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National Academy for Integration of Research, Teaching and Learning
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Threshold Concepts:
FROM PERSONAL PRACTICE TO COMMUNITIES OF PRACTICE

PROCEEDINGS OF THE NATIONAL ACADEMY'S SIXTH ANNUAL CONFERENCE AND THE FOURTH BIENNIAL THRESHOLD CONCEPTS CONFERENCE
[E-publication]

Editors: Catherine O'Mahony, Avril Buchanan, Mary O'Rourke and Bettie Higgs

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FOREWORD

The 6th Annual Conference of the National Academy for the Integration of Research, Teaching and Learning (NAIRTL) and the 4th Biennial Threshold Concepts Conference was held at Trinity College Dublin on 27-29 June 2012.

The conference theme – *From Personal Practice to Communities of Practice* – challenged us to broaden our views of the idea that there are disciplinary and interdisciplinary Threshold Concepts. We looked at our own practice from new perspectives and extended our understanding of co-existing concepts and frameworks.

We were delighted to bring the 4th Threshold Concepts Conference to Ireland. This year's conference aimed to build on the successes of previous Threshold Concepts conferences which were held in Sydney, Ontario and Glasgow, and to support the development of new connections and collarborations. We welcomed close to 300 delegates, representing sixteen countries on four continents, and feel that many new connections have been made, and the nascent Threshold Concept community in Ireland will develop and flourish.

At each Threshold Concepts conference ideas are developed and move forward. This year was no exception as we debated the sub-themes of *Engaging Students with Threshold Concepts, Interdisciplinary Threshold Concepts, Threshold Concepts in Professional Development,* and *New Developments in Threshold Concepts*. This publication contains a selection of papers from the conference. The papers provide insights into how we can apply the Threshold Concepts idea to gain a deeper understanding of how students learn, and also how we can use it to gain new ways of looking at our own disciplines.

We hope that this publication will be of use to scholars and practitioners who are interested in the idea of Threshold Concepts to advance student learning.

Dr Bettie Higgs

Bettie Higgs

on behalf of the Threshold Concepts Conference Steering Committee

Conference Steering Committee members

Vicky Davies, University of Ulster; Dr Bettie Higgs, University College Cork (Committee Chair); Dr Brian Foley, Trinity College Dublin; Professor Ray Land, Durham University; Dr Sarah Maguire, University of Ulster; Professor Erik Meyer, University of Queensland; and Dr Catherine O'Mahony, NAIRTL

ACKNOWLEDGEMENTS

The financial support of the Higher Education Authority, under the Strategic Innovation Fund, has enabled the wide range of activities carried out by the National Academy for Integration of Research, Teaching and Learning (NAIRTL).

We were delighted to host the fourth biennial Threshold Concepts conference in Ireland and we are grateful to Trinity College Dublin for providing the venue and to the many Trinity staff and students for their assistance leading up to and during the event. Particular thanks go to Dr Brian Foley, Jade Concannon and Sarah O'Sullivan who worked closely with the NAIRTL team in organising the conference.

Close to 200 abstracts for papers, posters and workshops were submitted for consideration and we wish to express our gratitude to all of those involved in the initial selection process and to the members of the Abstract Selection committee.

The conference featured more than 100 presentations and 40 posters, and we are immensely grateful to all presenters and exhibitors, particularly those who took on the Pecha Kucha challenge. The papers published in parts 2-5 of the proceedings were peer reviewed and we are grateful to all who contributed to this process.

We wish to thank the following peer reviewers:
Dr Barbara Bender, Rutgers University
Dr Jonte Bernhard, Linkoping University
Professor Patrick Carmichael, University of Stirling
Dr David Easdown, University of Sydney
Dr Mick Flanagan, University College London
Dr Brian Foley, Trinity College Dublin
Dr Anne Graham-Cagney, Waterford Institute of Technology
Ann Harlow, University of Waikato
Leif Hokstad, Norwegian Technical University
Dr Sally Male, University of Western Australia
Professor Bairbre Redmond, University College Dublin
Dr David Pace, Indiana University
Dr Charlotte Taylor, University of Sydney

Recordings of the keynote presentations are available to view on the NAIRTL website from a link at www.nairtl.ie/conference2012.

ABOUT THIS PUBLICATION

The e-publication version of the 2012 Conference Proceedings contains additional papers to the print version of the Proceedings. The papers were accepted for the e-publication, but did not undergo a formal peer review process organised by the editors. The papers are included in Part 7 of the e-publication and can be accessed by clicking on the hyperlink beneath each related abstract. The e-publication also contains links to the conference posters.

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Part 1: Keynote Speakers

NAIRTL

A CLOSER LOOK AT LIMINALITY: INCORRIGIBLES AND THRESHOLD CAPITAL

Ray Land and Julie Rattray, Durham University, Peter Vivian, Open University

Biographical Note

Ray Land, PhD, is Professor of Higher Education and Director of the Centre for Learning, Teaching and Research at Durham University, UK. He is a member of the OECD international expert panel for Higher Education and has also acted as consultant to the European Commission. His research interests include academic development, threshold concepts and troublesome knowledge, research-teaching linkages, and theoretical aspects of digital learning. He has recently edited two new volumes: Threshold Concepts and Transformational Learning (2010) and Digital Difference: Perspectives on Online Learning (2011) both published by Sense Publishers.

INTRODUCTION

I would like to look at four areas this morning. First, the nature of liminality followed by an analysis of spatial metaphors in learning. We then consider liminality as a conceptual space and finally as ontological space, which brings in the notion of threshold capital. It is my pleasure to be delivering the paper, which is a collaborative venture with my colleagues Peter Vivian and Julie Rattray.

The notion of liminality as a space is a metaphor we use. But what do we mean by a 'space'? Is it a space or is it a period of time? Or is it more a set of social relationships? Let's ponder what we mean by a 'liminal' space and unpack that metaphor which we have been using for quite a while in this framework. Then I would like to focus in on two dimensions of liminality, looking at it both conceptually and then ontologically on the assumption that if liminality is the place where students often get stuck, then there is something intellectual, conceptual or cognitive going on. There is something difficult happening. So clearly there is a conceptual dimension to that, but, as we have argued in some of the papers, it is also related to the affective dimension, the experiential element of learning and struggling through these difficult areas of learning; these stuck places. It might be useful to approach this in terms of ontological space and to consider what kind of 'threshold capital', cultural capital or psychological capital students might need in order to negotiate that space well.

THE NATURE OF LIMINALITY

Let's have a look first of all at what we said about liminality and what we need to consider. I think that the area of liminality is the one part of the thresholds model, or framework, that is not terribly well thought through; it remains rather ill-informed and something of a black box. What I want to explore is to what extent we might be able to say useful and purposeful things about liminality, or whether there are aspects of this which we just can't access. I am indebted to my colleague at Durham, Jan Smith, who pointed me towards the notion of 'incorrigibles', which was a word originally used in this sense by the philosopher Ayer (1956) for things which are very difficult to get at because they are part of other peoples' experiences and very hard to extract from those experiences.

We have said in some of the early papers that liminality is a kind of flux. It is a space provoked by some encounter with a threshold concept and it renders things fluid, less certain than they used to be, and starts to transform the learner. As they move through it the space itself seems to change. We have claimed that it is a transformative state and that the thresholds notion is a dimension of transformative learning. The notion of transformation is problematic. Some commentators have critiqued the notion of transformation as a humanist model, an essentialist model which might be problematic. We have said it is a suspended state in which students sometimes can struggle to cope and in which they might revert to mimicry. We have also said it often feels like a space where you are losing things and I think you are losing things in liminality. It is a space where you have to let go of your prevailing way of seeing, your prior understanding, and your prior schema. That has to weaken, or loosen, or be transformed, in order to gain a newer way of seeing, or newer mode of being. Letting go in that way is challenging and I think that is one of the key sources of troublesomeness. We don't like letting go of things that we think we have a very good handle on, or that we have become reasonably good at.

We have emphasised and used images in our books of transformation. We have said that what happens in the liminal state is a changing of function or a changing of state. Such changes often involve the kind of oscillation that anthropologists discuss in liminal states, such as in adolescence, for example, where individuals fluctuate between childlike and adult behaviours. Here's a nice quote from Marina Orsini-Jones' (2006) work.

Q. "Did you feel the same as student 1?"

Second student: "Yeah. I felt lost".

Q. "In lecture times as well?"

Second student: "You know, I understood the concept for about let's say 10 seconds, yes, yes, I got that and then suddenly, no, no, I didn't get that, you know, suddenly, like this".

The changed perspective here slips in out of focus and eludes the learner's grasp. The new understanding comes into view and goes out of view again. The student thinks she's understood it but then is unsure whether she's really got it.

It certainly seems to be a space where language is important and those of you familiar with Vygotsky's (1978) theory will know of his emphasis on the encounter and engagement with language and of how it becomes a space, the writing space, which can be a key factor in transformation. I have spoken to many doctoral students who say it is when they start writing, or when they start analysing data that their conceptual framework starts to emerge and starts to make sense. We recall 'the intolerable wrestle /With words and meanings' to which T.S.Eliot (1943) referred in Four Quartets. Here is a quote from a group of medics (Becker *et al.,* 2005) discussing how, in a very powerful way, this takes place in medicine.

> *"...students acquire a point of view and terminology of a technical kind, which allow them to talk and think about patients and diseases in a way quite different from the layman. They look upon death and disabling disease, not with the horror and sense of tragedy the layman finds appropriate, but as problems in medical responsibility".*

Medical students employ medical discourse to talk about things like pain. Pain signifies something very different to medics than it does to the non-specialist lay persons who are experiencing it. It serves partly to effect an important ontological shift in practitioners who have to deal on a daily basis with extreme and often distressing situations that most ordinary folk do not, but it also serves as an essential tool for diagnostic reasoning. It is part of the way medics think and practise.

The liminal space can also be seen as a creative space. It can be the space where, as we have mentioned, people get stuck, but it is also the space where things become fluid. Once, when I was speaking with some colleagues in an art school in Scotland and we were discussing liminality, I made a reference to students emerging out of the liminal space. They immediately commented, 'No, you are misunderstanding us; we are not talking here about our students coming out of this liminal space. We want them to stay in it. We want them to stay precisely in that fluid state, that complexity, because in that way their ideas won't become crystallised; they won't harden'. What they were seeking was a space in which their students' thinking and practice would stay emergent and fresh, without becoming stylised. In this sense the liminal offered a provisional, exploratory space with plenty of unexplored possibilities, where things were held in tension – an almost perpetual liminal state of creativity.

It can of course often be the place where students encounter conceptual and other kinds of difficulty and they have to try and cope with that. We have seen in some of the earlier writings on thresholds that this can produce what we call 'mimicry', which sounds somewhat negative but is often a coping mechanism for students. We have talked about 'compensatory mimicry' where sometimes students just try to convince themselves that they are in fact learning something. So it's not uncommon to see students revising for exams and perhaps revising completely the wrong stuff but they think they must do something purposeful even though they are not doing what they should be doing. Another form of mimicry is 'conscious mimicry', when the student is aware that what is required is beyond their grasp, other than through the mimicry of pretension. They are consciously trying to make sense of something and cutting and pasting, but recognising that *'this probably isn't it, but we will see what the tutor says'*. Many academics like yourselves will recognise and be familiar with this kind of mimicry.

So liminality is a difficult space, but it is also a space of emergence in which emergent entities (in this case thoughts or states) 'arise' out of more fundamental entities and yet are 'novel' or 'irreducible' with respect to them (Lewes 1875). Transformation, as an emergent, is a higher-level property, which cannot, in Lewes' sense, be deduced from or explained by the properties of lower level entities. As King Lear observed 'nothing will come of nothing'. But some of the re-thinking, re-formation or re-authoring of ideas, or the re-scripting or re-inventing of identities in a liminal space do seem to have this quality of emergent property, where you can't see very clearly how it has arisen from, or can be reduced to, the lower level entities.

If the liminal state is seen as something which is transformative and does help students, then perhaps what it should do is oblige the learner to countenance something new and try to integrate it. At the same time there is a recognition that their existing view is no longer adequate, and that they have to let go of it. This is troublesome in itself, but seems to be a requirement. Hence the progressive function of the liminal state might be characterised as follows:

- a countenancing and integration of something new
- a recognition of shortcoming of existing view
- a letting go of the older prevailing view
- a letting go of an earlier mode of their subjectivity
- an envisaging (and accepting) of an alternative version of self through the threshold space (as a practitioner) – 're-authoring' of self, 'undoing the script' (Ross, 2011)
- acquiring and using new forms of written and spoken discourse and internalising these

My fellow keynote speaker Glynis Cousin has observed that 'you are what you know' and that all learning to whatever degree involves both a conceptual shift and also an ontological shift from an earlier version of yourself. I often cite the movie 'Educating Rita' as a nice example of where you see a sequence of such ontological shifts in dramatic form.

I once attended a seminar led by Etienne Wenger, of 'communities of practice' fame. We discussed the extent to which people on the periphery of a community practice, and seeking to participate within that community, might be said to be in a liminal state. He observed that one condition of effective entry to a community practice was the capacity to envisage (and accept) a re-worked version of yourself as viewed through the threshold into the community. You need to be able to see or imagine a potential version of yourself practising whatever it is that the specific community in question practises. You see yourself 'doing it'. This entails a 're-authoring of self' as Jen Ross (2011) terms it, or as one of her students refers to it, 'undoing the script of yourself'. This student, discussing the transformative potential of reflection, notes that 'It kind of gives you an opportunity to undo the script if you like. If somebody asked me to dissect the magic of it, I can't tell you. I can just tell you it's a blend of things. I can't tell you the proportions. It's like cooking it is like an intuitive response to what's needed I suppose.' Ross (2011, p. 225) notes that, 'Reflection here is described as a magical process of empowerment and emancipation', but the magic is almost the Harry Potterish School of educational thinking. It works at the level of a metaphor, but it is not very helpful beyond that. This brings in the notion of the incorrigible, the phenomena that you can't find a way of 'getting at'. Is transformation an incorrigible notion? Is liminality? There is the risk here of what Theresa Lillis (2001) terms 'practices of mystery'. There are probably many to be found in pedagogical thinking, in all sectors of education. As a still somewhat mysterious process, the notion of liminality probably falls currently into that category and transformation itself does look like a 'practice of mystery'. Ross however helpfully observes that:

> *"In my view transformation has to be understood as a matter of shifting subjectivity, not as deep changes to any essential selfhood. Subjectivity is best understood as always in process, and so shifts are common place. They are part of negotiations that take place as a result of the discursive nature of subjectivity...".* (Ross, 2011, p. 226)

We are continually shifting; everything we read, everything we write. One of the students she cites says, 'by the end of my paragraph, I could have changed completely, just because the process of writing seems to help me inform my opinion' (p. 227). We can shift our thinking and being through the engagement with particular words in small, subtle ways. Ross summarises (p. 226):

> *"By approaching subjectivity as a process, we can demystify transformation and view it as a response to the uncertainty and iterativeness of subjectivity. To initiate, and then channel, these shifts in a particular direction could be seen as the purpose or project of both reflection and education more broadly. This is a purpose that may still be complex and contestable, but which at least has the benefit of being open to analysis".*

This, I think, is where we are with thresholds. We need to see where we can open up areas such as transformation and liminality to analysis, or at least the areas which seem to have the character of incorrigibles. Usher *et al.* (2002) argue that 'subjectivity is a discursive effect', seeing it as part and parcel of language, and 'it's about writing stories of yourself'. 'Subjectivity is a character in a story as much as the author of the story, representations of self instead of being seen as truth', in a more humanist sense.

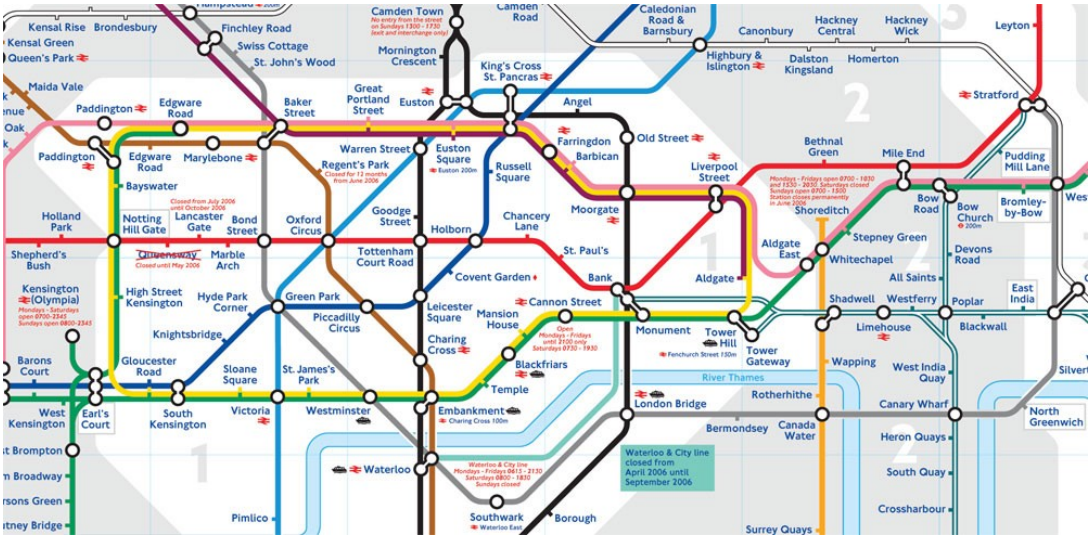
> *"Representations of the self, instead of being seen as 'truth', need to be seen more usefully as stories, often very powerful stories, which perform a variety of social functions, including the construction of selves with appropriate characteristics. … Subjectivity is never a once-and-for-all construction, and the experience that meaning can have is never permanently fixed. …Subjectivity is therefore always shifting and uncertain and has to be continually 're-formed"'.* (Usher, Bryant and Johnson, 2002, p. 88)

ANALYSING SPATIAL METAPHORS

We have been talking about liminal space and much educational thinking, many educational tropes, use this spatial metaphor. The most famous one would probably be Vygotsky's notion of a 'zone of proximal development (ZPD), used extensively in primary and secondary education. Here we have the idea of the learner trying to shorten or close the proximal gap, to get closer to the performance or practice of someone who is just a little more expert than him or herself, trying to cross that space. But is it a space or is it just a relationship with someone else? When we talk about the doctorate as a kind of taxing, long four year, five year, seven year liminal space, is it a space or is it better thought of as duration of time? What kind of metaphors can we employ usefully to talk about a learning space?

John Douglas, an architectural educator at the University of New South Wales, considers that the notion of threshold space might be too limiting (Douglas, 2011, pp. 45-46). He points out that if we imagine a line; as soon as that line closes on itself we have a closed interior space. This also creates simultaneously an interior and an exterior space, whereas a curving line which never closes leaves other things open. An open curve 'may create zones of partial closure, administer relations of proximity, or mark changes of state, but it does not establish a dialectic of absolute interiority and exteriority'. This distinction indicates two possible types of space. We can, on the one hand, think in terms of space as a closed curve in which we have a threshold space and material to be learned to enable us to cross beyond a boundary into a new bounded space. Architects, according to Douglas, think of space in other ways, they think of multiplicitous space, of open passage, connection and transformation; spaces that connect you, rather than impose boundaries on you.

We regularly talk about threshold space as being 'bounded', and of crossing boundaries or borders. A threshold, it could be argued, is to some extent about borders, and disciplines are about boundaries, protected tribal spaces and territories (Trowler *et al.,* 2012). Douglas however argues that we need to move away from such modes of seeing. He proposes a distinction between the idea of space as a container and the idea of space as a connection. In a 'threshold space' he suggests, things, effects and events are contained or exteriorised whereas in a 'transformational space' they are transmitted (pp. 45-46). He cites as example the famous London Underground Plan published by Beck in 1931 (Figure 1).



It had occurred to Beck that since the Underground operated mainly underground, then the physical locations of the stations were irrelevant to passengers wanting to know how to get to one station from another. Only the topology of the system mattered. What the map emphasises, Douglas points out, is connectivity. He says 'containment is secondary to connection, to pass outside the threshold space is to cross a line demarcating an interior whether by choice, accident or ejection'. In transformational space there is no strict exterior, only degrees of connection. We use the Underground map to ponder 'how do I get to here, from somewhere else?', or 'what is the best way to get there?' On the map Charing Cross station differs from Edgware 'not because it is a more capacious station, with better amenities and more platforms, but because it has greater connectivity'.

So what might an educational space look like which emphasises notions of connectivity? How might we help students get from here to somewhere else? What is the best way to do it? What are the different possible ways of doing that and negotiating learning spaces that we use?

A compounding factor in this regard may be the nature of 'knowledge structures'. In his later work Bernstein (1999) distinguished between horizontal and vertical discourses, and within vertical discourse between 'hierarchical' and 'horizontal' knowledge structures. The former, most typically represented by empirical sciences, would take the form of

'a coherent, explicit and systematically principled structure, hierarchically organised' and 'attempts to create very general propositions and theories, which integrate knowledge at lower levels, and in this way shows underlying uniformities across an expanding range of apparently different phenomena' (Bernstein, 1999, pp. 161-162). The latter, on the other hand, (most typically exemplified in the disciplines in the humanities and social sciences) is more likely to take the form of 'a series of specialised languages with specialised modes of interrogation and criteria for the construction and circulation of texts' (Bernstein, 1999, p. 162). In hierarchical structures knowledge tends to be accretive, building on the work of earlier scholars and concerned with universal and commonly agreed application and procedure. In horizontal structures competing narratives may well co-exist alongside each other and remain in contestation and mutual incompatibility with each other. In the former epistemological concerns tend to take precedence over social or 'tribal' considerations, whereas in the latter who is promoting particular knowledge stances, and the academic company they keep, may be of as much significance as the stance itself. These structures present different challenges and priorities for new entrants to communities of practice and can add to liminality difficulty in terms of being sufficiently able to read and adapt appropriately to knowledge terrain and interpret the necessary signals and cultures encountered therein.

Another influential metaphor comes through the work of Homi Bhabha. He coined the widely used phrase 'Third Space'. He says 'it is in this space that you will find those words with which we can speak of ourselves and others, and by exploring this third space we may lead to politics, polarity and emerge as the others or ourselves' (Bhabha, 2006, p. 209). It's a space where you can think otherwise and to some extent that is what threshold concepts provoke you into doing, into thinking otherwise and letting go. As Engels-Schwarzpaul and Azadeh Emadi (2011, p. 1) observe:

> *"Bhabha's dynamic third space is an interstitial realm, like the threshold, which accommodates ambivalence, conflict, confusion, movement, change and notably, potentiality. It is held open by the tension between different spaces and temporalities and generates relationships in which both sides are changed through the negotiation of incommensurable strategies, rules and identities in cultural processes and practices".* (Bhabha, 1994, p. 218)

This is a space where things can be re-thought, re-authored, where, as we discussed earlier, one can undo the script of self and re-script.

Finally, the psychologist and psychotherapist Winnicot, whom we have cited a number of times in the early literature on thresholds, talked of potentiality and talked about potential space as a kind of intermediate or third area. This is 'neither the individual's inner world, nor actual, nor external reality' (Palombo, Bendicsen and Koch, 2009, p.154). In potential space, creativity develops in the 'discovery, creation, and development of a self' (ibid). The characteristic of potential space is a negative capability. Keats the poet used to talk of negative capability as a 'capacity not to do anything' which in the West we find very difficult, to resist action and remain in a state of potentiality. In potential space, according to Bonz and Struve (2006, p.152):

> *"Inside and outside are kept suspended: the inner and outer touch each other in a dance-like movement ... Characteristic of potential space is a negative capability [Keats] to endure in a psychically open process yet remain coherent in changing circumstances"*

So the nature of liminal space appears complex. Envisaging it as a space of connectivity rather than blockage, of potentiality or re-formation is something we might want to draw from. For us as educators it still has the feel of 'a practice of mystery'. We attempt to come by it through proxy or metaphor, as if it remains an incorrigible.

Let's now approach liminal space and attempt to talk about it first conceptually and then ontologically.

LIMINALITY AS CONCEPTUAL SPACE

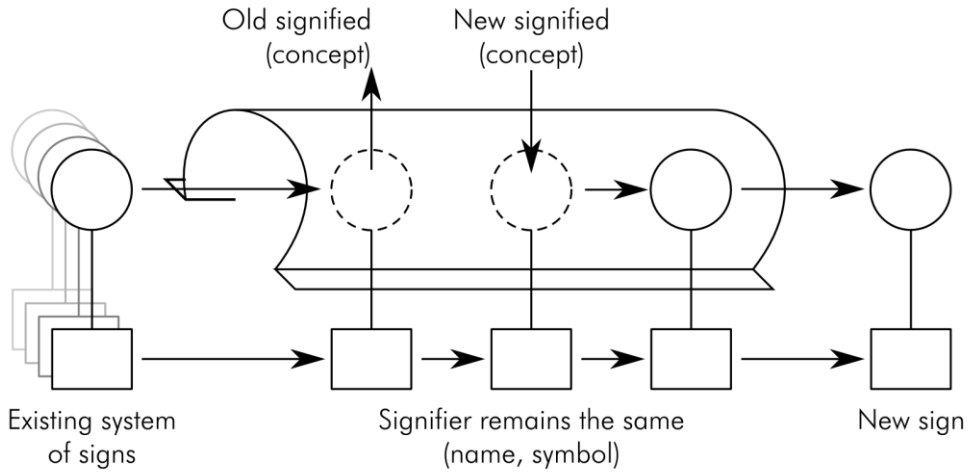
Peter Vivien (2012) has undertaken recent work using semiotic analysis and theories of signification (particularly Saussurian notions of the sign) as a means of extending the threshold literature. Saussure was a linguist in the early twentieth century who spoke about signs. We might argue that all learning is about signs, and the understanding of signs and acquisition of new signs, an area normally referred to as semiotic analysis. A sign can be a word, it can be a sound, it can be an image, it can be a book, and it can be a film and so on. All signs, Saussure argued, have a signifier in the physical word. For example I am sending out signifiers now– aural ones in my words, visual ones through the data projection screen. These are signifiers; they are part of the sign. The other part of the sign is what they mean, which is the signified. But what Saussure argued is that that relationship is always arbitrary and is always provisional.

For example, the sign 'mouse' is both a sign and a written word. We agree in anglophone cultures that 'mouse' means (as one meaning) the furry animal with a tail. If it were agreed across the world tomorrow to call mice cats then that would work as well, as long as we all agreed to make the change. In this case we would have the same signifier, aurally and

written (though not visually), and the signified changes. If we apply this to learning a lot of liminal space is about students wrestling with the notion of (a) what is the signifier here, what does it mean, what does it signify, or (b) is what is being signified changing? If you study anthropology, for example, you realise that in anthropology, the signifier 'culture' is very different from what 'culture' signifies in everyday lay discourse.. Of course signs only mean something in relation to all the other signs in the system. So the word cat only means cat because it is not hat or mat or pat and so on.

Fashion is a potent example of this and signs in fashion are characteristically in flux. Being of a certain age, I remember a time when bell bottom trousers were a cultural signifier of certain 'coolness'. At some point, probably around 1973, the signifier started to shift, the signifiers were still around but the signifier was no longer coolness but an increasingly sad quality of being passé. Later of course, probably around 1983, they underwent a re-signification. Now they were retro – cool. However the signifier had shifted, being now a newly fashionable and subtly differentiated boot cut. You get the drift. No doubt bell bottom trousers will endure further re-signification in future.

How does signification relate to liminality? Learners have an existing stock of existing concepts and they all have labels for these signs. As we go through a programme of learning in higher education we can see this as a process of adding signs to our collection. Where does this sign fit in, how do I link this to all the other signs I already have?' Our analysis of what a particular sign means, or signifies, is related to all the other signs we have in our system. Vivien (2012) represents the liminal process graphically as a tunnel rather than a threshold, in that for most of the time the learner cannot discern the exit.



Note that the tunnel is drawn in the conceptual domain, which is internal to the individual learners and tutors. Communication between these individuals, however, is in the physical domain where the oral and graphic signifiers play their part. For example, here we are in the lecture theatre listening (I hope!) to the signs I'm putting out. However, in your personal interior domains you may be asking 'what is being signified'? Whatever is signified will be in the liminal conceptual domain, not in the physical domain of sound or vision.

But how might the teacher become aware of the individual learner's liminal state? Is this one of Ayer's incorrigibles again? Within a module of, say, twelve weeks, can we in feasible, practical terms get at this? Or are these understandings as in Richard Gomm's (2004) opinion, 'unverifiable because they are matters of self-knowledge and not accessible to others'? The student's understanding of these new signs, or 'altered' signs, depends on bringing together in a coherent way a number of conceptual elements – for example the student may have to get a grip on a number of economic concepts and bring them all into a coherent relationship. If any of those representations are poorly understood or misunderstood then the student will have difficulty bringing them together. Any concept has to be described or represented using already familiar signs, and if any of these are poorly understood then the description or representation will be misunderstood. Perhaps the threshold concept is so troublesome not because the concept is so difficult but because it challenges the learner's understanding of its component concepts and this is why it acts as a check point for the learner's progress.

Learners need to engage with and manipulate conceptual materials i.e. the physical means of describing, discussing and exploring concepts. These are the signifiers in the physical domain. What tends to happen in most teaching sessions is that the teacher physically exchanges these signifiers by providing images, diagrams, words, written textual statements – all the different kinds of signs, hoping that what the student will pick up is what the teacher is signifying, what is in the teacher's understanding as a signifier, and that this will bring about the desired transformation. The teacher creates a framework of engagement by setting tasks designed to motivate the learner to engage with conceptual matters (i.e. the

signifieds) by transforming the signifiers from one context to another. The teacher can then infer understanding on the part of the learner by comparing the learner's transformation with their own transformation.

The assessment evidence, the student's new representation, has to indicate this changed signification, their understanding of a new set of signifiers or an altered set of signifiers. Sometimes this is patently obvious by what students produce and at other times it isn't. It can be hard to know whether they have got it or not. What complicates it further is that students during an assessment may not want to reveal their lack of understanding to the teacher-as assessor, that they haven't understood what is being signified.

What does seem to happen is that when a new or an altered sign enters a sign collection we get a new collection of signs. The new sign affects the other signs in some way. It alters the student's discourse as they start using these signs and these new signifiers. The student has to integrate them and use them in a sense which links up with all their other existing signifiers; otherwise they experience a form of dissonance.

As Peter has said, 'generally speaking different dialects can be recognised because there are changes in the signifiers, but sometimes the signifiers stay the same and so the altered understandings are not self-evident. The change in dialect goes unnoticed'. Sometimes students haven't realised how their tutor is now using a particular signifier or particular term or particular image or particular diagram or model in a more sophisticated, elaborate, or advanced way. The students may not be getting that. They may be working with an earlier model and therefore missing that. Similarly the tutor may not realise that their student is actually working from an earlier signifier because they are both in the physical domain, still using the same signifier but it has shifted and have they got it; We don't know it?

From a threshold point of view how can the acquisition of a single concept, e.g. gravity in physics, evolution, osmosis, how can that change the learner's perception of themself?

> *"Adding a new concept to a learner's collection can affect the understanding of other concepts in that collection, so that over time the whole collection develops and changes. The threshold concept can be a conceptual straw that breaks the camel's back – or a piece in a jigsaw of concepts that causes them to coalesce and produce a step change in perception".* (Vivian, 2012, p. xxx)

Adding a new concept to a learner's sign collection can affect the understanding of all the other concepts in that collection. So over time the whole collection morphs and develops and is transformed. This is likely to involve a troublesome process of integration in which this new fitting of everything together in a new fashion requires a letting go of a previously strong end enduring schema. Relinquishing this is likely to entail an ontological shift.

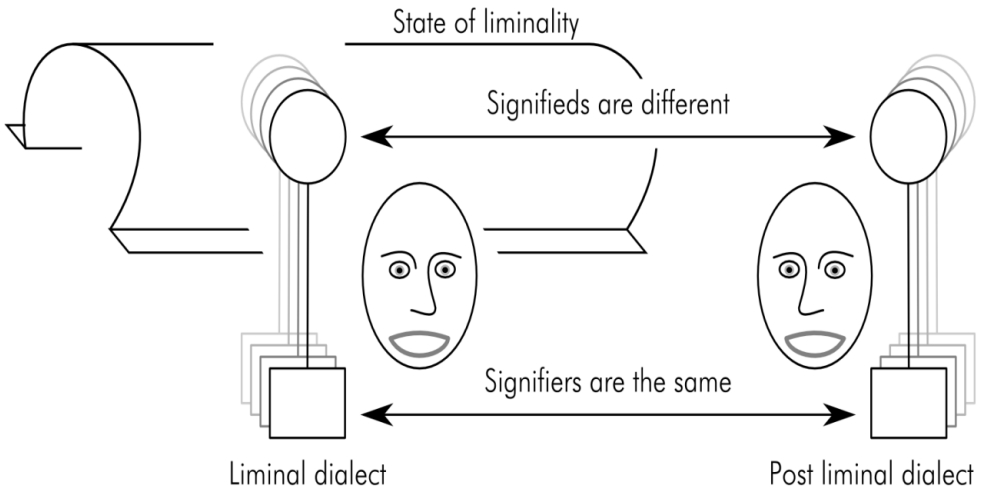
I recall a female colleague talking about encountering a specific aspect of feminist theory. This one new piece, this one sign, occasioned a 'coalescing' of all the others into 'a new big picture'. Thinking in terms of signification in this way, we would argue, may aid our insights into how students gain new understandings. We have written in the past a paper about thresholds concepts and course design (Land *et al.,* 2005), in which we argued that the student has an important part to play in being prepared to tolerate uncertainty. Very often students acquire these signs sequentially in the world of time, in the physical world, whereas concepts are not necessarily sequential but holistic. The world operates as an integrated whole. A certain amount of holistic understanding is always required. This inevitably means that there will be periods of conceptual uncertainty in which the reason for introducing the concept and perhaps the concept itself are not understood. It is a challenge for the course designer to minimise these periods and threshold concepts are required to integrate these concepts at significant points otherwise the course remains conceptually fragmented. The physical learning of signs is sequential in that the processes of learning are sequential by nature i.e. reading, listening, writing, and thinking etc. This does not preclude repetition (recursiveness) or digression (excursiveness). In practice with minimum pass marks of 40% it is likely that many learners will move from one pedagogic block to another with shortfalls in their understanding. Such blocks are created by the definition of courses, years, modules and even assignments.

So the learner, in a typical learning sequence, receives a set of signs in a linear, time-related sequence – a drip feed – and often it doesn't make sense to them. Very often we have to try and persuade students that it will come together eventually. In the end hopefully these signs will coalesce and the students will gain a transformed understanding. But there will be, whilst that is happening, a period of conceptual uncertainty. This is a mark of the liminal state and it is a challenge for course designers to try and minimise that, to shorten that liminal period in which the student experiences uncertainty. Doctoral learning would be an illustration of this. One hears doctoral students talking of struggling for long periods, months, perhaps years trying to figure out for example what a conceptual framework consists of. They don't get it, principally because they do not yet have all the signs, all the signifiers that they need eventually for that particular conceptual understanding to come together. It may take time and come later in the process.

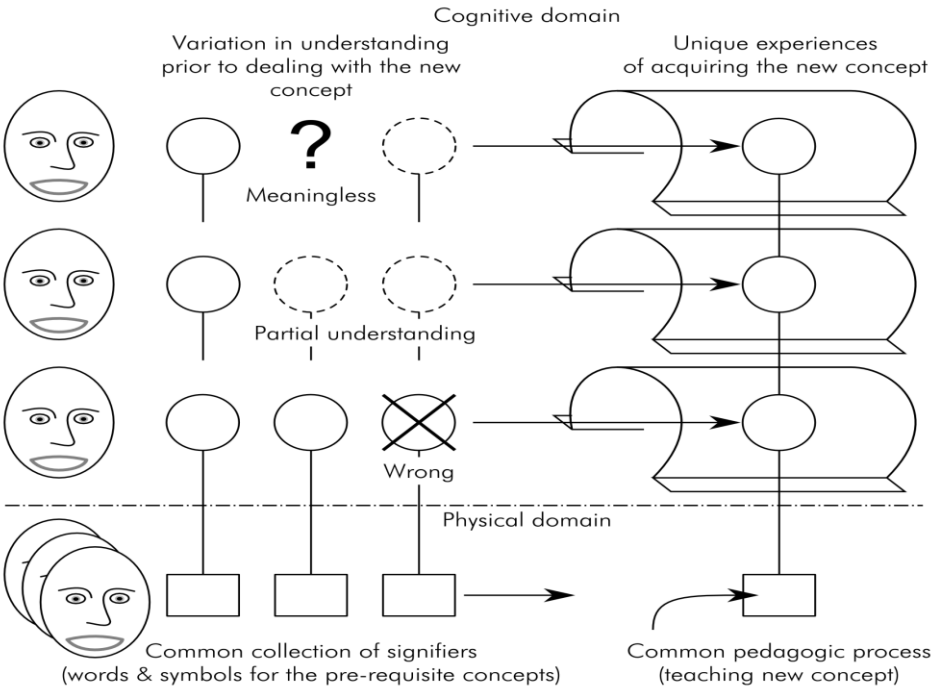
The sequential nature of many of our learning episodes, and the design of our courses through lectures, modules and semesters, results in students encountering new conceptual challenges in bits and pieces. The student progresses to the next module whilst still in the process of trying to piece together the signification of the prior module, and then in the subsequent module encounters a set of new signs. Marek's (1986) article 'They misunderstand, but they'll pass' suggests that we continue to pass students even though we realise that much of the signification that has been taught to them is still not too meaningful to them. But we keep them moving because probably we realise that eventually their understanding will come together, will integrate, in a recursive fashion.

Any concept has to be described or represented using already familiar signs, and if any of these are poorly understood then the description or representation will be misunderstood. Perhaps the threshold concept is so troublesome not because the concept is so difficult but because it challenges the learners understanding of its component concepts and this is why it acts as a check point for the learner's progress.

The transformative and integrative effects of threshold concepts cause the meanings of the existing signs in the learner's collection to change – a new collection of signs, a new 'dialect'. Generally speaking, different dialects can be recognised because there are changes in the signifiers but sometimes the signifiers stay the same and so the altered understandings are not self-evident. The change in dialect goes unnoticed.



So in terms of liminality as a conceptual space Vivian (2012) suggests that there are, semiotically, four possible outcomes for students. They may encounter signs and just not know what to make of them or how to use them. It is a meaningless response. Alternatively students may gain a *partial* understanding. Kinchin and Hay's (2000) analyses of conceptual mapping indicate that different degrees of partial understanding are a common outcome. One rarely finds students with a total understanding. Thirdly the student may just have got it wrong; they have got the theory wrong, they have got the maths wrong, or they have misunderstood the algebra. We tend to assume that they have a common understanding of the component concepts but that probably isn't the case. We are all using the same signifiers, the same words, the same symbols in the physical domain, but students might be interpreting and manipulating them in very different ways. Or finally, they may have a correct and coherent understanding.



Two things emerge from this diagram. One is that the potential complexity of signification is immense. If you think of a theory that contains, for example, three component concepts, this could reveal 48 possible permutations. Some of the theories that we teach might contain twenty concepts, thus the potential for misunderstanding, partial understanding, wrong understanding is enormous. It would not be reasonable for teachers to be expected to map such variation across their student cohorts. And there is always the possibility of course with complex theory that some of the component concepts may not be fully or correctly understood even by the teacher.

What is interesting, and this is reflected in Kinchin and Hay's work also, is that putting students together, letting them discuss the conceptual material to be understood, sometimes works better perhaps because they feel less threatened revealing their misunderstandings and partial understandings to each other than they would to a tutor who is assessing them. Students often use a different discourse; they interpret what is being signified through slightly different signifiers. They use more accessible signifiers which might be more meaningful. The understanding of the language being used is critical. The teacher's use of language, signs and syntax, may fail to communicate meaning because of the learner's inability to handle that usage. This is one possible reason why learners are able to grasp concepts from their peers that were meaningless when supplied by their teachers. Another reason could be the recursive and excursive nature of the peer support process.

Finally knowledge is often troublesome because, from the student's perspective, some critical component may have remained implicit or tacit. We may think we have given the students all the signs and signifiers they require but a critical component may not be accessible to them. For example, critical reasoning might be a concept that students are required to understand to perform certain assessment tasks satisfactorily. Critical reasoning is in my collection of signs, as the teacher, but it may not be in theirs because it was never presented to them, but, rather, left implicit. They have never been exposed to it. Without a signifier there is actually no reminder in the physical realm that the concept exists and hence, since it is left underlying, this may have a deleterious impact on their understanding and required performance.

So one way of gaining further insight into the conceptual difficulties that students may experience in the liminal space may be through semiotic analysis, and thinking in terms of signifying practices.

ONTOLOGICAL SPACE (THRESHOLD CAPITAL)

Finally there remains the notion of liminality as an ontological space.

There may be signifiers which the learner recognizes but are meaningless to them. These empty signifiers are particularly interesting and important as they are then susceptible to unfortunate connotations of anxiety, stress, fear even. 'I don't get this and we've got an exam looming'. We have said on previous occasions that knowledge is often necessarily troublesome in order to provoke a process of transformation and to unsettle students out of a prior way of seeing. It can

of course be discomfiting for students dealing with some of these conceptual shifts and some students seem to deal with them better than others. To use David Perkins' phrase 'dispositional learning', it seems important to ask what dispositions might help students get through the liminal state more effectively. Is it possible to identify which affective states would be more beneficial? Do they constitute another incorrigible or are they open to analysis and susceptible to measurement?

There is interesting work currently being conducted in the psychological domain in relation to the notion of psychological capital, often abbreviated to 'PsyCap'. The latter is defined (Luthans *et al.*, 2007, p. 3) as 'an individual's positive psychological state of development' that is characterized by:

1. Self-efficacy – having confidence to take on and put in the necessary effort to succeed at challenging tasks;
2. Optimism– making a positive attribution about succeeding now and in the future;
3. Hope – persevering toward goals and, when necessary, redirecting paths to goals in order to succeed; and
4. Resilience – when beset by problems and adversity, sustaining and bouncing back and even beyond to attain success.

The first dimension of PsyCap is 'self-efficacy' (Bandura, 1997) and is associated with a learner's belief in their own capabilities to succeed at a specific task. Self-efficacy is the most popular positive psychology variable used in the educational setting, and has strong research and theory supporting its effect on academic achievement (Bandura, 1997; 2002; Schunk, 2011). Thus a learner who believes they are capable of making sense of troublesome and initially just-out-of-reach knowledge is more likely to expend effort on trying to understand the new idea and more likely to cross the threshold than one with no such belief.

The second dimension of PsyCap relates to an individual's ability to make positive attributions about their potential for success in both the short and long-term. 'Optimism', as this factor is known, correlates with academic performance with a more optimistic explanatory style being associated with higher performance (Carver and Sheier, 2002; Huan, Yeo, Ang and Chong, 2006; Ruthig, Perry, Hall and Hladkyj, 2004; Seligman, 2006; Smith and Hoy, 2007). A positive attributional style or optimistic outlook would seem to be essential if a learner is to sustain motivated behaviour during a difficult phase of their study. If one is to make an ontological shift, one needs to be optimistic that such a shift can indeed happen and that the long-term benefits of such a shift will outweigh any current difficulties and challenges during the transition phase.

