergo his own "re-education" from a TC perspective. The pedagogic improvement arose by asking the students to fill out the same questionnaires midway and near the end of the course prior to the final assignment. Only then were their original questionnaires returned to them. This gave students the ability to track changes that may previously have been missed. The courses also concluded with discussions of how fit students felt to lead and how this related to their subjective view at the start of the course. To address threshold concepts explicitly, as part of the final reflective assessment the students were asked to: provide their definition of leadership (with reasons), identify in themselves and/or others any TCs, and to explain what they understood by these TC ideas/experiences and how they made a difference to them in terms of their attitude and behaviour.

The analysis of the reflective essays revealed that with more explicit teaching of TCs there was no clear indication that students' ideas about leadership had changed significantly in comparison to previous years where there was no focus on TCs. Nevertheless, students in two first-year classes did experience transformation in their understanding of what leadership is truly about. They reported that the course changed their ideas about leadership, their beliefs in themselves as leaders and increased their self-awareness. However, as most of the students had come straight out of school, they had difficulty in understanding what these actions would look like in real world situations (see Figure 3). They found it hard to comment on their own leadership style since many had not held a leadership position previously.

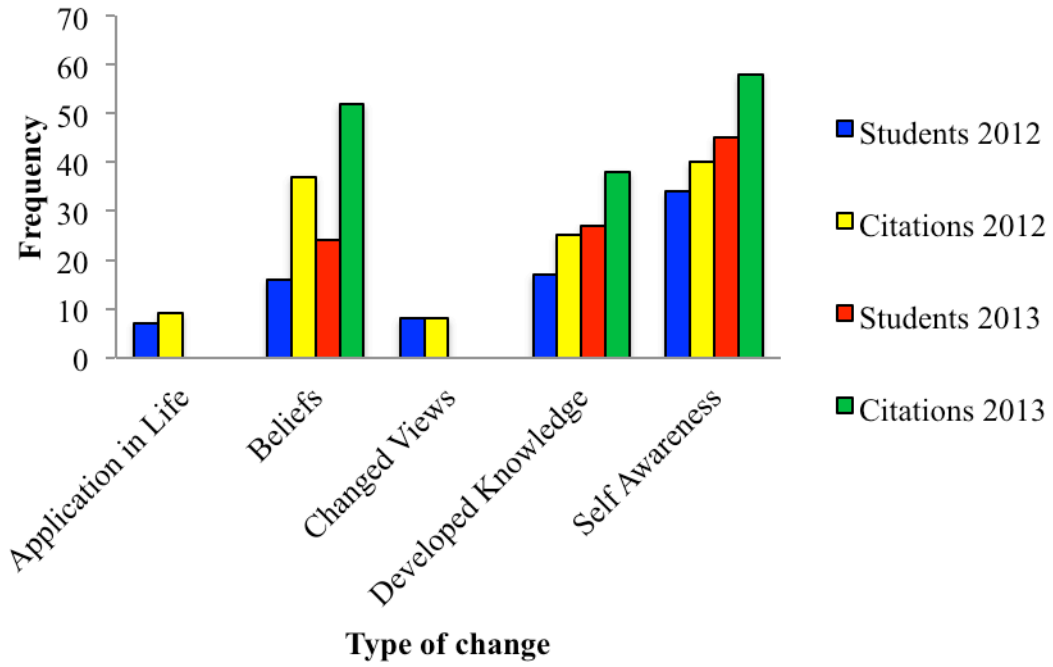

Figure 3. Number of Year 1 leadership students and comments (citations), in 2012 (N=7) and 2013 (N=23), identifying areas of change in students' understanding of leadership

The summary of reported changes in corporate students' views on leadership is illustrated in Figure 4 and for Māori corporate students in Figure 5. These students struggled to find ways to adapt their current leadership style, especially if they had been working in a leadership role for many years. In line with recent TC theory, they might also have had difficulty since "learning within the liminal state is sometimes experienced as oscillative, as the changed perspective slips in and out of focus and eludes the learner's grasp" (Land, Rattray, & Vivian, 2014, p. 201).

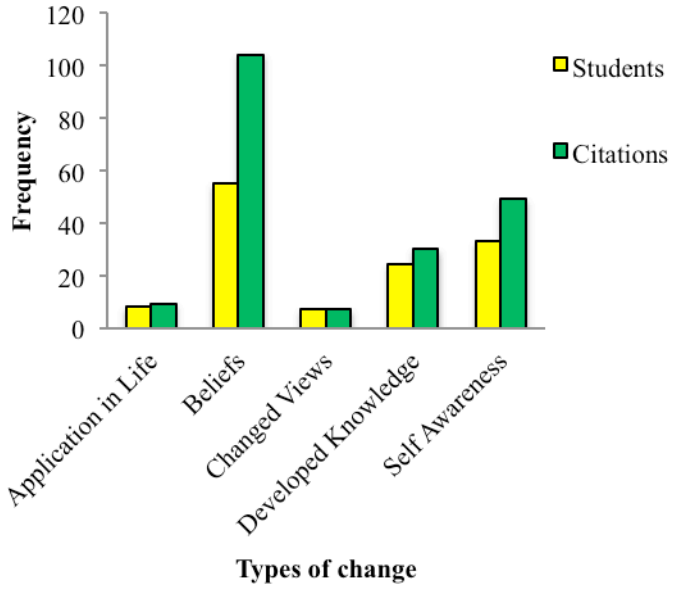

Figure 4. Number of three day intensive corporate students and comments (citations) in 2012 (N=18) in leadership course identifying areas of change in corporate students' understanding of leadership

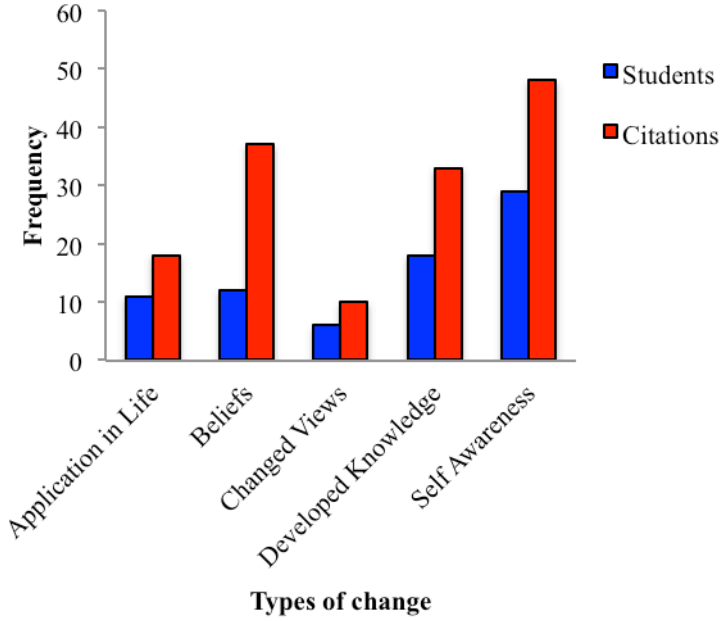

Figure 5. Number of three day intensive corporate students and comments (citations) in 2013 (N=18) identifying areas of change in Māori corporate students' understanding of leadership

While the students recognised the need for a change they were not sure how to achieve it. Their changed views of leadership related to their beliefs around good leadership, their role as a leader and the roles of others in leadership, and related to the identified TC 'the job of leaders is to create leaders'.

In sum, leadership coursework transformed perceptions of leadership for both the novice and expert groups of students. The course enhanced their understanding of leadership through the use of class discussions, group exercises, assessments and self-assessment tests. However, for many students perceptual change did not translate immediately into an ability to see how to become a leader or a better leader. This indicates that students may still be in the 'liminal state' (Meyer & Land, 2003) of learning. Two recent publications addressing TCs in leadership also highlight difficulties in identifying TCs in leadership and the divide between the conceptual and the experiential: Yip and Raelin's (2012) article identifies only "two leadership concepts—situational and shared leadership—that qualify as threshold concepts" (p. 334) and Hawkins and Edwards (2013) suggest that in order to cross the leadership threshold, students "must grapple with symbolic monsters … and experience doubt and uncertainty" (p. 1). In sum, there is little question that focus on TCs and threshold crossings can add to leadership teaching and learning but much research remains to be done in this area.