The third dimension of PsyCap is 'hope' and this seems to be an important driver in relation to the acquisition of threshold concepts. As we discussed earlier, learners might need to navigate the liminal space using a number of paths as they go down blind alleys and take wrong turns until they finally make it through the tunnel. Hope is about *"Persevering towards goals, and when necessary, redirecting paths to goals in order to succeed*" (Luthans *et al.*, 2007; p3). Researchers have found that hope leads to higher academic performance in children, adolescents, and college students as it facilitates a willingness to explore and engage in trial and error learning – something that is crucial when navigating a new and troublesome concept (Curry, Snyder, Cook *et al*., 1997; Curry and Snyder, 2000; Gilman, Dooley, and Florell, 2006; McDermott and Hastings, 2000; Peterson, Gerhardt and Rhode, 2006; Snyder, Shorey, Cheavens *et al.*, 2002).

The final dimension of PsyCap is 'resilience', which refers to an individual's ability to continue in the face of difficulty or challenge and even to start over after failure. Resilience has a well-established relationship with academic performance (Borman and Overman, 2004; Gordon, 1995, 1996; Kwok, Hughes, and Luo, 2007; Morrison and Allen, 2007). The extent to which a learner faced with a new and challenging concept will continue to struggle with the concept, even after repeated efforts to understand the concept have failed, will partly determine how willing they are to persist in their efforts to understand. It will also ultimately partly determine their success in crossing the conceptual threshold and emerging with a transformed subjectivity.

These four factors might explain why certain learners are able to negotiate the liminal state and acquire a new conceptual understanding and others, despite having the intellectual capacity, are unable to make the same transformation. A learner who believes they are capable of understanding new ideas (self-efficacy), who is optimistic about their chances of success, who can monitor and re-align goals and the pathways to attaining these goals and who does not give up in spite of the difficulties they encounter with the new knowledge, is likely to be able to expend the necessary levels of sustained effort (motivation) to bring about ontological change. The learner who is unable to do this will suffer from a lack of motivation and quickly give up when they encounter difficulties, leading to a lack of belief in their capabilities, a pessimistic outlook, and lack of hope.

CONCLUSION

The categorisation of PsyCap as a malleable state rather than a fixed trait (Luthans *et al.*, 2007) means that it is subject to influence and manipulation via pedagogical practices, curriculum design and implementation, and learning experiences.

Thus educators wishing to facilitate learners' motivation to navigate the liminal state and engage in the process of ontological shift might consider embedding the principles of positive psychology in their pedagogy and curricula as a means of enhancing students PsyCap and facilitating the engagement they seek.

In order to determine the extent to which PsyCap might influence learner's motivation to make an ontological shift and successfully negotiate the liminal space, the specific nature of the relationship between PsyCap and learner performance and understanding needs to be explored more fully. We need to establish the extent to which students with varying degrees of PsyCap might display varying levels of understanding and other cognitive skills associated with motivated learning such as self-regulation. We propose to undertake a series of studies to investigate these relationships to establish the extent to which PsyCap might mediate passage through the liminal space. It may not be as incorrigible as we imagined.

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THRESHOLD CONCEPTS: NAVIGATING THE ROUTE

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Biographical Note

Dr Bettie Higgs is the co-director of the Teaching and Learning Centre at University College Cork and is also a lecturer in the Department of Geology. She is interested in the nature of learning, and the public understanding of science, and since 2002 she has also coordinated activities designed to support staff in their teaching and learning role in University College Cork. She was a 2005 Carnegie Scholar, at the Carnegie Foundation for the Advancement of Teaching and received an MA in Teaching and Learning in Higher Education in 2007. She is also an associate lecturer for The Open University, and she tutors geology to students in the Centre for Adult and Continuing Education, UCC.

INTRODUCTION

In Higher Education, teachers are usually researchers within their own discipline, as well as designers and assessors of the undergraduate curriculum. They are best placed to identify the crucial or 'threshold' concepts that must be understood on the journey from novice to mastery within their discipline. These teachers are responsible for setting appropriate learning outcomes and designing curricula, including assessment, that encourage students to grapple with these crucial concepts, in what Meyer and Land (2003, 2005, 2006a, 2006b) call the 'liminal space'. In this space, engaged students work to resolve conflicts in their understanding.

As teachers, we know from experience that some students will engage enthusiastically with the opportunities presented, while others will need more encouragement. All can survive and thrive in liminality and emerge transformed by the learning that has taken place, and the deeper understanding that has resulted. These students progress through the 'portal' or across the threshold, and continue to develop new ways of looking at, and thinking within, the discipline. We love working with these students and derive great professional satisfaction from their progress.

But what about the other students? We can create the opportunities for students to approach the liminal space but if they don't even get there, let alone struggle to navigate it, what can we do? Is it anything to do with us? Some colleagues would say "*it's up to the students*", and leave it at that.

In a study over the past six years, one of the questions that has intrigued me, and will be briefly explored in this paper, is why some students don't make the most of the learning opportunities that are presented to them? Students appear to enter higher education full of enthusiasm, wanting to be inspired. What happens to them on their journey? To begin to answer such questions we must look at what students and teachers do along the route to prevent learning – unintentionally or intentionally.

Using Meyer and Land's idea of Threshold Concepts as a framework, we can begin to see what is needed to assist students to 'navigate the route' to understanding more successfully. The insights gained in this study align topics that are sometimes looked at in isolation. This paper will suggest a new way of looking at some familiar topics, using the perspective of threshold concepts, so that all students can benefit. It is an approach that builds students' capacities to grapple with the threshold concepts that they will encounter throughout their undergraduate career, and beyond when we as teachers may no longer be there with our learning opportunities to assist navigation. This study also helped tackle a great question – one that Glynnis Cousin posed as far back as 2006 – *"is it always the threshold concept that is so troublesome?"* (Cousin, 2006)

WHAT DO STUDENTS DO TO HELP OR HINDER LEARNING?

Both students and teachers have a part to play in learning, but most would agree that the role of the student is key. My own work has shown quite clearly, time and time again, that when learning is not progressing satisfactorily it is not usually the ability of the student that is lacking, but more often the attitude to learning and the level of commitment to action. Ron Ritchhart (2002) calls this the ability-action gap. In response to this, colleagues have asked *"Can it just be that I'm teaching something I love…. to students who don't love it?"* Or is there more to it?

It seems that some students never reach the liminal space, or only superficially engage in it. Any teachers dealing with final exam grades will recognise students who underperform, or who rally late in the day when the prize of qualification is in sight. These students may be happy with 'just enough' competence. Perhaps they can't see the portal, and they

definitely can't see beyond it, and don't know what they are missing. Their main objective may be to pass the exam, with learning goals limited to the short term gain. They ask *"What do I need to do to pass the course?"* What is worrying to me, as a teacher, is that some of these students can pass their exams without having grappled significantly with the threshold concepts in the discipline. Many valuable studies give us insights into such behaviour. I will refer briefly to only two examples here, one in the cognitive domain, and one in the affective domain.

AN EXAMPLE FROM THE COGNITIVE DOMAIN (WITH SOME AFFECTIVE)

David Perkins has been influential in the Threshold Concepts debate, and has spoken at previous Threshold Concepts Conferences. One visualisation I like, and I think is really powerful, is his representation of students' emerging understanding using a series of troughs or valleys (Perkins 2000). Students can quickly think themselves into the wrong valley of understanding, perhaps due to some misconception. If students ask superficial questions then the answers they find in that valley may 'fit'. At this shallow level of questioning there could be 'cognitive coincidence'. The valley looks right – so why expend the energy needed to ask deeper questions, or undergo the struggle needed to climb out and to continue the search for understanding? Students may not know that they haven't 'got-it'. They "*may think they understand, and cease to journey any further*" (Perkins, 2000). Deeper understanding is unlikely to be uncovered if students think *"I know what I know – that'll do", "I'll stick with what I know", "I haven't time", "I've done that assignment adequately", "All looks well".* They may be so near and yet so far away, and will find moving on difficult.

Can we blame the students for this? There are numerous cases within our own disciplines where even the experts have come to conclusions based on coincidences. Some of you may know of the famous 'Chondritic Coincidence' that held us back in our understanding of the Earth's interior workings for many years. In this example, our observations of heat flowing out of the Earth's surface appeared to be explained by the theoretical model of Earth's composition, gained from the study of chondritic meteorites. That is, the observed data seemed to 'fit' an accepted model. The whole of the science community did not sufficiently question this, and the conclusions were widely accepted. It was only when eventually we began to look from a new angle, and ask more searching questions, that the apparent 'fit' was seen to be a coincidence. We were then able to make a huge leap forward, transforming our understanding of how the Earth works. These cognitive coincidences are common along the learning route, and strengthen the call for on-going assessment and timely formative feedback in order to help students to realise that more needs to be done.

How might a more motivated student react? They would ask more searching questions. They would test the model more rigorously. They may find that the evidence does not entirely fit. They would try to resolve any conflicts in their understanding. They would struggle to get out of that valley of mis-understanding and look again. To do all of this, students must be allowed, and even challenged, to view a concept from multiple perspectives, to align and integrate these perspectives, and to continue to question and test their understanding until it is robust. However time is often short for students and deep understanding takes time.

AN EXAMPLE FROM THE AFFECTIVE DOMAIN (WITH SOME COGNITIVE)

In exploring the ability-action gap, the work of Jegede and Aikenhead (2004) is helpful. They allude to something more affective – and find there can be a mismatch between campus life with its disciplinary conversations, and off-campus or 'real world' life. They refer particularly to the science disciplines, and discuss their findings in terms of border crossings where students are constantly moving between one world and the other, each with their own sub-cultures.

Crossings can be difficult or *rough* (where students are doing well to just 'get by'). There is no integration of the two worlds, and they may even be in conflict. Conventional campus science may seem disconnected from the 'real world' and not all learners have the capacity to resolve these conflicts. The authors use the term cognitive apartheid to describe this. However, for some students the crossings are *manageable* (they manage to travel on two parallel tracks; hold two world views). There may be some integration. For other students the border crossings may be *smooth*, where their 'real world' life is underpinned by, and supported by, campus life and vice-versa. In this case the two worlds together are greater than the sum of the parts. One may be a catalyst for the other. These students are likely to see the 'portal' and enjoy navigating the route.

In reality there are not just three 'stages' of rough, manageable and smooth, but a continuum, with each learner being somewhere along the continuum, moving back and forward depending on changing circumstances. When these border crossings are proving rough for students, 'troublesome knowledge' could be seen as social or cultural, rather than purely academic and linked to a particular concept. Jegede and Aikenhead (2004) witnessed the development of unproductive coping mechanisms such as silence, accommodation, ingratiation, evasiveness and manipulation. They suggest the result

is not meaningful learning, but communicative competence. The concern is that many students may not be poor learners, but they learn how to learn just sufficiently well to succeed.

WHAT DO WE AS TEACHERS DO TO HELP OR HINDER STUDENT LEARNING?

Students have coping strategies that mean we may not notice they don't really understand. They may just do the minimum learning, and yet still pass the exam. The students have ability – but the 'ability' may go into developing ways to pass their courses without engaging with important concepts in a meaningful way. If we, as teachers, do not ask students to demonstrate their understanding, and if there is no reward for striving to grasp a threshold concept – for struggling to approach and pass through a portal – then students may not expend the required time and effort.

Jegede and Aikenhead (2004) found that this process of 'getting-by', if not recognised, made explicit and discussed with students, can result in students' alienation from the discipline. They urge us to make border crossings explicit for the learners. Examples of great work going on in Irish institutions can be exemplified by the work of Carmel Halton, University College Cork, who challenges new social work supervisors to discuss the disconnect between their real world experiences and their campus courses – trying to make connections and smooth the border crossings (personal communication). This conforms to the findings of Huber and Hutchings (2004) who urge us to connect with the real world to help build capacity for integrative learning.

What else do we as teachers do that causes difficulty for student learning and prevents students from reaching and revelling in the liminal space, and deprives them of dancing on the bridge between naive and deeper understanding? When experienced teachers are asked this question, their answers, summarised below, suggest that it is not always the threshold concept that is so troublesome.

Shopkow *et al.* (2012) suggest that teachers can create bottlenecks in the learning process. These authors held what they call 'bottleneck interviews' – not with students, but with the academic staff. Teachers who reported that students don't 'get it' were asked, what is it that you are really wanting the students to know, understand, and be able to do. What is important? The results were very revealing. Typically interviews took 2 hours, with constant coaxing before eventually the teacher would get to the points that he/she wanted the student to get, and the detail of how the journey to understanding might be navigated. These authors have highlighted the tacit knowledge that we as teachers have – but don't reveal – even to ourselves! The authors say *"we discovered something about our discipline!"* Their work has become known as 'decoding the disciplines' and it is succeeding in getting academic staff to make the implicit explicit. In a parallel study in engineering, Foley (2011) asks *"is there something about the disciplinary way of knowing that staff are not getting – and so not passing it on to the students?"* Cronin (in Higgs and Cronin, 2013) – working again within the discipline of history – shows how he guided postgraduate students, who begin to teach in the way they were themselves taught, through the liminal space towards a new way of thinking, acting and therefore teaching within the discipline. He reveals just how difficult it is for the beginning teacher to leave old beliefs behind. Such bottlenecks are typical of the liminal space – and must be identified and made explicit in order to successfully navigate the route to understanding.

Higgs (2007) conducted a seminar-in-the-field at which experienced geology tutors identified 'we talk above their heads' as a bottleneck to student learning in the field, acknowledging that teachers may talk with an unrealistic assumption of theory. Again, tacit knowledge may not be revealed. In one particular first year geoscience residential field course the students reported that they loved the field-trip, but then did not choose to progress into second year geology. The course contained a high level of 'lectures-in-the-field'. When assessed, the students showed little understanding of the key concepts crucial for the field geologist.

Similarly, 'we leapfrog students to conclusions that have taken scientists decades to formulate and understand' has been identified as a bottleneck to learning. We don't give students time. For example, in undergraduate chemistry classes teachers say they expect students to leap-frog over twelve steps and balance chemical equations – a threshold concept – and wonder why students always find this difficult. If the balancing of chemical equations is a threshold concept maybe the students need to go through all of the twelve steps to get to understanding. In an idea borrowed from the study of evolution, 'ontogeny reflects phylogeny', we may have to help students to fast-track through the history of disciplinary development, in order to make personal and robust shifts in understanding. Colleagues have given the example of the development of the ideas of flat-Earth, through geocentric and heliocentric models for the workings of the Solar System. Each individual must experience the evolution of understanding before meaningful and robust progress can be made.

In addition to these, structural barriers are put in place. We arrange modules into disciplinary programmes, or we arrange multiple disciplines into one programme, and we assume that the students will connect up the separate parcels of learning in a meaningful way – that is, with the same meaning that we ourselves have. While studies lead us to conclude

that deep understanding takes time, the students tell us that time is short. The institutions have introduced semesterisation, which can mean that students have only a short time to reflect, assimilate and 'get-it'. The urgency to help students develop coping capacities has never been greater.

So, how can we, as teachers, help students navigate the route? We must first of all be aware of the transformative concepts in our disciplines. We must know what it looks like when these concepts have been grasped and what it looks like when they haven't. We must know the terrain, and what causes bottlenecks to learning. We may then be able to help students to navigate the route – knowing that for each student that route could be a bit different.

I was asked recently what do we mean by "Teaching and Learning" written with capital letters. Is it a proper name, a catch-phrase, or is it a discipline in its own right? This is a good question. If 'Teaching and Learning' is a discipline, then we must ask what are the threshold concepts? For some of us, when we began to change the focus from ourselves as the teacher and focus on the student as learner, we experienced 'aha' moments. When we came to realise that design of curricula is less about 'covering content' and more about uncovering and discovering threshold concepts, then we were transformed as teachers. It seems that these journeys are necessary for many teachers, and may suggest they are threshold concepts in 'Teaching and Learning'.

LINEAR OR MESSY?

To help students navigate the route we must know something about the route – or the process of learning. Some studies describe the route to understanding as linear, circular or spiralling, while others describe the route as messy and less orderly.

If the route is linear what can we as teachers do to help? Samball *et al.* (2009) believe that students can have blockages, and sometimes all it needs is a small piece of information to close the 'circuit' and allow the flow of understanding. They believe that various forms of feedback are crucial, with the student as self-assessor analysing this feedback. The students must be able to ask themselves 'What do I need to help me close the circuit and progress?' This suggests it can be a variety of small things that help students to approach the portal, and turn ability into action. In one example from the University of Reading, UK, generic feedback on an assignment, was given in the form of a 'feed-forward' podcast on the VLE. The feedback was thus available when the students felt they needed it, usually when completing the next assignment.

In our teaching, we may treat the steps towards the threshold concept as linear – but is that the whole picture? Perkins describes the learner struggling to make sense of messy data, going over and over it, until suddenly something clicks – an 'aha moment' – a transformation. He introduced the concept of breakthrough thinking to capture this. We need at least some of our students learning to be like this. We need to build students' capacity to cope with the messy complexity that we believe they will encounter in their lives. Perkins gives examples of significant breakthrough thinking historically, creating new knowledge for society. Our students may not be at this level but must undergo breakthrough thinking creating personal new knowledge. They must be allowed the satisfaction of their own 'aha' moments.

How can we distinguish between linear and messy paths? In assessment we often just look at the final product, and lose the messiness of the learning. An analogy in geoscience is when an earthquake occurs and seismic signals travel through the Earth. At the receiving stations we filter out the messiness or 'noise' – so that we can better 'see' the main seismic event. However the geoscience community has discovered that the seismic 'noise' contains important information that was being discarded. They are now researching and using the messy signals as predictors of future earthquakes.

Similarly we can learn from the student's messy learning path, but this is often hidden. We need to encourage students to document this messiness, and we need to find ways of rewarding the process of learning and not just the final product, in order to help students. We need to see not only the product, but also the steps they have taken to get there. In this way we learn something about learning.

CHARACTERISTICS OF THRESHOLD CONCEPTS

The characteristics of threshold concepts as concluded by Meyer and Land (2005) are summarised in Figure 1.

Taking a closer look, I want to highlight one very important characteristic that sheds light on the part we can play in student learning, and I want you to carry this with you as we interact throughout the conference. A Threshold concept is integrative – and grasping this integrative concept involves making meaningful connections that reveal the hidden inter-relatedness of knowledge and understanding. I want to propose to you that this characteristic is of prime importance in

navigating the route for students. Integrative learning must take place. I will concentrate on this, and outline an approach being taken in Ireland that is providing pathways to aid both teachers and learners in relation to threshold concepts.

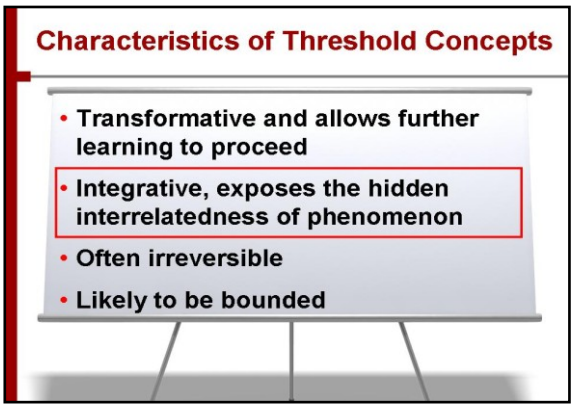

Figure 1: Characteristics of Threshold Concepts

What is integrative learning? We know that one of Boyer's 4 scholarships was the Scholarship of Integration – where he urges us to "*look at and research connections within and between disciplines; to broaden perspectives and bring new insights to bear"* (Boyer, 1990). We know that a study 'Integrative Learning: Opportunities to Connect' carried out by the Carnegie Foundation for the Advancement of Teaching, and their collaborators, between 2003-2006 concluded that all four of Boyer's scholarships urge us to promote and foster integrative learning. Subsequently the CASTL scholars programme in 2005-2006 was themed 'Integrative Learning'. Books emanating from the CASTL scholars included Nowacek *et al.* (2010) largely in the humanities, and Ferrett *et al.* (2013) concentrating on the sciences.

In Europe, the Irish Integrative Learning Project (IILP) resulted from a successful grant application to NAIRTL in 2008, initially involving three institutions and sixteen courses across the disciplines. Some early results are captured in Higgs *et al.* (2010). The IILP has allowed teaching for integrative learning to be embedded in numerous programmes in multiple disciplines.

For example, Ryan (2010), in University College Cork, working in a neonatal intensive care unit, gives medical students an overview of neonatal care from four different perspectives, teaching beyond the diagnostic and therapeutic core concepts. This encourages students to think integratively and ultimately practice as reflective, humanistic doctors who care. Here, the concept of humanism is a threshold concept, and is transformative. In another study, Kilcommins (2010) outlined the deficiencies of formalistic legal education, where learning was not integrated with the realities of legal practice. By encouraging students in University College Cork to examine psychological and sociological perspectives, and experience the realities of law enforcement on the streets, students are empowered to demonstrate their own transformation within the discipline. This is partially captured through assessment, using a reflective learning journal.

Integrative learning may not just happen automatically. In a study by Conneely and O'Leary (2010) in Waterford Institute of Technology, the integrative learning potential of a new interdisciplinary criminal justice degree programme was examined. In assessment the authors discovered that students were not making the meaningful connections between disciplines that had been assumed. The insights they gained allowed the course team to adjust their practice in the next iteration of the programme to encourage more meaningful connection making, thus building students' capacity for integrative learning. The chances of success, for students grappling with the threshold concepts, were thus improved.

This early work has encouraged many subsequent studies in Irish institutions. Integrative learning was a sub-theme of the 4th NAIRTL annual conference in 2010, held in the Royal College of Surgeons, Dublin, and is the subject of a workshop at this 4th Biennial Threshold Concepts Conference (O'Mahony, 2011). Phase two of the IILP includes the preparation of an Integrative Learning Handbook. Due for completion in 2014, it is intended that this will be a valuable resource for teachers in higher education.

ALIGNING INTEGRATIVE LEARNING OUTCOMES WITH THRESHOLD CONCEPTS

How can the alignment of ideas and frameworks help us to help students navigate the route to understanding? As experts in our disciplines, we can design the learning opportunities to help student to make meaningful connections.

To illustrate this, let me come back to the example of first year students in geoscience on a residential field course. The learning outcomes are aligned with two identified threshold concepts related to the understanding of geological time and 3-D interpretation (see Figure 2). Two of the learning outcomes explicitly refer to these threshold

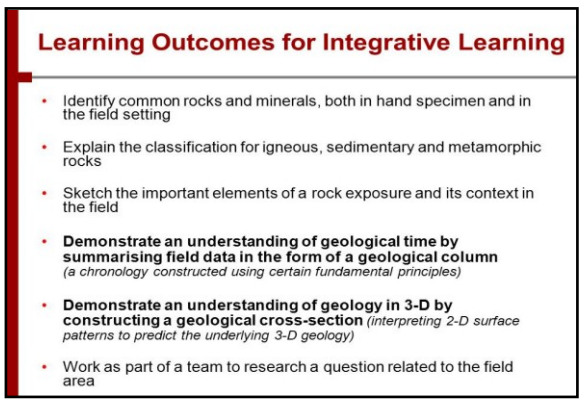

Figure 2: Learning outcomes for Integrative Learning

concepts, and the remaining learning outcomes support their achievement. All of the learning outcomes are encouraging integrative thinking and integrative learning.

Here, students are challenged with bite-size performances – not mastery performances. Taking the first of these threshold concepts, as a teacher I can't just say the Earth is 4.6 billion years old and expect students to grasp the concept of the enormity of time, and all that goes with it. So, on the field course first year students constantly revisit this concept – it pervades everything they do (as opposed to everything they listen to). They look for clues, describe, measure, record, and articulate with peers in their small groups. They are practicing, replicating, using, applying, and mimicking the work of experts. They have some time to play with the data they find – but are then challenged in the evening whole group seminars to reason and justify, and to pull their findings together into a timeline – or geological column. It is an exercise in connection-making and synthesis. They are building capacity to be integrative learners. Crucially, in this setting the students are encouraged to formulate questions, to ask for help, and in the end to carry out an authentic task and begin to internalise what it is to be a geologist. Such opportunities for discussions and reflection prove powerful in beginning to build the students' (and the teachers') attributes identified as necessary for integrative learning.

After three full days in the field have the students grasped the concept of geological time? No, because constructing the geological column is only a small step along the way, drawing students into the liminal space. Perhaps after four years of study and 40 days of field courses these students will be coming close to grasping this threshold concept. It can take an exceedingly long time before we fully understand and appreciate a threshold concept.

However, the number of students progressing to second year geology courses has dramatically increased. Some of these students had previously no intention of studying for a degree in geology. What changed their minds? What transformations take place over those three days? There are small aha moments that happen on the first field course – and motivate students to progress to second year geoscience. For some students it appears to be the element of research and discovering something for themselves. A quote from a first year student, reflecting on some early misconceptions in the history of geology, reads *"When we were at Portrush discussing whether or not igneous rocks were precipitated out of sea-water, a few of us were discussing what could have happened. We came up with the idea that magma came out on top of marine environment mudstone and that the heat baked the mudstone into a fine grained splintery rock. It was an 'aha' moment because it turned out to be right!"* This is an experience that motivates students to do more, to close the ability-action gap and to navigate the route.

To encourage students to thing about their own learning, they were asked on the first day how they learn best. Their perceptions were that they learn best from teacher-dependent learning. By the 3rd day students perceptions had changed – they were recording over 50% peer and social learning, such as group work and discussion. In a separate exercise, students were asked to record their 'aha' moments so that we could track their mini-breakthrough moments. The data revealed that 1% of students had the breakthrough while listening to an expert, 99% had the breakthrough when actually doing something for themselves.

The insights gained from these experiences show that we must be intentional in our teaching for integrative learning. Colleagues involved in the IILP reported spending time before a teaching session to focus intentionally on how they could maximise the integrative learning opportunities. Perkins, in a keynote address at the 3rd biennial Threshold Concepts Conference in Sydney Australia, referred to threshold experiences, and warned that in the design and enactment of our curricula *"a learning episode can easily miss critical characteristics needed for threshold experiences"* (Perkins, 2010).

WILL THE STUDENT NEED THIS GUIDING FOR EVERY THRESHOLD CONCEPT?

We can build activities that bring the students *"back and forward over the conceptual terrain"* (Cousin, 2006), but what will happen when we are not there to guide them? What I'm suggesting is that we must also look beyond the individual threshold concepts. We must start from day one to help students to build their capacity to be integrative thinkers and learners.

It can be helpful for us to identify the capacities and characteristics of an integrative learner, so that we can design our curricula and assessment intentionally. An integrative learner will make meaningful connections

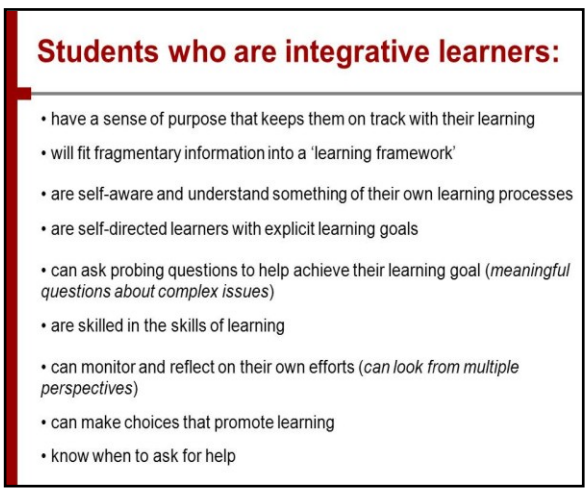

Figure 3: Characteristics of integrative learners

between separate learning experiences within the discipline, or between disciplines (see Figure 3).

Huber and Hutchings (2004) believe that for most people integrative learning does not just happen. It requires the student to be intentional about their learning.

HOW CAN WE AS TEACHERS ENCOURAGE INTENTIONAL, INTEGRATIVE LEARNING?

Huber and Hutchings (2004) suggest that we can scaffold integrative learning by what they call intentional teaching. The characteristics of intentional teaching for integrative learning can be distilled from the case studies that have been reported here and elsewhere (see Figure 4).

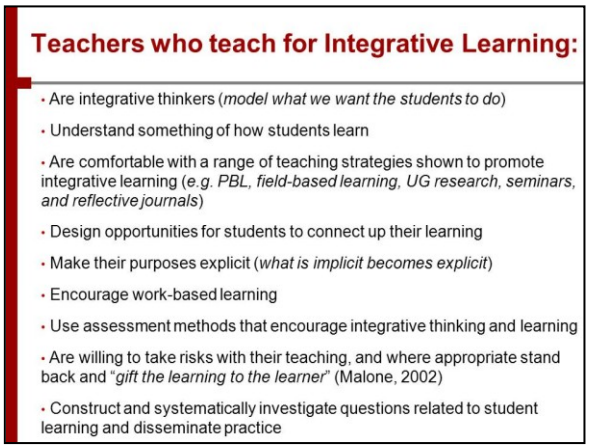

Figure 4: Characteristics of intentional teaching for Integrative Learning

WHAT ARE THE IMPLICATIONS FOR TEACHING?

Huber and Hutchings (2004) suggest we look to curriculum design, pedagogy, assessment and staff development, to help build capacities for integrative learning (Huber, 2006; Hutchings, 2006; Gale, 2006; Miller, 2006). When rolling out something new do we ask ourselves if the alignment of learning outcomes, assessment, and teaching methods helps students to not only survive in the liminal space but to be creative, and thrive? Will the introduction of some innovative technology be helpful or just novel? Can we generate a generic feedback podcast that conveys the importance of connection-making to students, as well as feed forward comments encouraging them to consider the topic from different perspectives? Can we set an assignment that simply asks students to come up with good questions related to a topic – and replace yet another 3000-word essay?

Quite quickly we may see what the students understand and the effort they are making. It is clear that we must find ways of making what is implicit explicit. We must model what we want the students to do, so that it becomes natural to them. We cannot expect students to do it if we don't model it ourselves. We must connect with real world examples, and in assessment we must reward what we value.

INTEGRATIVE LEARNING AND INTERDISCIPLINARY THRESHOLD CONCEPTS

Before I conclude, research work has mainly focused on threshold concepts within disciplines. The alignment of integrative learning with the idea of threshold concepts, led me to suggest in 2007 that it seems likely that interdisciplinary threshold concepts also exist, and once identified and negotiated, could be integrative, transformative and irreversible (Higgs 2007, 2008). In workshops, I have challenged colleagues in University College Cork to come up with interdisciplinary programmes. They have come up with wonderful ideas for connection-making. The harder part is to state the interdisciplinary threshold concepts. The challenge is to consider what is integrative, because there lies the threshold concept and the potential for ontological shift. Programmes may be multidisciplinary, but not integrative. We must know what it is that will make the integrative whole greater than the sum of the disciplinary parts, in order to recognise if a student has grasped the threshold concept. I'm delighted that we have a subtheme in the current conference on this aspect.

CONCLUSIONS

My work with the first year students in geoscience meant I was fully primed and ready to take on the idea of threshold concepts. Many people are in that same position. They are expert in their discipline and know the troublesome but crucial concepts. They want to help students to 'get it', and this could be why there has been significant disciplinary buy-in to this idea.

Aligning ideas and frameworks has changed the nature of the debate on threshold concepts, and opened up the questions being asked. This will benefit both teachers and learners. I've posed more questions than answers in this brief discussion, but in summary the take-home message is that we must:

1. Foster integrative learning by designing opportunities that allow and assist students to uncover the often hidden connections between their discrete learning experiences;
2. Build capacity for integrative learning so that students can continue to engage successfully with the threshold concepts that they meet beyond the current course, and in their life beyond the University. Students must develop the capacity to be creative in future liminal spaces, when we are not there to assist them.
3. Helping students to be 'world-ready' in this way necessitates a standing back of the teacher, and 'letting-go', even from first year onwards – allowing students to be creative and innovate and to do the learning for themselves. They can do it.

Our own disciplines have lessons for us. We must use these lessons to be creative with ideas and understandings of teaching and learning. For example, we could identify cognitive coincidences in our own disciplinary areas – and relate these to our students to encourage them to question perceived wisdom, and think outside of the box. We could fast track through the history of ideas in the discipline to situate the student's struggle, that is, to put the struggle in context.

I have been asked if Threshold Concepts is a fad that will disappear in a year or two. I think not, but if the term disappears and is replaced, it is of small importance. What is important is the debate that is currently ensuing, and has done for almost a decade. It has had, and continues to have, a very positive influence on current thinking in teaching and learning, and links with research, and has brought a wider range of practitioners into the debate.

For many teachers, there just needs to be some tweaking here and there, some rewriting of learning outcomes and refocusing of assessments, not a revolution, because they were already employing their expertise as teachers to these issues. Ray and his colleague Eric have named the parts. Their work has unlocked a wealth of talent. Great minds have been applied to the idea of Threshold Concepts, and will continue to develop and influence our thinking.

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THRESHOLD CONCEPTS AS AN ANALYTICAL TOOL FOR RESEARCHING HIGHER EDUCATION PEDAGOGY

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Biographical Note

Glynis Cousin is the Director of the Institute of Learning Enhancement in the University of Wolverhampton. She has joined the University from her previous role as Senior Advisor at the Higher Education Academy. She is one of the UK's foremost educational researchers and has extensive experience working with teachers in many disciplines. Throughout her work as a higher education researcher and developer Glynis has published in the areas of diversity, internationalisation, evaluation and pedagogic research. She is also strongly associated with the field of curriculum inquiry that is centred on threshold concept theory. Her most recent book Researching Learning in Higher Education has just been published by Routledge.

My exploration centres on the notion that liminality is not just about a stage/state of conceptual mastery, but it is also about the process of entering studenthood. I will build my argument through a discussion of two research projects and an undergraduate course with which I have been involved. Each of these contexts enabled me to advance my thinking about threshold concept mastery.

OTHERNESS AS A THRESHOLD CONCEPT

My first exploration into threshold concepts concerned the teaching and learning of Otherness (Cousin, 2006) which I saw as a threshold concept because its grasp is potentially transformative. In my research into this potential, I came up with student positionalities with respect to what students might bring to mastery (I called this 'emotional capital' of which more below). The extent to which this is important varies according to the concept to be mastered but in terms of Otherness we are talking about profoundly emotional questions concerning how we view ourselves through the lens of social difference.

POSITIONALITIES

The positionalities that emerged from my data were: defended; vicarious/voyeur; victim-identified and reflexive. This typology was based on a mix of student and teacher comment, observation, relevant other studies and speculation. In a nutshell, if we take the question of hearing stories from those vulnerable to racism, some of those who are unlikely to be so vulnerable might become defensive in the face of such stories; others might view the stories with a kind of intrigue that doesn't affect them (voyeur), still others might over-invest in a victim stance and those who have a good grip on the issue will be reflexive. This is perhaps a simplistic typology but the main point to be made in recalling this research is to point to the space threshold concept theory gives to a concern with the affective side of mastery. My positionalities are not quite liminal states but they have some resonance with them.

EMOTIONAL CAPITAL

I also offered a notion of 'emotional capital' to refer to the experiential knowledge students bring into the classroom that can shape their positionality. This overlaps with the idea of emotional intelligence but it differs from this idea in that it is concerned with variation of exposure to experiences. If I stay with my example of racism, a student who is vulnerable to it is likely to have substantial relevant emotional capital about its nature. Another possibility might be a student who is not directly vulnerable to racism but comes from a family with a strong anti-racist ethos. In different ways these two students bring a good measure of emotional capital to their studies.

THE DOVE PROJECT

An opportunity to advance my thinking about student positionality and emotional capital was provided by my involvement in a project with Joelle Fanghanel (Fanghanel and Cousin, 2011) in relation to a reconciliation project involving Palestinian and Israeli students at a UK University (the Dove Project). The project wanted to build the capacity of the students to lead a peaceful solution to the Middle East Conflict. We interviewed eight students, four from each 'side'. One student summed up the experience of this brave project:

> *"The programme put a mirror up to yourself; you had to do a kind of reflection"*

This seemed to me to be good definition of the reflexive learner. Getting to this point was no easy matter: Each side talked about the limitations of their world:

> *"If you are educated in the Jewish narrative, you are born in it, and that's what they teach you, you don't have a choice. The programme allows that there are different narratives, and then make up you mind about those different narratives".*

When you live in Gaza, all that you think about is how to pass your day, how to manage to think about your evening, the maximum you will do is think about tomorrow. You will never think about the future. So life in Gaza makes your ambitions very limited. So the fact that I came here, I managed to do many things that I would never have been able to do in Gaza, it opened my eyes on the world.

We found that all of our respondents valued the expert lectures on the Middle East that were an important means by which they expanded their world. Here is one testimony from an Israeli to that effect:

> *"I never had the confidence to express my views because they were not based on knowledge of the history of the conflict and of the region; and also because of my own my cultural heritage, the things I was born into, that I grew up with but never really analysed academically and spiritually as well".*

The unanimity of opinion among the students about the value of academic expertise is one pointer towards education as a gift, of which more below.

NOISES OFF

I want to develop a fresh angle on liminality. In threshold concept theory, we think of liminality as an ontological learner state to do with being betwixt and between conceptual mastery. In our research, it expressed a different kind of edginess or oscillation, one that was to do with what we called, after Michael Frayn's play 'Noises Off' (1982). This is a play about how what goes on in the wings of the stage (noises off) affects what goes on at the centre. This seemed to perfectly capture a predicament for the Dove Project tutors.

A significant disturbance to the students' ability to connect to the narratives of 'the other side' was the fact that the efforts of teachers to get dialogue going were against the backdrop of a very live conflict. In our report of this project (Fanghanel and Cousin, 1995), we wrote:

> *"The students were brought together into an educational experience in the UK, and yet in permanent contact with their regions through their families and friends, visits, media reports, and the ubiquity provided by today's media. This programme took place in the context of a live conflict with periods of escalation in the hostilities. This created a troubling climate for some respondents as the 'noise' of the conflict was always an offstage presence. They found themselves at the same time within and out with the conflict".*

From this dramatic example, I now move to my third example in order to apply this idea to a more ordinary context, namely that of a university striving to educate students who are the first in their family to enter higher education.

RULES OF ENGAGEMENT

This example concerns a first year module, intercultural awareness. My colleague, Pliny Socoomane, and I tried to sustain a threshold concept approach throughout the course. We took 'Otherness' as the central concept and mapped out themes and sources that would enable uncoverage of this concept. Before each session we asked ourselves what mastery we were hoping for.

I expected to bring news from this curriculum exploration about how we supported conceptual mastery of Otherness. And indeed we learnt much through this process. But our attention was drawn to the 'noises off' that threatened our students' chances of entering studenthood and thus of engaging with our curriculum, however thoughtfully designed.

What emerged clearly was the question of the meta-learning level; that learning rules of engagement for university education is necessary. I am going to suggest that this engagement involves accepting a gift relationship with teachers and that without this acceptance (which can also be a refusal from teachers), the students remain in a liminal state, a state in which she is not-yet a student; she may never become so. I will illustrate through two cases: Leroy and Jaswinder – one failed, one achieved a clear A

When I first saw Jaswinder after a lesson it was late evening; she was sitting on the steps alone; she looked anything but part of a student group; I had been doing research at the time into degree disparity and one of our findings was about the importance of an interlocutor, someone who convincingly says 'you can do it'. I decided to take on this role. I said to her: *"listen if you attend all the classes and read beyond the text, you can head for a first".* When I interviewed Jaswinder a year later, I asked her if she remembered this conversation. She didn't but she did say that her brother gave her insights

about how to be a student. When I said to Jaswinder *"my door is open"* she took this seriously and came because her brother said it is ok to accept support. Here is an extract from our conversation:

> *"Q. How do you account for your success, for getting an A?*
>
> *You have to learn to be a student… you have to learn that university is not like school or college, you have to learn to research by yourself*
>
> *Q. What changes do you think you have made?*
>
> *I now feel like a student*
>
> *Q: What does it mean to feel like a student?*
>
> *It's about belonging somewhere, being part of a group, being able to see lecturers as people who can help you; who you can go to"*

Now here is a contrasting example: We had to transfer one of our sessions to a room in the chaplaincy one week; Leroy a sporadic attender at the best of times phoned us half an hour into our session, saying he could not attend because he couldn't find us. We said no matter, we will come and meet him opposite the football stadium. He said he did not know where that was either but he will see what he can do. He never showed up. It is quite hard to miss the Molineaux football stadium in Wolverhampton even for the most direction-challenged of us. It seemed to me that Leroy was in a liminal space, geographically (outside our classroom) and affectively (not wanting to enter the classroom). On the few occasions he participated, it was clear that he had capabilities but for whatever reason (and it would be invasive to speculate), he declined our invitation for a relationship. At another point, I noticed that he had the tiniest of notebooks – about two square inches. I said to him: 'you cannot note take for a degree with that'. I gave him a large pad. He never used it. You could say that he refused the gift at two levels. First he refused the pad; second he refused the invitation to relate. What we noticed dramatically in the example of Leroy, but also to a lesser extent in other students, was a combination of ignorance about the rules of engagement and a reluctance or ambivalence about entering into an educational relationship. This expressed itself in terms of poor attendance, low class discussion participation, not doing the reading. We can see that this was not the case for Jaswinder.

One lens with which to make sense of this contrast is to frame the educational relationship as a gift one. Robert Sessions (1995), a US community college academic, suggests we conceptualise this relationship as a gift one because it is outside an economic relation; it is not a contract, barter or exchange of equivalents.

STUDENT-TEACHER RELATIONS AS A GIFT RELATION

A gift relationship is asymmetrical in a good way; it creates indebtedness that is not in the marketplace because it cannot be repaid. When we gift our expertise and encouragement to students, they respond through self-development and growth. Indeed ask most students and they will say that they want a good degree but many will also say that they want to be stretched, changed. By way of example, here are some comments from Art and Design students in my University. I am very confident that similar comments can be found in any university

> *"Animation lectures are amazing… they push you to achieve your best"*
>
> *"Brilliant teaching… lecturers were very supportive and opened up doors into the art world"*
>
> *"My mind went up and down with ideas and I came across work I never had before which inspired me"*
>
> *"The staff teaching on my module are very creative and helpful; they have pushed me all the way and I am very thankful to them"*
>
> *"My confidence has grown since I commenced university when I was a timid little thing. Thanks to the constant group tutorials and presentations, this forced me to 'get out there'"*
>
> *"I have been able and encouraged to be a more independent person and this has not only affected me academically but also on a personal level"*
>
> *"Very thankful to them"*

From my regular examination of free text comments on student evaluation forms, I can confidently say that among the criticisms of cold classrooms, death by powerpoint, etc. the most common phrase I read is 'thank you', either to individuals or to the institution as a whole for providing the space and support to grow. Here is Sessions' (1995) view:

> *"Perhaps one way of clarifying how gifting differs from economic exchange is to examine what parents are doing when they invest in a college education for their children. In what is usually the most expensive as well as capstone purchase most parents make…few would say it is simply like buying their child a new coat only on a grander scale. Most in fact probably would be terribly disappointed if all their children got was a product…**people sense that college is a gift, a bequeath of culture wherein their child takes major strides in becoming a person"**.* (my emphasis)

The quotes from students above seem to me to verify Sessions' point about 'major strides in becoming a person'. This is not an outcome of a contractual agreement alone.

Let me summarise so far. In drawing on threshold concept theory, I argue that the idea of liminality extends to the meta-learning level. Alongside conceptual mastery, students have to master the business of entering studenthood; for some there are 'noises off' that threaten passage towards such studenthood. For those who manage this passage, it can be associated with entering into an exchange relationship with teachers and the institution. Conceptually connecting this exchange as a gift one allows us to see its depth beyond a contractual relation (which is also present). My final point is that this conceptualisation raises questions around notions of student-centeredness or of 'student experience' research. It seems to me that acknowledging, as students often do, the asymmetrical nature of the teacher- student exchange allows us to avoid symbolic erasure of the teacher, of his or her expertise, effort and care through the unhelpful deployment of a student- centred/teacher-centred binary. Teaching is simultaneously rewarding and exhausting because it requires a giving of self; for students to succeed, they have to accept this giving and turn in commensurate effort. Our language needs to reflect the centrality of the teacher-student relationship rather than split off one element of it.