Threshold concepts in doctoral writing

Insights from the research supported the lecturer to identify and make explicit what it means to be a doctoral writer. This included, for example, understanding that writing incorporates the ability to understand research practices, extract meaning from data, clearly articulate ideas, and present, shape, and reshape text on the page. Understanding writing also means developing an enhanced tolerance of ambiguity while searching for meaning, and includes a belief that understanding will emerge as ideas are discussed, clarified, written, and refined.

Research has identified that students frequently start their doctoral studies with scant understanding of the hurdles they will face, culturally, linguistically, or educationally (Cadman, 2000). There is an emerging body of research evidence that argues for the efficacy of cohort models of supervision and writing groups (Ali & Kohun, 2007; Larcombe, McCosker, & O'Loughlin, 2007). Such models, by their very community-based orientation, change the physical and conceptual spaces in which doctoral students meet and work. The Doctoral Writing Conversations facilitated by the lecturer encompassed this philosophy—that regular cohort-based conversations around doctoral research and writing *in general*, as well as discussion of students' *specific* writing concerns, were attractive to students.

Interviews with students and data from an online survey revealed that virtually all doctoral students 'get stuck' during the process of thesis writing and they do so in a variety of ways.

> There were many instances [of 'stuckness'] and particularly around the literature review and finding a conceptual framework. (New Zealand PhD student)
>
> The writing has been a lot more difficult than I expected it to be. [Why?] "Well, putting it all together and getting a structure." (New Zealand PhD student)

Interviews with students revealed that they often felt a lack of prior preparation to undertake doctoral study, lacked the confidence to be an independent researcher, and wanted better institutional support. Lack of understanding of what writing actually means—that it is not simply 'words on the page'—and a lack of confidence in being able to structure ideas and present them at the required level emerged as the most troublesome concepts.

Using insights from interview data the lecturer refined the Doctoral Writing Conversations programme to include more shared conversations and disciplined practice, the aim of which was to assist students in the building of a collaborative postgraduate writing culture. This contributed to students' sense of personal well-being, achievement, and academic success.

> They [writing groups] help me to realise that other people also have the same problems as I do. They provide me with useful 'tips' or strategies to make progress. They allow me to voice myself. (New Zealand PhD student).

In addition, the lecturer found that students gained important insights into their writing after attending a writing retreat to which they had brought some of their own work. The communal environment

sparked a shift in students' perspectives of how well they were doing; they wrote more than they had expected and were able to better articulate their thoughts and arguments.

Threshold concepts in electronic engineering

In electronic engineering the lecturer found two TCs that were important in the first-year course—Thévenin's theorem and dynamic resistance. The lecturer identified TCs based on his experience and knowledge of his students' struggles with grasping these concepts. In addition, in the first year of the project, the lecturer identified precursor ideas necessary for grasping TCs: exam results in the first year of the project revealed that few students (16%) had a complete understanding of the *holistic current flow* required for an understanding of Thévenin's theorem.[i] Consequently, most students provided an incorrect answer to questions, including TC questions, requiring an understanding of holistic current flow. Importantly, students who answered the TC questions correctly in a midterm quiz but failed to get the precursor questions correct acknowledged, in an interview with researchers and the lecturer, that they had guessed the answer to the TC question. This finding motivated the lecturer to focus on early assessment of precursor and threshold concepts using Instant Feedback Assessment Technique (IF-AT), 'scratchy cards' which provided an instant feedback (Epstein et al., 2002). The lecturer also used the cards for small group collaborative problem solving and formative assessment to address any misconceptions students might have. Overall, findings from the first year of the study indicated that troublesome travel through the liminal space can be eased by an explicit and sustained teaching focus on threshold concepts (Baillie, 2012; Harlow, Peter, Scott, & Cowie, 2014).