My aim has been to throw up some issues connected to our inquiries into threshold concept mastery. I did not foresee these issues in researching the effects of our curriculum design on learner response. I think it was John Dewey who said learning is always co-lateral by which he means that when something is going on in a class in terms of the formal curriculum, something else is always going on at the informal curriculum level. There is always 'noises off'. Listening to these noises might support our understanding of what inhibits some of our students from accepting the gift we offer of education and their gift of commensurate engagement. Lastly, in acknowledging the asymmetrical nature of this exchange, I do not want to suggest that such student engagement is deferential and uncritical. The outcome of a gift exchange is a relationship of mutual obligation. I have touched the surface of this argument but I hope enough to prompt further inquiry into just how we see this mutuality.

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FROM THIS CURRICULUM TO THAT WHICH IS TO COME: THRESHOLD CONCEPTS, COMPLEXITY AND CHANGE

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Biographical Note

Patrick Carmichael is Professor of Education at the University of Stirling. He has been a Principal Investigator of a number of educational and education technology research projects, including several which have applied and explored the ideas of 'threshold concepts' and 'troublesome knowledge' in widely divergent educational settings. His recent work has focused particularly on teaching and learning in interdisciplinary settings and on rethinking the nature of 'design' as it applies to learning technologies.

KEYWORDS

Threshold concepts, interdisciplinarity, curriculum-making, learning technologies, linked data

INTRODUCTION: THE VIEW FROM BEDFORD GAOL

It is noteworthy that a range of authors have articulated the idea of threshold concepts, and drawn attention to their transformative aspect in particular, by using religious imagery and references to epiphanies and revelations. In this paper I offer a further contribution to this aspect of the debate around the nature, role and influence of threshold concepts: no Damascene conversion or sudden enlightenment here, though. Rather, I draw on the long and arduous journey of the protagonist of *The Pilgrim's Progress From This World to That Which Is to Come*, written by John Bunyan in the latter half of the 17th Century (Bunyan, 2008). This story describes the journey, both physical and spiritual, of its protagonist and the various people that he meets along the way. There are many portals in The Pilgrim's Progress, the first significant one being the 'wicket gate' which signals a departure from that which is familiar. Interestingly, in the opening chapter of the book, the Pilgrim is not even sure he can see this particular portal and it becomes visible only once he has begun his journey.

If we continue to examine The Pilgrim's Progress for themes relevant to our study of threshold concepts and troublesome knowledge, we soon see that there are troubling points of challenge all the way through the Pilgrim's journey. While many of these are concerned with overcoming various trials and temptations, there is also a strong sense of personal learning: it's an allegorical book, but it's also an instructional one, as Bunyan was seeking to offer a model of how one might live one's life as a pilgrimage at a time when political radicals and religious non-conformists were being persecuted. Bunyan invites the reader to empathise with those in liminal spaces (the Pilgrim is able to recognise his plight before he begins his journey and can read and recite scripture, but still he *"knows not whither to go"),* but at the same time he has little time for those content to remain there, content to get by, or who profess their faith without seeking to explore it fully, let alone living it.

In later editions of the book there are attempts to map the territory through which the protagonist travels, and there is a frontispiece showing their journey either as a straight line or as an inward-trending spiral. These impose a sense of linearity and predestination which is not quite as evident in the book: although there is a sense of following the right path, there is little indication of what is coming next and there is much more of a sense of one encounter directing to the next and no clear indications of distance or the time it might take to complete any stage of the journey, which is a space of connections and relationships. I think that the later attempts to represent these as a linear path is very much the way that curriculum is thought of, with students negotiating a territory that is relatively well explored and to which someone, if not students, then teachers and course designers, have a copy of the map.

As an aside, I should also explain that since I presented the original version of this address in Dublin in June 2012, I have been on a journey of my own, and I now live and work only a mile or so from Bunyan's birthplace in Elstow, Bedfordshire, and the site of Bedford County Gaol, where, while incarcerated, he wrote many of his books, including The Pilgrim's Progress itself.

THRESHOLD CONCEPTS AND PEDAGOGICAL PRACTICE

In the course of a series of research and curriculum development projects, my colleagues and I have explored the ideas of threshold concepts, troublesome knowledge and liminality in a range of learning environments in higher and pre-

professional education, and in doing so, we brought together teachers and students with different disciplinary affiliations. These are reported elsewhere (for example, Carmichael, 2010; Irvine & Carmichael, 2009), but I want to draw attention to some aspects of this work. Rather than trying to identify threshold concepts that are troublesome across disciplines, as, for example, Hall has done with his studies of 'uncertainty' as a threshold (Hall, 2006), we have been more interested in how thresholds and troublesomeness themselves were conceptualised, examples identified, and materialising practices developed differently across disciplinary and pedagogical settings.

What is evident from this work, and, indeed, is reflected in the papers presented in these conference proceedings, is the range of understandings 'the concept of threshold concepts', the different roles that they then play in academic and pedagogical discourses: and how they function as integrative (or for that matter disintegrative) elements within curricular settings. We can see examples of case studies, analyses and interventions in which the idea of threshold concepts are still largely an analytic category, measured against the original five characteristics described by Meyer and Land (2006), or against the subsequent extensions of that framework. But we also see the ideas of thresholds and troublesomeness being located within thinking about pedagogical practice; in discussions of disciplinarity and interdisciplinarity; and as important aspects of reflexive discourses on the part of both teachers and learners. Some of these are described elsewhere, particularly in Irvine and Carmichael (2009), but I want to draw attention to some examples in particular that highlight the importance of the pedagogical expertise of teachers, and the ways in which they work with the 'threshold of concepts' rather than simply carrying out a 'mapping' task in order to redesign the curriculum or assessment activities.

The first of these emerged from work with teachers of undergraduate Engineering, who, as a part of a multi-disciplinary seminar on threshold concepts, presented the example of 'spin', and justified its inclusion initially in terms of its potential to support transformative, integrative and irreversible learning. However, interviewed subsequently, one of them explained that spin was often used in activities such as schools outreach events as it was a good way of introducing the 'engineering way' of thinking, highlighting distinctive disciplinary approaches. There were 'better' threshold concepts, but they were less tractable for non-specialists, and were less useful as boundary objects capable of initiating cross-disciplinary discourse:

> "*We chose that particular example [Spin] because it is something that works well in a mixed group. If I were to talk about some different things I think it would be a very different matter… let's say, Mohr's circle, a fantastic threshold concept, but, try and talk about Mohr's circle in a mixed audience".*

'Mohr's circle' is a graphical method of showing stresses and strains within objects subject to loading. It is interesting as an example of a threshold concept, as it is 'integrative', but also because it involves a conceptual model, a process, and a specific kind of representation whereby the stresses and strains within complex objects are reduced to a particular kind of inscription which is widely recognised by engineers. It was characterised by the engineers as the kind of threshold concept that is only discernible from 'within' the discipline, with others, like 'spin' fulfilling a more outward-facing role. The task for the teacher, then, is to ascertain when, with whom, and how, to introduce these different kinds of troublesomeness into the learning journeys of their students. Some are pointers to a new way of thinking and practicing while others represent a different kind of challenge that one meets once the journey is under way.

The second example emerged from our work with teachers of undergraduate Social Anthropology. Having first argued that the existence of their entire discipline represented a threshold concept, they settled on the centrality to their disciplinary practice, and therefore of student learning, of the concept of 'reflexivity'. Reflexivity was particularly significant not only as a theoretical position, but also as an associated set of practices, and teachers were concerned to effect a shift in the thinking of many of their undergraduate students (who had often developed an interest in the subject through out of school activities rather than through any specific curricular experience) as they were, they commented, often *"excessively interested in spears"*. In contrast to many of the other groups of teachers with whom we worked, the Social Anthropology teachers, did not keep the idea of threshold concepts as an analytical category or use it as the basis of teacher interventions or curriculum redesign. Instead, they presented students with the idea and encouraged them to engage with it and interrogate it as they would any other concept or construct, elegantly exposing their own views about the importance of reflexivity by asking students to, themselves, reflect on their own learning (Carmichael, 2012).

But while this approach is less based in an idea of the curriculum as a process of representation and reproduction of knowledge, it is still about reproduction, albeit, in this case, of practice. The teachers of Social Anthropology had a clearly articulated notion of the ways of thinking and practicing that they wanted their students to develop, even though these involved tolerance of uncertainty and liminality: and they were keen to develop learning environments and activities that encouraged students to *"hang around in troublesome and liminal spaces"*.

BEYOND THE WICKET GATE

More recently, I have been working in different educational settings in which the curriculum is not at all well mapped. These are teaching and learning environments which, because they are contested, rapidly changing or highly complex, are in flux: here, it makes sense to think of the curriculum as a space of emergence and the emphasis is trying to find moments of stability in flux, rather than troubling periods of liminality in otherwise well-mapped territories. We are beyond the 'wicket gate' here, and that applies to teachers as much as students: practice is emergent, let alone any notion of 'curriculum content'. This means that we need to explore what Fenwick, Nerland and Jensen have described as:

> *"... practice [that goes] beyond stable communities and beyond given knowledge. We need to account for the dynamics of knowledge and materiality 'on its travels', as well as for the multiple and the creative-constructive dimensions of practice"* (Fenwick, Nerland, and Jensen, 2012, p. 3)

One of the richest examples of this was found in the context of Contemporary Dance education, where the incorporation of new technologies is not only enabling new kinds of performance and audience engagement, but also new pedagogical discourses. Working with teachers and students who were using live video links to perform with others in different locations so that there were two 'live' performances spaces each with an audience, and a shared 'virtual space' in the form of a shared screen visible in both locations and online allowed the exploration of emergent practice, together with all of its new opportunities and challenges (Brooks and Kahlich, 2009; Brooks, 2012). Against such a background, asking teachers or students what they thought were the threshold concepts of 'telematic dance' was meaningless: they were (and still are) developing the practices and the pedagogical points by working together in this new environment. How would we even recognise thresholds here? This is a situation in which the new understandings and practices are being collaboratively co-constructed, and thresholds and areas of troublesomeness are emerging with them. And new language with it, for that matter, as the students and teachers have to convey not only how they want to collaboratively choreograph a performance, but also the technological aspects. In discussion, the students talk, for example, about the 'cone of capture' – the area in which one can be seen 'on screen', but outside of which you can, of course, still be seen by the 'home' audience and have to react accordingly. So new practices, new concepts, and new signifiers, for that matter, are all emergent.

As our work was concerned with developing learning technologies to support these practices, these became oriented not towards addressing students' difficulties in learning, but supporting the discursive practices of teachers and students as they work in uncertain new areas in which everyone is working in liminal spaces (see Morris, 2012, for an account of the technology platform that in fact emerged). The online tools and environments that were developed were part of the space to be explored and an aspect of the new practice to be developed, as likely to throw up new areas of conceptual uncertainty and troublesomeness as any other. In curricula which are rapidly transforming (as in the case of performing arts) the technologies are often another aspect of the new and alien knowledge with which teachers and students have to engage.

So, I would offer readers the challenge of thinking about the how the threshold concepts 'project' might be taken forward as an aspect of curriculum development, but not seeing the curriculum solely in terms of representation of well-mapped territories or the reproduction of established practice. Instead, let us engage with tentative and exploratory curriculum making that involves teachers and learners working together; in which spending time in troublesome places is valued and encouraged; and where this is recognised as the means by which we may together make something that is new and beautiful.

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Part 2: Engaging Students with Threshold Concepts

CREATIVITY AS THRESHOLD – LEARNING AND TEACHING IN A LIMINAL SPACE

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Biographical Note

Belinda Allen is an Educational designer, Academic developer and Adjunct lecturer at the University of New South Wales. As an artist and designer she is interested in exploring the creative dimensions of learning and teaching, and is engaged in doctoral research around technologies to support creativity in curriculum in higher education. Her background is in visual art and graphic design.

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KEYWORDS

Creativity, liminality, identity formation, transformative learning, praxis

ABSTRACT

Creativity is increasingly represented in higher education aspiration statements as an attribute that graduates in all disciplines require to successfully engage in contemporary and future professional life, but it is not clearly conceptualised in Higher Education learning and teaching (Jackson *et al.*, 2006). Can creativity be conceived of as a threshold concept, or disposition? Some of the characteristics of threshold concept (Meyer and Land, 2003) – transformative, probably irreversible, integrative, possibly bounded, potentially troublesome – seem quite applicable to conceptions of creativity as a learned capability.

The idea of liminal space, defined by Land, Meyer and Baillie (2010) as a 'stuck place', where understanding lacks authenticity because it has not been fully internalized, seems to parallel the "*disorienting dilemma"* inherent to transformative learning (Mezirow, 1991), but also the liminality of creative activity – where chaos rules, unexpected connections are made and outcomes are uncertain.

This paper re-envisions liminality as an authentic creative space for learners and teachers, a space for unknowing and unlearning, a disorienting and productive space. It explores creativity as a threshold in higher education, and the notion that inhabiting liminal space is intrinsic to learning and teaching creativity.

How puzzling all these changes are! I'm never sure what I'm going to be, from one minute to another! However, I've got back to my right size: the next thing is, to get into that beautiful garden—how IS that to be done, I wonder?'
('Alice's adventures in wonderland', Carroll, 1974).

CREATIVITY IN HIGHER EDUCATION

Creativity, as a quality to enhance the performance of workers in industry and business, and for personal and social development, has been promoted as a desirable outcome of education, at school and in higher education (Robinson, 2000; Craft 2001; Jackson *et al.*, 2006). Emerging views of creativity see it as democratic rather than the domain of a creative elite, and emphasise the social/cultural context, collaborative nature and cultivate-ability of creativity (McWilliam and Dawson, 2007). A systemic view, seeing creativity as the result of interaction of personal practice with field and domain (Csikszentmihalyi, 1999) relates to this current view of creativity as "*dispositional and environmental*" (McWilliam and Dawson, 2007, p. 4). Considering how individual creativity may be understood by, enacted in, and influence its context – in Bourdieuian terms, how the creative 'habitus' interacts with its 'field' (Bourdieu, 1983) – opens up notions of how creativity as a dimension of being or 'becoming' (Deleuze and Guattari, 1994) can not only respond to perceived economic and social needs, but influence and create the social conditions – to re-create rather than reproduce the world.

Creativity as a disposition goes beyond personality, aptitude, capability or skill – it is the inclination and determination to behave in a certain way, for instance a drive towards self-discovery and self-discipline that is enacted in a context. Abilities such as creation of analogies and mental models, crossing disciplinary boundaries, exploration of alternatives (Perkins, 1981), and cognitive playfulness (McWilliam *et al.*, 2010) demonstrate dispositions for creativity. The dispositions essential for a creative response to future unpredictable challenges require a capacity of "*being-for-uncertainty*" (Barnett, 2004) – this capacity to respond confidently to uncertainty, to perpetually learn, reflect on understandings, and act for positive change is at the heart of creativity as a disposition.

In another moment down went Alice after it, never once considering how in the world she was to get out again.

CREATIVITY AS THRESHOLD

In disciplines where creativity is explicitly intended as a learning outcome – in design or visual art studies for instance – it has previously been suggested that creativity could be viewed as a threshold concept (Reid and Solomonides, 2007). Some of the characteristics of threshold concept (Meyer and Land, 2003) – transformative, probably irreversible, integrative, possibly bounded, potentially troublesome – seem also applicable to conceptions of creativity as a generic disposition. The transformative nature of creativity as a threshold disposition implies a perspective shift that changes the learner's world-view. Flood (2011) relates the characteristics of a threshold concept to personal learning dispositions rather than to conceptual thresholds: *"I suggest that learning thresholds are dependent on a readiness to learn that comes from a more emotional and personally driven position. Before one can move to a new level of understanding the confidence and ability to make a leap of faith into a new zone of learning needs to be achieved"* (p. 65). She cites Meyer and Land (2003) as finding that transformation extended to aspects of identity, feelings and values.

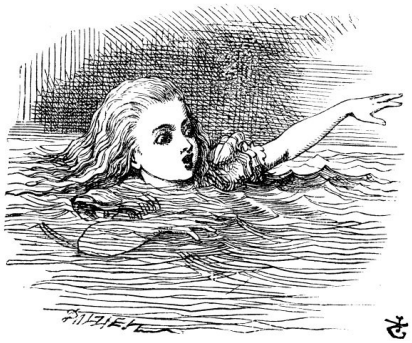
Perkins also believes that developing a learning disposition may itself be a threshold: "*Educating for proactive knowledge calls for a threshold-like shift from a culture of demand to a culture of opportunity. In a culture of opportunity, what learners do … becomes more open and ranges more widely"* (Perkins, 2008, p. 14). Educating for creativity calls for similar shifts, from identity as learner and consumer of knowledge to creator and active agent; from seeking problem solutions externally, to internal generation of not only solutions, but problems themselves.

A disposition for creativity – to embark for unknown destinations, to overcome reliance on habitual responses to unfamiliar states, entails passing through a threshold – from the place that is well-known, without the promise of emerging. This requires courage, confidence in the creative process, and in one's ability to navigate the unknown space. If the creative disposition is not fixed, but is one of becoming – more courageous, more curious, more determined, more patient, is it something from which one emerges, or a perpetual liminality?

THOUGHTS ON LIMINALITY

Liminal space can be thought of as one of insecurity and uncertainty, also of liberation, receptiveness and growth. The origins of this concept are in anthropological studies of tribal and religious ritual, where the state of liminality is induced through requiring the inductee to become bare of the trappings of their identity, not only material but psychological and spiritual, in order to be reborn in a transformed state. Three stages are identified: separation, the liminal period and reassimilation (van Gennep, 1909). Turner (1967) developed the idea to refer to social structures generally, citing three manifestations of being in relation to social structures: in between (liminal), on the edge (marginal), and beneath (inferior).

Adopted by political anthropologists, liminality is now envisioned as *"a major concept in cultural and social anthropology*" and as a



She soon made out that she was in the pool of tears which she had wept when she was nine feet high... 'I wish I hadn't cried so much!' said Alice, as she swam about, trying to find her way out. 'I shall be punished for it now, I suppose, by being drowned in my own tears! That WILL be a queer thing, to be sure! However, everything is queer to-day.

tool to investigate the cultural dimensions of socio-political situations, seeing the prevalence of existential crisis as representative of a liminal (political) state (Horvath, Thomassen, and Wydra, 2009, p. 3). It is used to "*refer to in-between situations and conditions that are characterized by the dislocation of established structures, the reversal of hierarchies, and uncertainty regarding the continuity of tradition and future outcomes*" (Horvath *et al.,* 2009, p. 3).

From its anthropological origins, conceptions of liminality are expanding to refer to any state of flux: *"Liminality exists between all cultures and between all people within cultures, and arguably, within each of us"* (Lang, 2012). The emerging concept of 'threshold concepts' in education proposes that for learners to engage in hard-to-grasp or 'troublesome' knowledge entails entering a liminal cognitive space of unknowing in order to pass through the threshold of 'knowing' (Meyer and Land, 2003).

Liminality is seen by anthropologists and educators as a dangerous and difficult place to linger – the usual structures have been stripped away, and the participant is vulnerable and suggestible, needing guidance to complete their transformation (Thomassen, 2009). Mimicry may be a strategy for making the liminal state 'safe' without achieving the mastery required to emerge (Meyer and Land, 2003). However, mimicry is the antithesis of creativity.

LIMINALITY AND CREATIVITY

To inhabit and be productive within a liminal space of unknowing is characteristic of creative thinking and creative activity – the disequilibrium and uncertainty of the liminal space is an essential element of creative activity and transformation (Reid and Solomonides, 2007). It reflects the creative process itself, where the risk of embarking on an original idea, design or action is likely to provoke discomfort and insecurity during the transformation of existing ideas, understandings and products into new representations.

Land *et al.* (2010) characterise the *"stuck place"* as inauthentic, where knowledge is mimicked rather than lived. But in the context of creativity the stuck place may provide the combination of uncertainty, possibility and constraint that characterises creative practice. Land *et al.* suggest that "*Insights gained by learners as they cross thresholds can be exhilarating but might also be unsettling, requiring an uncomfortable shift in identity"* (2010, p. x-xi). But if the process of entering liminality is deliberate, 'jumping' rather than 'falling' or 'being pushed', there is potential to develop confidence and self-efficacy – the unknown space that was scary becomes something that is able to be inhabited without disaster, and the mundane and unadventurous space of un-creativity begins to seem a dull and lifeless place.

Discussing the 'impossibility' of implementing critical pedagogy in schools, Lather (1998) has suggested that aporia – state of perplexity – is the space where praxis can reinvent itself: exactly where one becomes 'stuck' is where the possibility for creativity occurs: *"praxis as a ruin made habitable by a fold of the between of presence and absence, …a praxis of the undecidability and constitutive exclusions of praxis, a non-reductive praxis that calls out a promise of practice on a shifting ground"* (p. 497).

Emergence from liminality is generally thought of as a fitting in to the relevant social (or disciplinary) structures and understandings. But in the case of teaching for creativity, there is an inherent contradiction in rewarding students who conform to performative expectations in demonstrating creativity (Thomas, 2007). It is more expected that creativity involves iconoclastic, or even subversive behaviour; again there is a sense in which the emergence is into ongoing liminality.

LIMINALITY AND TRANSFORMATIVE LEARNNG

How can conceptions of liminality inform the learning process? Transformation conceptions of creativity relate it to characteristics such as 'disorientation and encountering the unexpected', 'the desire and the ability to engage in change' and 'engagement in risk-taking' (Kleiman, 2008, p. 211). According to Kleiman (2008, p. 214), "*creativity in learning and teaching is experienced as an engagement in a process that is transformative either in itself, or is undertaken with the intention (implicit or explicit) of being transformative".* This relates distinctly to ideas of transformative learning, where the process of challenging the learner with pre-existing beliefs and assumptions in order to induce transformational perspective changes is highly scaffolded, but predicated on learner transformation, not teacher transmission (Mezirow, 1991).

'It was much pleasanter at home,' thought poor Alice, 'when one wasn't always growing larger and smaller, and being ordered about by mice and rabbits. I almost wish I hadn't gone down that rabbit-hole—and yet—and yet—it's rather curious, you know, this sort of life! I do wonder what CAN have happened to me!!

In transformative learning, a disorienting dilemma followed by self-examination initiates a learning process involving critical reflection, and investigation of options for action. Liminality is intrinsic to this process, in the requirement to question and divest oneself of assumptions as a precursor to transformation of perspective.

Land, Meyer and Baillie (2010) have acknowledged the potential relationship between the liminal space of threshold concepts, and the transformative learning process, and Reid and Solomonides (2007) have also related this to teaching and learning creativity. So, a transformative learning approach seems appropriate for the development of the attributes for a creative disposition, providing a framework for personal transformation in the context of a learning process, and a method of managing the liminal space intrinsic to both learning thresholds and creative practice (Allen, 2011). Phases of transformative learning (Cranton, 2002, p. 66) reflect the uncertainty of occupying a liminal learning space, and show that a collaborative criticality is brought to the transformative process of identity formation.

'Who are YOU?' said the Caterpillar. This was not an encouraging opening for a conversation. Alice replied, rather shyly, 'I—I hardly know, sir, just at present—at least I know who I WAS when I got up this morning, but I think I must have been changed several times since then.'

LIMINALITY AND IDENTITY FORMATION

Contemporary conceptions of identity have emerged from postmodern notions such as the aesthetic self – life as a work of art (Foucault, 1992), technologies of self (Foucault, 1988), the reflexive self (Giddens, 1991), identity inherent in practice – the 'habitus' (Bourdieu, 1983), and self as desire and difference (Deleuze and Guattari, 1994). A common theme is the self as an evolving and transitory accumulation of experience, interaction and communication. Deleuze's idea of identity as a constantly negotiated function of 'difference', the process of 'becoming', the 'folding' the 'outside' world into our own experience, is intrinsically creative (Deleuze, 1993). Foucault defined the 'aesthetic self', seeing the *"arts of existence"* as *"those reflective and voluntary practices by which men … seek to transform themselves, to change themselves in their singular being, and to make of their life into an oeuvre that carries certain aesthetic values and meets certain stylistic criteria"* (Foucault, 1992, pp. 10-11). In these views, self is conceptualised as an endless becoming, and 'being' itself is seen as both creative and liminal. A conception of creativity as 'becoming' reflects this postmodern view of the creative self in a state of flux, and suggests that development in life inevitably involves traversing, contesting and re-defining thresholds, and that a definition of creativity could be the ability to be imaginative and productive in this dynamic state.

The transformation from learner (or teacher) to creator entails developing a creative identity. Csikszentmihalyi (1996) found that a belief in one's own creative identity was universal amongst the highly creative individuals that he interviewed, with a strong sense of cultivating a life narrative in which the creative voice and identity are integral, and making decisions and cultivating dispositions which allow them to deliberately shape their lives.

Flood (2011) has looked at artistic identity as a threshold, and her ideas could relate to the creative disposition more generally. She sees as central the developing narrative of life: a recording, explicit or otherwise, of experiences and encounters that accumulate to create identity, recalling Foucault's development of aesthetic self. The thresholds of identity are the points at which decisions are made; why and how decisions are made may be influenced by many aspects of the 'creative system' (Csikszentmihalyi, 1999) or the 'power/knowledge structure' (Foucault, 1992) that a person inhabits.

Flood's study found that a significant threshold was to fully identify as an 'artist', to be able to say without misgiving *"I am an artist"* (p. 66). This is a threshold that both learners and teachers will encounter in teaching and learning for creativity – to be able to believe *"I am creative"*, authentically engaging with what creativity means to them, in their context, and for their professional and personal practice. The learner engaging with the concept of creativity in their context and with their own developing creative identity may be the first troublesome step into the liminal space of creative transformation.

LEARNING AND TEACHING IN LIMINAL SPACE

Liminality is to be valued in learning and teaching. While curriculum attempts to pin down and make explicit the outcomes of the learning situation, it is often the unexpected outcomes that emerge from engagement, interaction and risk-taking in learning, that promote individual and collective growth of the kind that Barnett envisages. Transformative learning aims

to develop the capacity to manage one's own ongoing learning (and transformation) and so is an iterative process, and is also conceived as collaborative. Collaboration within the liminal space, and a critical creativity which enables both scepticism and imagination, could provide the dynamic and the structure required for the ritual to become self-guided.

Using ideas around ritual to think about how education is organised and how learning takes place means adopting terminology such as novice, induction, guidance, separation, identity, transformation and liberation. Again, such ideas closely parallel the process set down for transformative learning. But ritual can also imply unthinking compliance and external imposition of boundaries, hurdles and processes that may alienate and disarm the inductee, and anthropologists warn of the danger of entrapment in liminality (Thomassen, 2009). Teachers therefore must not only be aware and critical of the oppressive aspects of enacting pre-ordained educational ritual, but should have a deep understanding of the ritual aspects of transformative learning, in effect becoming transformative learners themselves. This recalls McWilliam's (2005) exhortation to teachers to 'unlearn pedagogy' and become a 'meddler in the middle', co-learner and mentor on the learning journey.

Barnett (2004) proposes a mode of knowledge that surpasses problem-solving, suggesting that "*knowing the world is a matter of producing epistemological gaps*". He suggests that the role of higher education is to prepare students for an uncertain and complex world not by inducting, training and releasing them into particular epistemological certainties, but by enabling them to not only discover but create epistemological gaps. This challenges the idea that emergence from transformative ritual is into an identified role in a stable world, and implies that liminality is indeed an ongoing dimension of perpetual transformation.

How can teachers approach transformative teaching for creativity in an uncertain world? Cranton (2002, p. 66) suggests that "*this challenge must be combined with safety, support, and a sense of learner empowerment, it is, at the center, a challenge of our beliefs, assumptions, and perspectives that leads us to question ourselves".*

The role of the teacher as transformative learner themselves, engaging in creativity in their own teaching practice, models this approach for learners, and develops for teachers a disposition that can be brought to bear on the changing and uncertain environment of the academic workplace.

RESEARCHING IN LIMINAL SPACE

If liminality is a useful, even important, idea for thinking about learning and teaching, might it also have implications for the conduct of research into teaching and learning? The idea of teaching as praxis (Carr and Kemmis, 1986) and curriculum as praxis (Grundy, 1987) integrates research of teaching and curriculum into the practice itself. In praxis, practice and critical reflection on practice are integrated to drive development of practice, and inform theory in an action-research cycle that closely resembles the transformative learning process (Mezirow, 1991).

In its transformational aim, there is a potential for a creative praxis, referring to both a creative approach to praxis (emphasis on imaginative and exploratory techniques) and a focus on creativity enacted in practice (for university teachers). Participants in praxis will become responsible for engaging with, critiquing, developing and transforming their perspectives on, beliefs about, and practice of creativity.

Barnett sees that a purpose of higher education is enabling the production of epistemological gaps, and this seems an apposite description of the purpose of research into higher education itself. While the ultimate aim of creative praxis in teaching in Higher Education is the development of a critically creative disposition in graduates, this is intrinsically related to critically creative practice in teaching, in research, and in the administration of the organisation.

"Would you tell me, please, which way I ought to go from here?"
"That depends a good deal on where you want to get to," said the Cat.
"I don't much care where" said Alice.
"Then it doesn't matter which way you go," said the Cat.
"—so long as I get SOMEWHERE," Alice added as an explanation.
"Oh, you're sure to do that," said the Cat, "if you only walk long enough".

CONCLUSION

The idea of liminality relates to conceptions of creativity as a (threshold) disposition, to contemporary conceptions of identity formation, and to creative practice itself. Embedding transformative learning and action research into teaching as creative praxis could scaffold an approach to teaching, learning and research

in higher education which enables creativity within the liminal spaces of learning and teaching, preparing both academics and graduates for positive engagement with an uncertain future. Learning, teaching and research all inevitably take place in a liminal space of becoming – in a praxis of critiquing assumptions, opening possibilities and imagining futures. While it may be difficult to see how this can be enacted in the current higher education climate of managerialism and accountability, maintaining an emancipatory focus for praxis may enable the subversive potential of creativity, reinvigorating idealistic notions of university as a critical and creative organisation.

So she sat on, with closed eyes, and half believed herself in Wonderland, though she knew she had but to open them again, and all would change to dull reality.

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'DOING' HISTORY: WHAT MAY LIMINAL SPACE AND TRANSITION TIME EXPOSE DURING THE PROCESS

James Cronin and Postgraduate tutors in School of History, University College Cork

Biographical Note

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KEYWORDS

Decoding the Discipline, Indiana University History Learning Project, bottlenecks to understanding, liminal spaces, Scholarship of Teaching and Learning, threshold concepts in professional development

ABSTRACT

Meyer and Land (2006) liken the crossing of learning thresholds to a 'rite of passage' in which a transitional or liminal space has to be traversed. Tutors, in early formation, may get stuck in a liminal space between crossing from students to disciplinarians or 'stewards of the discipline' (Golde and Walker, 2006). This paper, prepared in collaboration with postgraduate tutors in the School of History, University College Cork, focuses on challenges involved in mentoring graduates newly come to teaching an academic discipline. It employs a 'decoding the discipline' approach, following the work of Díaz *et al*. in 2008, to make explicit some of the liminal tensions affecting tutors' shifting notions of selfhood and identity over time.

Over the duration of an academic year, through mentored face-to-face seminars and online peer-to-peer discussions, ten history tutors were asked to interrogate their own teaching:

(i) To reflect on their own learning by examining the 'bottlenecks' to understanding they encountered in learning the discipline of history (Díaz *et al.*, 2008). This allowed tutors to better understand what it is to be a novice being inducted into a discipline, why their own students get stuck, and how best to help them. Reflecting on experiences of learning provides insights about their own encounters with disciplinary concepts and how they did – or did not – come to understand them (McLean, 2009).

(ii) To chart their own processes in teaching history by examining disciplinary thresholds through dialogue with their peers. This was to encourage a collaborative examination of the process of disciplinary learning, and to reveal some of their tacit beliefs and to manifest assumptions they may make about the ways their students learn.

Teacher narrative exposed formation as a liminal state showing that changes in subjectivity involve messy journeys back and forth across conceptual and affective terrains.

INTRODUCTION

Historian, Marc Ferro, in his classic study *The Use and Abuse of History*, considers the role school history textbooks have had on conditioning and shaping historical consciousness. His study concludes with recognition that *"progress in historical knowledge will come about not through the accumulation of knowledge of more events, but through the acquisition of a better methodology of comprehension"* (Ferro, 2003,1981, p. 363).

For graduates, the first year of a doctorate is often a transition time when they are required to take some assistant teaching duties. Teaching itself may be a source of anxiety for many new to it. During this transition time, postgraduates may operate in a liminal space between their 'student' selves and their 'teacher' selves. Coming to disciplinary mastery involves acknowledging stages of liminality. Here, 'liminality' is defined as a suspended state of partial understanding, or 'stuck place', in which understanding approximates to a kind of mimicry or lack of authenticity (Cousin, 2006a and 2006b; Land, Meyer and Baillie, 2010). The performance of teaching, as with learning, is initially imitative or mimetic. Graduates learning to teach a discipline initially model their teaching on how they themselves have been taught that discipline. A threshold concept for novice teacher-disciplinarians is learning to experience their chosen discipline holistically; not just as

a cognitive field, but also as one requiring dispositional aptitudes. Here, disciplinary dispositions are defined as attitudes and beliefs, about the discipline; about themselves as emerging academic teachers and about building a capacity for empathy with their students as disciplinary novices.

Over the past decade, the Indiana University History Learning Project has made significant contributions to enquiry into the teaching and learning of history in higher education. In a seminal paper, focusing on a history department's 'decoding' its students understanding of the discipline, the Indiana University History Learning Project sought to begin a conversation where the scholarship of teaching and learning was invoked to reveal the process of understanding academic history (Díaz, Middendorf, Pace, and Shopkow, 2008). The authors argue that it is only by making explicit the processes of historical performance that disciplinary understanding can be made intentional. The paper concludes with an invitation to colleagues at other institutions *"to compare our findings with the implicit demands of their classes and the profiles of their students in order to widen our understanding of teaching and learning history in higher education"* (Díaz, Middendorf, Pace, and Shopkow, 2008, p. 1124).

This paper responds to the Indiana University History Learning Project's invitation by encouraging postgraduate teacher-historians in the School of History at University College Cork to reflect on their formation as disciplinary stewards through their teaching practice. By encouraging tutors to reflect on themselves as liminal subjects, transitioning from students of a discipline to 'stewards of a discipline', this paper exposes tensions in shifting identities in formation, from postgraduate researchers to teaching assistants, over the duration of a single academic year.

METHOD: DISCIPLINARY 'DECODING' THROUGH TEACHER NARRATIVE

In the humanities and social sciences, narrative communication is central to negotiating situated meaning. Through narrative the subject moves across the threshold of one experience into another. However, this process is frequently not smooth, but protracted and recursive (Kubler, LaBoskey and Hamilton, 2010; Bondi, Carr, Clark and Clegg, 2011). Scholars acknowledge that teacher narrative, as qualitative data, is 'messy' (Chi, 1997, p. 271). It has to be remembered that stories, ascertained through narrative inquiry, are textured by particularity and incompleteness (Clandinin and Connelly, 2000). Verbal analysis, as captured through narrative sequences, quantifies the subjective content of verbal utterances (Foucault, 1978; Chi, 1997; Clandinin and Connelly, 2000; Jaworski, Coupland and Galasinski, 2004).

Tutors' narratives, articulating processes of performing or 'doing' history, can only be fully understood within a wider semantic web of utterances, situating tutors and students within the curriculum and the educational institution. Likewise, the experiences of tutoring first-year undergraduates cannot be easily disentangled from prior expectations of students carried over from experiences of teaching and learning in the secondary school system. Situating teacher narrative, in this manner, within a wider semantic field reveals complexities involved in promoting curriculum change.

Here, a case study approach is used as a conduit between theory and practice (Bromley, 1986; Shulman, 2004/1997, pp. 26-30) from which to isolate and compare teacher narrative with observations disseminated through an international study on teaching disciplinary history (Díaz, Middendorf, Pace, Shopkow, 2008). This paper draws on computer mediated communication, posted over a year-long academic seminar (November 2011 to May 2012). This 'blended' (online and face-to-face) seminar in the School of History at University College Cork discussed four themes: (1) decoding the discipline of history; (2) disciplinary identity and selfhood; (3) professional values of the historian; (4) history in education. During six-week intervals, between seminar meetings, tutors were invited to post their reflections within a moderated collaborative workspace. The responses of one tutor have been selected as a micro-study which is paradigmatic of incremental shifts in subjectivity over a single academic year.

BECOMING A 'STEWARD OF THE DISCIPLINE': STATES OF LIMINALITY IN GRADUATE FORMATION

Carnegie scholars, Chris M. Golde, George E. Walker and associates, enquiring into the role of doctorate education in the United States, drew on the metaphor of stewardship that has deep cultural resonances with guardianship. A 'steward of the discipline' is a scholar in the fullest sense of the term – someone who can imaginatively formulate new knowledge, critically conserve valuable ideas and responsibly transform those understandings through teaching, writing and application (Golde and Walker, 2006). Indicative qualities and dispositions of the historian, as disciplinary steward, are demonstrated by mastering such explicit and implicit competencies as the following: fostering independent thinking; acknowledging history's crafted nature by interrogating how history is written and studied; assessing key historical periods and patterns of change over time and within and across nations, cultures, and time periods; determining why people view and interpret historical events differently; exhibiting knowledge of research methods, archives and new media resources; demonstrating skill in both constructive critical analysis and empirically grounded creative synthesis; showing awareness of the philosophical foundations of historical knowledge and of current thinking about fixing the

grounds of historical 'truth'; exhibiting a capacity to evaluate good historical work in fields outside of one's own special field; knowing how to communicate with diverse audiences; demonstrating an ability to work collaboratively; assuming professional responsibility for the institutional governance and management or in the discipline's professional structures; demonstrating a commitment to mentoring young historians (Bender, 2006, pp. 307-308). Crucially, the disciplinary steward has a central role in mentoring the formation of disciplinary novices. In this, disposition is as important to foster as cognition.

Most academics learn how to become professional historians, *"more or less by osmosis, without explicit instruction on how to perform many of the operations necessary to produce historical knowledge"* (Díaz, Middendorf, Pace, Shopkow, 2008, p. 1211). The principle of transparency represented by the Indiana University History Learning Project as 'decoding the discipline' (Díaz, Middendorf, Pace, Shopkow, 2008, pp. 1212, 1213, 1220, 1221) provides for teachers making practices explicit.

To model disciplinary practices is to unveil an intentional demonstration of process (Brockbank and McGill, 2007, p.218). The Indiana University History Learning Project, by adopting a 'decoding the discipline' approach, emphatically advocates scaffolding disciplinary knowledge and dispositions:

> *"When faculty express concern about the inability of students to do the work in a history class, the problem may not be a lack of the component skills, but rather that most of our students do not understand what historians do" (Díaz, Middendorf, Pace, Shopkow, 2008, p. 1218).*

The 'doing' of history is performative. Ideally, it enfolds dispositional practices within knowledge formation.

Misalignment of expectations between staff and students, as highlighted by the Indiana University History Learning Project, mirror experiences participants in the Teaching History Seminar encountered at Cork. An anonymous postgraduate teacher-historian, who was a first-year tutor, reflected:

> *"[first-year history] lectures emphasise the importance of understanding values in societies... but students in their essays were more inclined to provide a narrative of the time period"* (Anonymous, personal communication, January 19, 2012).

Lack of experience, in a discipline, is a bottleneck:

> *"Students also must accept that sources are created by human beings and are as complicated as life itself. Faculty expect students to re-create imaginatively the cultural context in which such artifacts were produced and to re-create the meanings and perspectives of the people who produced them"* (Díaz, Middendorf, Pace, Shopkow, 2008, p. 1214).

At Cork, First-year tutors, teaching medieval history, encouraged students to make connections between history and disciplines such as archaeology and English literature where artefacts and period literature are studied. These tutors noticed, to their surprise, that many first-year undergraduates, despite being familiar with this material from other disciplines, were unable to intuitively recontextualise these as historical source materials without the explicit intervention of the tutor. For first-year undergraduates, whose formative experience has been the Irish school-leaving certificate, with its emphasis on the narrative of a textbook, a myriad array of potential sources widens the scope of history, but also introduces bottlenecks of historical subjectivity and ambiguity:

> *"…students who have been led to see history as the chronicle of elites and of world-altering events have difficulty in conceiving of literary sources, pictures, maps, diaries, or songs as legitimate sources for studying history"* (Díaz, Middendorf, Pace, Shopkow, 2008, p. 1214).

To expose subjectivity, tutors participating in the Teaching History Seminar at Cork were initially encouraged to narrate their earliest memories of engaging with history. The majority of online posts identified the family unit as sparking their initial interest, but formal education gave them a language in which to articulate it. The anonymous postgraduate teacher-historian articulated how his personal engagement with the 'forgotten history' of the Smerwick massacre of 1580, during the Second Desmond Rebellion (1579-1583) in Ireland began during secondary school and was continued into his undergraduate studies in history.

Through the online posts, the anonymous postgraduate teacher-historian follows his engagement with Smerwick, through his historical education, to elucidate his growing awareness of the practices involved in crafting professional history. He relates that it was only at the end of his undergraduate degree:

> *"...in Third Year that I became aware of how most of the historiography relating to Ireland's early modern period has remained within a national framework, for example, Gaelic Scotland is ignored. Understanding this concept of*

> *how one can adopt a post national framework allowed me to step outside political history and dabble in social and cultural history".*

In the same online post, following directly to the next paragraph, he makes a seamless connection between his awareness and with what he is attempting to foster in his tutorial group. He recounts:

> *"I have tried to get my students to look beyond the political history that they are so used to by examining primary sources. Using an extract from Beowulf [Anglo-Saxon elegy], I asked the students to identify what they considered to be the values of the Anglo-Saxon elite, hinting at how these kind of sources offer a window into the past. In stepping outside the narrative, I think some students began to see that one can explore the past from a different perspective entirely"* (Anonymous postgraduate teacher-historian, personal communication, November 19, 2011).

While professional historical writing is predominantly narrative in form, novices of disciplinary history find difficulty comprehending how historical knowledge is produced and crafted (Shopkow, Díaz, Middendorf, Pace, in press). To the novice historian, primary sources document the 'facts' of history and are therefore not subject to analysis or interpretation (Díaz, Middendorf, Pace, Shopkow, 2008, p. 1213). Unwillingness to take risks, arising from a lack of confidence, is a significant bottleneck for the novice historian:

> *"Lacking both the experience and the confidence of their instructors, many history students are understandably nervous about claiming to understand the meaning in the words or actions of someone in a very different era"* (Díaz, Middendorf, Pace, Shopkow, 2008, 1215).

Most first-year students initially hold to a dualistic world-view before transitioning to multiplistic and relativistic thinking (Perry 1999/1968; Kurfiss, 1988; King and Kitchener, 1994; Baxter Magolda, 2002; Clinchy, 2002; Erickson, Peters and Strommer, 2006). Judicious risk-taking and imagination, essential for holistic historical thinking, are habits of mind intersecting domains of cognition and affect (Díaz, Middendorf, Pace, Shopkow, 2008, p. 1215). The Teaching History Seminar at Cork encouraged the tutors to identify a problem in their teaching that they could reasonably attempt to change through a teaching intervention of their choice. The anonymous postgraduate teacher-historian's intervention engaged his tutorials of ten sessions a week, comprising one hundred and twenty students, in a close reading of historical documents in translation, described as follows:

> *"One approach that I found useful to move the students away from the political narrative was greater analysis of a primary source. In one instance we took a document dealing with Pope Urban II's announcement of the First Crusade in November 1095. Ironically, this unlike other literary sources such as Beowulf was very political in nature. Yet, I attempted to bring in elements of cultural and social history and combine them with political history by first asking them why there was a crusade? Jerusalem had fallen to the Muslims. Secondly, why call a crusade in November? What was special about this time of the year in relation to the religious calendar? They answered that it was Advent and I explained that the Pope was linking the idea of religious war with a time of fasting and prayer. This quickly got a lively discussion going and I think the students could see that there was indeed a cultural side to history, i.e. the belief-system that existed in medieval times. Finally, I asked them why call a crusade in November, but not launch it? They quickly answered that it was too cold and so we discussed the social implications of going to war in medieval times, which helped stimulate further debate in the class. I followed this template of linking the various frameworks for studying sources for the next few classes and it seemed to work well"* (Anonymous postgraduate teacher-historian, personal communication, November 19, 2011).