Students' comments in interviews and surveys in the first year of the project highlighted the need for learning examples to be progressively more complex and to be varied so that students can practise new knowledge in different contexts. Consequently, an online tutorial system was developed in the second year of the study. The analysis of student activity indicated that students used online tutorials both for initial learning (to pass the tutorial) and to review questions. The majority of students went through waves of activity that peaked prior to assessment points, such as before the week 4 and 12 quizzes, and before the final exam in week 16. However, there were a number of students who regularly (i.e., every week) visited the online tutorials (see Figure 6).

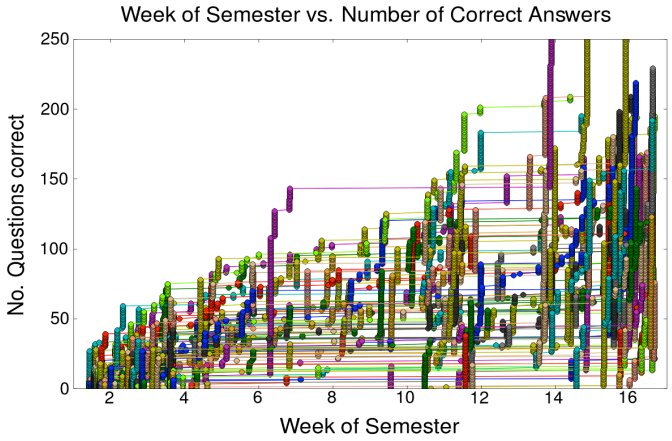

Figure 6. Frequency of first year ENEL 111 students' activity in online tutorials during the semester in 2013.

Note: Each line/colour in Figure 6 represents a student and each dot represents an attempt in solving tutorial questions

[i] Thévenin's theorem is the first example of circuit modelling that students encounter in electronics & circuit theory. It causes learners an inordinate amount of trouble. It is not Thévenin—any model would present the difficulty.

Assessment results revealed that on the *midterm exam*, students from the 2012 cohort and those from the 2013 cohort achieved, on average, equally well (74% vs. 73%).

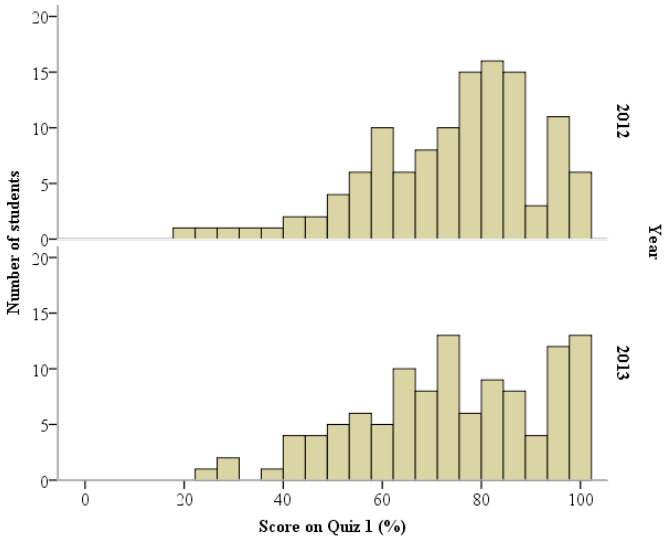

Figure 7. First year ENEL 111 students' achievement in the midterm quiz (Quiz 1) in 2012 (top panel) and 2013 (bottom panel)

However, 2013 students' *final exam* scores (M = 49.32%) were significantly higher than the students' scores in 2012 (M = 42.76%), $F(1, 225) = 12.57$, $p < 0.001$. These two results taken together were taken to indicate that the use of online tutorials had a beneficial effect on student learning. Moreover, in 2013 there was also an indication that there were two distinct groups of students—those who *got it* (TCs) and those who *did not* (see Figure 8).