Here, the tutor 'decodes' the discipline by judiciously guiding students through the labyrinth of intention and argument emerging from a close reading and questioning of a primary historical source in translation. The anonymous postgraduate teacher-historian's guided intervention demonstrates principles that the Indiana University History Learning Project identify as intrinsic to historical performance, namely, empathetically mentoring students to interpret the words of historical actors as conditioned by the limits of their particular historical thought-world.

CONCLUSION

At the conclusion of the Teaching History Seminar at Cork tutors broadly advocated a research-focused teaching and learning curriculum intervention because of its potential to model authentic performances of historical thinking essential to professional historical studies. Learning a new discipline involves laying down new patterns of thought and action which become habitual over time. Imitation or *mimesis* is a key step in this process.

Narrative enquiry, as a form of teacher research, is 'a search, a "*re-search*," a "*searching again*", "*a sense of continual reformulation*"...' (Clandinin and Connelly, 2000, p. 124). Extracts quoted from the anonymous subject's experience hint at

the potential of narrative to facilitate the subject re-connecting with memories and experiences from a wider field of personal and professional associations in order to encourage a realignment of empathy for the experiences of the disciplinary novice. Reflecting on his experience, the anonymous postgraduate teacher-historian writes:

> *"[The seminars helped me] to reflect on the values which I personally believed important to the study of history, but more importantly it enabled me to step back from these values and explore the discipline of history from a wider perspective. With these issues in mind I became more sensitive to my own students' perceptions of history and I feel that this perhaps made for greater facilitation of the learning process both for me and my students"* (Anonymous postgraduate teacher-historian, personal communication, May 11, 2012).

A minority of tutors found the processes of reflecting on their disciplinary formation puzzling. These would have preferred more procedural guidance. Current scholarship on the formation of disciplinary identity suggests that learning to become a disciplinarian incorporates both cognitive and affective dimensions (Middendorf, Mickute, Saunders, Najar, in press). In the liminal space between 'student' self and 'teacher' self the identity of stewardship is in flux. An emerging scholar, often experiences it as recursive, involving messy journeys, back and forth, over a prolonged period, across cognitive and affective domains of subjectivity.

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NOVEL THRESHOLD CONCEPTS IN THE MATHEMATICAL SCIENCES

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Tertiary mathematics, liminal spaces, teachers, threshold concepts

ABSTRACT

The purpose of this research is to identify and examine some unusual, unexpected or novel threshold concepts in mathematics. This is ongoing work that contributes towards the development of a suite of resources and strategies for helping learners in the mathematical sciences work towards fulfilling their potential by successfully negotiating and passing through liminal spaces. This project is an offshoot of an ongoing Professional Development Unit for training tertiary mathematics teachers, initiated by the second author, supported by the (former) Australian Learning and Teaching Council, and sponsored by the Australian Mathematical Society. This Unit is linked to the Society's website.

INTRODUCTION

Threshold concepts appear to be pivotal in formative processes that lead to positive or negative dispositions towards mathematics, especially from early childhood, though 'rebirthing' can occur at any age. On the positive side, one hears of so-called 'eureka moments', typified by the legendary Archimedes leaping out of his bath after making a monumental discovery about the displacement of volumes in a liquid. There is no doubt that Archimedes (almost certainly an apocryphal representation of a whole school of ancient Greek scholarly enquiry) passed through a portal, or sequence of portals opening up to ever-increasing vistas, and used such physical or geometrical experiments, combined with logical thinking, to develop or spawn an entire science. The mathematics of area and volume, and relationships with irregular patterns or shapes, has intrigued mathematicians for thousands of years, culminating, in the seventeenth century, in the extraordinary discovery of the close relationship between differential calculus and integration. An irrevocable explosion of progress in the mathematical sciences followed.

On the negative side, however, it is common to hear of people who have been irreparably damaged by an experience, stopped in their tracks or slipped and fell over, losing confidence in their mathematical ability and developing a distaste or abhorrence towards even the simplest kinds of quantitative or algebraic reasoning. How tragic it is for such people never to experience, or get to the point of experiencing, the Archimedean feeling of elation or sense of transformation that is possible through mathematics. Courant and Robbins (1941), in the introduction to their classic text *What is mathematics?: an elementary approach to ideas and methods*, write that everyone should learn calculus, and that the associated mathematics is within the grasp of every educated and informed person, who desires knowledge and an appreciation of the greatest achievements of our civilization.

From the point of view of mathematics, William Rowan Hamilton (1805-1865) is surely a candidate for Ireland's Archimedes. In 1843, whilst walking along a Dublin canal with his wife, he discovered the celebrated equations describing the arithmetic of the quaternions *"$i^2=j^2=k^2=ijk=-1$"*. He felt so moved by the occasion that he inscribed them in stone on Broom Bridge, a few kilometers away from Trinity College, where he had been a student, and from the present day Hamilton Building, named in his honour (and where the 4th Biennial Threshold Concepts Conference was held, in June 2012).

These are remarkable equations. They establish the foundations of a well-defined arithmetic on a four-dimensional vector space that turns out to be non-commutative. The real numbers form a one-dimensional arithmetic, and the complex numbers a two-dimensional arithmetic. Both of these are examples of *fields*.

In the early nineteenth century, it was an important open problem to determine whether there exists a field in three dimensions, extending real arithmetic. Hamilton attempted for many years to create such an arithmetic, and came to a sudden realisation that the attempt was in vain: the next smallest dimension for which an arithmetic existed was four (not three), and commutativity was necessarily lost. He discovered *division rings* and founded non-commutative algebra, with far-reaching applications to mathematics and physics (and now also in present-day computer science and engineering). His tortured pathway, backwards and forwards through liminal space, is well documented through letters and correspondence with family, friends and other mathematicians and scientists (Graves (1975)). Glynis Cousin (2012) raises the question whether liminality is about space or relationships, and in a mathematical sense Hamilton tells us that it is both simultaneously: his discovery is a prototype for the sublime interplay between freedom and constraint, and the delicate balance between imagination, fantasy and mathematical reality that confronts all serious researchers in mathematics.

There is a paucity of research specifically on threshold concepts in mathematics, the remedy of which we hope might be stimulated by some of the examples in the following sections. The role of proof as a pivotal threshold concept in mathematics has been explored in Easdown (2007), from both heuristic and more formal technical perspectives, and Jooganah (2009), with sociological implications. The notion of a function, and the interplay between *functions as processes* and *functions as objects*, has been explored by Pettersson (2011), who conducts a detailed longitudinal study involving a prospective mathematics teacher. This has the advantage of viewing progress backwards and forwards through liminal space, from both the perspective of a learner in the discipline of mathematics and someone aspiring to become a mathematics educator. Indeed, this dichotomy, between learner and educator, is a constant theme in the training of primary teachers by Jacqui Ramagge (2010) and her team, and for tertiary mathematics educators, by Wood *et al.* (2010) (and see also Brown *et al.* (2010)), through workshops and online learning modules, stemming from the (former) Australian Learning and Teaching Council Project – *Effective Teaching, Effective Learning in the Quantitative Disciplines* (now accessible online through the website of the Australian Mathematical Society).

We offer a sprinkling of contrasting and seeding examples that fall, roughly speaking, into one of the following categories: *formative* stage (primary or early childhood); *middle developmental* stage (secondary or early tertiary); *professional or meta-cognitive* stage (late tertiary to postgraduate). In each case, the examples exhibit characteristics of being *transformative*, *troublesome* or *counter-intuitive*, *integrative* and *irreversible.* They also involve some kind of journey that begins with a pre-liminal state of aimlessness or incomprehension. The person may remain trapped there, possibly rebounding or repelled from liminal space. Alternatively, the person may successfully pass through liminal states of suspension or instability, culminating in a post-liminal state of empowerment or 'enlightenment'. The final extended illustration below is one of the most striking examples of tortured, convoluted movement through pre-liminal and liminal space, by eminent mathematicians and philosophers. It culminated in a sudden explosion or revolution of ideas and progress in modern mathematics. This serves as a tribute, on the centenary of his birth, to Alan Turing (born 23 June 1912), one of the most creative and original thinkers of the first half of the twentieth century.

PRIMARY OR EARLY CHILDHOOD OR STAGES

Ross Fitzgerald (2010), in his autobiography, describes a personal anecdote of the role of zero in putting him off mathematics at a young age. He came to school with oranges in his bag, and showed his teacher. He put out his right hand holding all three, and also held out his left hand with none. He then asked a simple question: *"If I multiply the no oranges by the three oranges, where do they go?"* The teacher could not explain where the oranges went and destroyed a small boy's confidence in mathematics. Ross describes this as a pivotal moment that turned him away from mathematics

permanently. (He also notes that he discovered much later that the primary school teacher had not been trained in mathematics.) In the language of threshold concepts, Ross had arrived at school in a pre-liminal state, possibly with high hopes and even enthusiasm. His interaction with the teacher entered a slippery liminal state that unfortunately led to repulsion and a disastrous outcome. What was the underlying threshold in this example? Clearly the young boy understood the notion of zero, or 'nothingness', but the issue was how zero interacted with *multiplication of numbers.* Multiplication is a highly nontrivial operation in general and exceedingly difficult to explain to a young child, and takes careful thought and preparation even for integers.

Ramagge (2010) emphasises the importance of training primary school teachers in mathematical thinking, not so much for the knowledge content, but to consolidate their own understanding. Even when teachers pass through portals, there needs to be self-reflection about the journey, in order to successfully guide others. Stephen Brookfield (1995) describes an incident when he wanted to learn to swim from an expert, who, despite his obvious prowess, was incapable of explaining basic steps, or even seeing the problem from the point of view of a complete novice. This is related to the *Principle of Reflected Blindedness* (introduced by Easdown (2006)), interpreted in terms of the interplay between syntax and semantics, which says our own profound or ingrained knowledge or expertise can make us blind to the point of view of the learner.

The behaviour of numbers and the way they interact leads to abstract algebra, and Easdown (2011a) recalls a pivotal moment for him that led to a life-long love of mathematics and cemented at a very early age the notion that mathematics is all-powerful and provides keys to unravelling mysteries. The teacher had entered the room of third-graders and gave a sequence of instructions: "*Think of a number between one and ten. Keep it secret. Double it. Add four. Halve what you now have. Subtract the secret number you started with. You are now thinking of the number two!"* This was astonishing to a small child and the teacher used it to illustrate a key concept in algebra. If the secret number is *x* then the teacher's instructions were to progressively evaluate *"(2x+4)/2–x"*, which always simplifies to the number 2, regardless of the choice of secret number. Several pathways through liminal space opened up: first, the teacher was consolidating simple arithmetic, not as a chore or boring exercise, but as a means to an end (to read minds); second, he surprised all of the class and piqued their interest, savouring the sensation of suspension and uncertainty; third, and most importantly, he explained how one could represent a number as a symbol, and by manipulating symbols produce an astonishing conclusion. This last aspect creates a hybrid of threshold concepts: an unknown value *x*, algebraic manipulation and proof. Separately, each ingredient may seem unremarkable or uninteresting, but brought together they create a dynamic that takes the learner towards and through a portal that opens up to a fascinating landscape. After this demonstration by the teacher, the third-graders were switched on and excited. They subsequently created their own more elaborate mind-reading games, actively seeking out problems for which *"solve for x"* or *"get rid of x"* became tantamount.

SECONDARY TO EARLY TERTIARY STAGES

The ability to add, subtract, multiply and divide, and understand when each operation is appropriate and effective, is, of course, taught from elementary primary school. However, Frank Quinn (2011) writes in detail about the vagaries of teaching fractions (directly related to division), which he describes as a *"perennial source of trouble".* His examples demonstrate clearly that the learner must negotiate many twists and turns before reaching a portal that can come in many different guises. The problems this creates in training teachers is explored further by Wu (2011), who explains the gulf between effective abstract mathematics and what is possible to convey in the classroom. Algebraic manipulation is one of the core devices for producing mathematics, and solving equations in particular, and there comes a point, somewhere between secondary and even tertiary education, where a student has to develop awareness of the processes involved and not simply react intuitively and *"hope for the best".*

Easdown (2011b) was initially surprised when a group of university students asked him how to get beyond an apparently plausible manipulation they had made in attempting to complete an assignment:

> *"We are trying to solve for t given the equation* $2P = P(1 + i/100)^t$. *We take P away from both sides to get* $P = (1 + i/100)^t$, *and now are stuck! Help!"*

The students were attempting to isolate *t* with a view to taking logarithms and rearranging, to explain the well-known *Rule of Seventy* used by investors to estimate the time it takes to double an investment compounded at *i* per cent annually (taking approximately 70/*i* years). Unwittingly they had used subtraction of *P* on the left-hand side instead of division by *P* (used correctly on the right-hand side). This simple error made the problem essentially meaningless and impregnable. It was as though a door had slammed shut on a distant portal, and no light remained. Fortunately for them, a nudge from the lecturer, pointing out that they had confused and compounded subtraction and division in the same manipulation, unblocked the pathway and they were able to return to liminal space and successfully solve the problem.

Success or failure in formal mathematics is sensitive to even the slightest perturbations. Debugging computer programs, for example, is notoriously difficult, and mathematics has a similar sensitivity, certainly at the level of syntax of formulae. Even if an error is trivial, finding it can be like searching for a needle in a haystack, and exacerbated if, through inexperience, one doesn't know in advance what the needle looks like!

Walter Bloom, in one of the workshops (Easdown (2011a)), gives a beautiful example of the ambiguity of arithmetic operations:

> *"(One haystack) + (One haystack) = (One haystack)"*

A young person can understand the heuristic conveyed by this equation: if one pools two haystacks together one gets just another single haystack (albeit larger). If size is not being modelled by the mathematics, then this makes perfect sense, and it leads to a variation of the operation of addition. Indeed with usual addition of integers we have 0+0=0, but the haystack example suggests even the possibility of, say 1+1=1, and that leads to the notion of *semiring arithmetic*, important in theoretical computer science and applications to algebraic geometry, in particular the emerging field of *tropical geometry*. Beyond this threshold, the mathematical scenery becomes vast and exotic, and examples such as this one of Bloom's provide simple entry points for a curious student.

PROFESSIONAL OR META-COGNTIIVE STAGES

The hallmark of a successful professional mathematician is the ability to step back and think about mathematics as a whole and seek relationships. Stated this way, this may seem trite and obvious, but in fact many students get embroiled in detail and find themselves stuck or bogged down in the unistructural and multistructural phases of the SOLO taxonomy (see Biggs and Collis (1982) and Biggs and Tang (2007)), without passing into the relational or extended abstract phases. The notion of *movement through the boundaries* between phases is closely related to the successful passage through liminal spaces, and becomes a threshold concept itself. Easdown (2007) explains the way this malleability of boundaries is exploited by practising mathematicians, by free and unashamed use of the so-called *Plateau Principle: look for and be prepared to use a variety of plateaus as starting points for a mathematical investigation.* He likens this to using a helicopter to fly to the top of a glacier, in order to embark on an amazing skiing journey, rather than first trudging through the ice flows with the constant risk of slipping into a crevasse. Flying over terrain in a helicopter is not cheating, but a recognition of the power of utilising what others have invented or achieved in the past. Isaac Newton famously stated *"If I have seen further than others, it is because I have stood on the shoulders of giants".* The entire feat of strategically negotiating liminal space and finding portals that one knows in advance exist is one of the most effective of threshold concepts in mathematics and involves meta-cognition: the ability to reflect about what one is doing in relationship to what others are doing or have done.

Meta-cognitive threshold concepts are especially important in higher mathematics and we give an extended example that relates to the foundations of mathematics. Gottlob Frege (1903), a philosopher and mathematician, set himself the task of developing what he believed to be unequivocal and apparent 'self-evident' premises on which to base set theory. His so-called *Comprehension Principle* states that any set may be defined by a well-formulated condition, using whatever symbolism is appropriate in the context. This principle is used so widely and commonly in mathematics that it seems unassailable and impregnable. However Bertrand Russell, in 1901 (see Von Heijenoort (1967)), had sent Frege a note:

> *"Consider the set S of sets that are not members of themselves. Is S a member of itself?"*

This is now famously referred to as *Russell's paradox*: the set *S* cannot be a member of itself, as this leads to a contradiction, so it therefore must be a member of itself, which also leads to a contradiction. There is no way out of this dilemma unless one abandons the notion that *S* is a set. Frege (1903), in his major treatise *Grundgesetze der Arithmetik,* then about to go to press, realised his Comprehension Principle was on quicksand, as it was capable of allowing fallacies, and published an addendum:

> *"Hardly anything more unwelcome can befall a scientific writer than that one of the foundations of his edifice be shaken after the work is finished. I have been placed in this position by a letter of Mr Bertrand Russell just as the printing of this volume was nearing completion".*

Russell felt so bad about this turn of events, caused by the discovery of his paradox, that he and Alfred Whitehead spent the next decade developing their theory of types, intended as a solid foundation of set theory (and all of mathematics) that avoids paradoxes, in their major work *Principia Mathematica* (Whitehead and Russell (1913)). Frege had firmly believed himself to be taking the academic world through a major portal with the development of the foundations of mathematics, only to have the door slammed in his face, then sliding backwards through liminal space to a chaos from

which he never fully recovered. Russell and Whitehead however struggled for many years through their own liminal spaces and published their own treatise in an incomplete form (*Principia* was intended to be four volumes, but only three were finished). Nevertheless they created their own *"shoulders of giants"* and Kurt Gödel (1931) was to pick up on their main ideas and forge his celebrated and revolutionary *Incompleteness Theorem*, which tells us that number theory is essentially incomplete, in the sense that true statements can be formulated in number theory that cannot be proved within number theory (but only by stepping outside number theory). The proof relies on setting up within number theory the so-called *Gödel statement*, which is essentially an elaborate reformulation of Russell's Paradox:

> *"This statement is unprovable".*

This self-reflective statement (accepting that it can be formulated somehow in number theory) must be true, by the soundness of first order logic, and therefore, at the same time, unprovable. Gödel (1929) had earlier, in his doctoral thesis, proved the completeness of first order logic (all statements that are true in all models are provable in first order logic) and it was an open problem whether provability was decidable, that is, whether a simple algorithm exists for deciding whether any give statement in first order logic is provable or not. This is the famous *Entscheidungsproblem* of David Hilbert (see Hilbert and Ackermann (1928)). For example, monadic first order logic (that uses only predicates, not binary or other multivalued relations) had been proven to be decidable by Lowenheim (1915) and there appeared to be major stumbling blocks to taking this further. The first thirty years of the twentieth century were a seething whirlpool of activity amidst uncertainty, as people strove towards false hopes and conclusions, with only partial results and shifting sands, with elusive apparitions of portals in the distance. In 1936 Alonzo Church (1936) published a negative answer to Hilbert's question, that indeed first order logic is undecidable. His method used the so-called *lambda calculus*, which was equivalent to another invention by one of Church's students, Alan Turing, the so-called *Turing machines.* Turing had also proved, independently of Church, the negative answer to the Entscheidungsproblem, and rushed his answer into print (Turing (1937)). He first set up the so-called *Halting Problem* and proved this to be unsolvable: no algorithm exists that can decide whether any given Turing machine halts with any given input. Turing then showed that the logical consequences of the list of instructions defining any Turing machine may be encoded using the language of first order logic. This implies that any decision algorithm for first order logic necessarily entails a decision algorithm for the Halting Problem, which does not exist. Hence no decision algorithm for provability of first order logic exists. This method yields a template for undecidability results in general that has become the golden standard ever since:

> *"To prove that a given problem in mathematics is undecidable, reduce it to the Halting Problem for Turing machines".*

The unsolvability of the Halting Problem is one of the grandest portals in modern mathematics. The key that unlocks the door is the idea of self-reference, in this case a machine that looks at its own instructions, the ultimate navel-gazer. Turing's lock and key were forged in the sea of liminality that evolved from the extraordinary saga of Russell and Frege (superbly paraphrased and illustrated in *Logicomix* by Doxiadis and Papadimitriou (2009)).

CONCLUSION

It has not been the purpose of this paper to preach about mathematics: good mathematics speaks for itself. However, we have offered examples and anecdotes that are novel in nature, with the intention of seeding or provoking reactions from the reader or from participants in our workshops and training sessions for tertiary mathematics instructors and educators. John Dewey (1933) advises that we do not learn from experience but rather from *reflecting* on experience. Brian Foley (2012) refers to this process as *meta-learning* and applies the idea systematically and successfully to pedagogy in engineering. Land *et al.* (2005) emphasise the naturally oscillatory or recursive behaviour that typifies successful movement between pre-liminal and liminal phases. Recursion is, in essence, reflective or self-referential. Cousin (2006) distinguishes this dynamic and often troublesome or unsettling process from the more counterfeit alternative of superficial 'mimicry' (which is, unfortunately, often encouraged and even rewarded). Plato tells a pupil to *"know thyself"* (Jowett (1892)), with the intention of developing the habit of lifelong, self-reflective learning. In the spirit of Plato, we have invited and continue to invite people, from all backgrounds and interests, to engage in profitable introspection of their mathematical experiences and

1: Offer their own examples where they have been switched on or turned off mathematics by some pivotal incident that behaved like a threshold or impenetrable barrier.

2: Explore underlying reasons for the importance of such incidents and how they relate to threshold concepts, especially the means by which learners become stuck or repelled, but nevertheless find their way through liminal spaces.

3: Make suggestions about how these incidents and experiences can inform practice towards improving the teaching and learning of mathematics. (Easdown (2011a))

This models our own practice in university classrooms where we encourage tertiary students to confront their prior learning in mathematics.

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ENGINEERING PROBLEM SOLVING: UNCOVERING A THRESHOLD EXPERIENCE AND TRIGGERING A META-LEARNING RESPONSE

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Biographical Note

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KEYWORDS

Threshold concepts, threshold experiences, problem solving, metalearning

ABSTRACT

Problem solving is core to both the formation and practice of engineering. While students are typically nonplussed by routine textbook problems, when confronted by less straightforward scenarios, such as open-ended problems, multisolution problems, or serious complexity, they can find the experience troublesome, particularly freshman students. Treating engineering problem solving within a threshold experience framework, this paper seeks to investigate both the troublesome and transformative aspects with particular reference to electronic engineering and to investigate the impact of induced metalearning.

Many College-based engineering programmes now incorporate some formal training in generic problem solving skills. While the reaction to such modules is typically positive, the longterm impact is limited, mostly because the training is inadequately grounded in the particular discipline. A similar critique can be made in respect of efforts to make students aware of their own learning in a metalearning sense. Meyer (2010) has suggested that better results might be obtained from metalearning initiatives by making them less generic and embedding them more in the target discipline. This, he further suggests, can be given effect within a threshold concepts framework.

This paper reports on a study of this type in which the problem solving practices of a group of engineering students were investigated over a period of time. The design of the study is such that not only are the troublesome and empowering dimensions of electronic circuit problem solving under scrutiny, but the participants are required to consciously and critically reflect on the approaches they adopt. The study reveals a definite progression in problem solving skills with an increasing degree of sophistication in the discourse of problem solving being a particular outcome.

INTRODUCTION

Problem solving is very much core to both the formation and practice of engineering. Problems can range from the straightforward tasks of formula selection and data manipulation through a development style of problem extending or applying basic principles, coping with multiple methods and/or solutions and dealing with model limitations. At the upper end of the range are found truly complex problems where complexity can arise from the scale of the problem, from ill-defined given information, or from the nature of constraints. While students are typically reasonably adept at routine textbook problems, the evidence suggests that, when confronted by the developmental or complex style of problem, they can find the experience troublesome, particularly freshman students (Entwistle, 2005).

In this study of engineering problem solving, we make use of not only the threshold concepts framework but also the linkage to metalearning (Meyer, 2010) – the capacity of a student to be aware of and to take control of their own learning. Meyer *et al.* (2009) have demonstrated a link between developing metalearning capacity and overcoming threshold concepts in economics. The question posed here is: can we find a mechanism to trigger the development of a metalearning capacity in relation to engineering problem solving? If so, can such a capacity help in guiding the students

through the threshold experiences associated with engineering problem solving? One particular thread that was found useful in these explorations is that of self-explanations (Chi *et al.*, 1989, 1994).

ENGINGEERING PROBLEM SOLVING AND THRESHOLD CONCEPTS

As a discipline, engineering is primarily about devising systems, components, or processes as solutions to real world requirements. The discipline is thus characterized by a very tight relationship between declarative, procedural, and constraint knowledge, as epitomized by the focus on all levels of problem solving. Some college engineering programmes now incorporate an element of formal training in generic problem solving (Woods, 1997) and, while the response to such initiatives is undoubtedly positive, the longer term impact is less clear-cut, perhaps because the training is not sufficiently grounded in the target discipline. One particular advantage of the threshold concepts paradigm is that the disciplinary basis is firmly embedded (Meyer and Land, 2003).

In common with other disciplines, the research literature identifies many engineering threshold concepts of the declarative type (Streveler, 2008; Flanagan, 2010). Inevitably, however, the studies broaden out to also incorporate knowledge of procedural and constraint types (Carstensen and Bernhard, 2008; Harlow, 2010; Foley, 2010). In these broader contexts, rather than the term 'threshold concept,' the terms 'threshold function' (Meyer and Land, 2003) or 'threshold experience' (Perkins, 2010) have been used. In particular, Meyer and Land (2003) have seen the achievement of a threshold concept/function as leading to new and distinctive ways of thinking and practicing; that one begins to think and act like an engineer or economist. Perkins (2010) posits conceptual development as a three-stage journey with threshold experiences present at all stages and necessary for progression to the next stage. The object stage focuses on key features and concepts, basic applications, comparison and critique. The tool stage is characterized by operative concepts, fully developed applications, and the ability to select one from many and apply. The frame stage features systems of many concepts, open problems, new applications. Threshold experiences are associated with fundamental shifts of role on the journey through these stages. Transposed to the engineering problem domain, these three stages can be seen as corresponding to the three levels of problem solving.

METACOGNITION AND SELF-EXPLANATIONS

The notion of metacognition posits a two-way communication link between the level of actual learning and the metalearning level (Christof, 2006). On the one hand, if the metalearning level is to be brought into the picture, the learner has to become aware or be made aware of their actual learning, how it is characterized, its strengths and weaknesses etc. In tandem, if the metalearning resources are to be deployed, appropriate guiding information has to be communicated back to the level of actual learning. In this way, the learner takes control of and regulates their own learning.

A key question then is: can mechanisms targeted at opening up and enhancing this two-way communication process assist in the attainment of threshold concepts and threshold functions/experiences? Meyer *et al.* (2009) report on one approach aimed specifically at declarative threshold concepts in economics and based on the use of a learning inventory tool. The threshold experiences embedded in the more procedurally oriented domain of engineering problem solving might necessitate a different, broader approach to opening up the metalearning level. In a series of papers, Chi *et al.* (1989, 1994) have investigated the use of self-explanations in supporting both problem solving and general understanding. In relation to problem solving, Chi's work focused not so much on problem solving per se as on students' study of worked problem solutions such as one typically finds in textbooks. Having studied a number of such examples, students were then asked to explain the examples in their own words. Their later performance at tackling both similar and 'far-off' problems was monitored and basically showed that 'good' students offered more complete explanations and could better identify their own successes and failures. For the study reported here, use has also been made of the self-explanation mechanism but as applied directly to problem solving activities.

THE STUDY

This study was carried out in conjunction with a one-semester foundation course in electronics, a module taken by all freshman students on the engineering programme at the University of Dublin, Trinity College. A relatively small, but representative of all abilities, volunteer group of fifteen was drawn from the full cohort of 175 students. The course features an introduction to both digital and analogue electronics, with analogue traditionally regarded as the more difficult (Entwistle, 2005). In addition to a lecture and laboratory programme, there was a weekly one-hour tutorial slot given over to problem solving. Each week, there was an individual problem sheet with a set of problems carefully selected so as to range from the straightforward to the complex. The essential methodology employed was as follows. Each

volunteer student was asked to complete a response exercise in tandem with a problem sheet and there was a succession of such exercises distributed across the semester. There were three components to each exercise:

I. The student was invited to provide a detailed self-explanation for that problem closest to the limit of their capability. It could be a problem they had managed to solve or one at which they had failed; at the very least, it would have caused some trouble.
II. The student was then invited to specify and discuss the troublesome aspects.
III. Finally, the student was invited to reflect on what they might have learned from the exercise.

While some prompt headings were provided, the three questions were framed as broadly as possible – including unresolved ambiguities – to allow students free rein with their responses. The idea behind the first two questions was to open up the channel to metalearning by triggering the awareness/monitoring function. Question 3 was an attempt to elicit whether there might have been any overall gains at either the metalearning or actual learning level.

What might distinguish this study from others is that the response exercise was repeated at semi-regular intervals throughout the semester with the intention of identifying changing patterns of problem solving. Despite keeping the exercise as brief as possible, it did nevertheless constitute a workload overhead for the participating students so that, over time, some of them fell out of step with the distribution of the response forms. Eventually eleven of the fifteen completed the full set of response exercises, enough to build a reasonably coherent picture of how patterns evolved over the semester.

RESULTS

Having read and re-read the responses numerous times and attempted various categorization schemes, the following three-stage picture emerged.

STAGE 1

As might be expected for the early weeks of a new subject – albeit the supposedly easier digital component – students were experiencing difficulties. Some were completely at a loss:

> *"As soon as I saw the symbol ⊕, I was completely put off by the question…You could say that my initial problem with the question was panicing when I didn't recognize the problem, which blocked my logical reasoning and made me give up".*

Others were prepared to confront this new territory:

> *"As this question was new to me, I also had some difficulty with analyzing this unfamiliar scenario. One of the methods I personally use to solve any problem is to try and relate it to something that I have seen before. I tried to do this by comparing this question with question 3, but I still found it difficult to analyse what exactly I was required to do".*

And there was even a hint at meta-learning opening:

> *"When I looked over the questions, I found that I was quickly able to retrace my thought process and visualize how to go about tackling the problems. I feel that by revisiting these questions and consciously thinking about the specific question that I struggled with the most I have given myself a good starting point in order to tackle a question like this in the future".*

The overall impression though is that at this stage problem solving is very much in the liminal state.

STAGE 2

Not unexpectedly, this stage is characterized by progression, coming to terms with the unfamiliar territory, and better articulation of what is causing trouble:

> *"Firstly, the wording of the question was a bit confusing, as I was not sure how to write the truth table agreeable to the conditions. After working that out, it became easier, until using XOR gates only, which caused a bit of an issue, however after a lot of moving things around (including a few completely wrong attempts) I managed to obtain the solution".*

A capacity to self-diagnose appears:

"Writing out the second tier of the circuit showed me I am not effectively solving the problem by drawing circuits. It is a very hit-and-miss method and I would be more successful if I could mathematically change the expression into something that I could relate to an exclusive-OR function".

Most interestingly, there is the first appearance of direct evidence for self-explanation reaching the metalearning level:

"I have consciously thought about the other ways that the question could be solved and have made myself feel much more comfortable with doing similar or harder problems like these in the future. It has allowed me to link many of the things learned so far and use them all together".

It should be noted that the above is but one of a number of possible similar quotes. So, clearly, we can observe that, while the students are still struggling with their problem solving and are therefore still in a liminal state, things are not static. There is a heightened sense of awareness and purpose; the level of discourse has developed.

STAGE 3

Although the syllabus for this stage exclusively encompasses the traditionally more difficult analogue electronics, the pace of progression is maintained. Unusual scenarios do not intimidate to the same extent; there can even be a degree of confidence with respect to how complex problems are handled:

"Rc is an unusual case because the resistance can vary depending on the length of the cable. To find Rc I must let Rc be the only unknown in the equation… Now I have all the values I need. I have my Rc equation in terms of Rc squared, Rc, and the constants. This is the first time two possible values have been possible. There is one positive and one negative answer. Negative resistances are not considered answers, so I now have a value for Rc and can find the length of cable".

The self-explanations are now clear, lucid, and detailed, consistent with the conditions identified by Chi *et al.* (1989, 1994) for better problem solving and understanding:

The most striking element to emerge at this stage is the integrating feature of threshold concepts:

"I think where I struggled here was bringing together different things I know to get a solution.

I found the problems really made me think about everything we had discussed in the lectures and which needed to be applied in these particular problems and how they should be applied".

The vista is broader and the student is looking outward to other applications and 'variations':

"I am now more assured when I encounter a problem which can be solved using Thevenin's theorem; I will recognize the type of problem and deal with it accordingly.

It made me think deeply about the concepts involved… I can now see how to apply my knowledge to other variations of amplifier circuits… I realize that applying theories such as voltage divider and superposition are key concepts in simplifying these problems".

DISCUSSION

The results from the analysis indicate a clear and definite progression in problem solving capacity. Framing the progression in threshold concept terms, we first encounter strangeness and intimidation, but then, with the territory gaining some familiarization, we progress to 'giving it a go' and a clearer articulation of the difficulties. Students begin eventually to consciously think about their approach to a problem. The discourse develops clarity and lucidity, and incorporates sophisticated technical detail. Parts, once separate, begin to integrate and a broader vista comes into view.

Unlike the achievement of a threshold concept, a single event, significant progress in problem solving can be seen as a series of threshold experiences along the developmental lines of Perkins (2010). Recognisable features of the threshold concept, such as the troublesome element and the liminal space, are apparent, but the increasing powers of discourse and the sense of previously disparate elements coming together are particularly noticeable, as is the wider perspective for applying the skills gained.

CONCLUSION

This study has shown that self-explanation applied directly to the activity of problem solving can open up processes associated with metalearning. By interrogating these processes in a group of engineering students taking a foundation course in electronics, it was possible to observe a definite progression in problem solving skills. Discourse was suggested

as the key mediating agent in linking the self-explanations with, and promoting, metalearning capacity. An increasing degree of sophistication in discourse in and around problem solving was noted as one of the outcomes from repeated triggering of the metalearning level. Further work is required to establish a direct link with actual problem solving ability.

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THE HERO'S JOURNEY: UNCOVERING THRESHOLD BARRIERS, DISPOSITIONS AND PRACTICES AMONG OCCUPATIONAL THERAPY STUDENTS

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KEYWORDS
Narrative research, threshold barriers, transition-to-practice, self-confidence, teamwork

ABSTRACT
This paper reports the findings of a study of final year La Trobe University occupational therapy students and their journey through their program. The study aimed to ascertain what learning concepts and elements of professional practice they identified as troublesome or challenging along the way. Reflective narratives tracing the student's journey into and through the course were collected and thematically analysed. A subsequent focus group served a member-checking function. Students were prompted to structure a written narrative using an adaptation of the American mythologist and writer, Joseph Campbell's *Hero's Journey* phases. The students utilised these phases to identify key thresholds and troublesome concepts, in addition to reflecting on their 'ah-ha' moments where they felt they had emerged transformed. The study was set within the final academic subject for the course, a capstone subject which aims to build upon a range of professional competencies for imminent practice. Higher education research has described troublesome ideas as threshold concepts and sees the crossing of these thresholds as critical to successful educational journeys (Meyer and Land, 2006). It is proposed that students' reflection on their (we hope, transformational) journeys from learner to practitioner can provide critical information to raise staff awareness of troublesome knowledge in the curriculum. Improved understanding about students' perceptions of troublesome knowledge should inform curriculum modification and/or a need for enhanced support to students at points identified as troublesome. The ultimate aim is to be better informed about threshold concepts and troublesome knowledge in the curriculum. The Hero's Journey structure provided a novel framework enabling increasingly 'feedback jaded' students to enthusiastically plot out their story, to be kept as an educational, personal and professional record as they approached the student-practitioner threshold of their journey.

INTRODUCTION
This paper describes the process and findings of a study of final year occupational therapy students' journey through their program. We aimed to pinpoint barriers or thresholds (Kabo and Bailey, 2010) in learning from the perspective of students transitioning to practice in an effort to understand more about threshold concepts for the discipline of occupational therapy. We reasoned that confronting barriers and crossing learning thresholds was critical to successful educational journeys, and that evidence of this may be revealed in students' *learning journey* narratives. It was proposed that analysis of narratives would reveal critical information about troublesome knowledge (Perkins, 2006) that could inform curriculum modification.

EXPLORING THE JOURNEY: UNCOVERING STUDENTS' '*AH-HA*' AND TROUBLESOME MOMENTS
As part of the final academic subject *Advanced Professional Practice*, a masters level capstone within a graduate entry program, students are required to reflect on their entire program experience, in preparation for graduation and entry to professional practice. The narrative is submitted as part of the subject, and among consenting students, was used as empirical data for this study. In keeping with the idea of a *journey* we turned to the work of Joseph Campbell, the American writer and mythologist to help us create an inspirational task to prompt students to elucidate key moments of the journey that they had undertaken. Drawing on James Joyce's idea of the 'monomyth', Campbell summarised the hero's *adventure* (1993, p. 245) as a common pathway followed by all mythic heroes, and marked by three key phases: *Departure*, *Initiation* (the beginning of transformation) and *Return*. A simplified version of the journey is represented in Figure 1.

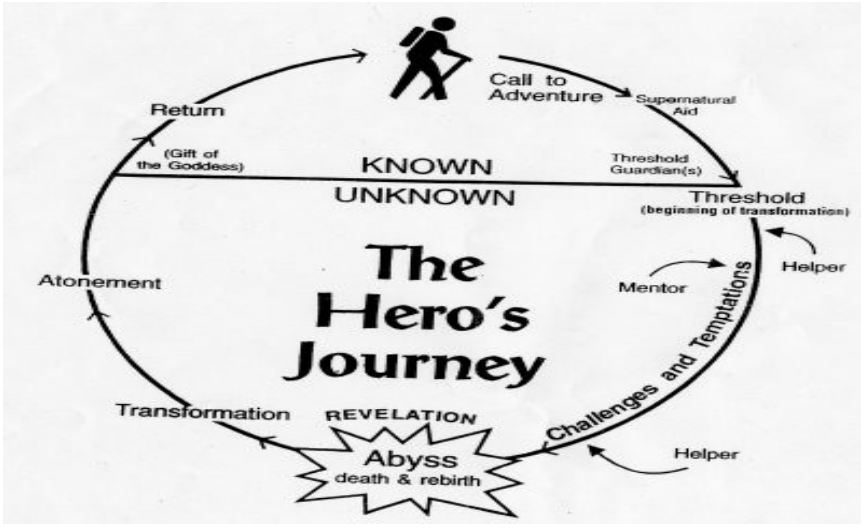

Figure 1: Joseph Campbell's Hero's Journey stage[1]

As captured in Figure 2 below, the *hero's journey* stages were felt to be highly salient to the student journey. While all students were required to submit a narrative, they were free to decline consent in terms of analysis. Thus, only the reflective accounts of those students who consented to participate form part of our findings. In total, ten students consented to analysis, approximately 30% of the total cohort. The average word length of narratives returned was 1,500 words.

Campbell's Stages	Our students' journey
Departure Call to adventure – a 'haphazard' stumble, duty, need for change Supernatural Aid – amulets; wands	A strong desire to help Seeking a "useful" & practical degree Motivation, $$, High marks, parental/partner support
Initiation Crossing the first threshold; Meeting threshold guardians Transformation begins	Selection; Campus/Systems Introduction to a new language and way of thinking
The road of trials, challenges and temptations 'Belly of the whale'	Assessment tasks, Deadlines; Working with peers; Part time work The quagmire of theory;
Mentors, allies, enemies, helpers	Tutors, fieldwork supervisors, peers
Crisis, Abyss, Death & Rebirth	Failure; personal problems, Loss of faith
Return Transformation, atonement, re-birth; Seize the sword	Ah-ha! New understandings. Realisation of understandings & skills gained Emergence as a professional.

Figure 2: Comparison of hero and student journey

Narrative analysis (Riessman, 1993) was used to interpret the reflective accounts. We identified and generated themes within each response and searched across responses for recurring and contrasting themes to develop an understanding of troublesome knowledge and learning barriers among individuals and the cohort.

FINDINGS

Our analysis of the narratives highlighted the following four themes: *Teamwork as a barrier to learning and practice; Conceptual learning as a barrier to practice; Practice as the bridge to conceptual understanding;* and *Confidence as barrier*

[1] Source: http://en.wikipedia.org/wiki/File:Heroesjourney.svg

and boon. The themes satisfy some of the criteria for threshold concepts in that they were troublesome and transformational, at least for some students. We were less convinced however, that they were bounded and/or irreversible. The way the questions were framed may not have allowed students to describe these elements fully and is noted as a limitation of the study.

TEAM WORK AS A BARRIER TO LEARNING AND PRACTICE

Students are put into groups and asked to work in teams for many learning tasks. Students' reflections on this important graduate attribute indicate that teamwork was a genuine barrier in terms of negotiating the program.

"One part of the degree that has been hard at times is the group work… there have been some challenging moments".

The teamwork barrier created stress and problems with time management

"...I am suddenly needing to put in 30 hours of school work a week due to problems with group dynamics… I have never been so stressed".

Students' reference to the problematic nature of teamwork highlighted for us that they seemed to see their engagement in teamwork primarily as participation in various learning tasks, rather than viewing teamwork as a learning process and outcome in its own right. They appeared to be 'stuck' between a space of *enduring tasks as part of a group*, and a more professional space where *interdependent teamwork is embraced* as vital. Toward the end of the journey, students seem to oscillate closer toward that professional space.

"I have learned better ways of dealing with conflict and strategies for working with conflicting personality types so I suppose it hasn't been all bad".

The notion of teamwork as a learning barrier highlights for us the need to more explicitly foreground the team challenges that students are likely to encounter in practice, and to ensure that learning about teamwork is modeled on authentic tasks that graduates need to be adept at managing. Educators and students need to view teamwork as a more complex and sophisticated learning concept and practice skill, and while it may not be a discipline specific skill, it is critical to *effective* professional practice – to ways of thinking and practising as a health professional (Fossey, 2001). Our students appear to acknowledge the importance of teamwork as they near the end of their journey, and the challenge we have in the curriculum is a recursive one.

CONCEPTUAL LEARNING AS A BARRIER TO PRACTICE

Students' narratives revealed that thinking conceptually, or learning about theory, was a potential barrier to practice. Conceptual learning created a barrier that effectively got in the way of getting on with 'doing' occupational therapy. A barrier to learning 'how to do it' is having to learn the 'concepts that support the doing'. Student comments included:

"At times there seemed to have been too much theory and not a lot of field work experience".

We reasoned that academics who focused on conceptual understanding versus practical know-how could be viewed by students as *threshold guardians*, holding the student back from practice, while the real heroes, the *archenemy* of the conceptually minded academic, were the practice based supervisors. One student stated:

"Many 'ah-ha' moments happened for me during placement, for example, when I first really understood what a 'psychotic episode' was. I had a great supervisor who worked me through the moment and helped me reflect and learn from the experience. There weren't too many 'ah-ha' moments in terms of theoretical concepts".

This student's reference to a mentor, further establishes the practice educator as 'heroine' and saviour:

"She is the a clinician I hope to become with more practice and experience. I had many ah-ha moments under her guidance, and feel so lucky that I had her as a supervisor, especially at a time when I was getting fed up with the course. The placement helped me remember why I wanted to be an OT".

Occupational therapy students and the profession generally, have a strong common sense orientation toward doing. Kabo and Bailey's (2006) explorations of engineering students' struggles with the concept of social justice in engineering practice revealed that those students had a collective 'common sense' orientation towards professionalism, which was grounded in technical development. Having to think about social justice issues was a potential barrier to students' common sense understanding of engineering, which emphasises technological development, rather than solving social problems. We wondered if similarly, occupational therapy students' pragmatic orientation to occupational therapy practice predisposed their struggle with using theory. The barrier is perhaps also reinforced by the tacit knowledge of

both the student and the supervisor. As Perkins states *"learners' tacit presumptions can miss the target by miles, and teachers more seasoned tacit presumptions can operate like conceptual submarines that learners never manage to detect or surface"* (2006, p. 40).

Conceptual thinking was also revealed to be a different sort of barrier to practice among conceptually 'predisposed' students. While the majority of students struggled with the conceptual and thrived with the practical, for one student, who identified strongly with the conceptual and philosophical underpinnings of the profession, the opposite was revealed. The student described a personal crisis when congruence with these underpinnings was not encountered in practice.

"… I began to see that occupational therapy was not only a profession but a philosophy... Reflecting back now I see that this was both good and bad… bad because I started to create high expectations of what I thought I… should see happening in the field... this is something that proved quite challenging in a number of placements… this worried me greatly as I did not want to appear like a know-it-all, but I was also aware that sometimes clients' needs were not being met".

A number of studies focused on transition-to-practice have highlighted that fieldwork supervisors and employers can reinforce the idea that conceptual thinking is something for doing at university rather than during fieldwork or in the workplace. For example, Barnitt and Salmond (2000) noted that some employers said they wanted 'therapists' rather than 'graduates', and highlighted how graduates can encounter colleagues who discourage evidence based and reflective practice. How we help students confront these barriers as they attempt to apply theoretical understanding in the context of practice, '*pragmatic reasoning',* requires further thought by educators, because, as Kielhofner (1992) states *"without the force of that conceptual foundation, which explains and justifies the service, the pragmatic work of therapists would have little value for society"* (p. 3). There is a need to prepare students to skilfully manage their response to fieldwork supervisors whose work appears to lack an accepted conceptual base, or is otherwise obscured by its tacit nature. A possible threshold skill relates to how students and new graduates manage resistance to their *conceptual or questioning disposition* that ideally we as educators wish to encourage.

PRACTICE BARRIERS AS THE BRIDGE TO CONCEPTUAL UNDERSTANDING

Challenging our original idea that students' thirst to practice was in some cases, leading them to fail to engage deeply, or see the relevance of theory, it became apparent that amid the practical learning, a number of students were coming to appreciate that theory did matter, and that intuition or common sense were not enough. We reasoned that practice presented barriers that demanded rapid re-acquaintance with theory; that learning 'to do it' could only proceed so far before one had to re-engage with the concepts that support and help to make sense of practice. Practice thus, becomes the conduit or bridge that triggers the use of theory to support action when simply 'being pragmatic' wasn't enough. One student talked about being encouraged to think conceptually by their supervisor.

"It was during my last placement where my supervisor pulled me up... and asked me to use a model… It helped me join up all the dots and make sense of things…"

These supervisors could be thought of as constituting what Land *et al.* (2005) refer to as a *"supportive liminal environment"* (p. 55), a powerful determinant of a student's ability to fully integrate threshold concepts. Another student wrote about how the theoretical 'struggle' can be made intelligible by the practical.

"I found that when you learn the conceptual models and theory it can be a struggle to make sense of it all. However, when applied to a real life situation… it all comes together nicely".

The idea of practice as a bridge is consistent with Meyer and Land's (2006) identification that some concepts are like gateways or portals, capable of opening up previously difficult conceptual material.

CONFIDENCE AS BARRIER AND BOON

Many students referred to confidence as being a barrier to learning. The nature of the program means that in many ways, students' confidence is tested from the start, as they engage in small group problem based learning tutorials, and peer learning and teaching. The course structure has the capacity to support or challenge confidence as did mentors, and peers. For example:

"Confidence was always a big issue due to the competitive nature of some of the people in the course".

An important threshold that some students appeared to have crossed in relation to confidence was evident in their newfound understanding that they did not need to know everything in order to begin practice.

"After speaking to my supervisor, and with time, I came to understand that it was early days, I would get there, and that part of being a good OT is having confidence... While I doubt myself less now, this is something I'm still working on".

Another said

"I wouldn't say I am confident that I will know everything I will need to know for a given job but I feel confident I can learn".

Barnett (2004) implies that accomplishments such as knowledge and understanding, and the acquisition of skills form only part of the picture; another part is the development of '*self-belief, self-confidence and self-motivation'* (p.254). Our final quote captures how trust, evolving competence and motivation are interdependent, and capable of carrying the student forward into the future on a continuing learning journey.

"At the beginning of this course I felt I was lacking in practical skills... I feel like I have improved in all of the skills the course promises – communication, teamwork, problem solving, leadership. Most importantly I've come to trust that OT works and I want to learn how to do it well".

Our students' comments about confidence highlight the importance of our duty to foster dispositions that support lifelong learning. Again Barnett has much to say on this: *"tutors have no more significant responsibility than that of helping the student to acquire a proper level of self-belief"* (2007, p. 58). All of this prompts us to question the existence of *threshold dispositions*.

DISCUSSION

Many of the students' narratives highlighted a 'call to adventure' centred on being helpful, useful, "*excited by the wide range of applications"* or because *"OTs fix things".* In a context where students are pragmatically motivated from the outset, different considerations are required on the part of educators to ensure theory is not sidelined in what is (to the layperson at least) a visibly commonsense practice. In a study of threshold concepts in practice education, Tanner (2011) highlighted that students do possess conceptual understandings relevant to practice contexts, but have trouble with application. The need to enable students to apply theoretical understanding in the context of practice, *pragmatic reasoning,* raised in our minds whether pragmatic reasoning was a 'threshold skill', similar to Tanner's (2011) proposed threshold concept "*practising in the real world"* (p. 433).

Our findings raise interesting issues about us as educators. While our original study justification centered on identifying and redeveloping troubling aspects of the curriculum, our subsequent reflections lead us to question this need to fix or remove the barriers for students. The Hero's journey framework has enabled us to view that all significant transformational journeys are comprised of thresholds or barriers to be traversed. Our reflections reveal much about our discomfort with our students' troublesome but necessary journey. Learning to 'sit' knowingly with students' discomfort rather than rushing in to 'fix up' the curriculum has been a critical 'ah-ha' moment for us. Salient to these reflections are Mezirow's idea of transformation following disorienting dilemmas (2000), and Meyer and Land's (2006) observations that liminality as a state of being may have a transformative function. Despite these insights, how we work with graduate entry students eager to learn 'through' practice needs consideration, in terms of additional strategies to be utilised before, during and after practice experiences (Billet, 2009). Helping students make more of the conceptual insights we hope they will have beforehand, and teasing out relevant points for conceptual 'deepening' during and after practice education, seems warranted.

CONCLUSION

While threshold concepts for the discipline were not revealed through this study the threshold concepts framework, and more specifically the notion of *thresholds* or *barriers* to learning, has been highly useful in attempting to pinpoint what is troubling to students in their journey toward practising as an occupational therapist. Like other practice professions, occupational therapy is characterised by an apparent commonsense way of working, which for students can be at odds with the sorts of conceptual know-how that educators demand they have. It is evident that students struggle with this conceptual-practice dichotomy, and that these struggles can be reinforced in the field. Equally, however, in 'supportive liminal environments' students can make sense of material that appears conceptually complex in another environment, and gain much needed confidence to make that ontological shift from student to professional. For after the journey is complete, one of the hero's solemn tasks is, according to Campbell, *"to return to us, transfigured, and teach to us the lessons he has learned of life renewed"* (1993, p. 20).

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STUDENTS' PERCEPTIONS OF TRAVEL THROUGH THE LIMINAL SPACE: LESSONS FOR TEACHING

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Biographical Note

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KEYWORDS

Threshold concepts, liminal space, analogue electronics, teaching strategies

ABSTRACT

This paper presents findings from a study in which educational researchers followed the progress of analogue electronics students over their first two years at university.

In this study, the lecturer's main motivation was to examine how a teaching-focus on threshold concepts might help students grasp troublesome ideas and if those students who grasped the threshold concepts achieved higher scores in the end-of-course examination. The lecturer identified two concepts in the first-year course which students repeatedly found hard to grasp. He focused his teaching on these concepts in the first year, and revisited them, albeit indirectly, throughout the second-year course.

Over the two years, the lecturer utilised a variety of teaching strategies to facilitate students' learning of the troublesome concepts. In order to evaluate the effects of these strategies on student learning, an educational researcher, in collaboration with the lecturer, explored students' perceptions about where they 'got stuck' and what helped them understand the selected threshold concepts. Data from student surveys, individual interviews, and focus groups contributed to insights about their experience of transition through the liminal space. The lecturer and researcher reflected on and analysed the lecturer's teaching strategies using video-stimulated reflective dialogue.

Findings revealed that many students did not fully grasp the two identified threshold concepts in their first year, however, repeated experiences with threshold concepts through varied teaching strategies, and a diversity of learning contexts contributed to students' understanding. In the second year, the continuing students felt that they took the threshold concepts for granted and had ceased to regard them as troublesome. They reported that grasping these threshold concepts was necessary to progress in analogue electronics. Findings of this study indicate that travel through the liminal space can be supported by an explicit and sustained focus on threshold concepts.

INTRODUCTION

"*I don't know why this is so hard for me! I'm trying so hard to grasp this!" (First-year student)*

In first-year tertiary analogue electronics courses there are threshold concepts (TCs) that students repeatedly find hard to grasp. Over two years we examined if and how a focus on threshold concepts teaching might help students grasp these TCs. The lecturer identified and focused his teaching on two TCs in the first year, and revisited them throughout the second year. He utilised a variety of teaching and assessment strategies to facilitate students' learning. Data from student surveys, interviews, and focus groups revealed that students did not fully grasp the two TCs in their first year. However, repeated experiences with these concepts through varied teaching strategies and a diversity of learning contexts contributed to students' understandings in the second year. Findings indicate that travel through the liminal space can be supported by an explicit and sustained focus on threshold concepts.

THE STUDY

In 2010, our preliminary study examined first-year electronics students' understanding of two lecturer-identified TCs: Thévenin's theorem[2] and dynamic resistance[3]. Findings revealed that a TC lens was useful for the lecturer to revise the pedagogy (Scott *et al.,* 2010). The study uncovered places where students 'got stuck' as they encountered the two TCs (Harlow *et al.,* 2011). In 2011 student surveys and interview data were correlated with grades in first and second-year courses. This paper focuses on second-year students' perceptions of learning, outlines teaching and assessment strategies, and offers recommendations for teachers.

TEACHING AND ASSESSMENT STRATEGIES

From our 2010 study, the lecturer knew that students had difficulty understanding the troublesome concept of dynamic resistance. He was aware that analogies could provide learners with new ways of thinking about a phenomenon (Roth, 2006; Bishop, 2006), so to help second-year students understand this threshold concept the lecturer used a *chocolate bar cost* analogy. This threshold concept in the field of economics was employed as a window through which students could view the troublesome concept of dynamic resistance.

> *"I wrote on the whiteboard, 'If I pay $10 for 10 chocolate bars, how much does each bar cost?' I tell them the price depends upon which bar and how you calculate it. I explain that 'marginal' and 'overall' costs are different. This is the same idea as static or dc resistance and dynamic or ac resistance, that we might have called 'marginal resistance'. They seem to get this. Sometime soon after that lots of them get the idea of the two definitions of resistance, and we are on the road through the portal".*

The lecturer also trialled two new assessment approaches – scratch cards and repeated Year 1 questions.

- *Scratch cards:* The use of an *Immediate Feedback Assessment Test* (IFAT[4]) was combined with student collaboration. Namely, several students in collaboration choose answers to ten problems by scratching out a square on a scratch card for each problem. If students do not answer correctly the first time around they have the opportunity to collaborate to choose another answer. The correct answer is worth four points and so on down to zero points for the fifth attempt. Students are encouraged to argue their case when an incorrect answer is selected by the group.
- *Repeated questions:* The TC question on dynamic resistance from the first-year final exam was given to all second-year students (six months after the exam). Students did not do well on this occasion. The lecturer attended to the gaps in their knowledge in a follow-up lecture. At the end of the semester the same question was given to the students again. Table 1 shows results for the fourteen students participating in the research over two years.

Table 1: Threshold Concept question on Dynamic Resistance (DR)

	1st year exam DR question (Dec '10)	2nd year start of semester DR question (Aug '11)	2nd year end of semester DR question (Oct '11)	2nd year exam question requiring an understanding of DR (Dec '11)
Average grade (14 students)	71%	50%	96%	48%

Results indicated that a year after first learning the TC many students were not able to answer the same question. After revisiting the TC within a shorter timeframe, students were more confident in recognising the problem. Applying that same knowledge in a different context, in the final 2011 exam question proved troublesome and the correct response rate was comparable to that from the start of the semester.

[2] Thévenin's theorem is an example of modelling. It is the idea that any circuit can be modelled with a voltage source and a resistor in series.
[3] Dynamic resistance is the ability to substitute a bias-dependent linear component for a non-linear one, subject to the application of only small-signal AC signals.
[4] An Immediate Feedback Assessment Test (IFAT or scratch card) is a card with squares that are scratched away to reveal a star if the chosen multi-choice answer is correct.

The eighteen second-year students' total grades (internal and final exam marks) were categorised into three groups: A (over 69%); B (between 49-69%); and C (under 49%). Figure 1 shows a comparison between 2010 and 2011 average exam marks for the three groups.

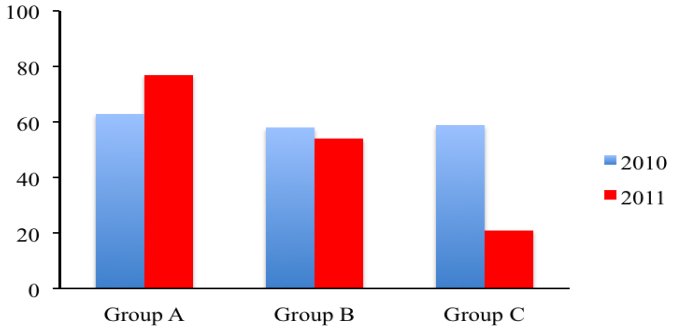

Figure 1: Average exam marks (%) of three categories of 2nd year students over two years (N = 18)

On average, the seven group A students improved their exam marks by 14% points over two years. The six group B students' marks declined by 8% points, and five group C students performed significantly less well ($p < 0.05$) in their second year exam than in their first year exam.

Before the second-year final exam, a sample of fourteen students was interviewed about their understanding of the two TCs and what helped their understanding of difficult concepts in electronics. The lecturer graded students' explanations of TCs and these data were compared to their total grade in 2011 (see Table 2). Quotes from these students are denoted by group and number.

Table 2: Second-year students' understandings and grades, 2011

	Explanation of TC (NVivo analysis of interview data)	**TC understanding** (lecturer's grades for interview TC statements)	**What helped TC understanding** (2011 student interview data)	**2011 Average total grade** (%)
Group A	Comprehensive and coherent understanding (2010 and 2011)	A (N = 6)	Worked examples	86
Group B	Confused understanding (2010); developing understanding but unsure (2011)	B (N = 5)	Labs, practical work	53
Group C	Muddled, incomplete understanding (2010 & 2011)	C (N = 3)	Staff support, step-by-step instructions	31

Table 2 shows that both researchers' evaluation of the students' explanation of and the lecturer's grade for TC understandings were a good predictor of students' second-year total grades. An interesting finding was that students in the three categories preferred different ways of learning.

WHAT HELPED STUDENTS TO MOVE THROUGH THE LIMINAL SPACE?

Survey responses from the fourteen students showed both differences and similarities between student groups regarding *"what helps you learn difficult ideas in electronics?"*

In particular, group A emphasised using examples to help them learn:

> *"The way I learn is to do as many examples as I can to understand the different forms things can come in and even if the form is unfamiliar to me, I can relate it back to something I have already done". (A5)*

Group B found practical work most valuable to their learning:

> *"Being in the lab and doing Thévenin equivalents to simplify your measurements. I normally read through the lab sheet to get the gist of what we're doing – measuring or calculating. Then I start with measuring. I understand from how it is written what to do". (B2)*

Group C found they needed staff support, and step-by-step instructions. One group C student gained a high grade for lab work (75%) in the second year, but failed the exam (19%); in the first year he had passed the exam with 52%:

> *"In labs I read through the question, and set up the circuit from the diagram. But I am not sure what to do then. Where to start is hard. They just go "measure this" – they don't say how (it would be good if that was more explicit). I would be in big trouble if there weren't any demonstrators!" (C3)*

DISCUSSION: LESSONS FOR TEACHERS

If travel through the liminal space does indeed mean that students oscillate between old and new understandings (Meyer and Land, 2006), resort to mimicry on occasion (Cousin 2006), and have anxieties about their learning (Eckerdale *et al.,* 2007), teachers need to look for new ways to encourage learners to remain engaged and to move forward. This can be done in several ways as suggested by Land *et al.* (2006). The following recommendations come from our current findings.

LISTENING TO STUDNETS

In order to build on basic understandings find out about students' prior knowledge. A simple pre-test allows the lecturer to identify gaps in students' knowledge and provides opportunity to give immediate feedback to students.

Teachers need to find out how students like to learn. They need to provide varying learning opportunities, including time for students to articulate their understandings and test their own knowledge. Our data show that students appreciate small-group discussions.

We demonstrate that students' TC understandings were a good predictor of their total year grades – those who could articulate their knowledge well achieved the highest grades. These students were not reliant on the materials they had manipulated while working on problems and could give coherent explanations using acquired knowledge. Group B students still needed to manipulate materials to anchor their understanding of TC. Like the students described by Roth (2006), the group C students in our study had a few vague ideas about the TC and required specific instruction from their tutors. The C group's low achievement in Year 2 may be a consequence of poorly structured precursor knowledge and a successful guessing strategy up to Year 2 when the course content prohibited 'educated' guessing.

Teachers may trial different teaching strategies, but unless they realise how their students learn new ideas and transfer knowledge from one situation to another, these may be of no avail. While presenting to students the *chocolate bar* analogy, the lecturer observed that learners must attend to and coordinate different kinds of information in order to perceive the difference between static and dynamic resistance. Teachers need to design formative assessment tasks as TC *learning tasks* – students appreciate immediate feedback. Use short test-questions, and have students discuss questions and answers. A first-year student comments:

> *"When you go to a tutorial you discuss problems a lot more easily amongst peers. You have the same kind of level as the other people when you tackle a question – that is SO useful. It means they can understand why you are confused". (First-year student)*

The lecturer was most impressed with the way there was a sense of intense involvement during the second-year scratch-card quizzes. He could move around the class listening to students trying to convince each other that their arguments were valid and could be used to solve the problems in front of them. Additionally, students appreciated an opportunity to practise for the exam.

TOLERATING LEARNER CONFUSION

As students progress in their studies the materials and content become more complex. Consequently, students have to have a firm understanding of less complex concepts in order to assimilate the more complex ones.

One student said he was more confident in his first year as he had a basic physics background, but that in the second year the theories had become more complex (B4 – final grade 56%). Another student (A6 – final grade 97%) agreed that the second year work was harder, and said he was not so confused in the first year as the questions were simple and although he did not really understand the concepts he could *"do the question without knowing it".*

Further evidence of confusion came to light in the lab books – some students seemed to have great difficulty in writing complete sentences to explain what they understood (Harlow *et al.,* 2011), had misinterpreted a circuit diagram, did not have a complete understanding of circuit theory, or could not interpret a graph. This revelation has led the lecturer to place an initial focus on 'holistic current flow', 2D-3D representation, and graph interpretation as pre-cursor TCs. These ideas have now been included in a concept inventory of analogue electronic TCs (Scott *et al.,* 2012). It is imperative then that teachers devise activities that reveal uncertainties as many students may suffer in silence, continue to be mystified, and resort to mimicry.

To further reduce the likelihood of confusion it is important to plan a coherent course that provides adequate feedback to students about how well they are doing. To keep students moving forward there needs to be continuity in teaching and assessment of TCs. This includes sequencing theoretical and practical work and planning courses end-on-end.

Results demonstrate that the second-year students had moved from a state of conceptual, procedural, and/or technical confusion observed in first-year laboratory sessions (Harlow *et al.,* 2011). However, if there was a significant gap between first encountering the TC and coming across it in a new situation, or some disruption (e.g. change of lecturers) students reverted to a state of confusion as this student commented:

> *"This is the worst paper in my whole year. I don't really understand the lectures. It's going too fast and not creating the basic knowledge. This year with different lecturers they are jumping from one thing to another – it's difficult to see the links". (B5)*

REVISITING THRESHOLD CONCEPTS

"*If the threshold nature of a certain concept is to be used to refine or revolutionise curricula, we need to identify the concepts". (Lecturer)*

Thus it is crucial that teachers are able to pinpoint areas where students have trouble getting to grips with the subject. When asked why Thévenin was a TC, the lecturer said it was the first example of circuit-modeling that caused learners an inordinate amount of trouble in electronics and circuit theory although modeling is one of the most uniformly accepted unifying concept/themes in engineering and technology. The lecturer made the TCs explicit from the first time he introduced them to the class, and reiterated their importance each time they surfaced in discussion, lectures, labs and tutorials. A second-year student reported:

> *"After the time this year where we did the exam question [dynamic resistance] I got it – before that, no. He recapped and explained it to us after we handed our answers in. If we hadn't had that chance to recap we would still be lost". (B4)*

It is important that teachers help students develop a bank of experiences of the TCs in different contexts and support them in extracting similarities and differences across these contexts. High-achieving students emphasised the need to do 'lots of examples' before they 'got' the TCs. This 'pattern sniffing' in order to understand what is the same and what is different about problems, enables transfer of learning and is essential for 'crossing the threshold'. A second-year student commented:

> *"In terms of learning, more assignments and tutorials may have helped especially if we get to go through them after we have had our attempt at them, then different fully worked examples of how to do it". (A5)*

It is important to notice that students recognised that they were oscillating between old and new understandings and began to gain a clearer idea of the importance of TCs as they met them in different situations:

> *"In our first year we only did dynamic resistance for diodes. It's become much easier this year to figure it out. We do a lot of simulations to do with it. Now we've seen it with transistors as well as diodes. This year we've done applications and it has been more important to look at dynamic resistance". (A1)*

CONCLUSION

Our data demonstrate that the lecturer had refined the curriculum to focus on a limited number of TCs in the first year.

The pedagogy had moved more towards promoting learning through understanding. The lecturer placed more emphasis on formative assessment with immediate feedback. The students became more aware of the TCs and had more opportunities to share their understandings with their peers as they encountered TCs in different contexts.

The comments from the second-year students who grasped the TCs showed evidence of understanding that travelling through the liminal space is about making connections between the different aspects of learning. They highlighted the need for examples to be progressively more complex and varied for the learner to utilise new knowledge in different contexts. Student interviews demonstrated that the liminal space was often one with a long and rocky trajectory, from thinking in concrete forms through to the evolution of forms of talk about abstract entities.

In this study two TCs have provided the focus for changes in teaching and assessment (Scott and Harlow, 2012). We plan to continue to track students through their liminal space to uncover what it is in the process that allows the learner to show continuous success in demonstrating transfer of learning. The trajectory of grasping of difficult ideas could provide a framework for teaching students to learn to think like an expert.

The collaborative research between lecturer and researchers has generated 'lessons for teachers' that will inform a new research study looking at TCs in and across several disciplines. A knowledge of TC theory and collaborative, interactive teaching and assessment strategies can be used effectively to engage students with troublesome concepts. The liminal space can be an uncomfortable place for many students as they overcome their uncertainties. One student's comment illustrates this point vividly:

> *"I kind of got it last year but then this year, although it was tough at the start, I actually fully understood what was happening. It's a very difficult subject, but once you get it it's like easy. I don't know why I didn't quite get it before".* (C1)

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THE ROLE OF DESIGN PROJECTS IN ASSISTING ENGINEERING STUDENTS FROM LIMINALITY TO UNDERSTANDING

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Biographical Note

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KEYWORDS

Design, engineering, project-based learning, small group learning

ABSTRACT

Design is a central activity in engineering, and project-based design courses are increasingly common in engineering programs. Their open-ended nature presents challenges in evaluating and assessing their effectiveness. Identifying the troublesome knowledge encountered in these courses could provide a means of understanding and improving student learning. This paper describes an exploratory study aimed at finding troublesome knowledge in project-based mechanical engineering design courses. An ethnographic approach was used to determine the troublesome knowledge encountered by students in two design courses, one with a focus on universal design and the other on medical device design. Five categories of troublesome knowledge were identified: engineering science, project management, tacit skills, domain knowledge and tools and equipment. The results will be used to redesign course elements, and to inform further investigation of threshold concepts in engineering design.

INTRODUCTION

This paper describes an exploratory study aimed at identifying troublesome knowledge in project-based engineering design courses. Such courses are becoming increasingly common in response to a large body of engineering education research which has demonstrated the shortcomings of the traditional, lecture-based education model (Crawley *et al.,* 2007; Spinks *et al.,* 2006).

Design involves open-ended, unstructured problem solving, and is the central element of engineering. It is an integrative activity, in which students must select from a mixed toolset of techniques and theories, by evaluating and synthesizing what they have learnt in a range of courses covering fundamental science and mathematics, applied science topics and project management. Ideally students are working at the upper end of Bloom's Taxonomy – analysing, synthesizing and evaluating their learning (Bloom *et al.*, 1956). In terms of threshold concepts, this could represent a move from liminality to understanding.

However, the open-ended, integrative nature of design courses also presents some difficulties in understanding and evaluating the learning taking place. Much of the knowledge that students are interacting with and applying cannot be identified from the course lectures or syllabus, and most of the learning activity takes place outside of class time. Due to the open-ended nature of the projects undertaken, each student may follow a completely different path and require different conceptual tools and skills. While students may be integrating a range of fundamental concepts, it is also possible that the majority of their time is spent acquiring facts specific to the problem being solved or learning how to use required virtual and physical tools. This type of activity is the equivalent of rote learning in traditional lecture-based courses, in that it results in very little meaningful, transferrable knowledge being acquired. As such, educators in this area require tools to identify the learning taking place, so that they can assess student learning and improve their courses. Dym *et al.* (2005) propose a set of open research questions in the area of engineering design education which include questions on how best to evaluate learning in design courses.

The theory of threshold concepts (Meyer and Land, 2003) may provide a useful framework for investigating learning in open-ended, project-based courses. Focusing on core concepts that are troublesome, transformative, etc. would allow

educators to look beyond the range of activities undertaken by students and assess the underlying pedagogical content of their courses. Much work has been done on developing methods for identifying threshold concepts. Quantitative approaches include using Likert-scale questions (Holloway *et al.,* 2010) and multiple-choice questions (Gray and Yavash, 2007) to determine the more troublesome and transformative concepts in a subject area. Qualitative approaches include curriculum mapping (Quinnell and Thompson, 2010), concept maps (Hay, 2007), focus groups (Galligan *et al.,* 2010), think-alouds (Miller-Young, 2010) and analysis of students coursework (LeBard and Quinnell, 2008). These techniques seem useful in situations where a list of candidate concepts or a well-bounded curriculum is available. In engineering design courses however, as explained above, this is often not the case. In this study, therefore, an exploratory approach was taken to identify candidate threshold concepts by focusing on the troublesome knowledge encountered by students.

METHODS

A mixed-methods research design was used in the collection, analysis and interpretation of data. Engineering design courses at Harvard University and Trinity College Dublin (TCD) were selected as the sites for the study. The main research was carried out in a medical device design course in Harvard. The class of sixteen was made up of a mixture of undergraduate and postgraduate students. During the course, four teams of students worked with surgeons to identify a medical need, design a solution to it and have a prototype manufactured by an outside vendor. The TCD course in mechanical engineering design was taken by eighty one third-year undergraduate students, who worked with elderly people to develop universally designed solutions to common needs. The TCD course was used to expand the results from the Harvard research.

Ethnographic methods were used to study the students and teaching staff throughout the fifteen-week medical device design course. The difficulties they faced, as well as the skills and knowledge they used to overcome these difficulties were studied. Data was gathered through participant observation and unstructured informal interviews by a teaching assistant, supplemented by online questionnaires completed by the students and reflection sheets completed by other members of the teaching staff. The observations and interviews were conducted during the weekly meetings that teaching staff held with each team, the weekly laboratory sessions, and the student team meetings outside of class time. The observations and informal interviews were detailed in handwritten fieldwork notes, which were later transcribed on a computer.[5] Students in the universal design course completed the same open-ended online questionnaires.

The resulting dataset consisted of dozens of text files composed of units, short paragraphs describing individual events or statements. In the first round of analysis, those units which described students' difficulties or misunderstandings were identified and comments describing the relevant concepts and skills were made. These comments were then clustered around similar themes, which were used to create basic codes. This process of clustering and coding continued until higher-level codes emerged. These higher-level codes describe the broad types of concepts and skills that were troublesome for students. Table 1 shows an example of a text unit and the associated comments and codes.

Table 1: Analysis of a unit of text

Text unit	**Comments**	**Basic codes**	**Higher-level codes**
Students have calculated the power requirements of the motor from the force measured on the Instron multiplied by the displacement. Lecturer thinks the value sounds way too small. After looking up motor specs in a catalog, they calculate that the gear reduction required would be >10,000:1 (impractical)	Interpreting the results of analysis Using manufacturer specs to guide design Difference between idealized models and real systems Motor selection Gear ratios Power calculations Relationship between force and torque	Modelling & Analysis Mechanics Testing Actuation & Control Working with Vendors	Engineering Science Project Management

[5] Approval for this work was granted by the Harvard Committee on the Use of Human Subjects in Research

RESULTS AND DISCUSSION

The analysis resulted in a list of skills and concepts that proved troublesome for students on the course, organised under the five broad categories described in Table 2. This section contains examples of the difficulties faced by the students for each category.

Table 2: Description of categories

Skill/concept categories	**Description**
Engineering science	Modelling, analysis, testing, evaluation
Project management	Planning, budgeting, communicating
Tacit skills and knowledge	Interpersonal skills, creativity, decision making
Domain-specific knowledge	Knowledge related to the specific problem which the students are attempting to solve, e.g. a surgical procedure
Tools and equipment	The knowledge and skills required to operate machines, use software applications and select off-the-shelf parts

ENGINEERING SCIENCE

Fundamental engineering activities such as modelling, analysis and testing proved troublesome for many students throughout the course. Foley (2010) describes modelling as a threshold function in engineering. Modelling requires students to make assumptions and simplify a problem, while analysis involves selecting and applying a mathematical technique or scientific theory to solve a problem.

> *"We don't know enough about material selection, manufacturing processes, and other aspects that are also incredibly important in the design".*
>
> *"Unclear on what sort of analysis would be needed..."*

These responses are surprising as they describe concepts and skills that the students have covered in previous courses. The difficulties reported here are examples of Perkins' (1999) inert knowledge; engineering students know how to do the required modelling and analysis, or have the conceptual tools required to find out, but without specific prompts to trigger that knowledge they feel lost. Similarly, despite having knowledge of manufacturing science the students had difficulty reconciling their ideal designs with the realities of manufacturing processes.

> *"… after spending many long days on looking for vendors, we basically changed many design ideas (and even discarded some of the functions) to adjust our models to the vendor capabilities."*

PROJECT MANAGEMENT

The main management issues faced by students related to decision-making and communication. In working with users to define needs and deciding on possible solutions, the students often found it difficult to adapt their plans to changing circumstances.

> *"Having to scrap ideas that you'd worked on for hours. Knowing when to scrap these ideas and that it was essential to progress in the design process"*
>
> *"…the priority of our design goals keeps on changing. How flexible should that really be?"*

Engineering students are used to being provided with all the information required to solve well-defined problems that have unique correct answers. However in project-based courses decisions must be made when the information available is incomplete or ambiguous. Handling this ambiguity was one of the most commonly reported problems.

> *"It is extremely difficult to take decision under uncertainty. It is really difficult to evaluate each possible design before going into extremely detailed designs. At the end of the day we choose strategies/concepts guided by hunches or by the positions of the stars that night".*

Osmond (2010) proposes 'the toleration of design uncertainty' as a threshold concept. After having spent some time working through this issue with others, and receiving guidance from the teaching staff, one would hope that the students learnt that uncertainty is an unavoidable part of project management and the design process. However, when asked towards the end of the course what would have helped them to deal with uncertainty, many still felt that there was supplemental information that they didn't have access to.

> *"Just talking with more experts that have straight answers."*

TACIT SKILLS AND KNOWLEDGE

Much of the knowledge required for engineering practice is not taught explicitly. When working on a team project, interpersonal skills are of course an issue.

> *"…the team […] is small, and conflicts become harder to resolve because we don't have enough people to survey more opinions and ideas…"*

Working within time constraints was frequently mentioned as a difficulty; however there was very little discussion of what was consuming students' time. From the observation data it is clear that a contributing factor to students' time management problems was spatial reasoning. During the first half of the course, the majority of team meetings were spent trying to describe and interpret descriptions of three-dimensional systems. Often an apparent agreement had to be revisited because team members had each interpreted a mechanism or process in a different way. Miller-Young (2010) identified visualizing and describing three-dimensional forces as a troublesome activity for engineering students.

DOMAIN KNOWLEDGE

In order to understand a problem and design a solution to it, the students had to acquire a lot of information related to the problem area. The students designing medical devices, for example, needed to learn about elements of surgical practice, physiology, anatomy, and so on. The observation data contained many examples of students making incorrect assumptions about the problem being investigated. The troublesome knowledge encountered here was how to approach problem-solving in a new field. Engineers often design technology to be used in a domain in which they are not experts, so the ability to quickly assimilate knowledge and navigate a new field is essential.

TOOLS AND EQUIPMENT

Throughout their projects the students made use of a large number of software applications, machine tools, testing equipment and off-the-shelf parts. A common problem was underestimating the planning and evaluation required in using these tools. For example, patent search engines and literature searches were conducted to understand the prior art in each problem area. This required skills such as compiling a search strategy and evaluating the resulting information. Yorke-Barber *et al.* (2008) have mentioned these as possible threshold concepts in the field of information research. Some student teams struggled to find enough information and discovered relevant prior art towards the end of the process, while other teams were overwhelmed by too many search results which resulted in them feeling that it would be difficult to contribute to the area.

> *"We need to be really clever considering the large number of patents on this problem"*

Similarly, the use of engineering and mathematical analysis software required students to carefully design input data and evaluate results. There was a tendency among students to accept the results of software tools uncritically.

CONCLUSIONS AND FUTURE WORK

This study has identified a range of troublesome knowledge encountered by students in mechanical engineering design courses. These results will be used to improve the courses investigated, for example by redesigning laboratory sessions to better address the problems and misconceptions of students. Many of the examples presented here have been proposed as threshold concepts by others, which indicates that they are worthy of further study. Having identified a range of problems faced by students, the next step is to design a more focused set of data-collection instruments. For topics such as modelling and analysis, concept questionnaires will be designed and used to test for changes in understanding throughout the course. For skills that are less easily measured, such as tolerating design uncertainty, concept mapping and self-explanation exercises will be used.

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NOW I KNOW WHY I HAVE BEEN KNOCKING MY HEAD AGAINST A BRICK WALL: DOCTORAL CANDIDATES AND STUCK PLACES

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Biographical Note

Dr Margaret Kiley research and teaching has focused on research education including: the examination of theses; candidates' and supervisors' conceptions of research; mapping Honours across Australian universities; and the introduction of coursework into the Australian PhD. Margaret works at the Australian National University, where she is the Convenor of the Graduate Research Network of Education. She also holds a conjoint position at the University of Newcastle.

KEYWORDS

PhD, stuck place, research education, threshold concepts

ABSTRACT

The research reported here was motivated by a comment from a doctoral candidate. I had asked her, as a Research Assistant not as a candidate working with me, to check a manuscript on Threshold Concepts in doctoral education in preparation for publication. Her main comment after reading the paper was, *"If only I'd known that I was just in a stuck place it would have made it so much easier".*

So began work with doctoral candidates to help them understand doctoral study as:

- an extended period of learning where the candidate might be in a liminal state until crossing the threshold of completion and 'graduation', and
- a period made up of a number of threshold crossings as candidates understand the various concepts that challenge them (Kiley, 2009), each preceded by a state of liminality and maybe being in a 'stuck place'.

BACKGROUND

There is considerable research on doctoral education (for example (Mowbray and Halse, 2010; Walsh, 2010; Platow, 2012) and some initial work on Threshold Concepts in research learning through the doctorate (Leshem and Trafford, 2007; Kiley, 2008; Wisker and Robinson, 2009; Kiley, 2010). Trafford and Leshem (2009) suggest that 'doctorateness' *"combines both 'doing' and 'achieving' a doctorate and so it merges the issues of research process and research technique"* (p. 205). They suggest this activity is made up of twelve components, which when understood as a whole actually make a Threshold Concept, and which they term 'doctorateness'.

In one of the early works on Threshold Concepts in learning to be a researcher, Kiley (2009) identified six possible Threshold Concepts: argument/thesis, theory, framework, knowledge creation, analysis, and research paradigm. However, these concepts had been identified by supervisors and I was keen to see if candidates identified the same concepts. Furthermore, and more importantly for this paper, I wanted to learn if it was helpful to candidates in understanding their learning situation to introduce the idea of Threshold Concepts and the related research, for example, liminality, mimicry and being stuck.

Therefore, the question I set out to ask was: Does having an understanding of Threshold Concepts in research learning assist doctoral candidates to appreciate their own learning?

METHODOLOGY

Ten candidates, undertaking a PhD in Higher Education, were given a copy of a paper which outlined the notion of Threshold Concepts and identified a number of possible concepts in learning to be a researcher (Kiley, 2009). The aim was to ensure that they had some understanding of Threshold Concepts.

Following ethics approval, discussions occurred in the regular monthly group meetings (two groups of five candidates each) which had been established over twelve months earlier. Group members had become very collegial and open with opportunities to share experiences and to seek assistance from others. As part of this study, during the group meetings

participants were asked to share, if they wanted to, any concepts with which they were struggling. One of the aims of undertaking this exercise in groups, rather than individually, was to develop the existing peer support within the groups.

While the discussion was occurring, as the researcher and supervisor, I took notes. Also, along with the others in the group I asked questions for clarification. This was very much a discursive activity with no intention of trying to gain consensus within the group but rather to identify the experiences of individuals. Unsurprisingly, given that they were all doctoral candidates, in many cases their experiences were similar.

The notes were analysed following each of the meetings and then the analysis reported back to the next meetings of the groups. Manual coding of the notes was undertaken through seeking particular ideas and comments and these were then clustered into themes. The analysis was then taken back to the next group meeting where the participants were invited to comment on the analysis and if necessary, modifications were made in consultation with the group.

In the reporting back, each candidate had been coded, e.g. 02, rather than using their name. What was particularly interesting was to note the number of times, having read the findings, participants would comment along the lines of, *"Number XXX must be XXX, that sounds just like him"* even when the person had been in the other group. To me this indicated how close the candidates had become in appreciating the experiences of their peers.

FINDINGS

The analysis suggests that there were four major themes: learning about…; liminality; specific Threshold Concepts; and strategies for learning.

***LEARNING ABOUT** …*

The theme of learning about included four main categories and these were learning about self as a person, self as a learner, teaching, and the research process.

One of the strongest findings was candidates' reports of *learning about themselves as a person.* For example, 01 had recognized a pattern in herself and that is, she encounters a challenge, panics and feels she can't meet it, then tells herself, *"OK I can do this".* Following from this, once she feels she is in a position to teach the new concept to someone else, then she knows she has 'got it'. In a similar vein, 07 has discovered that he had a tendency to be a quitter and he would feel defeated and then someone would say something positive and he would decide to have another go. However, through his doctoral studies he is beginning to feel he has*, "developed a sense of perseverance".* And 04 reported that she is gaining substantially in confidence; now she won't take 'No' for an answer, she wants to 'have a go'. In a very different way 07 had learned that, *"I think I am too applied for academia. I think I can do more in industry, in professional development for example".*

In *learning about self as a learner* for example, 06 suggested that something that has been important for him is understanding himself as a learner. Whereas 02 has realised that she likes the challenge of being busy, especially intellectually, and 01 has discovered that sometimes if she really wants to learn something she puts herself into the position of having to teach it.

Something that 04 has learned about herself as a learner is that that she needs to 'do' something to be able to actually understand it. She thinks she knows something but then when she goes to do it she realizes she doesn't. But by trying to do it, she manages to learn it. *"I also needed to practise research"* reported 06 *"I am sure it reflects my learning style, I learn by practice, very hands-on and many iterations of the process*".

Given that all candidates were in the graduate field of Higher Education it is not surprising that one of the findings related to candidates was *learning about teaching,* although not in a formal way through coursework but by being a learner. For example, *"The words [in Research Methods] had no actual meaning"*, says 02 *"so you can't ask a question because you don't know what you don't know".* However, once she was in this position herself as a learner she could appreciate the difficulty in other learners that she was teaching.

Finally, and unsurprisingly, participants talked about *learning about the research process.* For example, 01 reported that she has gained a good understanding of qualitative methods and would like to teach Research Methods when she has finished her doctorate, especially as now she has experienced that, *"Analysis is the reality, prior to that it is a bit of a fantasy".* Perhaps more prosaically was the comment by 06 regarding the time–consuming nature of research. *"In the PhD [report] you say you developed a survey and piloted it, but the whole thing took a year and so I guess that was part of the learning to do it".*

LIMINALITY

Being in a state of liminality, as Meyer and Land (2006) suggest, involves mimicry, oscillation and being in a stuck place, all experiences reported by participants.

As 06 commented, *"This [being in a liminal space] really resonated, especially mimicry. I had no idea what they meant but I used the terms anyway. At the beginning I thought of myself as a researcher but I soon realized the difference between being a researcher in Social Science compared with Science. I can see now that my understanding of Social Science research was very limited".*

"The examples of Threshold Concepts at the doctoral level resonate with me" reported 03. "Also the idea of oscillation – of movement around concepts, thinking away from a position then back to that (or a similar) position is credible. I find that the same key ideas I was working on two years back are still in the foreground – notwithstanding an elaborate dance around these, and my research question".

'Being stuck' was something that only a few spoke of specifically which, as their supervisor, I found particularly interesting as I had observed each of them at different stages being quite 'stuck'. The sense of being in a stuck place often resulted in, or came close to tears of frustration. This frustration was further explained by 03 who suggested, *"It is very visceral trying to cross the threshold. It is probably when you really think about opting out".*

SPECIFIC THRESHOLD CONCEPTS

From the analysis, there were two concepts which the participants discussed which have not been reported in the previous literature; these were research as an iterative process and the concept of unlearning previous ways of thinking.

Several of the participants talked about their new-found understanding that 'research is an iterative process'. For example, in her previous research experience, 04 had found that the research, *"had all been planned out and ran to plan with no changes"* but with her PhD research, she came to the realisation that she needed to be open to changes and developments as the research progressed. Similarly, for 06, *"The other thing is that research is an iterative process especially understanding the actual process of collecting data and seeing what's there".*

'Unlearning previously held ways of thinking or views' was a concept that several raised. For 03, this unlearning was that he had to unlearn his ingrained approaches to thinking about data and its analysis. In a similar vein 06 commented, *"That was one of my Threshold Concepts when I realized I had to look at what my data said, not what I thought".* For another candidate, he reported that he felt he was forever fighting his ideological position and that he was imposing ideological judgments on the data, rather than seeing what the data were indicating. *"When I actually understood this it was a monumental change"* (07). Another 'light-bulb' moment for 06 came from talking with another student who said, *"You've already made your assumptions and now you are setting out to prove them, not to find out what your participants think. I know this is another thing that you [the supervisor] had talked about a lot, but it wasn't until that moment that it actually clicked".*

Three other concepts already reported in the literature, and which were discussed by participants, were the concepts of theory, epistemology, and argument.