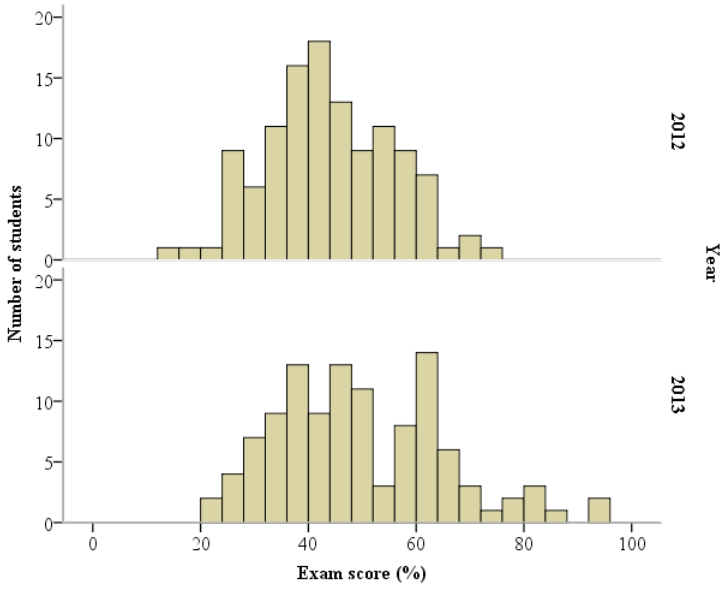

Figure 8. First year ENEL 111 students' achievement in the final exam in 2012 (top panel) and 2013 (bottom panel)

About 20% of students did not complete the eight sections covering analogue electronics in the online tutorials (see upper graph in Figure 9). On average, these students achieved significantly lower scores on the final exam (37.53%) than the students who completed eight or more online tutorial sections

(51.53%). Nevertheless, as the lower graph in Figure 9 illustrates, even among those students who completed eight or more online tutorials about 50% did not achieve high scores on the final exam.

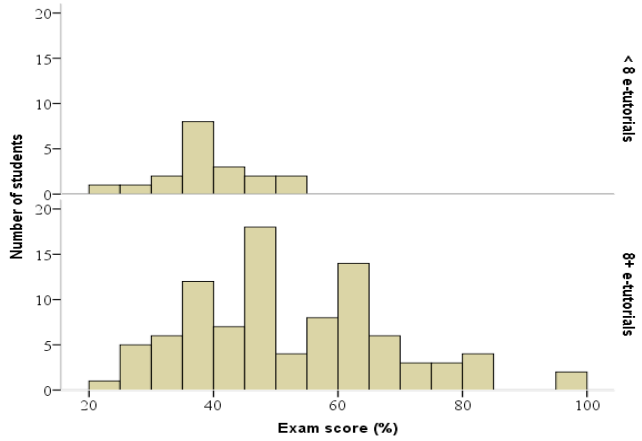

Figure 9. First year ENEL 111 students' achievement in the final exam in 2013. Top panel shows achievement of students who completed fewer than eight sections in online tutorials. Bottom panel summarises achievement of students who completed eight or more sections.

These results point to troublesome learning and positions students within an unstable liminal knowledge space. This was consonant with the earlier findings (Harlow, Peter, Scott, & Cowie, 2011) where a student comment exemplified the need for students to suspend belief and almost 'forget' certain knowledge in order to successfully integrate the new threshold concept in the pre-existing body of knowledge.

Discussion

Each vignette described in this article shows that the lecturers' hypotheses about which concepts could be TCs were confirmed by the students in each discipline. The findings from the four case studies illustrate how a focus on TCs helped lecturers better understand their students' learning experience and reconceptualise their teaching through role-play, small group work, and various formative assessment techniques.

The learning experience

The students' experience emerged as a common thread in the project. The findings showed that students in all disciplines became aware of the importance of threshold concepts, experienced the liminal space of oscillation between knowing and not knowing, and were passing through a portal of understanding at varying rates and by means of varied teaching strategies. The student learning experiences and achievement data support the idea that phase transitions and their anticipatory signatures (e.g., loss of stability) are common across a broad range of complex systems and disciplines, including human learning (Treffner & Peter, 2002).