With regard to theory, 02 learned to let go of her own ideas about theory and realize she could develop her own theoretical perspective, that is, a framework made up of several different theories. From a different perspective, and with hints of mimicry, 06 commented, *"Theory was another thing I didn't understand, people kept asking me about my theoretical perspective but I didn't have a clue what they were talking about".*

'Epistemology' was another concept with which, as their research supervisor, I had noticed many of the candidates struggle. What had helped 05 with a breakthrough was from the Research Methods class about the bottom-up and top-down approach to research. As he worked through the readings for the course he commented that he finally understood epistemology, *"Now I can see that 01 is doing her research the way she is because she is who she is and I am doing it this way because I am a top down sort of person"* (05).

Finally, 'argument', which had challenged a number of candidates including 06 who commented, *"A major threshold concept for me was argument. I was really stuck on argument and the meaning of argument. I finally had a breakthrough when talking with peers. I know you [the supervisor] had gone on about it for years, but when I was talking with [two peers] it suddenly clicked"* (06).

STRATEGIES

As a supervisor I was very keen to learn if the candidates could suggest strategies that had helped them with the learning challenges that they had encountered during their period of candidature. From the data, three particular strategies emerged, the importance of peers, the importance of time, and the use of outside milestones in addition to the formal ones of the university.

With regard to the 'importance of peers', 06 reported, *"As a part-time student I felt isolated and then I made an effort to get more involved and it made it much easier. It was all about peers, being able to chat, and go to Morning Tea, that's nice. Especially when there are visitors, it is good to be in an academic community. That's the big difference between here and where I was before"* (06). For 02, a relatively new candidate, her observation was particularly telling, *"Yes you can see that others have moved through it. There was a time when it seemed everyone was stuck and very depressed and I wondered if it [this depression] were contagious and I didn't want to catch it, but I think it was because everyone was at the same stage [that is, analysis]".*

The 'importance of time' was of particular interest to me as a supervisor and I specifically asked the question, *"With some of these light-bulb moments [that they had discussed], could they have happened earlier if someone other than your supervisor had talked about them?"* It was in response to this question that the most common response was epitomised by 06 who suggested, *"No, I needed to lead up to it. I don't think I would have understood until I had a marriage between theory and an understanding [of research methods]".*

The third strategy that was suggested was 'the use of outside milestones' to assist with learning, development and confidence. As 03 suggested, *"The university's concrete milestones like ethics etc., these are all helpful but the outside milestones are also very helpful like conference presentations"*. Candidates had raised the benefits of attending conferences in earlier discussions. They had suggested that having to prepare a presentation for a conference or a manuscript for a journal provided a strong motivation for getting the work done as well as an opportunity to monitor their learning.

DISCUSSION AND CONCLUSION

From the nature of the discussion and the comments made, it was clear that doctoral candidates found it helpful to have explicit discussions related to Threshold Concepts in research learning and reflect on their own learning. Through the discussions they indicated that three of the previous Threshold Concepts noted in Kiley (2009), that is, theory, epistemology, and argument were of particular concern to them. Furthermore, they identified two additional concepts, not reported in the earlier study, that is, research is an iterative process and unlearning previously held ways of thinking or views. Also, of particular interest to me as the supervisor was the level of debate and discussion among the participants in the group. Only one, that is 08, commented that she wasn't sure she had learned any of the specific concepts but she had certainly learned about alternative approaches to research.

The activity will be ongoing with current and new candidates as I have found that it is a way of helping them to appreciate that there are specific concepts related to learning to be a researcher and that a) if they are having difficulty they are not on their own, and b) there are strategies to assist in learning those concepts, and c) there are ideas such as liminality that can help explain the situation.

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TOWARDS A ROLE-REVERSAL MODEL OF THRESHOLD CONCEPT PEDAGOGY

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Biographical Note

Marina Orsini-Jones is Leader of the Applied Research Group Pedagogical Innovation in Languages and Literature in the Department of English and Languages at Coventry University. She has published work on both subject specific (the structure of a sentence) and generic ('becoming a researcher at undergraduate level') threshold concepts at undergraduate level. She is currently investigating troublesome knowledge in intercultural international online exchanges.

KEYWORDS

Role-reversal, students, thresholds, action research, grammar, graduate employment

ABSTRACT

This paper discusses how a previously designed e-learning role-reversal model (Orsini-Jones and Davidson, 1999) was merged with threshold concept pedagogy to create a new model of action-research supported threshold concept pedagogy that originated as 'student-centred' (Orsini-Jones, 2008) but subsequently became 'student-driven' (Orsini-Jones *et al.*, 2010).

The distinguishing feature of the methodological choice illustrated here is that action research is used in conjunction with threshold concept pedagogy to develop student-centred and student-initiated cycles of pedagogical inquiry. Land, Meyer and Smith (2008, pp. ix-xxi) suggest that the identification of threshold concepts allows tutors to put in place targeted curricular interventions aiming at transforming the students' learning experience, identifying troublesome knowledge and making such 'troublesome knowledge' less troublesome. The joint use of action research with threshold concept pedagogy provides a unique opportunity for a constructivist staff/student exploration of the transformational challenges learners face when they encounter troublesome knowledge.

The initial encounter of the author with threshold concept pedagogy was motivated by a drive towards helping first and second year undergraduate students reading English and Languages at Coventry University with their transformational learning journey across the challenging terrain of difficult or alien knowledge. However, working closely with students on troublesome linguistic knowledge brought into view the realisation that their insights would benefit other students more than the lecturer. This resulted in the development of a new approach, where 'expert' undergraduate students are taking the reins of the curricular research interventions to better understand why some of the peers struggle with the threshold concepts identified previously in the field of linguistics (Lund, 2010) or even to explore new ones (Lee, 2011). The lecturers therefore learn from their students' research into threshold concepts, in a role-reversal pedagogical model.

There was a book lying near Alice on the table (…), she turned over the leaves, to find some part that she could read, '-for it's all in some language I don't know,' she said to herself.

It was like this.

YKCOWREBBAJ

sevot yhtils eht dna ,gillirb sawT'

;ebaw eht ni elbmig dna eryg diD

,sevogorub eht erew ysmim llA

.ebargtuo shtar emom eht dnA

She puzzled over this for some time, but at last a bright thought struck her. 'Why, it's a Looking-glass book, of course! And if I hold it up to a glass, the words will all go the right way again.

This was the poem that Alice read.

JABBERIWOCKY

'Twas brillig, and the slithy toves

Did gyre and gimble in the wabe;

All mimsy were the borogoves,

And the mome raths outgrabe.

(Lewis Carroll, Alice through the Looking Glass, and what Alice Found there, pp. 13-14)

INTRODUCTION

This paper discusses how the adoption of the threshold concept framework to implement curricular change in languages and linguistics at Coventry University between academic years 2003-2004 and 2011-2012 re-defined the roles and identities of all agents involved in the learning experience on some key mandatory modules. It illustrates how the process resulted in a new model of action-research-supported role-reversal threshold concept pedagogy. The implementation of the model helped tutors to see their curricular through the eyes of 'expert students' in a way that could be compared to Alice's view of the world in Through the Looking Glass (hence the quotation above). The quotation also well expresses the bewilderment that students can experience when faced with 'alien' knowledge. It is interesting to note that that the mirror (or decoding lens) will not always help with untangling the epistemological and ontological challenges posed by 'alien knowledge' – and it does not in fact in Carroll's work either, as demonstrated by the fact that the decoding of the text in front of the mirror only unveils its obscurity, with a twist that is arguably very postmodern.

TOWARDS A ROLE-REVERSAL MODEL OF THRESHOLD CONCEPT PEDAGOGY

Cousin (2009, pp. 209-211) describes threshold concept pedagogy as a partnership amongst educationalists, tutors and students who 'tackle' together the scene of difficulty occasioned by the encounter with troublesome knowledge. While the role-reversal model presented below (Figure 1) is dialogic and stems from Cousin's, the identification of threshold concepts is driven by undergraduate student researchers, who, having embraced threshold concept pedagogy for their own research, help staff with discovering nodes of troublesome knowledge and help tutors to approach such nodes from the students' perspective. This in turn causes tutors to transform their own 'thoughts and identity' (Land, 2012) in pedagogical terms as they can then observe their curricular intervention through the looking glass of the expert student's perspective. The inquiry becomes therefore student-driven, rather than student-centred or tutor-driven.

Another distinguishing feature of the methodological choice illustrated here is that action research is used in conjunction with threshold concept pedagogy to support student-initiated cycles of pedagogical inquiry. Land, Meyer and Smith (2008, pp. ix-xxi) suggest that the identification of threshold concepts allows tutors to put in place targeted curricular interventions aiming at transforming the students' learning experience, identifying troublesome knowledge and making such 'troublesome knowledge' less troublesome. The joint use of action research with threshold concept pedagogy provides a unique opportunity for a discursive staff/student exploration of the transformational challenges learners face when they encounter troublesome knowledge. Issues relating to language and 'languaging' via subject specific epistemes are central to this field of inquiry. Meyer and Land stress that at the heart of threshold concept pedagogy is the *"inter-relatedness of the learner's identity with thinking and language. Threshold concepts lead not only to transformed thought but to a transfiguration of identity and adoption of an extended discourse"* (2005, p. 375).

The initial encounter of the author with threshold concept pedagogy was motivated by a drive towards helping first and second year undergraduate students reading English and Languages at Coventry University with their transformational learning journey across the challenging terrain of difficult or alien knowledge. Working closely with students on troublesome linguistic knowledge brought into view the realisation that the students' insights would benefit other

students more than the lecturer's (Orsini-Jones, 2008, 2010a). This resulted in the development of a new approach, where 'expert' undergraduate students work with staff, but take control of the curricular research interventions to better understand why some of their peers struggle with, for example, the threshold concepts previously identified in staff/students collaborative projects in the field of linguistics (Lund, 2011) or even to explore new threshold concepts relating to the difficulties students have with engaging with the reflective language of personal development planning for graduate employment (Lee, 2012). The lecturers therefore learn from their students' research into threshold concepts in a role-reversal pedagogical model that is illustrated in Figure 1 and discussed in the case study reported below.

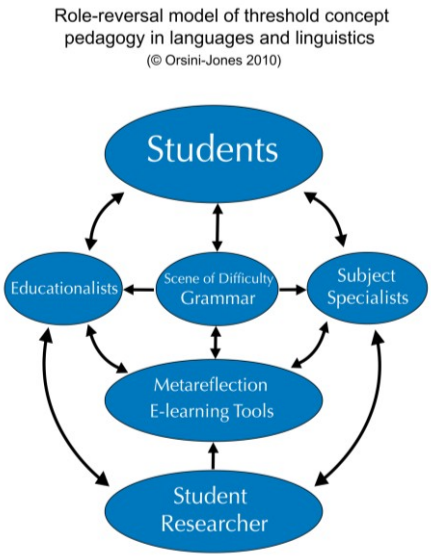

Figure 1: Role-Reversal Threshold Concept Methodological Model, Orsini-Jones 2010

CASE STUDY: STUDENT-DRIVEN INVESTIGATION INTO TROUBLESOME ACADEMIC AND PROFESSIONAL REFLECTIVE DISCOURSE

Fiona Lee, a student on a French and TEFL (Teaching English as a Foreign Language) BA Honours Degree, decided to base her dissertation on the linguistic analysis of the reflective reports written by second year English and Languages students for a mandatory assessment task linking academic and professional development. The reflective reports are part of coursework 2 submitted for module *Career and Project Planning* that includes both a project plan in preparation for the final year dissertation and a personal development planning reflection on the links between the academic and employment-related phases of the project plan development. Coursework 1 consists of an individual presentation of the project outline and can be developed into the project plan submitted for coursework 2.

Lee (2012) collated 168 reflective reports to form a corpus of 58,035 words and used a corpus linguistic analysis tool, *Wmatrix* (Rayson, 2009) to study *Parts Of Speech* (POS) in order to identify troublesome semantic nodes. She used both quantitative data analysis (number of occurrences of tags in the corpus) and interpretive qualitative approaches (data interpretation and triangulation of data with interviews with selected students).

The idea for this project came to Lee while she was a student herself studying on the Career and Project Planning module. As she was a mature student who had experience of work, she was puzzled by how many of her peers found the module challenging. The aim of the module is twofold: firstly, to prepare students for undertaking their dissertation project and secondly, to engage them with personal development planning. She realised that her peers found the concept of researching and writing a dissertation a daunting prospect and many also struggled to see the existence of any links between the world of academia and the world of work.

Once the reports were collated and the interviews carried out, she also realised that there was an obvious discrepancy between what students were willing to discuss with one of their peers, and what they would write in a summative coursework assignment addressed to their lecturer. This is the reason why the Hallidayan framework of *Systemic Functional Linguistics* (SFL) analysis (Halliday, 2009) was chosen to investigate the linguistic choices made by students in order to be able to 'read between the lines'. SFL enabled Lee to discover both explicit and implicit expressions of the understanding of the links between the students' academic and professional progress and identify any employability-related problematic articulation. The major 'surprise' to Lee was the extent of 'mimicry', possibly 'conscious mimicry?' (Land, 2012a), that she found in the students' reflective reports. Meyer and Land (2006, p. 24) discuss how mimicry occurs

when a student inhabits a liminal space and processes troublesome knowledge. They state that the effort to understand, or partial or problematic understanding can result in mimicry, where the students either mistakenly believe they understand, or know they do not fully understand something but give a false appearance of understanding. Other researchers have also found evidence of this (for example: Flanagan and Smith, 2008; Orsini-Jones, 2008). Lee focused in particular on expressions of probability such as possible, probable, perhaps, certain or maybe (and the adverbs probably and possibly*)* and expressions of degree such as almost, hardly, quite, scarcely, totally, utterly, completely, entirely, absolutely or nearly. Reporting Eggins' work (2004, p. 174), Lee stated that the above expressions come under the area of modality and communicate the writer's attitude towards their statement. According to Eggins, the structure is possible or probable, i.e. a grammatical metaphor that can reveal the writer's subjectivity behind what appears to be an objective arrangement of words. In a sentence like *"I have adopted this advice, which I believe shows strong receptive skills, which are essential in terms of employability"* (Reflective report no. 8, 2011) the student appears to be claiming an understanding of what employability is, while the wording actually betrays mimicry. Eggins (2004, p. 174) states that the presence of modality in itself always renders a statement less convincing than using no modality at all. Lee thus argued that the students who used *I believe* were not wholly convinced about their own statements.

The semantic discovery above and the obvious mismatch between 'signifiers' and 'signifieds' in the students' reflective narratives on employability gave Lee ammunition to hypothesise that the connection between academic practice and reflection for graduate employment is a threshold concept for her peers. In this respect, Lee went one step further in terms of student-driven role-reversal pedagogy in comparison with Lund, as the latter 'expert' student had investigated further a threshold concept previously identified by staff, while Lee was venturing into new threshold concept terrain. Lee discussed in her dissertation whether there is a specific 'underlying epistemic game' – a way of understanding and knowing (Perkins, 2006, p. 42), which students need to be acquainted with in order to make the successful transition between university and full-time graduate employment.

The novelty in Lee's work consisted in the fact that she proposed that the tacit knowledge that students need to have is knowledge of the workplace and suggested that future research could investigate whether students who had worked displayed a stronger awareness of the links between their academic and their professional skills (2012, p. 60). Lee concluded her dissertation by stating the challenge for students was to visualise themselves not as students but as researchers and by the same token 'see' a future (i.e. professional, employed) 'version' of themselves through the portal as suggested by Land (2012b) in order to make the successful transition from the world of academia to the world of work.

Lee's findings were discussed amongst staff teaching the Project and Career Planning module and informed changes to its syllabus for a 2012-2013 implementation. Lee's work brought into view the fact that the discourse of graduate employment is possibly even more alien to students than that of academic practice and, to use Land's terminology (2012b, quoting Ferdinand de Saussure), it is full of meaningless 'signifiers' that translate in obscure 'signifieds'.

Following on from Lee's recommendation it will be necessary for staff to try and develop a meaningful 'narrative discourse of connectivity' between academia and the world of work. The discourse of graduate employment could therefore possibly be a threshold concept, something staff will now have to investigate and address further.

CONCLUSION

The student-driven research reported here would appear to confirm one of the threshold concept tenets proposed by Land in his plenary talk at the Threshold Concepts conference. Land (2012b) stated that threshold concepts could be viewed as 'check points of connectivity' in the curriculum. Their transformative, integrative and bound nature bringing into view hidden landscapes of new, empowering knowledge.

Lee's discussion is very poignant in this respect as it helped tutors to realise how troublesome the link between academic practice and the world of work is in the eyes of undergraduate students. Lee's work revealed new landscapes of troublesomeness and enabled tutors to reconsider their practice through the looking glass of expert students via role-reversal threshold concept pedagogy.

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USING A MIXED METHODS APPROACH TO EXPLORE STUDENT UNDERSTANDING OF HYPOTHESES IN BIOLOGY

Charlotte Taylor, University of Sydney, Vicky Tzioumis and JHF Meyer, University of Queensland, and Pauline Ross, University of Western Sydney

Biographical Note

Charlotte Taylor, Vicky Tzioumis and Pauline Ross established a framework for identifying Threshold Concepts in Biology (http://sydney.edu.au/science/biology/learning/threshold/) and continue to investigate their importance in student learning. They also integrate these ideas into biology teaching through the Vision in Biology Education (VIBEnet.) Network (www.vibenet.edu.au/). Jan Meyer is the acknowledged international expert in the area of Threshold Concepts and currently investigates their significance in the area of engineering.

KEYWORDS

Threshold concepts, hypothesis, biology, diagnostic instrument, variation

ABSTRACT

Our investigations of conceptual understanding of biology have led to the formulation of a matrix of threshold concepts for the discipline (Ross *et al.*, 2010), of which the creation and testing of a hypothesis is a key component. Previous studies of this threshold concept (Taylor, 2009; Taylor and Meyer, 2010) confirm that it is fundamental to thinking and reasoning across the sciences, and that the complexity of the concept requires detailed elucidation if we are to design teaching experiences which track students in this extended liminal space (Lawson, 2000; Oh, 2010; Pederson, 2011).

We employed two approaches to identifying the dimensions of thinking about hypotheses and their testing: 1) a generic question 'what is a hypothesis', and 2) a scenario question requiring students to write a relevant hypothesis for a field investigation. Both questions were given to 900 incoming undergraduate science students in an introductory biology course. Responses to the first question yielded seventy two item stems, which covered a broad range of conceptions of a hypothesis, and could be further categorized into thirteen groupings. The responses to the scenario question were analysed phenomenographically and provided seven categories of understanding which were broadly hierarchical.

Despite this concept being a fundamental area for study throughout the high school science syllabus, a significant proportion of the cohort demonstrated unsophisticated conceptions of the structure of the hypothesis. There were distinct commonalities in the dimensions of problem areas, namely the conception and delineation of variables, relationships between variables, the construction of a testable statement, and the language used to describe the hypothesis.

Further refinement of our approaches has led to the development of a diagnostic psychometric instrument about hypotheses, and the creation of a range of scenario questions, currently in use in high school investigations and in longitudinal surveys of students in biology-related degree programs.

THE CONCEPT OF THE HYPOTHESIS IN BIOLOGY

A complex web of threshold concepts characterises the field of biology, encompassing a series of overarching abstractions (Ross *et al.,* 2010). Many of these concepts, e.g. scale and complexity, are recognised as fundamental to the discipline (McCune and Hounsell, 2005; Underwood, 1997), and teaching of these concepts will require a multifaceted approach, which highlights the linkages between the elements (Taylor, 2006).

The understanding and application of experimental design, and the formulation of questions, predictions and hypotheses, provide challenges to thinking, both in terms of the 'how' and the 'what' parameters, and about the intersection of these ideas (Taylor, 2008; Taylor and Meyer, 2010). Developing this understanding requires an 'ontological shift' to a model of thinking involving scepticism, cycles of critical evaluation, and a reliance on evidence subject to rigorous and reliable testing (Lawson *et al.,* 2008; Meyer and Land, 2005). Learning such abstract thinking requires early introduction to the model, aligned with constant practice within an appropriate learning environment (Lawson, 2003; Duit, 2007). This learning environment is invariably established with a highly didactic phase focusing on the 'what', coupled with more limited opportunity to practise the 'what' in a hands-on context (Timmerman *et al.,* 2008).

Our ultimate aim is to design more appropriate laboratory learning activities which are based on hypothesis testing and the scientific method. We describe the first part of the project, in which we developed a validated instrument to measure prior knowledge and the variation in understanding, or misunderstanding, of hypotheses, which can be used as a diagnostic tool and to inform curriculum design.

COLLECTING QUALITATIVE DATA TO CONSTRUCT CATEGORIES OF UNDERSTANDING

A question was constructed which required a response of one or more sentences about the definition of an hypothesis.

> Someone wants to know how biologists carry out their investigations and research, and they have been told that hypotheses are an integral part of this process.
>
> *How would you, as a biologist, answer the following questions:*
> In your own words describe what an hypothesis is.
> Do you think it has a structure? Y/N
> If YES what does this structure consist of?
> Why do biologists need hypotheses?

This question was given to first year undergraduate students in their first semester of a biology course. Demographic data were collected for all students, and a sample of 850 responses was analysed. The initial coding of responses provided a set of seventy two items (Table 1), grouped into ten categories, which characterised the types of understandings of hypotheses.

Table 1: Categories of understanding hypotheses extracted from a sample of 850 undergraduate student responses about the definition of an hypothesis.

Category	**Items**	**Example statement**
A testable idea	13 items	A testable idea concerning an experimental question.
Involves variables	8 items	A statement to be tested via a controlled experiment.
An inference	2 items	An inference based on a relationship that is yet to be tested.
An explanation	4 items	A statement giving a potential explanation for a tested phenomenon.
A model	10 items	A testable prediction derived from a proposed model of some set of observations.
A fact	1 item	A proposal of a fact.
An assumption	3 items	Some assumptions on a matter that is considered tested.
Is a theory	8 items	A theory put forward for scientific analysis or testing to determine its validity.
Involves guesswork	5 items	An educated guess as to what the results of an experiment may be.
A prediction	18 items	Prediction on the outcome of an experiment prior to carrying it out.

THE FIRST PSYCHOMETRIC TRIALLING OF THE ITEM STEMS

The pool of seventy two items was subjected to a trial in two separate subsets to account for frequency of near-similarly worded items.

The first 'selected set' of forty items was constituted by initially choosing one typical item from each of the ten categories. The subjective judgement made here was based on the degree to which the items within a category matched the description of the category. The 'best' item was thus selected and, within each category, more items were included that provided conceptual contrast within the category. The aim here was to minimise what students might perceive to be 'precision alternatives'. In the next step, subgroups of similarly worded items (typically items that differed only in terms of one key word) were examined and a subjective decision made to select items that best captured the meaning of its subgroup. Finally, to allow for more variation in response, items were selected that expressed something different to the

items already selected in steps one and two. The remaining items constituted the second 'residual' *set* of thirty two items, which, where possible, contained sample items from each of the ten categories, and therefore mirrored the structure of the forty item set.

The items in each set were randomly ordered and the completed lists formatted into an electronic survey requiring a single response to each statement based on a 5 point Likert scale. Students in two first-year courses, running in parallel, were approached to complete the survey and given two weeks to answer. Students in the Human Biology course (n=1740), answered the selected set of items, and students in the Concepts in Biology (n=891) course were administered the residual set.

Response data were captured and incomplete responses and extreme responses containing obvious repetitive choices discarded. This resulted in 354 responses from the selected set and an independent sample of 176 responses from the residual set.

ANALYSIS

The analytical procedures that were respectively applied to the two independent datasets were directed towards achieving two outcomes: Exploratory factor analyses (maximum likelihood extraction, using squared multiple correlations as initial communality estimates, followed by oblique rotation) were employed to explore and reduce the dimensionality of the data and, in so doing, also facilitate, through repeated subsequent analysis, (a) the elimination of items exhibiting same-sign, cross-factor loadings with absolute magnitudes >0.20 (that is, items that were empirically ambiguous), (b) the retention of items in terms of relatively high absolute factor loadings (typically > 0.5 in absolute magnitude) in subsequent solutions of reduced dimensionality.

Item correlation analysis was also used to indicate the retention or exclusion of items *within* factors. By the same process the item correlation analysis also revealed items which, while not candidates for retention on a within-factor basis, were nevertheless retained in the respective item-set pools for additional trialling purposes, either on conceptual grounds and/or because of distribution considerations.

ANALYSIS OF THE SELECTED SET OF ITEMS

An interpretation of the underlying structure for the *selected* set was based on a four factor solution, which retained twenty five items.

FACTOR 1 captured variation in terms of 'hypothesis as prediction' with seven items ranked from high to low in terms of factor loadings (alpha 0.69), and two items exhibiting low factor loadings and thus possibly constituting 'conceptual outliers'. Item-correlation analysis did not support their retention in terms of their contribution to alpha, but these two items were nevertheless retained. Example statements indicate the complexity of the thinking about hypotheses with the central role of the prediction and differences in the relational understanding of the components of the process, namely observations, predictions, questions and testing.

> *A prediction based on earlier observations that can be tested by posing a question about the observations*

This problem has obvious potential to lead to further confusion with the use of hypotheses for experiment design and interpretation (Lawson *et al.,* 2008; Taylor and Meyer, 2010)

FACTOR 2 also captured variation in terms of the 'testable character' of an hypothesis for nine items (alpha = 0.68), and two additional items were excluded from this factor as they cross-loaded.

> *A testable statement which preferably only has one testing variable*
>
> *A testable idea that forms the basis of an experiment*

The focus on testing may indicate a more mechanistic approach to hypothesis generation and points to a 'reverse thinking' process whereby the 'how' is determined first and the question follows. Such an approach would be consistent with experiences of learning science with predetermined hypotheses and highly structured outcomes (Timmerman *et al.,* 2008), where hypotheses are linked with the testing of variables. A further level of variation appears here with the appearance of single or multiple variables associated with carrying out a test or experiment, and again, may reflect the didactic element of science experimentation in schools with its heavy focus on independent and dependent variables.

FACTOR 3 captures variation in the dimension of an 'educated guess' for six items, with two items eliminated because of cross-loadings.

What you think, which can be testable, might be the outcome of an experiment?

This dimension again demonstrates a thinking process grounded in the test, but provides an insight into a more measured and thoughtful process where the scientist oscillates between the various phases of the hypothesis generation and testing.

FACTOR 4 retained three items focusing on 'explanation', and excluded a further four items.

A possible explanation (for an observation) that can be tested and either accepted or rejected

This factor focussed on the process at a more statistical level with the potential for determining the outcome through null testing, an area fraught with confusion for both students and teachers (Lawson *et al.,* 2008).

ANALYSIS OF THE RESIDUAL SET OF THIRTY ONE ITEMS

For the residual dataset, a three factor solution, eventuated which retained a total of nineteen items from the original thirty two items, and had one item which did not load on any factor.

FACTOR 1 was readily interpretable as variation in terms of 'prediction', with four items with highest loadings retained, and a further five items excluded through cross-loading.

Prediction of the results or outcome of an experiment or study

FACTOR 2 identified twelve items with a general theme of 'testing', and eliminated three items from the proposed instrument set.

A testing statement to find out the relationship between two variables or others based on the theory

FACTOR 3 included only one unambiguous item, based on the idea of a 'guess', and three items which were eliminated.

A guess as to the outcome of a testable theory or idea

A four factor solution for the residual set retained much of the integrity of the three factor solution and failed to introduce any further meaning into the final set of items.

CHARACTERISTICS OF THE TRIAL INSTRUMENT

A clear picture of the problems faced by students thinking about hypotheses can now be examined both in terms of addressing the diagnostic elements of the instrument, and designing learning activities to highlight the dimensions of difficulty. A distinguishing feature of the items in two factors focused on the concept of the 'prediction', or predictive character of an hypothesis. This clearly resonates with students' understanding of the role of the hypothesis in experimentation or explanation of phenomena, but raises interesting questions *vis á vis* the relationship between hypotheses and predictions. The position and role of each in the hypothetico-deductive process has been deliberated in terms of the confusion arising when the two are used interchangeably (Lawson, 2003; Lawson *et al.,* 2008); such confusion requires careful consideration when designing curriculum activities. Furthermore, the conflation of these two areas detracts from a focus on the arguably central theme of inquiry and investigation in science education, namely the *question* (Taylor and Meyer, 2010). Characteristics of the other factor items point to a student understanding of the nature of *testing* associated with hypotheses, which may suggest a previous history of a highly structured science investigation process in school laboratory classes (Timmerman *et al.,* 2008), or a better handle on the 'how' of the process. Finally a focus, for the remaining factor items, on *explanations* and *guesses* may indicate that students view hypotheses from the 'what' perspectives in terms of answering questions (Taylor and Meyer, 2010).

Clearly the *question* is paramount in the thinking process, but is lost in a cloud of activity associated with getting a right answer. To compound the problem, students rarely have the opportunity to ask the original question which initiates the investigative process, thereby further losing ownership of the process. They are thus reduced to drifting in an anchorless liminality, where there is apparent 'scientific' activity but no 'what' statement for guidance and purpose.

MAKING USE OF THE INSTRUMENT

The trial diagnostic instrument has been used in 2011 and 2012 at two different universities. Meanwhile information from the factor analysis of the items has been used to design curriculum changes which a) extend initial teaching and testing about hypotheses, b) develop discussions about hypothesis testing where students design their own experiment, c)

highlight the significance of the question and hypothesis in developing an experimental protocol and d) emphasise the centrality of the hypothesis in effective interpretation of results. Student evaluations indicate that the thinking process has changed, for example responses included:

> *"It was an interactive course where you had to think... we liked designing the photosynthesis experiment… very challenging".*

Despite these promising initial outcomes, students still have difficulty seeing the underlying question which guides the investigation and the thinking process (Lawson, 2003), and this proves a significant hurdle when writing reports and interpreting the data. Overall, the instrument provides a profile of individual students which is useful in tracking their progress, while a profile of the extent of variation in understanding of the whole cohort provides reliable information for the design of subsequent teaching and learning activities.

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Part 3: Interdisciplinary Threshold Concepts

INTERDISCIPLINARITY AND INFORMATION LITERACY INSTRUCTION: A THRESHOLD CONCEPTS APPROACH

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Biographical Note

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The authors began collaborating in 2008 while teaching a required, 2-unit information literacy at California State University, East Bay, and applied threshold concepts to restructuring their classes.

KEYWORDS

Information literacy, library instruction, threshold concepts, interdisciplinarity, librarians

ABSTRACT

Librarians are uniquely positioned to identify characteristics of the information landscape that occur across and between disciplines. We work with radically shifting models of scholarly communication and information formats, and, further, explain to students and faculty how these changes vary in different disciplinary contexts. The identification of threshold concepts within such mutable territory raises questions about disciplinary boundaries, leading us to reconsider what it means for threshold concepts to be bounded by a discipline.

INTRODUCTION

Librarianship is an interdisciplinary practice. Perhaps no other role in academia so regularly moves between different disciplinary perspectives, through both collection building and the teaching that librarians do. Publishing, information sharing and formats, the research process – all disciplines communicate knowledge in a variety of ways, yet the librarian is the only person in the university with a bird's-eye view of these processes.

Consider the following scenario. A student approaches a librarian at the reference desk, assignment in hand, seeking primary sources. The method of assisting her will depend on the discipline she is engaged with: primary reporting on a clinical trial is in order if she is a health scientist, but she will need newspapers, diaries, or letters if she is a historian. As librarians instruct students in finding, evaluating, and ethically using information sources, we constantly adjust the message to address students' respective disciplines.

Information literacy (also referred to as information fluency or information competency), as defined by the Association of College and Research Libraries of the American Library Association, is a blend of skills and knowledge required to *"recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information"* (ACRL, 1989). This term has gained little traction outside of the library literature and librarians have had difficulty securing broad-based curricular integration of information literacy (Derakhshan and Singh, 2011, p. 219), though there are a growing number of well-developed information literacy programs at institutions such as University of Alberta, Augustana, or Baruch College at the City University of New York. Complicating matters, information literacy is easily lumped together with critical thinking or the general goals of higher education, or with other 'new literacies', such as media literacy, visual literacy, transliteracy, and so on.

The authors, all librarians at universities in the United States, posited a series of threshold concepts intended to reframe our teaching of information literacy. Through teaching a credit-bearing information literacy course, we identified areas where students struggle with content. We theorized about the underlying concepts students need to grasp in order to progress, then assessed these according to Meyer and Land's (2006) definitional criteria. Additional research has queried other teaching librarians in North America, the UK and Australia about their perceptions of troublesome content.

In the process of our research, it became clear to us that the thresholds we proposed were informed by an interdisciplinary perspective. At the same time, our interdisciplinarity presented a conundrum for us in that we struggled with the idea of information literacy being 'bounded' in the same way as a traditional discipline, like mathematics or

economics. We believe that exploring this problem with respect to information literacy sheds some light on the general issue of interdisciplinary and threshold concepts.

INFORMATION LITERACY: DISCIPLINARITY AND INTERDISCIPLINARITY

Librarians are trained in information science, a field that sits at the intersection of the philosophy of knowledge, computer science, law, library science, communication, management and more. As opposed to professional training in librarianship, the typical information literacy curriculum is a sort of 'information sciences lite', or basic applied information science. Our initial approach to threshold concepts for information literacy was complicated by the gap between what we do as professionals and scholars on the one hand, and what we actually teach on the other. Reading Meyer and Land's early work, we wondered whether it was possible to apply threshold concepts to a less established discipline. What does 'bounded' mean with respect to defining threshold concepts for applied disciplines or interdisciplinary fields?

Unlike teaching scenarios where students are trained to think like practitioners – even in courses for non-majors – within librarianship it is commonly accepted that *"we don't want to make little librarians out of our students".* This differs from an introductory biology course, for example, where even the reluctant theater major must learn the scientific method. The concrete applications of information science, from searching databases to citing sources, are often taught with little or no attention paid to the underlying theoretical structures or abstract content of information science. This problem is articulated by Lucas and Mladenovic (2006) in the context of a compulsory accounting course in which instructors focus on teaching technique, or procedural content, in response to students' negative preconceptions about the subject.

Without depth, our curriculum becomes a shadow of itself, lacking color or interest. Students will only gain a superficial understanding of the ways and means of information, never grasping some of our most fundamental principles adequately enough to apply them in diverse settings. And this is a serious problem precisely because the principles of information literacy do not exist in a vacuum, but are shaped by context. Librarian William Badke likens information literacy to ethics:

> *"The discipline of ethics can form a good analogy [to information literacy] as it ranges through the academy as philosophical ethics, bioethics, business ethics, professional ethics, and so on. While the philosophical framework within which it operates has a strong consistency, it works out its methodology and application in different ways, depending on its subject matter"* (2008).

While what we teach is meant to be applied within the disciplines, our content draws from information science and does not belong anywhere else in academia. In fact, it seems that the most essential preparation for academic librarianship – not, to our knowledge, taught in any library science program – would be a course introducing library school students to the research methods of the major disciplines.

Initially, we struggled quite a bit with the possibility that information literacy threshold concepts should be 'bounded' by a discipline when they are both interdisciplinary *and* applied in every discipline. Once we discovered how useful the threshold concept approach is, though, we doubled back and theorized that 'bounded' could more loosely refer to content that is unique to our area of practice, as per Meyer and Land:

> *"Threshold concepts would seem to be more readily identified within disciplinary contexts where there is a relatively greater degree of consensus on what constitutes a body of knowledge (for example, Mathematics, Physics, Medicine). However within areas where there is not such a clearly identified body of knowledge it might still be the case that what the ETL project team (Entwistle et al., 2002; Hounsell and McCune, 2002; McCune and Reimann, 2002) have come to encapsulate in the term 'ways of thinking and practisin'g also constitutes a crucial threshold function in leading to a transformed understanding"* (Meyer and Land, 2003, p. 9).

This understanding was extremely productive for us when thinking through threshold concepts for information literacy. For example, understanding information formats as a process of production is unique to the information literacy curriculum – it doesn't belong anywhere else. But concepts about time management (e.g. starting a paper early enough to do good research) cannot be *"understood as unique and specific to information literacy"* (Hofer *et al.,* 2012, p. 389).

THRESHOLD CONCEPTS AND INTERDISCIPLINARITY

We found that the work of Patrick Carmichael and his colleagues (first described in Carmichael *et al*., 2007) resonated with our experience as librarians wrestling with defining threshold concepts for an interdisciplinary field. Their project introduced threshold concepts to a diverse group of faculty, then supported research and case studies within each discipline. This output was used to foster broad, cross-disciplinary discussion of threshold concepts. Carmichael also

describes how disciplinary identity was expressed through this project, which interests us precisely because *interdisciplinary* identity can be so difficult to pin down.

Participants in Carmichael's project, developing threshold concepts for their own fields, chose to work with concepts that *"exemplify discipline-specific conceptual frameworks"* (Irvine and Carmichael, 2009, p. 112). The threshold concepts that participants identified for their disciplines

> *"...were also being used to represent, in the context of a cross-disciplinary seminar, what was distinctive about the disciplinary 'ways of thinking and practicing'. These were not merely thresholds internal to the discipline, to be confronted by students as they developed subject mastery; they were also representations of disciplinary identity within a diverse multi-disciplinary group"* (Carmichael, 2010, p. 60).

This suggestion that threshold concepts can be used to engage those outside the discipline with its ways of thinking puts a new emphasis on the idea that threshold concepts are outward-facing. Students are by definition non-practitioners, outside the discipline, and are the most obvious audience for threshold concepts. We can similarly engage non-librarians with information literacy threshold concepts. This is crucial for librarians, who may struggle to communicate the content of information literacy to faculty in other disciplines, with whom we frequently collaborate.

Atherton *et al.* (2008) capture the dilemma of defining threshold concepts for 'soft' or applied disciplines, which we connected to information literacy through the applied field of information sciences. They point out that threshold concepts in the professions, though they are "*beyond traditional academic disciplines*" still

> *"...serve the same function as portals to new areas of knowledge, integrating other ideas, and defining the boundaries of the discipline or belief system. They are of course ontologically transformative..."* (p. 11).

What we find valuable about threshold concepts is that they push us to clarify and prioritize the core content of what we teach, a similar experience reported across disciplines. This clarity, in turn, helps us communicate with others in the organization about our practice – again, a benefit seen by practitioners of 'hard' disciplines, as Carmichael discovered. Perhaps the idea that threshold concepts are bounded unnecessarily causes threshold concepts to seem better suited to mainstream disciplines, when this theory is ripe for much broader applications to settings where teaching and learning take place.

Meyer and Land anticipated the difficulty that interdisciplinary practitioners might experience when attempting to formulate threshold concepts for areas of knowledge with uncertain boundaries, while leaving the theory open for others to refine in detail. Their original articulation of the bounded characteristic – *"any conceptual space will have terminal frontiers, bordering with thresholds into new conceptual areas"* (2003, p. 5) – may be especially difficult for scholars in interdisciplinary fields to interpret. Our own experience (and as documented by Carmichael) demonstrates that threshold concepts help us demarcate the boundaries of our area of practice. After a decade of research, it may be time to revise the 'bounded' criterion to simply state more broadly that threshold concepts are situated in a field of practice.

INFORMATION LITERACY THRESHOLD CONCEPTS IN PRACTICE

Following are some examples of threshold concepts we have formulated for information literacy that demonstrate the interdisciplinary nature of our field. While these are unique to the field of library and information science ('bounded'), they are simultaneously applicable in discipline-specific settings.

Earlier, we presented the scenario of a student seeking primary sources, and encountering the question of what constitutes a primary source in her discipline. This points to a threshold concept the student needs to grasp in order to progress in her discipline, as well as to become information literate. After explaining the nature of 'primary' to students many times over, and querying other teaching librarians via a survey on troublesome concepts, we proposed the following threshold concept: *"'Primary Source' is an exact and conditional category"* (Hofer *et al.,* 2012). The terms primary/secondary have precise meanings that change depending upon one's disciplinary lens, because information is created, used, and disseminated differently in different disciplines. The same source could be considered primary material in one context and shift to secondary when viewed through a different disciplinary or temporal lens.

Clearly, different disciplines have different notions about source types. But even within a single discipline, the question is not settled. For instance, most of us learn, in history classes, that a secondary source is a work that builds upon and synthesizes earlier, primary sources (first-person narratives, for example). But a source that is clearly secondary, such as a medical textbook from the 1950s, is primary to a scholar writing about the history of medical education during that period. Data from our research underscores that students struggle with the question of primary and secondary, and more broadly, the cycle of information production in academia. As one survey respondent observed, *"Information and*

knowledge is not a random sandpile, but a developed landscape of communities which have the information they need... Students don't yet see the structures of scholarly communication".

Understanding the fluidity of primary and secondary source types – that the categories are exact *and* conditional – leads to a deeper understanding of the purpose of research, the generation of new knowledge, and the dissemination of information. Moreover, getting to this threshold concept requires an interdisciplinary perspective on the ways that various disciplines understand sources. This concept surfaces the disciplinary meaning of 'primary' and 'secondary' source types, while also introducing the concept of primary/secondary from the LIS perspective as a mutable term. Educators in all branches of the academy can use this concept to both clarify the meaning of sources in their respective disciplines, and also to situate their own practices within the broader information landscape.

A second information literacy threshold concept addresses the confusion that students demonstrate when identifying publication types. This used to be a fairly straightforward process: a scholar would simply browse the library stacks to find the journals or monographs in her field. But a student of the millennial generation may not see how, for example, an online *Lancet* article is fundamentally different from a 'web page' when both are accessed via a browser. Faculty who contend with poor quality websites cited in student work often perpetuate common misconceptions when they ban 'internet sources' from bibliographies. Students are no closer to being able to differentiate formats – newspaper articles, books, government reports, etc. – all of which can be found in print or online.

The threshold concept we propose to move learners past this trouble spot is that format is a process (Townsend *et al.,* 2011). What makes a book a book and journal article a journal article has nothing to do with the mode of access, but is determined by the process that led to its creation (editorial guidance, peer-review, the return key on a blog page, etc.). That students have trouble with such differentiation was confirmed in our research, where format-related problems were mentioned frequently. As one respondent summed it up, students have difficulty *"...understanding different publication types (popular, scholarly, trade). They seem to see information as flat…"* The threshold concept 'format is a process' addresses tacit knowledge that falls within the information literacy domain and yet applies across all disciplines.

CONCLUSION

Information literacy threshold concepts can act as ambassadors. They can offer access to our teaching material for those who are not in our field but who nonetheless may be responsible for teaching information literacy concepts. It is hoped that information literacy threshold concepts will give teachers of research in any discipline a clearer picture of the information landscape and the challenges to learning that students face. At the same time, threshold concepts also sharpen our own understanding of the boundaries of information literacy content.

Yet, these observations are not unique to threshold concepts for information literacy instruction, or interdisciplinary threshold concepts more generally. They may apply to threshold concepts in any discipline, though interdisciplinary fields may stand to gain the most from clarifying their content in this way. We suggest that the 'bounded' characteristic of threshold concepts, while troublesome for interdisciplinary practitioners, may be very productive if it is generalized to unique concepts situated within areas of practice.

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"HOW DO YOU KNOW?" THE THRESHOLD CONCEPT, MULTI-DISCIPLINARY APPROACHES AND THE AGE OF UNCERTAINTY

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Biographical Note

Brendan Hall lives and works in Shetland. In 2010 he completed his PhD thesis entitled 'Teaching uncertainty: the case of climate change", in which threshold concepts played a key role as a theoretical framework. Since then Brendan has retained a keen interest in threshold concepts, particularly the emergent theme of interdisciplinary thresholds.

KEYWORDS

Uncertainty, multi-disciplinary, ontology, climate change, troublesome knowledge

ABSTRACT

Uncertainty is a concept that presents both challenges and opportunities for teachers. The 'Age of Uncertainty' in the 21st Century necessitates teachers developing or adapting pedagogies that allow them to teach uncertainty and prepare their students for life in an uncertain world. Treating uncertainty as a threshold concept facilitates the understanding of uncertainty in the context of teaching and may act as a robust framework around which to develop the pedagogy of uncertainty.

This paper presents research into uncertainty as a concept in the context of climate change. In this subject area uncertainty plays a fundamental role and has a variety of features which identify it as a threshold concept. It can be characterised as a troublesome concept in epistemological terms in that it is a difficult concept for students to grasp and it also possesses a strongly ontological dimension, which may be recognised in terms of liminal transitions on the part of teacher and learner. Uncertainty is also conceptualised in a wide variety of qualitatively different ways, many of which remain tacit in nature and there is also considerable liminal variation in how students come to understand the concept or not.

Uncertainty demonstrates enormous potential as a concept that can profoundly change how learners comprehend complex issues such as climate change and may play a major part in students' intellectual and personal development, allowing them to work and thrive in an uncertain world. The variation identified in relation to uncertainty also shows promise as a starting point for the integration of conceptions of uncertainty that have their origins in different disciplinary cultures and contexts. This may lead to new realisations on the nature of uncertainty, leading to students developing a deeper understanding of the concept in relation to the complexity of reality.

Indeed, a multidisciplinary approach may be necessary in order to teach the concept of uncertainty, particularly in subject areas such as climate change, which act as interfaces between a large number of different academic disciplines.

This paper aims to explore the role of multi-disciplinary approaches to teaching uncertainty and the potential of uncertainty as an inter-disciplinary threshold concept. The identification of uncertainty as a threshold concept in disciplines as diverse as surgical education[1] and physics[2] suggests that this could be a fruitful ground for discussion.

INTRODUCTION

This paper presents doctoral research into the concept of uncertainty in the context of climate change and how it is conceptualised and taught by academics working in the subject area. Data were collected in ten interviews conducted by the author with academics teaching about some aspect of climate change within Geography programmes at universities in England, Wales, New Zealand and Australia. The academics involved represented a wide range of academic backgrounds and interests and were drawn from institutions across the higher education sector, from newer, more teaching focused universities to older, more research-oriented institutions.

Climate change provides a highly useful context in which to investigate uncertainty as it is a subject area in which uncertainty is all pervading and the term uncertainty *"can range in implication from a lack of absolute sureness to such vagueness as to preclude anything more than informed guesses or speculation. Sometimes uncertainty results from a lack of information and on other occasions it is caused by disagreement about what is known or even knowable"* (Moss and Schneider, 2000, p. 35). Furthermore, teaching and learning about climate change *"necessitates the ability to deal with*

uncertainty on several levels – not only uncertainty about the workings of the complex physical climate system, but also uncertainty with respect to social and cultural processes that mediate human response to changes within the system" (Rebich and Gautier, 2005, p. 355). Climate change is also a subject area that is inherently multi-disciplinary in character (Hulme and Turnpenny, 2004); the research raised some interesting questions in terms of the role of threshold concepts in teaching uncertainty and the implications of multi-disciplinarity in relation to this.

THE AGE OF UNCERTAINTY AND IMPLICATIONS FOR TEACHING

Uncertainty has become a pressing concern for higher education in recent years as the need has been identified to prepare students for a 'supercomplex' world characterised as an "Age of Uncertainty" (Barnett, 2007, 2000; Baumann, 2007). In a supercomplex world, the complexity brought about by the accessibility and connectivity of knowledge and information is compounded by challenges to the frameworks that would normally be employed to synthesise and utilise such knowledge. This results in extreme difficulty orienting oneself to the world and even being able to describe it (Barnett, 2000). A key component of understanding the supercomplex world is understanding the concept of uncertainty, allowing for the ability to learn and operate in a world where knowledge and values are contested (Barnett, 2009).

'Uncertainty' in this case refers principally to epistemological uncertainty, associated with the status of knowledge or knowing related to a given subject or phenomenon. Uncertainty relating to knowledge includes a range of possible interpretations including that which is unpredictable, as yet unknown or even unknowable. The concept of uncertainty referred to here may refer to any or all of these interpretations such that an understanding of uncertainty may include understanding that something is uncertain, why and how the uncertainty arises and what the implications of that uncertainty are (Hall, 2011). However, the concept of uncertainty can also be said to be ontological as well as epistemological in character; bringing about feelings of being uncertain as challenges and realisations relating to the status of knowledge are encountered (Barnet, 2009).

Despite the fact that this study was focused on a multidisciplinary subject area as opposed to one distinct discipline, threshold concepts are a useful framework for analysing uncertainty in that they allow for an appraisal of both its epistemological and ontological characteristics.

UNCERTAINTY AS A THRESHOLD CONCEPT: EPISTEMOLOGY AND ONTOLOGY

The epistemology of uncertainty in the case of climate change is clearly troublesome; many of the participants identified it as a concept students 'struggled with' whilst also acknowledging that it is central to an understanding of climate change. Uncertainty is viewed as being conceptually difficult on account of its complexity and also a concept that challenges some students' 'naïve notions of fact' in relation to immutable scientific 'truths'. Uncertainty is also seen as a 'foreign' concept as it is not one that students necessarily expect to encounter in the course of their studies within a particular discipline (bearing in mind that all of those interviewed were teaching within Geography programmes). This issue of identity was also recognised by the teachers themselves who acknowledged the difficulty that they encounter when attempting to integrate diverse uncertainties within multi-disciplinary research groups – a fact further compounded by the complexity of the concept itself and the climate change subject area.

This in turn raises the issue of the tacit nature of uncertainty, in that it is a concept that teachers realised that they often did not teach explicitly. Many of the participants, whilst acknowledging that uncertainty was 'very important' in the context of teaching about climate change, also admitted that it was not a concept that tended to be 'formalised' in teaching. Uncertainty is referred to as 'implicit' on several occasions, either as a result of the other troublesome facets of the concept (i.e. conceptually difficult and foreign knowledge) making it difficult to teach and a concept to be avoided or internalised, or owing to its centrality, ubiquity and inherence within the multidisciplinary subject area of climate change. This centrality appears to lead to uncertainty not being articulated as it is *"just something climate researchers do"* and would also appear to suggest that uncertainty is tacit knowledge, as described by Polanyi (1958) and Wenger (1998), in that it is something that is learned through practice rather than formal teaching. That uncertainty is tacit in the nature of climate change also seems to lead to further troublesomeness in terms of assessment. Participants describe it as being *"hidden"* and something that either *"clicks or not"* and that it is extremely difficult to assess explicitly; it is said to be *"in there somewhere"*. Even those participants who assert that they do teach and assess an understanding of uncertainty explicitly are forced to admit that in fact they do not, that it remains hidden in almost everything they teach. This was certainly the case for one participant, who began her research interview with discussion of how uncertainty was *"explicitly and implicitly there in everything I do"* before coming to the realisation that the explicit teaching of uncertainty formed only a very minor element of the course in question.

The ontology of uncertainty is evident chiefly in the liminal transition that students experience as they come to understand the concept in its complexity and ubiquity. Liminality itself may be described as a state of uncertainty, a time in which learners may not know what they know or believe or even who they are (in the sense that their identity has been 'stripped' from them as part of the liminal transition) (Meyer and Land, 2005). As mentioned above, uncertainty is a sufficiently troublesome concept to provoke a state of liminality and students were characterised by the participants as 'defended learners' (Land, 2009) when faced with uncertainty. The participants also describe the profound ontological uncertainty experienced by students when attempting to come to an understanding of the epistemological uncertainty inherent within climate change – expressed in terms of *"bewilderment"* or a *"loss of hope"*.

However, it was also noted that the difficulties of liminality experienced by students are not without reward, it is also recognised as a powerfully transformative and reconstitutive concept. Participants opined that an understanding of uncertainty was linked to *"becoming a scientist"*, *"realisations"* about the uncertain nature of knowledge, developing an enquiring mind and developing criticality and skills of critical thinking. This transformation was also seen as *"fundamental"* for graduates, in a capacity that may be comparable to the notion of graduate attributes, particularly when one considers the stated desire to produce *"agents for an unknown future"* (Barrie, 2004, 2007). This links an ability to understand uncertainty with developing intellectual and personal maturity on the part of the learner; this was also a characteristic that some participants recognised in their own academic journeys.

VARIATION AND MULTI-DISCIPLINARITY

Considerable variation was identified in how learners and teachers alike conceptualise and engage with uncertainty in this context. The aforementioned resistance to learning uncertainty represents a species of liminal variation in that some students 'take to it' whilst others do not. Pre-liminal variation, which allows for the crossing of the threshold of understanding uncertainty, is characterised in terms of 'openness' and 'willingness' to accept the concept and its implications. This may be analogous to the 'will to learn' identified by Barnett (2007) as essential for students learning in an uncertain world.

Sub-liminal variation was identified in the (often tacit) conceptions of uncertainty held by participants, which differed widely across the selected group. It appears that the conceptions of uncertainty themselves represent sub-liminal variation among those teaching uncertainty, where they tacitly view uncertainty in a certain way, depending on their own personal identity or research specialism and, therefore, experience difficulty when integrating uncertainties from other areas within climate change. The understanding of uncertainty may be highly personal, making this sub-liminal variation difficult to recognise and accordingly giving rise to difficulty in teaching or learning the concept

This variation can be said to be fully expected in that the group of participants was drawn from a variety of academic backgrounds and disciplinary cultures. However, it has been interesting to note the applicability of the threshold concepts framework in this multi-disciplinary setting and the seeming benefit in addressing complex concepts such as uncertainty using multi-disciplinary approaches (Hall, 2011). Uncertainty is not an esoteric concept; however, the troublesomeness of integrating diverse conceptions of uncertainty (as encountered in complex subject areas such as climate change) indicates that uncertainty may be an interdisciplinary threshold that can act as a portal to new disciplinary ways of thinking as well as lending an improved understanding of the subject matter as a whole.

BEYOND CLIMATE CHANGE

Uncertainty has been identified as a threshold concept by other researchers in different teaching and learning contexts. For example, Åkerlind *et al.,* (2010) have published a report for the Australian Learning and Teaching Council seeking to identify threshold concepts in various disciplines and use these, and the application of variation theory, as a starting point for curriculum design. In physics, measurement uncertainty was identified as a threshold concept together with several critical features of the concept that could form the basis for teaching for and assessing an understanding of uncertainty (Åkerlind *et al.,* 2010). Land and Meyer (2011) have recently published a fascinating paper on surgical education that identifies uncertainty as a 'dominant' threshold concept in that field. The uncertainty in this instance arises from the complexity of the field itself and the fact that each surgical case is, literally, unique. This raises the intriguing possibility that ontological uncertainty is a constant, such that: *"every time surgical procedure is undertaken the degree of uncertainty renders the journey different. In this respect surgeons, in a similar fashion to that reported by both artists and engineers, do not ever permanently escape liminal space"* (Land and Meyer, 2011, p. 100). Even when one grasps the epistemological concept of uncertainty the ontological consequences remain and one remains in a constant and

prolonged state of liminality. It is perhaps realising and coping with this that may end up as the goal for those wishing to teach uncertainty or teach in uncertain subject areas.

The surgeons interviewed by Land and Meyer in the above paper also acknowledged the importance of 'being' multi-disciplinary – *"to be able to make a risk analysis for the other disciplines"* (Land and Meyer, 2011, p. 100). The juxtaposition of uncertainty, here identified in terms of risk, and multi-disciplinary approaches to learning and working mirrors the findings from the climate change study; both fields are highly complex and there is a strong emphasis on disciplines sharing the right information (and information of sufficient quality) for decision making. Once again, the interaction of various disciplines across certain key interfaces may facilitate an appreciation of uncertainty and an understanding of not only the concept itself but also its centrality, ubiquity and importance in all things. Another example of a threshold concept that may benefit from multi-disciplinary approaches and thinking is that of sustainability; Brooks and Ryan (2008, p. 12) posit that the concept of sustainability may be a *"permanently shifting threshold concept [where] both disciplinary and interdisciplinary understandings of it will […] be useful".* This brings in the idea of a degree of dynamism around a concept and that multi-disciplinary approaches may assist in bringing context to rapidly shifting understandings and conceptions – as typify the 'Age of Uncertainty'.

CONCLUSION

Uncertainty is a fascinating and potentially very fruitful area for exploration by the threshold concepts community. It seems to be a concept that both allows for, and is enhanced by, multi-disciplinary approaches to teaching. An understanding of uncertainty may be facilitated by (or even necessitate) multi-disciplinary teaching contexts and an understanding of uncertainty may itself enhance the ability for learners to interact with other disciplines and act as a threshold between disciplinary cultures and identities. The ontological implications of uncertainty also merit further investigation, as does the identification of critical features and development of pedagogy for teaching and assessing uncertainty.

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SEEING DEEPLY IN SPACE AND THROUGH TIME: INTERDISCIPLINARITY MEETS THRESHOLD CONCEPTS IN EARTH AND ENVIRONMENTAL SCIENCE

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KEYWORDS

Threshold concept, interdisciplinarity, earth and environmental sciences

ABSTRACT

Earth and environmental science (EES) students struggle, not only with the ideas of enormous time frames and 3-dimensional spatial thinking, they also grapple with integrative concepts such as change in space through time, or the recognition of patterns and anomalies in complexity.

Earth and environmental science (growing out of geology) integrates aspects of all other sciences in attempting to understand our world. With EES's long history of integrating disparate disciplines, it offers insights into the development of overarching threshold concepts in interdisciplinary fields. It is proposed here that the overarching threshold concepts in the EES include: (1) change through space and time; (2) recognizing patterns in variability; (3) living with complexity and uncertainty; (4) contextualizing space; (5) the interplay between equilibrium and disequilibrium, and (5) the integration of complex physical, biological, (with social, economic, psychological) and technological components.

Identifying and mastering these more complex overarching threshold concepts is key to students' development of a true interdisciplinary understanding. This also poses new challenges for us to create learning environments in which students cross these more complex thresholds rather than simply side-step through the already-difficult troublesome concepts in the sub-disciplines involved. It is possible, though not desirable for example, that students develop understanding of geologic time and of 3-dimensional space, but never cross the threshold where the linkage between these is mastered. True interdisciplinarity approaches in EES require the latter, and our task is to pave the way for such integration. In other words, there are threshold concepts which are 'inter-integrative' superimposed on those which are intra-integrative.

INTRODUCTION

Nature is complex and understanding or working with nature, requires an interdisciplinary approach with input from the various sciences, humanities, and more. Meyer and Land (2003, 2005, 2006) propose that there are those concepts within a discipline that may be considered threshold concepts (TCs), that is, concepts that are troublesome, transformative, irreversible, integrative, and typically serve to define boundaries for a discipline. To become expert, novices must cross these thresholds. If threshold concepts serve as boundaries to disciplines, then how do we study, problem-solve, or otherwise work to understand something broader than a given discipline? This overview explores some of the potential troublesome ideas that transcend disciplinary boundaries, and may therefore be considered interdisciplinary threshold concepts, through the lens of earth and environmental sciences. Some of these proposed troublesome ideas will span a range of disparate interdisciplinary connections, others will be more specific to the world of nature. Possible pathways to pursue additional research, which in turn may create a body of evidence from which to develop the idea of interdisciplinary threshold concepts, are also discussed.

Earth science, or geology, is a science rooted in understanding the physical earth. Whereas specific threshold concepts for the earth sciences have not yet been clearly and completely identified (Stokes *et al.*, 2007), a number have been proposed: geologic time (Truscott *et al*., 2006); spatial literacy (King, 2006); sustainability (Magnier, 2006); quantification (Stokes, 2006); knowledge, evidence, complexity and uncertainty (Knight, 2006); complexity and uncertainty (Hall, 2011); and interestingly, interdisciplinarity itself (Dalrymple and Miller, 2006). These can be considered key to expert thinking in

the 'discipline' of earth science, which has in turn drawn heavily from the fields of physics, chemistry, biology, math, and others. In other words, earth science is an established discipline in which interdisciplinary thinking has been the norm for many years. In more recent years, environmental science has risen as a discipline, and much like earth science, it draws heavily from many disciplines in defining its paradigm. In viewing the possibility of interdisciplinary threshold concepts through the lens of earth and environmental sciences, it is proposed here that there are a number of key gateway ideas that need addressing for effective integration of disparate disciplines. While not intended to be exhaustive, the following gateway ideas are proposed:

(1) Change through space and time

(2) Recognising patterns in variability

(3) Living with complexity and uncertainty

(4) Contextualizing space

(5) Interplay between equilibium and disequilibrium

(6) Integration of complex physical, biological, social, economic, psychological and technological components

Although somewhat artificial, each of the first five of these is considered separately below in terms of its significance as a possible interdisciplinary threshold. The ideas presented here evolve out of the kind of multifaceted thinking that is required in geologic thinking, or as Frodeman (1995) argues, the interpretive and historic thinking processes of geology. That is, geologic thinking provides a lens through which to view interdisciplinary thinking in the broader earth and environmental science realm, and beyond.

INTERDISCIPLINARY THRESHOLD CONCEPTS: BACKGROUND

1. CHANGE THROUGH SPACE AND TIME

> *This sequence of sediments, three kilometers thick, was deposited 400 million years ago.*

This is a relatively straightforward statement that describes succinctly an 'event', the 'amount of material involved' and the 'time'. On the other hand, the following statement also describes an 'event', a specific 'amount of material involved', and a given 'timeframe'.

> *The tsunami moved 10 tonnes of material up to 1 kilometer inland, and lasted several minutes.*

These statements however, are poles apart in terms of what happened, the rates involved, and the consequences. In order to UNDERSTAND the first scenario, students need not only to be able to somehow conceive of great periods of time, but also to imagine a realistic process or processes that might result in such volumes of sediment, and a myriad of possible changes over time. In the second example, students may be faced with a problem in which they must consider where specifically these sediments came from in order to determine what might be present as a contaminant, and decide whether the processes over time and space have resulted in additional changes. Both require that a student: (1) think in the present to link to the past; (2) recognise what has changed and what has remained the same; (3) conceptualize the significance of rate in establishing what really happened; and (4) consider that the present-day setting of the sediments most likely looks nothing like it did when the sediments were deposited. In other words, to fully understand, they need to recognise and comprehend change in space and time.

The integration of ideas of space and time prove thorny in such instances. We need to find ways to guide students as they move to make more complete sense of the whole by integrating these components in ways they have not previously considered.

2. RECOGNIZING PATTERNS IN VARIABILITY

Earth systems science attempts to integrate various components of the earth in order to better understand and to attempt to explain how the earth functions as a whole. Key components typically considered are the atmosphere, the hydrosphere, the geosphere, and the biosphere – air, water, land, and life. Inputs to the system effect outputs; the various components are interdependent; the paths through which energy and matter flow through these systems are almost infinite – so how does a person begin to make sense of such variability? It is quite possible that a student may have crossed key thresholds in one or two of these component systems, but unlikely that they are experts in all four of the component fields, and even if they were, the interconnections between the fields may prove to be thresholds. Cognitive load theory, introduced by Sweller in 1988 and refined by van Merrienboer and Sweller in 2005, suggests reducing the

amount of material the working memory has to draw upon, and capitalizing on the schema (Bartlett, 1932), the organizational frameworks of long-term memory, to make sense of new information received through the senses. Anderson *et al.* (1978) conclude that schema theory predicts learning from textual materials. Novices have less-developed schema than experts, with the latter relying on often complex and sophisticated schemata to make sense of new information. In other words, experts work with reduced cognitive loads when faced with new sensory information in their discipline. Recognizing patterns across earth systems is one way in which novices can reduce cognitive load, so we need to provide multiple opportunities for students to develop their pattern-recognition capabilities.

Driscoll (2001) discusses the importance of organization, context, and past experience in pattern recognition. By way of example, consider the concept of flow: flow results in patterns in the air, on the earth's surface (and indeed, within the earth), in water, and in organisms. The nature and rate of flow differs for different cases, but the patterns produced give us information about the processes involved. Building on the knowledge of flow in one context, providing support for its recognition in a newly-defined context, and creating an organizational framework that serves to build on such prior knowledge and contexts, maximizes opportunities for students to recognize flow patterns across disciplines. In this way, recognizing patterns across disparate fields, may allow students to make better sense of the more complex interconnected systems.

3. LIVING WITH COMPLEXITY AND UNCERTAINTY

Building on recognition of patterns in variability, are the notions of complexity and uncertainty. As humans, we like to be able to explain things in some 'tidy' manner, and complexity and uncertainty do not readily allow for such tidiness of thought. It can be argued that complexity itself is troublesome knowledge, however, when combined with uncertainty, it can lead to heightened frustration that may shut down learning, or result in retreat to 'simpler' explanations. Interdisciplinary thinking by its nature is complex and rife with uncertainty, as we begin to put together puzzle pieces from many directions into a broader whole. When students can transfer what they have learned in one situation to another, there is a greater likelihood that they can start to make sense of some of the complexity and potentially reduce some of the uncertainty, or at least, put some perspective on it. Perkins and Salomon (1988) offer suggestions for fostering such transfer, including carefully contextualizing new information, and explicitly pointing out connections between ideas that to the learner may not seem at all linked in any way.

4. CONTEXTUALIZING SPACE

Imagine the following: you catch a sniff... rotten eggs... in a warm, indoor space: someone has just broken a rotten egg. The same smell, outside near an active volcano: the volcano erupts. The context of the space changes everything. In this case, it is not just the specific location, but also the 'what surrounds', the 'scale' and the distance that contextualizes the space. Recognizing the significance of the context in this case changes everything, and novices need more scaffolding to recognize differences in contexts and their relevance, than do experts.

5. INTERPLAY BETWEEN EQUILIBRIUM AND DISEQUILIBRIUM

When I first learned of the idea of dynamic equilibrium, it was a crossing-the-threshold moment. My formal training identified the concept of equilibrium as an unchanging state of balance. The concept of dynamic equilibrium was particularly intriguing, as the word 'dynamic' was essentially an oxymoron of 'equilibrium'. Yet, much of what we observe daily in nature is in a state of dynamic equilibrium: a river is constantly changing, yet the changes are predictable: one river is much like another in that it flows downhill under gravity, it carries water and sediment that moves, and so on. This same river can experience inputs (heavy rain, snow melt, for example) that cause changes on a much more dramatic scale, and during this time, disequilibrium clearly rules. Eventually this river reverts to a new state of dynamic equilibrium in time, and the cycle continues. The interplay between equilibrium and disequilibrium in nature is very much about change: recognising, identifying, understanding, and predicting change – disequilibrium, and the reestablishment of the familiar – equilibrium. Novices may struggle with this order-disorder relationship, yet without making the connections, there is likely not full understanding of complex natural systems.

FROM THEORY TO PRACTICE: TEACHING THRESHOLD CONCEPTS IN AN INTERDISCIPLINARY CONTEXT

Drawing from the research on cognitive theory, there are a number of key cognitive elements that can serve to scaffold the learning for students as they move through these proposed thresholds. Four are briefly introduced here as a means to

link cognitive research with threshold concepts across the earth and environmental sciences, with implications for interdisciplinary contexts across other traditional disciplines in the sciences and beyond. The rationale for considering each of these four cognitive elements, together with approaches to addressing these in the context of the learning environment and the specific interdisciplinary threshold concept addressed in each case, are summarized in Table 1.

(1) Curiosity: Students who question, who are curious, are more likely to develop an intrinsic interest that in turn allows for deeper learning (Marton and Saljo, 1976). We can encourage a questioning disposition in students, and we can model questions, for as Merchant (2011) so aptly puts it: *"Good questions are treasure troves in life as in teaching because they so effectively open new vistas, provide new perspectives, and challenge our most basic assumptions*". Transformative learning requires such thinking, and passive, unquestioning assimilation of ideas is not sufficient. Indeed, Warburton (2003) argues that deep learning is particularly critical for interdisciplinary studies such as environmental sciences. Such curiosity or inquiry is key to understanding change through time, living with complexity and uncertainty, contextualizing space, and integration of complex systems. We help when we set assignments that require students to develop questions rather than just answers, or identify assumptions and biases in their readings. O'Beirne-Ryan (2008) further suggests that modelling good questioning, presenting a challenge or introducing incongruity, and using images to trigger questions, are additional means to encouraging curiosity and better questioning skills in students.

Table 1: Key facets of interdisciplinary threshold concepts: rationale, approaches, and significant threshold concepts.

Cognitive element	**Rationale**	**Approaches**	**Threshold concept of particular significance**
Curiosity	Increases motivation, which in turn, encourages deeper learning	Build on prior knowledge Model good questioning Present a challenge or introduce incongruity Use images	1. Change (space and time) 2. Pattern recognition 3. Complexity and uncertainty 4. Spatial context 5. Systems thinking
Pattern recognition	Aids in transfer Reduces cognitive load Forms connections	Organize material (stimuli) in logical manner Build on prior knowledge Make context explicit	1. Pattern recognition 2. Complexity 3. Change 4. Spatial context 5. (dis)/equilibrium 6. Systems thinking
Metacognition	Encourages transfer from one domain to another Reflective	Provide opportunities in regular activities or assignments for students to note their stuck-points, how they learn, etc. Model and discuss "how earth and environmental scientists think"	1. Systems thinking 2. Complexity and uncertainty 3. (dis)/equilibrium 4. Change (space and time)
Multimedia	Facilitates "meaningful learning"	Use verbal-auditory AND visual-pictoral stimulae together	1. Change 2. Pattern recognition 3. Complexity 4. Spatial context 5. (dis)/equilibrium 6. Systems thinking

(2) Pattern recognition: Together with the use of analogy, pattern recognition is considered a key component of the tacit knowledge that experts draw upon, in addition to their broad factual knowledge of the discipline.

> *"The ability to plan a task **to notice patterns**, to generate reasonable arguments and explanations, and **to draw analogies** to other problems are all more closely intertwined with factual knowledge than was*

once believed" (Bradsford *et al*., 2000, p. 16).

In particular in the case of an observational science such as earth or environmental science, providing analogies and sensory cues, providing visual cues, as well as allowing for time and opportunity to practice, all improve pattern-recognition, facilitating transfer from one situation to another.

(3) Metacognition: White and Frederiksen (1998), Scardamalia *et al.* (1984), and others, suggest that transfer is enhanced with the support of metacognition, in which a focus on sense-making, self-assessment and reflection is significant. Fostering opportunities for students to engage in such metacognition is critical to making connections and interdisciplinary thinking. Incorporating opportunities for students to write briefly about their stuck-points, how they learn, why they thought a particular way, as well as discussing the way in which experts think about the discipline, are ways in which students can reflect, and practice metacognitive processes. Reflection in this sense is not common in the teaching of sciences, however, when considering interdisciplinary sciences, it is particularly significant.

(4) Multimedia and cognitive theory: Cognitive theory of multimedia learning proposes that we process information through two distinct means: auditory-verbal and the visual-pictoral (Mayer, 2002; Baddeley, 1986, 1999; Paivio, 1986). Mayer and Anderson (1991) contend that *"meaningful learning"* happens when both of these pairs are operating together, and when these build on the prior knowledge of the learner. They further conclude that deeper learning happens when students are provided with visual AND verbal information, which is enhanced when the image and the verbal information are presented together, rather than sequentially. These findings have profound implications for students as they grapple with new ideas, and making connections with respect to contextualizing space in particular: visual and verbal cues together forge connections better than either alone.

CONCLUSION

Identifying interdisciplinary threshold concepts that arise in the realm of the natural sciences is key to developing learners with the understanding and problem-solving capabilities to deal with the complex problems facing our planet in the immediate future. Rooting these threshold concepts in the significant cognitive facets of curiosity, pattern recognition, metacognition, and multimedia approaches, allows for identifying potential pathways and approaches we may take in our teaching as we guide students in their learning (Table 1). Further research based on evidence from the learning environment itself, and focussing on the direct link between cognitive science and interdisciplinary threshold concepts, holds promise for creating not only enriched learning, but also for developing solutions to some of our more pressing environmental problems of the day.

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Part 4: New Developments in Threshold Concepts

THE "SCIENCE EDUCATION FOR NEW CIVIC ENGAGEMENTS AND RESPONSIBILITIES", A US NATIONAL INITIATIVE LINKING SCIENCES, PUBLIC ISSUES AND THRESHOLD CONCEPTS

Monica Devanas, Rutgers University

Biographical Note

Monica Devanas, a microbiologist at Rutgers since 1984, is active in issues of science education; programs for retention of women in science; NSF funded grants. Her course *"Biology, Society, and Biomedical Issues: HIV/AIDS"* is a SENCER model course. She is Director of Faculty Development and Assessment Programs at the Center for Teaching Advancement and Assessment Research, leading workshops on teaching portfolios, curriculum design, learning styles, pedagogy, instructional technology and assessment.

KEYWORDS

STEM education, general education, curriculum design, civic engagement, faculty development, model courses

ABSTRACT

The idea of Threshold Concepts was a foundational element incorporated into many of the courses that are 'models' in the United States-based, large-scale science education program, *"Science Education for New Civic Engagements and Responsibilities"* (SENCER), supported by the National Science Foundation. Faculty participants found that focusing on the threshold concepts of a subject, minimizing the disciplinary jargon and making connections of theory to real-world applications, i.e. the 'troublesome' complex questions of pubic consequence, produced improved learning in disciplinary and general education courses. These challenging and rigorous courses connect scientific knowledge to public decision-making, policy development, and the effective 'work' of citizenship. The consequence of mastery of threshold concepts encourages students to engage in research, to produce knowledge, to develop answers, as well as to appreciate the uncertainty of the knowledge and answers produced.

Faculty participating in SENCER Summer Institutes develop curriculum design elements, clear learning outcomes linked to essential threshold concepts and aligned transparently with classroom and related activities to support the learning that is desired. Outcomes are assessed continuously. SENCER models reflect the intellectual curiosity of the faculty who developed them. At the same time, they respond to students' interests, including personal interests, as well as public or civic foci.

SENCER model courses demonstrate success, showcase effective strategies, and evidence potential for broader implementation and adaptation across academe. The models also advance institutional aspirations to connect the learning of threshold concepts learning including scientific reasoning, inquiry, observation, and measurement as well as fostering interdisciplinary understanding and helping students develop an awareness of ethical issues leading to improved personal choices and behavior.

The SENCER Program and allied activities of the National Centre for Science and Civic Engagement will be presented to support the value of threshold concepts and links to civic issues as successful tools for curriculum development and design.

Have you ever walked into a room in the dark and stumbled over the threshold? Threshold Concepts are central to every discipline and mastering them is the only route to success in mastering the material and thus to success in understanding. The theory of Threshold Concepts holds that we must surmount these thresholds to fully understand the material. Doing this illuminates the path to knowledge. Engaging students in civic issues illuminates the value of the Threshold Concepts and the knowledge of the discipline. It motivates students to learn more about them. Science Education for New Civic Engagements and Responsibilities (SENCER) illuminates the threshold concepts through engaging students in the examining the concepts in the light of real world applications.

INTRODUCTION

SENCER incorporates the Threshold Concepts of disciplinary and interdisciplinary content knowledge and links them to public interest civic issues with a illuminating transformative effect on students, faculty and curriculum. SENCER courses and programs connect science, technology, engineering, and mathematics content to critical local, national, and global

challenges. Students and faculty alike report that the SENCER approach makes science more real, accessible, 'useful' and civically important.

The principles and elements of Threshold Concepts as defined by Meyer and Land (2003), and delineated by Cousin (2006), hold that there are concepts that, once understood, the learner is transformed internally with a new level or relativistic view of the subject. SENCER holds that through examining disciplinary Threshold Concepts through the lens of civic questions and public issues, the learner is transformed as well, but with a purpose and motivation for continued efforts for working through additional concepts. The learner continues to engage additional threshold concepts, recognizing the content, not only as transformative, irreversible and integrated, but framed in a value system of significance to the learner. The SENCER Ideals are listed in Figure 1. and overlaid with the Threshold Concepts characteristics, demonstrating the commonality of the two approaches. Both provide faculty with a way to engage students and enhance their learning in courses by focusing on the relevant content that is critical for understanding the subject matter. The SENCER model strengthens the learning process beyond the understanding level by making connections between content knowledge and its relevance for addressing, discussing and solving current civic and public issues, i.e. climate change, HIV/AIDS, nutrition, addiction, environmental health (SENCER, 2012b).

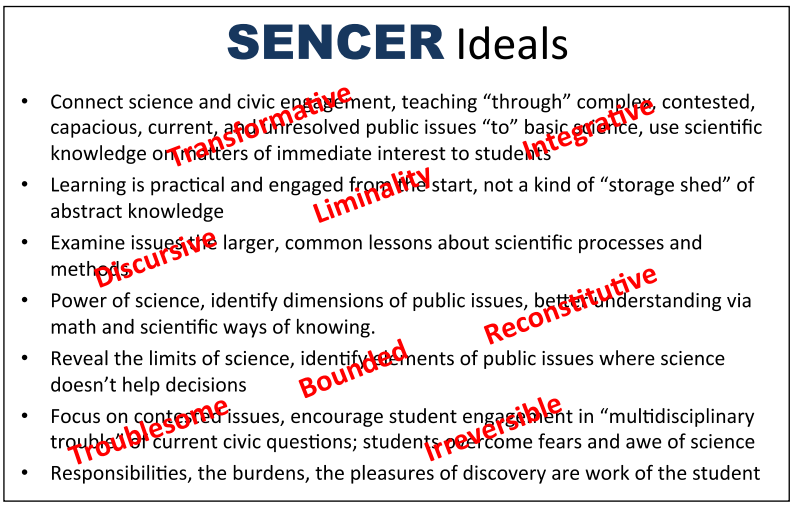

Figure 1: Elements of Threshold Concepts and SENCER Ideals

The SENCER project began in 2001 with a grant funded under the National Science Foundation's Course, Curriculum and Laboratory Improvement program national dissemination track. The idea for linking critical threshold concepts of science, technology, engineering and mathematics (STEM) courses to public issues began in a course developed at Rutgers University that focused curricular resources on the HIV epidemic. I first taught *"Biomedical Issues of HIV/AIDS"* in 1992 when the AIDS epidemic was of grave concern on college campuses in the United States. We found that by using the threshold concepts in microbiology, immunology and virology, those content areas critical for understanding the HIV epidemic, we observed high levels of student engagement. Making the difficult biological concept relevant for understanding the phenomenon of HIV/AIDS, resulted in increased student learning (Schneider *et al.*, 1994). Other faculty members using similar approaches to teaching reported similar results in learning (Burns, 2002, 2011).

Since 2001, SENCER has established and supported an ever-growing community of faculty, students, academic leaders, and others to improve undergraduate STEM education by connecting learning to critical civic questions. Most simply put, SENCER applies the science of learning to the learning of science, all to expand civic capacity.

SENCER improves science education by focusing on real world problems and, by so doing, extends the impact of learning threshold concepts across the curriculum to the broader community and society. We do this by developing faculty expertise in teaching 'to' basic, canonical science and mathematics 'through' complex, capacious, often unsolved problems of civic consequence. Using materials, assessment instruments, and research developed in the SENCER project, faculty design curricular projects that connect science learning to real world challenges. In designing SENCER we use methods and strategies derived from existing knowledge concerning undergraduate STEM education so that both the STEM learning and the curricular reforms will be durable. John Bransford, a member of the Board on Science Education of the National Academies and Mifflin Professor of Education at the University of Washington, claims that SENCER is *"bringing to life the recommendations we made in How People Learn"* (Bransford, 1999).

SENCER SUMMER INSTITUTES: WHERE THE WORK BEGINS

For most faculty, their work with SENCER starts with a four day residential summer institute to which teams of faculty come to work on a project specific to their interests. The SENCER Summer Institute (SSI) provides an opportunity for a community of educators, administrators, students, and community leaders to gather to consider how best to engage students in the sciences, technology, engineering, and mathematics and the civic issues in which they play an integral role. Teams in varying stages of planning, development, or revision of courses or programs, are welcome, as well as those interested in sharing results of established projects. All disciplines, including the humanities and social sciences, are represented at the institutes. There are plenary sessions, sessions on course design and assessment, sessions presenting the model courses, modern pedagogies and methodologies for improving learning, poster presentations and short talks reporting initiatives developing from earlier SSI's. Modest sub-awards are available to participating teams to support the implementation of some or all of their projects, curriculum revisions, community engagements or assessment activities. Reports and follow-up presentations and posters provide programming for subsequent SSI's. To date, the SENCER community of practice includes over 2,000 educators, administrators, and students from over 430 colleges and universities, educational associations, government and non-governmental organizations in forty six states and eleven foreign nations (SENCER, 2009, 2011).

THE MODEL COURSES: LINKING THRESHOLD CONCEPTS WITH CIVIC ENGAGEMENT

Part of 'best practice' is to provide models to illustrate examples of the on-campus work that inspires innovation in STEM education. The SENCER Models are field-tested courses and programs that are selected as demonstrations of effective representations of the SENCER approach. The published models present valuable resources in syllabi, readings, exercises, assignments, tests, and supplemental materials. But their real purpose is to provide guidelines and inspiration for others to consider their own ways to develop courses that improve threshold concept understanding with real-world applications.

Biomedical Issues of HIV/AIDS – This course that I conceived, teaches the biology of infectious diseases, immunology, and virology through the questions that surround HIV/AIDS: Where did it come from? How is it transmitted? Can I get it? What can we do to help those that have it? Such driving questions motivate students to learn complex scientific content in microbiology and immunology. But these questions cannot be answered solely by an appeal to biology, as they are also related to questions of economics, politics, education, and human emotion and psychology (Devanas, 2001).

Although this is a large (400+) lecture course for non-science majors, it emphasizes active learning through online discussion groups, guest lectures, and research and writing-intensive assignments. Students identify questions related to HIV/AIDS in which they have a particular interest. They investigate clinical studies and educational interventions for specific populations, negotiating library databases, collecting peer reviewed primary research articles, and using these articles and statistics to support their own ideas and proposals for improving the HIV/AIDS crisis in their target population. As an 'outreach' part of the assignment, they are then asked to have their friends, family members, and colleagues read and comment on their proposals. Additionally, one professional with special expertise relevant to their problem and solution is asked to critique and comment on their proposed solution on the medical, social, or cultural aspect of HIV/AIDS.

In the course of their research, students work hard to uncover the relationships between scientific and medical research and political agendas. They work even harder to find information about how their career choices are impacted by HIV/AIDS; how their projects and studies may help fight risky behaviors in target communities; how to grapple with the questions of AIDS in the workplace; how cultural influences work to obscure and repress acknowledgement of actual sexual behavior. Students are eager to engage their new knowledge and seek forums for discussions where they can debate issues and ask critical questions via online discussion groups. Expert guest lecturers, many of whom are HIV positive themselves, bring the reality and immediacy of living with HIV/AIDS to the classroom, helping the students to better understand the connection between their academic learning of threshold concepts and the applications of them to their everyday life.

The SENCER models are then curricular approaches to improving science learning and supporting engagement with complex issues. These courses require students to engage in serious scientific reasoning, inquiry, observation, and measurement. SENCER courses and programs connect scientific knowledge to public decision-making, policy development, and the effective 'work' of citizenship. SENCER courses ask 'troublesome' questions and guide students to develop answers, as well as to appreciate the uncertainty and provisionality of the knowledge and answers produced. Many more course models in which disciplinary content, interdisciplinary connections and civic issues have been proposed by members of the SENCER community. Over forty course models are presented for public dissemination with

both deep and far-reaching themes: *"Mysteries of Migration"* and "Science, Society and Global Catastrophes" (2001), *"Brownfield Action"* and *"Chance"* (2003), *"Nanotechnology"* (2005), *"Slow Food"* (2007), "The Science of Sleep" (2008) to *"Stem Cells and Social justice"* (2011) (SENCER, 2012b).

As most faculty realize in teaching, there are critical core concepts that provide the threshold to understanding the course content and discipline. However the deeper meaning and relationships between the conceptual knowledge and its application to real-world issues solidifies the threshold concepts with permanent changes. Students learn science but seeing it in context transforms them both in content and in civic awareness.

STUDENT TRANSFORMATION, WHEN SENCER REACHES STUDENTS

Indiana State SENCER Project – Faculty from Indiana State University (ISU) came to the 2009 SSI with the idea that their students, regardless of major would be engaged through civic questions and capacious problems to include STEM courses in their course offerings and expand this kind of learning across the curricula and into the community and broader society. After hearing the reports and discussions of the faculty, the students at ISU embraced the principles and began identifying many courses at ISU that had SENCER themes.

The goal of ISU-SENCER, to provide more study in STEM subjects, was firmly established on the ISU campus after just one year from the program's beginning. English classes now use the SENCER approach in writing and tutoring projects. Economics classes take field trips to local companies and evaluate economic issues faced by those companies. Psychology classes analyze poverty, homelessness, and hunger. More traditional 'scientific' classes in geology explore the 'Riverscape' in Terre Haute to conduct fieldwork. The success and impact of SENCER was demonstrated when in spring 2010, students used the SENCER concept to help the local Terre Haute community through such projects as measuring trees, looking for wildlife, and taking soil samples as part of field work for classes, and outreach activities in the local wildlife areas. By 2011 students were contributing data and participating in discussions that assisted ISU in determining the optimal placement for installing a wind turbine on their campus. Through the students' efforts together with those of Dr James Speer, the Interim Coordinator of the Center for Science Education, the SENCER Teaching Model has been incorporated into the strategic plan at ISU (Indiana State University, 2012).

CURRICULAR TRANSFORMATION – SENCER INSPIRES CHANGES IN CURRICULUM

Ball State University – At Ball State University (BSU) two SENCER courses have become catalysts for institutional change. The first, *"Weapons of Mass Destruction"*, developed after SSI 2003, takes a prominent social issue, and teaches 'through' it 'to' science and the history of science. Students learned biology, chemistry, and physics. But they also learned how history, sociology, and political science help to understand interactions between science and culture. The course, *"Food, Values and Politics"*, is a combined effort of a biology professor and a professor of social work. This course uses fast food and nutrition as the connector for threshold concepts in biochemistry, physiology, microbiology, ecology, and scientific ways of knowing. The SENCER approach has enabled BSU faculty to focus on course development and experimentation. This has permitted the faculty to incorporate the SENCER approach to teaching science and social science into the heart of their new University Core Curriculum (UCC). The overarching goal of the new UCC is for students to learn how to use their newly gained content knowledge to make sound judgments for acting wisely in the world (Eflin, 2005; Ball State University, 2012a, 2012b).

University of North Carolina at Asheville – The University of North Carolina at Asheville (UNCA) has adopted an Integrative Liberal Studies (ILS) curriculum in which students take general education courses in natural science, social science, and humanities or arts in topical clusters centered on a common civic question. The *"Food for Thought"* cluster focuses on the intersection of science and policy by exploring the role of food in chemical, biological, and social systems. Its aims to help the student become an informed consumer of food by providing a platform for discussion of what we eat, why we eat, where our food comes from and how it is processed, and how food affects our bodies and health. All of the cluster courses draw on a range of pedagogies, both traditional and innovative, including lectures and literature reviews, group projects, field trips, peer-led learning, poster presentations, laboratory experiments, and independent research (Wasileski *et al.,* 2008; University of North Carolina at Ashville, 2010).