Student data revealed that students had problems not only with lecturer-identified threshold concepts but also with some other (threshold) concepts. These were subsequently given a special focus and taught explicitly as well. Students found the engineering lecturer's focus on assessment for learning (Black & Wiliam, 2003) useful for their understanding of TCs. Leadership students viewed group formative assessment as valuable in helping them articulate their knowledge and become more confident in their learning. Engaging students in enacting learning tasks, as in the Bachelor of Arts foundation course, encouraged their enthusiasm and learning of troublesome concepts. However, the direct impact of changed teaching practice on student achievement was not always uniquely identified. Nevertheless, results from student surveys confirmed that students' learning experience had been

enhanced in all four disciplines. This study supported the findings of Knight, Callaghan, Baldock, and Meyer (2013) who reported that identifying a TC through dialogue, between students and lecturers, about conceptual understanding and capabilities can result in changing pedagogies and assessments to focus on students' conceptual understanding and thus enhance students' awareness of their cognitive strategies and promote their confidence and problem solving abilities.

Pedagogies to target the threshold concept

Our project began with some doubts about TCs, similar to those expressed by Rowbottom (2007) and O'Donnell (2010), when lecturers first met to discuss TC identification, but over the period of the study the lecturers came to see the benefit of using TCT for making sense of the curriculum from the point of view of the learners—something that had been quite difficult before. Transformative and troublesome characteristics of the TC's have interested lecturers the most. They conjectured that an understanding of a TC might entail a transformed internal view of subject matter, subject landscape, or even worldview and how people 'think' in a particular discipline, or how they perceive, apprehend, or experience particular phenomena within that discipline. The lecturers recognised that this transformation may extend over a considerable period of time, with the transition to understanding often involving 'troublesome knowledge'.

By focusing on TC theory the lecturers developed new pedagogical approaches, assessment tools, and educational research skills necessary for quality teaching and developing students as lifelong learners. Lecturers' awareness and emergent knowledge of threshold concepts made a substantial impact on what they taught, how they taught and how they assessed students' understanding of TCs. By thinking about, observing, and discussing their teaching, lecturers became aware that they needed to modify their teaching to accommodate students' varying rates of mastering threshold concepts. Lecturers also acknowledged the importance of precursor concepts that learners need to have mastered before they can grasp more difficult threshold concepts. The electronics lecturer used the TCT as an effective curriculum development tool and reduced the number of troublesome concepts in his first-year electronics course (Cousin, 2006; Land, Cousin, Meyer, & Davies, 2005; Meyer, Land, & Davies, 2006: Scott & Harlow, 2012).

One of the challenges for lecturers was to ensure that students reflected on their learning when they encountered unfamiliar, educationally critical content in their discipline. The lecturers facilitated student reflection by providing opportunities for students to learn actively. Consonant with learning philosophies (Martin & Gaskin, 2004; Silberman, 2007), lecturers invited students to participate in activities (e.g., role playing) that allowed them to experience what they are learning about (Martin, Fleming, Ferkins, Wiersma, & Coll, 2010). Students were also encouraged to articulate their arguments and knowledge to provoke conceptual change and deep understanding of the subject matter. This approach was of particular interest because deep understanding of concepts, including the basic ones, encourages learning of other complex, hard to grasp concepts and transfer of knowledge to new areas. And although deep thinking and articulation of arguments are neither easy nor intuitive, and can be a frightening experience, with practice and within a class where there is trust, students felt more confident to take risks and reveal their developing knowledge to their peers and lecturer(s).

The TCT focus also enabled energetic academic discussion between lecturers, and between lecturers and educational researchers. Although these discussions mostly focused on the potentially transformative power of threshold concepts and their troublesome nature it became clear that these characteristics could be applied to a greater or lesser extent to different TCs in each discipline. Importantly, these reflections increased lecturers' awareness and supported their knowledge of TCs, and inspired them to refine their curriculum and pedagogy, thereby contributing to discussion about the relationship between theory and methodology in higher education research (Shay, Ashwin, & Case, 2009).

Conclusion

Results of our cross-disciplinary project suggest that TCT is an effective tool to re-envision teaching and learning at the tertiary level. It provides opportunities to raise questions about what the important ideas are within a discipline and what it means to be an expert in the field. Thus, it is crucial that lecturers explore disciplinary TCs and explore the implications of how, what and when they teach in order to help students build a strong foundation of knowledge for future learning in their discipline.

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