Butler University – Civic engagement is becoming an important part of most forward thinking college curricula. Butler University has supported civic engagement for some time through a Center for Community and Citizenship and a University Service Committee. In addition, the faculty of the University has approved a new general education curriculum, called the Core Curriculum, which contains a number of civic engagement elements. The new Core contains a first year seminar with a central theme of self, community, and world along with a second year experience called *"Global and*

Historical Studies". In addition, the new Core has a junior or senior capstone course requirement that focuses on societal issues, and requirements for both university and Indianapolis community service (Kirsch *et al.*, 2007; Butler University, 2012a, 2012b).

FACULTY TRANSFORMATION – THE THRESHOLD CONCEPTS OF SENCER EFFECTS INSTRUCTION ACROSS THE CURRICULUM

One of the resources that SENCER provides are essays on topics of timely, capacious questions that is the *"SENCER Backgrounders*" (SENCER, 2012a). These backgrounders provide a thorough overview or synthesis of a complex civic issue that is sometimes the theme of a SENCER course. The backgrounders make the connection between the science, what is known or as yet unknown scientifically, and the issues at stake in the public arena. One faculty participant in SENCER, who now plays a major role in the SENCER community, has provided a reflection on the changes that his participation in SENCER has made in his teaching. Professor Terry R. McGuire is a professor of Genetics and the Vice Chairperson responsible for the undergraduate curriculum in the Genetics Department in the School of Arts and Sciences at Rutgers University. His backgrounder, "*Reinventing Myself as a Professor"* describes the effects of the SENCER ideas in his teaching that led to significant learning gains, increased his enjoyment in teaching and fundamentally changed his attitudes toward teaching and students. He discusses his use of SENCER principles, even using current events, news items, active learning and ongoing formative assessment of student learning to affect the kinds of changes that are threshold concept changes in his teaching and in his students' motivation for learning. Professor McGuire addresses his transformation and reflects on the nature of motivation in student learning and each student's potential to succeed in learning, and crossing the threshold to understand their own process (McGuire, 2005).

In 2010 the SENCER Project surveyed all program participants as to whether or not SENCER was meeting its objectives. The Impact Assessment Survey was distributed to 1,685 participants and from the 1,334 eligible responses, 45% responded. Overall, about 8-in-10 or more strongly agreed or agreed that SENCER participation influenced their instruction and this increased student opportunities to (1) identify scientific problems and questions; (2) conduct measurements and/or observations to develop data sets; (3) analyze data sets to determine evidence or the need to conduct more measurements and observations; (4) analyze evidence to determine patterns; (5) analyze evidence to construct models; (6) use evidence patterns and/or models to generate or evaluate explanations; (7) make connections between science and civic problems/topics; and (8) make interdisciplinary connections (Ballou, 2012).

CONCLUSION

Overall it seems that as discussions were emerging in the UK defining and refining Threshold Concepts, similar discussions were underway in the US in examining the process of *"How People Learn"* (Bransford *et al*., 2000) and among the SENCER community (SENCER, 2009). As both schools of thought maintain, there are transformational events attached to understanding critical concepts within and across disciplines.

SENCER illuminates the Threshold Concepts across disciplines when it focuses on the contested complex civic issues, encouraging students to engage with 'multidisciplinary trouble' of civic questions, requiring them to resolve or manage 'troublesome knowledge' that challenges their prevalent intuitive understanding. Like the Threshold Concept theory, SENCER connects science content, but by teaching through complex, contested, capacious, current, and unresolved public issues, i.e. the civic engagement component, students better comprehend the integration of the interrelatedness of the science content and its applications (SENCER, 2005). SENCER illuminates the threshold of content knowledge for the student and the threshold of the pedagogy of engagement for the instructors, transforming both in their respective processes. Additionally SENCER shows the power of science by identifying the dimensions of a public issue that can be better understood with certain mathematical and scientific ways of knowing. As a national project then, the SENCER Program and allied activities of the National Center for Science and Civic Engagement support the value of threshold concepts and makes additional links to civic issues as successful tools for curriculum development and design (National Center for Science and Civic Engagement, 2012). Each approach has its unique direction and path of development of these common ideas, i.e. Threshold Concepts began with and focuses on the content of disciplinary knowledge. The SENCER position holds that to reinforce content, the context is critical and our work has documented that this approach produces higher retention of content. Thus, to improve content knowledge, beyond the threshold to greater levels of retention and application of content, context matters.

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TOWARDS A TCT-INSPIRED ELECTRONICS CONCEPT INVENTORY

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Biographical Note

Jonathan Scott, Ann Harlow, and Mira Peter work at the University of Waikato. Jonathan worked for Hewlett-Packard/Agilent in California, is Adjunct Professor at Macquarie University, and is the author of over one hundred patents and refereed publications. Ann's research interests encompass primary, secondary and tertiary education. She works on technology, science, and engineering education. Mira's skills lie in data analysis and expertise in language, reading acquisition, and the role of phonology in reading.

KEYWORDS

Threshold concepts, concept inventory, analogue electronics, assessment

ABSTRACT

This study reports on the initial work on the use of Threshold Concept Theory (TCT) to develop a *threshold-concept inventory* – a catalogue of the important concepts that underlie electronics and electrical engineering (EE) – and an *assessment tool* – to investigate the depth of student understanding of threshold and related concepts, independent of students' numerical ability and knowledge mimicry in the first-year course in electrical engineering. This is both challenging and important for several reasons: there is a known issue with student retention (Tsividis, 1998; 2009); the discipline is relatively hard for students because it concerns invisible phenomena; and finally it is one that demands deep understanding from the very start (Scott, Harlow, Peter, and Cowie, 2010). Although the focus of this research was on electronic circuits, findings regarding teaching and learning of threshold concepts (TCs) will inform lecturers in three other disciplines who are part of our project on threshold concepts.

INTRODUCTION

Over the past two years the research team has been involved in an intensive study of pedagogy and learning informed by Threshold Concept Theory (TCT) in several disciplines. In one of the areas – analogue electronics – the lecturer has spent three years exploring how TCs can impact his teaching and student learning (Harlow *et al.*, 2011; Scott and Harlow, 2012; Peter and Harlow, 2012). The work with this lecturer has involved exploration of various types of assessment and has culminated in the development of a concept-inventory aimed at investigating students' understanding of troublesome concepts.

THRESHOLD CONCEPTS

To students, TCs are remarkably troublesome to learn (Cousin, 2006). To practitioners, their importance lies in the transformation of the learners' ways of perceiving, thinking and practicing (i.e. acquiring the competencies of the profession (Davies, 2006)). According to Meyer (2010), TCs are transformative insofar as grasping them can change the learner's very way of thinking. Further, it has been argued that threshold concepts are either *threshold* or they are not (Meyer, 2010) – there are no degrees of *thresholdness*. Since TCs are the hardest to learn and the most cogent to identity and ways of thinking within a discipline, it would seem important, to both learners and teachers, to identify them. Once TCs are identified, lecturers can focus on them and the inordinate learning difficulty can be anticipated and addressed in a timely and appropriate manner. However, for various reasons identification of TCs often proves to be difficult (Davies, 2006).

INVENTORIES AND THRESHOLD CONCEPT THEORY

Concept inventories (CIs) are an invaluable tool for the assessment of student learning and curricular innovations. Usually, they consist of multiple-choice tests ideally designed for two learner-focused purposes (Libarkin, 2008). At their most useful, CIs can be used to diagnose areas of learners' conceptual difficulty or misconceptions prior to instruction, and to detect changes in conceptual understanding related to a particular teaching approach. In this way CIs offer an insight into the influence of a teaching-learning environment on learning.

One of the first education inventories developed by Brown and Holtzman (1966) examined factors related to study-strategies that could predict students' academic performance. The inventory contained four subscales: effective study procedures; promptness in completing work; favorable opinions about teachers; and approval of educational objectives. In 2004, Entwistle and McCune examined the historical origins and development of a series of well-known study strategy inventories in higher education. The analysis illustrated how the development of succeeding generations of inventories built on the earlier ones. The inventories Entwistle and McCune (2004) analysed were shown to have focused on motivation, study methods, and learning processes, as well as mental models, metacognition, and self-regulation, thus creating confusion of overlapping terms describing apparently similar aspects of learning and studying.

In physics, the *Force Concept Inventory* (FCI) is perhaps the most well-known example of its genre (Hestenes, Wells and Swackhamer 1992). This FCI provided the physics community with a snapshot of student learning in introductory physics. The inventory represents a set of ideas embodying Newtonian mechanics and, more centrally an accompanying, multiple-choice, non-numerical questionnaire (i.e. assessment tool) designed to gauge the depth of student understanding of those ideas. It was actually painstakingly developed over a number of years up to 1991, and has been debated and verified thereafter.

The following two decades saw a variety of other concept inventories appear – especially within the context of engineering (Evans and Hestenes, 2001) – covering electronics (Simoni, Herniter, and Ferguson, 2004), materials (Richardson and Morgan, 2001), thermodynamics (Midkiff, Litzinger, and Evans, 2001), signals and systems (Wage and Buck, 2001), waves (Roedel, El-Ghazaly, Rhoads, and El-Sharawy, 1998). Some of these tools were more rigorously studied than others. The development of these inventories preceded the appearance of TCT (Meyer and Land, 2003). One might not be too surprised then to discover that a number of concepts addressed in these inventories, and their associated assessment tools, are neither indispensible to the discipline, nor particularly conceptually challenging to learners. In our own work we have found questions for which the so-called correct answer is theoretically and empirically wrong. Additionally, a number of questions tested only memorisation, not understanding. The premise of the current study is that TCT could provide a sound methodology by which one can arrive at a concept inventory that includes only ideas that are truly important to electrical engineering discipline.

ASSESSMENT FOR LEARNING TRIAL

An *Immediate Feedback Assessment Test* (IFAT) scratch-card test provided a trial for the development of questions for the electronics inventory and was found to have advantages for both the students and the lecturer. The IFAT test was done as a formative exercise: two students shared one scratch-card and argued their case to each other before selecting what they believed was the correct answer. Students could have multiple attempts to find the correct answer. By examining students answering trajectories the lecturer obtained information about students' understanding of the material and could identify problems that most students had difficulty with. In the second half of the tutorial session the identified problems were discussed with the lecturers help. A survey of students' opinions about the use of IFAT test revealed that:

- Students learned to articulate their knowledge;
- Students learned from each other;
- Students enjoyed the assessment and were fully engaged in solving problems;
- Students received instant feedback as they scratched the card;
- Students' incorrect ideas could be dealt with in a timely fashion; and
- If a scratch card was to be used in a formal exam, students will have practiced this type of test and know what to expect.

The use of IFAT test provided certain advantages for the lecturer as well:

- It was easier to mark than a long-answer test, but more difficult to mark than a simple multi-choice test;
- It was a good diagnostic tool, but care needed to be taken in the design of the questions;
- Feedback from students helped to make the questions more reliable;
- Misconceptions could be dealt with as they arose;
- Targeted tutorials could be planned to help students having difficulties; and
- Teaching became more informed about where students get stuck and how to help them move forward.

In sum, the IFAT test was found to be an engaging assessment tool when trying to ascertain whether or not students had the basic knowledge needed for the first-year analogue electronics course. It also confirmed that Thévenin's equivalent

circuit (i.e. one-port circuit can be simplified to a circuit with one voltage source and a resistor) was one of the most important threshold concepts taught in the first-year analogue electronics course. Namely, it emerged that students had remarkable problems in grasping Thévenin's theorem and it was where many students got stuck. Many years of teaching experience have alerted the lecturer to the fact that unless students grasp Thévenin's theorem they cannot move on in electronics engineering. Important, the use of IFAT test provided a clear insight into the precursor questions crucial for understanding and learning of Thevenin's theorem.

PERSONAL PRACTICE

Our recent findings revealed that some assessment questions evaluated only students' recall of facts, not deep understanding; others had ambiguous answers (Scott and Harlow, 2011). These and related findings on identification of threshold concepts involved in early electronics (Scott and Harlow, 2012) informed the design of a matching series of questions. Their effectiveness in assessing the depth of students' understanding will be the focus of our future work.

The creation of an *Electronics Threshold-Concept Inventory* (ETCI) has proven challenging for various reasons. Because the electronics concepts deal with invisible phenomena, students tend to have not *misconceptions*, such as *Aristotelian thinking* in the case of Newtonian mechanics, but *no* preconceptions. This makes it difficult to identify universal, misleading wrong answers for the incorrect choices in the multiple choice (MC) questions. Electronics involves deep understanding from the very start (Scott *et al.,* 2010; Foley 2010), resting crucially on ideas such as conservation of charge and the impact of conductors and insulators on current pathways, without which students cannot understand the questions, let alone identify their correct answers. Consequently, care must be taken to discount answers to such questions as reflecting upon the intended knowledge.

One of the criticisms of the several decades of effort in CI use in science learning and development is that standard practice in CI development results in production of isolated CIs, often with specific relevance to a single course or sub-discipline. It is argued that these CIs have no specific meaning relative to one another, inhibiting meaningful comparison across content. This results in understanding of student learning across very small time spans, from a few weeks during instruction to the more common semester long, pre-post evaluation. Rarely, students are given delayed CIs several months to a year post-instruction, providing some measure of short-term longitudinal effects. It is claimed that investigation of conceptual change across a program is currently outside of the reach of any existing CI (Mestre, 2008).

With these developments and issues in mind, we have managed to construct some parts of a complete ETCI in less than one year. We have showed that students' threshold concept (TC) understandings measured by our questions were a good predictor of their total year grades. Those students who could articulate their knowledge well achieved the highest grades.

DEVELOPING AN ELECTRONICS THRESHOLD-CONCEPT INVENTORY

Considerable work has gone into identifying the TCs that are associated with the introductory electronics curriculum taught at our university. We assert, with some confidence now, that there are only five threshold concepts in the syllabus (Scott and Harlow, 2011). The eventual aim, therefore, is to test students' understanding of these five ideas. Following the wisdom of Hestenes, Wells and Swackhamer (1992) and those who came after, the test is expected to be multiple-choice, substantially non-numeric, and strongly graphic.

The idea of an Electronics Concept Inventory (ECI) is not new. Simoni, Herniter and Ferguson (2004) developed questions through a four-step heuristic applied to evolve existing electronic problem questions into ECI questions. The steps are identified as: focus on a single concept, substitute graphical for numerical elements, produce distracting answers in the light of known student misconceptions, and finally eliminate use of terms with which students might not be familiar to ensure question clarity. Quite apart from the debate about what concepts ought to be included in their ECI, Simoni, Herniter and Ferguson (2004) were well aware of the difficulty inherent in trying to limit the focus of a question of a half-wave rectifier and RC filter that may emphasise the understanding of the impact of the filter, and particularly its time constant in relation to line frequency, but it depends upon many other understandings. In the case of TCs, one of whose defining characteristics is a tendency to integrate diverse concepts (picture an especially widely-connected idea on a concept map). This desire to capture in isolation seems especially fraught. How might one test the understanding of a single (threshold) concept, or more importantly identify that a failure to correctly answer a given question involving that concept was not caused by a failure to understand one of any underlying (or many connected) concepts, upon which the question depends?

In principle, our Electronics Threshold-Concept Inventory or ETCI would need perhaps as little as five questions, if we had high confidence that a given question tested the desired concept. We have found this confidence elusive in practice. Consider a question intending to test understanding of the Thévenin equivalent circuit through a request to measure the calculated equivalent resistance, whatever that might be. The problem is that a student who cannot associate the nodes in the circuit diagram with the correct conductors in the assembly depicted in photographs or who cannot use a multimeter will have great difficulty answering the question, even given an excellent understanding of equivalent circuits and how to obtain them. Simoni, Herniter and Ferguson (2004) included questions carefully chosen to reflect the background knowledge that is necessary to correctly answer the electronic questions, but did not expand on this comment.

CONCLUSION

Threshold Concept Theory and Concept Inventories seem to be two educational disciplinary pushes that are made for each other.

The use of Threshold Concept Theory has expedited our construction of this concept inventory. If we believe that the threshold concepts within a discipline are the ideas that are important to shaping practitioners and troublesome to students then a concept inventory should need only to assess understanding of these threshold concepts in order to usefully assess student ability and worth.

Creation of concept inventories in electronics is made complex, as is the teaching of the discipline, by the lack of phenomena that can be observed directly. Rather than having wrong ideas, weak students tend to have no idea about how to tackle questions. The authors hope to expand and verify the ETCI in the coming year.

There are two ways in which we propose that this development will inform the communities of practice in which we work. In order to investigate conceptual change across the programme (Mestre, 2008) we plan to give students delayed CIs several months to a year post-instruction, to provide some measure of short-term longitudinal effects. This will allow teachers of year two and three courses to benefit from the results. We also observe that our postulated TCs can be discerned in other disciplines, often far removed from engineering. This raises the possibility that TCs may be so integrative because they run across disciplines. Our research team is discussing the benefits and constraints of such an inventory within their own disciplines.

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THRESHOLD CONCEPTS AND DECODING THE HUMANITIES: A CASE STUDY OF A THRESHOLD CONCEPT IN ART HISTORY

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KEYWORDS

Humanities, Art History, 'Reading Art', semiotics, low consensus disciplines

ABSTRACT

Considering the volume of recent scholarship on threshold concepts, including the volumes produced out of the previous three biennial threshold concept conferences, there has been relatively little exploration of threshold concepts in the humanities (Meyer and Land, 2006; Land, Meyer and Smith, 2008; Meyer, Land and Baillie, 2010). Perhaps, considering the label as 'low consensus' disciplines, this should not be surprising. Because of the variability in how individual academic staff in the humanities conceptualize their disciplines, and the preferred manner in which their disciplines are organized and taught over the course of a degree program, the ability to come to consensus (if such was required) on what is or is not a threshold concept can be difficult, if not impossible.

This paper explores some of the issues related to identifying threshold concepts in the humanities. We propose using the process of 'decoding the disciplines,' articulated by Middendorf and Pace (2004), to engage academic staff in the humanities in a conversation about bottlenecks experienced by students, how those bottlenecks are overcome by discipline specialists, and how we provide students opportunities to learn, practice and get feedback on the operations used by those disciplinary specialists to overcome those bottlenecks. In so doing, one particular case study, that of students' difficulty understanding the 'language' of art in art history, is used to examine the ways in which decoding the disciplines can inform the identification of threshold concepts in the humanities, and the means by which we might adjust our curriculum development practices and pedagogical approaches to more effectively facilitate students' passing of these thresholds.

INTRODUCTION

Considering the volume of recent scholarship on threshold concepts, including the volumes produced out of the previous three biennial threshold concept conferences, there has been relatively little exploration of threshold concepts in the humanities (Meyer and Land, 2006; Land, Meyer and Smith, 2008; Meyer, Land and Baillie, 2010). Perhaps, considering the label as 'low consensus' disciplines, this should not be surprising (Biglan, 1973). Because of the variability in how individual academic staff in the humanities conceptualise their disciplines, and the variability in which their disciplines are organized and taught over the course of a degree program, the ability to come to consensus (if such was required) on what is or is not a threshold concept can be difficult, if not impossible.

This paper explores some of the issues related to identifying threshold concepts in the humanities. We propose using the process of 'decoding the disciplines,' articulated by Middendorf and Pace (2004), to engage academic staff in the humanities in a conversation about bottlenecks experienced by students, how those bottlenecks are overcome by discipline specialists, and how we provide students opportunities to learn, practice and get feedback on the operations used by those disciplinary specialists to overcome those bottlenecks. In so doing, one particular case study, that of students' difficulty understanding the 'language' of art in art history, is used to examine the ways in which decoding the disciplines can inform the identification of threshold concepts in the humanities.

THRESHOLD CONCEPTS IN THE HUMANITIES

Threshold concepts have been conceptualised in different ways – as the *subject matter* for learning and teaching, as the *process of learning* (students' mastery of disciplinary ways of thinking and practicing), or as the *process of teaching* (as the facilitation of transformative learning and the induction of students into disciplinary ways of thinking and practicing)

(O'Brien, 2008). No matter how the threshold concept is conceptualised, one still needs to ask how is the threshold concept fundamental to disciplinary ways of thinking and practicing?; what might be troublesome about the threshold concept?; and what transformation is needed or evoked by the threshold concept? (O'Brien, 2008).

As much as the recent literature in higher education has focused on threshold concepts, there is still a paucity of research exploring threshold concepts in the humanities. A quick analysis of the three books that came from the first three biennial conferences on threshold concepts shows that only a few chapters are dedicated to exploring threshold concepts in disciplines counted as part of the humanities (Meyer and Land, 2006; Land *et al.*, 2008; Meyer *et al.*, 2010). As mentioned in the introduction, this is perhaps due to the low consensus nature of these disciplines, where there is large variation in programs and in how academics conceptualise their field (Biglan, 1973).

Of the disciplines in the humanities where threshold concepts have been explored, English has perhaps had the most attention. In some of their original writing on threshold concepts, Meyer and Land (2003) articulated two threshold concepts in English – the signifier and deconstruction. Others have argued for such concepts as interpretation, signification or representation, contextual inflections, and structurally-related choices of language, each of which are foundational to the *episteme* of the discipline of English (Wisker *et al.*, 2008). Wuetherick (2011) has argued that post-colonialism, or rather many of the concepts underpinning post-colonial thought, is a threshold concept that underpins English, History and many other humanities (and social sciences) disciplines. In many cases, however, the threshold concepts that have been articulated in these disciplines are more theoretical in nature, tied to such theories as post-structuralism, post-modernism, critical theory, etc. Even when exploring these concepts, however, the notion of what is essential to ways of thinking and practicing in the discipline, and even what is counted as necessary precursory knowledge, can be contentious and contested in the humanities.

LEARNING FROM 'DECODING THE DISCIPLINES'

As articulated by Shopkow (2010), and building on the work of Pace and Middendorf (2004), one of the ways forward with respect to thinking about and identifying threshold concepts in the humanities is through the process of decoding the disciplines. Initiated in the discipline of History, under a project called the *History Learning Project* (where there is high contestability about what might constitute threshold concepts), these researchers identified seven important steps for decoding the discipline to identify and tackle the main bottlenecks students face in their learning (asked in the form of questions). Those steps are: 1. What is the bottleneck to learning in this class?; 2. How does an expert do these things?; 3. How can these tasks be explicitly modeled?; 4. How will students practice these skills and get feedback?; 5. What will motivate students?; 6. How well are students mastering these tasks?; and 7. How can the resulting knowledge about learning be shared among faculty? (Pace and Middendorf, 2004).

Through engaging in the process of decoding the disciplines, Shopkow (2010) argues that tacit knowledge can be revealed and made explicit, using as a *"launching pad the instructor's own disciplinary modes of thought and teaching concerns"* (p. 317). It has been argued that three types of bottlenecks may be made explicit through the decoding the disciplines process: 1) procedural obstacles learners have not mastered which are precursory steps necessary for successfully completing particular learning tasks; 2) epistemological obstacles learners face wherein they fail to understand the nature of knowledge construction in that particular discipline; and 3) emotional obstacles learners experience in reaction to the nature of the discipline or disciplinary content (Middendorf and Pace, 2004; Díaz, Middendorf, Pace and Shopkow, 2008). Using this process, the History Learning Project has articulated several key bottlenecks experienced in history that can be broken into categories that are disciplinary, evidentiary, and affective in nature. Examples of bottlenecks identified by this work include: misunderstanding the role of facts, understanding the limits of knowledge of historical actors, and identifying with people in other times and places.

By identifying these bottlenecks, the History Learning Project has made explicit the disciplinary *episteme* that is foundational to understanding the ways of thinking and practicing in the discipline. Upon these foundational thresholds that all history students must learn, there are additional theoretical thresholds that only certain students encounter in specific areas of history (postcolonial thought, for example). In essence it might be argued, at least in the humanities, that there are two levels of threshold concepts – one level tied to foundational disciplinary epistemologies that all students in that discipline encounter (like understanding the limits of knowledge of historical actors), and there are others specific to different practices and theories within the discipline that are encountered only if and when students take particular classes (like understanding the notion of hybridity in a postcolonial history class).

CASE STUDY OF ART HISTORY

Art history is a discipline dedicated to the exploration and investigation of social, cultural, and historical issues through art and visual culture – *"a way of looking at culture and society of different epochs and seeing how we think about these periods and how attitudes have changed over time"* (Arnold, 2004, p. 28). One of the authors (Wuetherick) used the Decoding the Discipline interview process, articulated by Middendorf and Pace (2004), as a guide for exploring the disciplinary epistemology of Art History via a guided discussion with the other author (Loeffler). One powerful bottleneck, which we argue is a potential threshold concept in Art History, experienced by one of the authors (Loeffler) in her teaching is students understanding how to 'read' art – or how to interpret the 'language' of art. This threshold concept can be conceptualized as an epistemological bottleneck related to how knowledge is created and transmitted in the discipline of Art History, which all students must learn to progress in the discipline.

The notion of art as a language may seem to be a simple concept in theory, but instructors who have already internalized this notion may not see the importance of verbalizing this explicitly for their students. Because it is such a key concept, however, it is a barrier that must be crossed in order to progress further in this discipline. What does it mean to 'read art' or understand and interpret the language of art? As Arnold (2004, pp. 90-91) articulates:

> *"Artworks can be read on a range of levels that can be derived from the objects themselves… Perhaps the most obvious starting point is the notion of the representational meaning of art. The idea of representation in relation to art is often connected with the perception of an image of the world we think we see. …Art is an illusion – paint on canvas, carved marble, or chalk on paper – it is what the viewer brings to it that makes it 'represent'. Clearly this act of reading is culturally determined".*

The issue of signification or the representation of meaning in signs and symbols, as experienced through art, is a critical element to understanding the episteme of the discipline – the hidden underlying ways of thinking and practicing in the discipline. Interpreting images is intricately linked to the analysis of signs and symbols, a practice that is only one part of the study known as semiotics. Semiotics is the study of signs from which humans interpret meaning. Although there are various definitions for semiotics and the aforementioned definition is perhaps overly simplistic, it should be noted that meaning may be found in various forms, such as language (written or spoken), body language, images, and symbols to name a few. While it is not the intent of this paper to explore the full properties of semiotic study, it is important to note that much of the process of interpretation is discussed and analyzed within the discipline of Art History.

People read images as text in their daily lives, usually without the recognition that they are engaged in this process of reading. Some of this process is intuitive, like when we read facial expressions and body language. The visual cues with which we are familiar in life inform our understanding of how to read those cues in a work of art. Other interpretations are based on our knowledge of a narrative and an image's place within that narrative. Further, more complex readings may require knowledge of meaning that has been codified in signs and symbols. Such meanings have usually been established over centuries, which is why it is useful to learn how images were read and used in the historical past.

One way of overcoming the challenge of reading art is through the time spent looking at art, which then helps to decode the meaning of the artwork (Perkins, 1994). Decoding the meaning in images (where such meaning may be found) is achieved by discussing the iconography of an image. One must ask: who/what are the main figures; what is going on; and how do I know this? Symbolism may also be present in an image to enhance its meaning. Some works, particularly abstract works of art, do not have an iconography to decode. Over time, some images carry meaning that is both complex and easily understood because the images are so familiar and ubiquitous. If we take the time, as Perkins (1994) suggests, to 'see' a work of art, much of what that work communicates is already within our grasp. Like reading poetry, however, reading a work of art may take time, and most people are not used to taking the necessary time to decode the elements.

A further challenge in overcoming this threshold concept is its discursive nature. Art history has a vocabulary, a disciplinary language that must be learned as part of the course material. Students who make an effort to truly understand the terminology will be able to intelligently discuss works that they have never seen before. And by knowing how a work was viewed and used at the moment of its creation, we may gain insight into a historical moment in time, affording information in addition to, or perhaps beyond, other evidentiary tools like the written word in historical documents or archaeology. Besides the knowledge of the historical past that art history engenders, examination of historical works often informs our reading of present-day monuments.

The troublesome nature of this idea, however, is witnessed most when students are confronted by an artwork they have never seen before (particularly in an examination setting), although it contains symbols and signs they have encountered repeatedly in class. Once they cross the liminal space of this threshold, however, they cannot help but see the signs and symbols everywhere as part of art and visual culture.

A useful example of a contemporary image that draws on meaning from the historic past may be found in a statue called *Slapshotolus: Ancient Greek Olympic Sculpture Meets Modern Canadian Sport* (2009), by the artist Edmund Haakonson. A viewer confronted with this work may be bewildered at first by the nature of this nude male figure because it is unexpected: a nude hockey player.

Slapshotolus by Edmund Haakonson

The subject of the nude figure in art is nothing new. In fact, the artist is relying on the viewer's previous experience with the male nude to inform his/her understanding of the meaning present in his own work. This 127 cm high bronze statue of a hockey player shown in an intense moment of action is not necessarily shocking in content, but the viewer's expectations of the nude seem to be upset by what Haakonson has created. Why is this?

Knowledge of previous historical works is central to understanding the primary message behind this work. Haakonson deliberately draws on ancient Greek statuary of nude male figures engaged in Olympic sport, but one in particular to which his own work's title makes reference – *Diskobolos*, or *The Discus Thrower*.

Diskobolos is a statue created c.a. 450 B.C. for the Greek Olympic Games (Davies *et al*., 2011). While the original was created in bronze, an expensive and durable metal which was likely pillaged, *Diskobolos* is known to us only as a marble Roman copy of the original. This roughly life-sized statue is not based on an individual, but is a generalized figure created according to a canon of proportions demonstrating ideal notions of human beauty at this period in time.

Haakonson's statue is true to its progenitor in many respects. It is also made of bronze and it depicts a nude male participating in sport. The sport, however, is modern, one that is indelibly linked with Canadian identity (where the author lives and where the artwork was displayed). Unlike the ancient Greek statues, Haakonson used a male model so the features are individualized, in keeping with how contemporary society celebrates individual achievements (Haakonson, 2009). The concept of a nude athlete engaged in contemporary sport, particularly one known for its violence and cold setting, is both unsettling and humourous. His statue, however, remains an homage to both its historical progenitor, a celebration of the nude male body and sport.

The original display location for this work is also significant in terms of deriving meaning, particularly meaning that was not necessarily originally intended for *Slapshotolus*, but in the end was very fitting. The location in which a work of art is displayed sets up a viewer's expectations of what they will see and how to read that work. In this case, *Slapshotolus* was displayed at the 2010 Winter Olympic Games in Whistler, British Columbia. In this context, a viewer with previous knowledge of the Greek male nudes engaged in sport would understand how *Slapshotolus* was a self-reflexive creation with a modern twist. The pose of the figure revealing its musculature demonstrates an understanding of the human body under tension in a manner similar to the Greeks. Further meaning, however, may be read in the statue due to the specific location of the work – PRIDE House in Whistler. PRIDE House was created as a residence and safe gathering place for Olympic competitors who were homosexual, bisexual, and their supporters. This statue, a centerpiece of PRIDE House, thus became representative of gay athletes, a meaning embraced by the artist who is also openly gay. *Slapshotolus*, though not originally created as symbolic of gay athletes, acquired that meaning through its placement and context.

It is important to understand that meaning, once established, never goes away. An image or symbol can acquire new meanings in addition to the old, but the fact remains that the context for images plays a significant role in establishing how they are read and which meanings are pertinent at any given point in time.

CONCLUSION

There is still a long way to go to really unpack the nature of threshold concepts in the area of the 'low consensus' humanities. The variability in how individual academic staff in the humanities conceptualize their disciplines, and the variability in which their disciplines are organized and taught over the course of a degree program, results in a low likelihood of consensus emerging on whether or not a particular concept is a threshold concept. Using the process of

'decoding the disciplines,' articulated by Middendorf and Pace (2004), and which Shopkow (2010) argues might be particularly useful to the identification of threshold concepts in the arts and humanities, we can engage academic staff in a conversation about bottlenecks experienced by students, how those bottlenecks are overcome by discipline specialists, and how we provide students opportunities to learn, practice and get feedback on the operations used by those disciplinary specialists to overcome those bottlenecks. Using this process, for example, it is possible that in the discipline of Art History one potential threshold concept is the reading of the language of art.

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Note: Attached image of *Slapshotolus* is provided with permission for use by the artist.

STUDENT UNDERSTANDING OF THE CRITICAL FEATURES OF AN HYPOTHESIS: VARIATION ACROSS EPISTEMIC AND HEURISTIC DIMENSIONS

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Biographical Note

Dr Zimbardi, Dr Chunduri and Associate Professor Lluka (University of Queensland) investigate the development of reasoning skills in large cohorts of undergraduate science students. Professor Meyer (University of Queensland) is an internationally recognised leader and founder of the field of Threshold Concepts. Dr Taylor, Dr Tzioumis (University of Sydney) and Associate Professor Ross (University of Western Sydney) investigate Threshold Concepts in Biology and lead *Vision and Innovation Biology Education* (VIBENet).

KEYWORDS

Threshold concept, biology, hypothesis, critical features, scientific reasoning

ABSTRACT

The higher education sector is now focussed on the task of creating graduates who are able to deal with the novel, complex, unstructured problems they will encounter in the 21st century workforce (Brew, 2010). Within science, the central role of hypothetico-deductive reasoning in 'thinking like a scientist' is well established (Dunbar and Fugelsang, 2005), and in bioscience education, understanding 'testable hypotheses' has become a threshold concept (Taylor and Meyer, 2010) and a key driver of curriculum transformation (Elliot *et al*., 2010). From a large database of responses provided by undergraduate biology students to the question *"What is a hypothesis?*" Taylor *et al*. (2011) developed a forty seven item psychometric instrument capturing variation in student understanding of this threshold concept. A version of this instrument has now been trialled with eight hundred undergraduate science students enrolled in a first year, second semester biology course. Exploratory factor analysis of their responses has revealed five factors which vary along dimensions of epistemic maturity and understanding of disciplinary heuristics. These factors are interpreted as representing the initial 'critical features' of the threshold concept as it 'comes into view'. Specifically, students were found to conceptualise hypotheses most simplistically as based on facts, or hold more advanced conceptions about the predictive utility of hypotheses (indicating an awareness of hypothetico-predictive reasoning) and to hypotheses as testable statements (indicating an awareness of hypothetico-deductive reasoning) used in the development of new scientific knowledge. Further, student conceptions varied on the role of observations, experiments and controlling variables in judging the validity of hypotheses. This snapshot characterises the conceptions about hypothesis held by early stage undergraduate science students, providing insights into the ways students are beginning to understand the heuristics used to judge the evidence that builds scientific knowledge in their discipline, as they embark on the journey toward thinking like a scientist.

INTRODUCTION

The higher education sector is presently focussed on the task of educating students to deal effectively with the types of novel, complex, open-ended problems they will encounter as graduates in the 21st century workforce (Brew, 2010). Within science, hypothetico-deductive reasoning has a central role, which is becoming increasingly apparent in science curricula (Dunbar and Fugelsang, 2005). In bioscience education Taylor and Meyer (2010) have argued that the concept of a 'testable hypothesis' represents a threshold for biology (Ross *et al.,* 2010). Based on interviews with graduate students Taylor (2008, p. 191) concluded that

> *"Most [students] saw an understanding of these concepts [hypothesis development, experimental design and data analysis] as a major change in the way they thought about these areas in biology, and such thinking required the integration of [other] concepts… involved a change which was transformational, irreversible and integrational..."*

Developing the capacity of students to create and use testable hypotheses is central to current curriculum transformation (Elliott *et al.,* 2010) because it better positions scientific knowledge as contestable, testable and subject to further inquiry (Jones *et al.,* 2011). Apart from a general trend toward embedding research-like experiences into the undergraduate

curriculum (Zimbardi and Myatt, 2012), how science and biology curricula should be constructed to scaffold student development in this area is less known. We need to determine how students vary in their understanding of the critical features of a hypothesis, in order to facilitate the development of student understandings as they move from novices to experts within the discipline. The aim of this study is to empirically determine student conceptions of 'hypotheses'.

INSTRUMENTATION

Taylor *et al.* (2012) reported on an exercise where a relatively large sample of first-year biology students (n=900) was asked to provide written responses to the open ended question 'What is a hypothesis?' The resulting qualitative data were subjected to conceptual analysis to yield inventory items which practically exhausted the variation in the qualitative data, yielding a psychometric instrument that economically translated the qualitative variation into statistical variation. We are now in the process of refining the set of items with several student samples of similar size (i.e. ~800-900 students). This process of refinement employs standard multivariate statistical analyses (factor analysis, item-correlation analysis), together with distributional considerations to reduce redundancy and identify those items with credible discrimination properties.

This instrument was administered twice in 2011 to students enrolled in a first year biology course (BIOL1040 *"Cells to Organisms"*), offered by biomedical sciences at the University of Queensland. A total of 839 students enrolled in the course, with just under half enrolled in the Bachelor of Science (45%), followed by Bachelor of Biomedical Science (12%), and Bachelor of Science and Bachelor of Arts dual program (8%). The remaining students were enrolled in a large range of specialty, applied science and dual degrees. The study was voluntary and conducted in weeks 2-3 (completed by 800 students), and then repeated in weeks 12-13 (completed by 759 students). We report here the analysis of the data collected in weeks 2-3 only.

Before students completed the instrument, they were provided with background notes to read in preparation for their first practical class for the course, which introduced the basic principles on the use of hypotheses and controls in scientific experimentation. These notes included an example of a scientific hypothesis in the format *"if X happens, then Y should be… "* In addition to the background notes, students also completed a voluntary, online formative pre-test that included questions such as *"If the kidneys regulate body fluid volume, increasing blood volume by 200 ml should increase the amount of urine produced in 1 hour; what is the independent variable in this hypothesis?"* and *"If the brain processes information, listening to 300 decibel music whilst watching 10 minutes of T.V. should increase the energy consumed by the cerebral cortex per minute; why is this a poor hypothesis?"* The students then completed the forty seven item instrument to capture their conceptions of a hypothesis at the beginning of the first practical class.

DATA ANALYSIS

Subsequent analyses of these data were aimed at explaining, in conceptual terms, the underlying dimensionality of the variation in the data. In all cases the dimensionality was exhibited via obliquely rotated (exploratory) factor solutions, using maximum likelihood as the factor extraction method and squared multiple correlations as initial communality estimates. Presented here are only the pertinent statistical details of these solutions and their extraction to support conceptual interpretation and discussion.

The dataset was analysed to explore the dimensionality of variation in students' initial conceptions of a hypothesis. The scree plot (not presented), and the eigenvalue > 1 factor extraction criterion, indicated the extraction of between four and six factors. All these factor structures were examined in turn and the five factor solution retained for its conceptual clarity.

INTERPRETATION

The five factors transverse dimensions of epistemic maturity and include dimensions of disciplinary heuristics. These factors are interpreted as representing the initial 'critical features' of the threshold concept as it 'comes into view'. Most simplistically, hypotheses were found to be conceptualised as being based on 'facts', represented by items in the psychometric instrument such as:

> A proposal of a fact
>
> Some assumptions on a matter that is considered tested

This suggested that student beliefs about hypotheses varied as to whether hypotheses are concerned with immutable facts, where hypotheses might be derived from these facts or be used to compare new data to these set facts. Such

conceptualisation of hypotheses seemed to describe the lowest level of epistemic maturity in the variation of conceptions present across the cohort. These statements appear to be consistent with lowest level of reflective judgement described by King and Kitchener in which knowledge is assumed to *"exist absolutely and concretely"* (2002, p. 41), where participants view knowledge in black and white, as right or wrong. Interestingly, this particular level of epistemic maturity labelled *"pre-reflective thinking"* also has three sub-levels; at each level, knowledge is seen as absolute, but how that knowledge is known varies from direct observation, to being obtained from authority figures, to being based on personal beliefs. This epistemological variation was present in the items that clustered together in this factual conception of hypotheses in the five factor solution, from items referring to facts based on previous tests or observations, to items describing facts based on scientific assumptions, theories or models.

More advanced conceptions about the predictive utility of hypotheses were also present in the factor solution, indicating variation in student awareness of hypothetico-predictive reasoning. This conception was represented by items which included words like guess and prediction, for example:

> The predicted outcome of an experiment
>
> A guess of what you think is going to happen

Compared to conceptions of hypotheses as based on facts that were pre-established, this conception of a hypothesis seemed to focus on the future tense, with the hypothesis used as a predictive statement. Given that the background reading for this practical included a hypothesis written in this predictive format, it is quite possible that this conception was influenced at least in part by the course curriculum.

There was also evidence of a more advanced conception of hypotheses as testable, exemplified by the items:

> A theory to be tested
>
> A theory put forward for scientific analysis to determine its validity

This conception introduced the notion of 'testing' and the sense that evidence is required in order for something to be known, suggesting variation in awareness of hypothetico-deductive reasoning in relation to biological knowledge. The association of evidence with hypotheses distinguished this conception from the previous two, aligning it with the more advanced epistemological understanding labelled by King and Kitchener (2002) as 'quasi-reflective thinking'.

Beyond the awareness that evidence was needed to test hypotheses, the factor solution also revealed variations in conceptions about the disciplinary heuristics used to judge different types of evidence. Specifically, the data revealed conceptions of hypotheses that varied depending on whether observations and/or controlling variables were important in testing hypotheses. The factor indicating variation in student conceptions about whether having a single variable is necessary to test a hypothesis was represented by items such as:

> A testable question which preferably has only one testing variable
>
> A testable prediction based on one variable

The key roles of variables and controls in biological science, and sound evidence-based reasoning more generally, are well established. Studies with middle school students have indicated a key developmental shift in which students move from randomly varying any number of variables during experimentation, to carefully varying only one 'test variable' whilst controlling all other variables between experiments (Kuhn and Dean, 2005). In biological science in particular, expert scientists and senior undergraduate science students are differentiated in the ways that they use specific controls in addressing experimental issues compared with non-science undergraduate students (Baker and Dunbar, 2000). Therefore it is clear that the ways in which variables are selected and controlled during hypothesis formulation and experimental design is an important reasoning skill in biological science, and a key dimension of variation in early stage students' understanding of the heuristics used to judge hypotheses.

Furthermore, we are beginning to see evidence of an additional dimension of variation in the conception of a hypothesis, where a hypothesis might be seen as being multivariate, represented by the items:

> A testing statement to find out the relationship between two variables or others based on the theory
>
> A testable theory to determine the relationship between two variables

In the data collected from students at the beginning of semester, it was not clear whether these two items were precipitating out of the analysis as an extra dimension of variation in student conceptions around hypothesis. In contrast, our preliminary analysis of the change in variation in conceptions of hypothesis between the beginning of semester and

our second use of the same instrument during the final practical class of the semester more clearly differentiated this additional dimension. This potential conception is currently only represented by two items in the instrument, but promises to represent very advanced conceptions of hypotheses held by undergraduate students. Therefore we are in the process of re-analysing the original data set of open responses on which this instrument was based, to develop additional items that may be used to explore this multivariate dimension further.

The final dimension of variation in student conceptions of the types of evidence used to test hypotheses was related to observational evidence, for example:

> A prediction based on observations
>
> An educated testable guess based on an observation

Interestingly, all four of the items representing this factor contained the phrase *"based on observations"*. This phrasing, grounded in students' original open responses, foregrounds observations as evidence in formulating hypotheses, rather than the evidence used to test hypotheses. This provides additional layer of complexity in considering the different ways that different types of evidence may be conceived as being used in relation to hypotheses. Indeed, developing the ability to judge and synthesise different types of evidence in complex contexts is a key element in the transformation from quasi-reflective thinking to the highest epistemological levels of reflective thinking (King and Kitchener, 2002). Therefore, determining the frames of reference that students use to judge the validity of different sources of evidence in this early stage of their science degrees will be crucial in understanding how these conceptions develop over time into more mature heuristics used by students as they become experts in their fields. Such information will be invaluable in scaffolding student experiences within biology curricula to facilitate the development of expert scientific judgement.

CONCLUSION

This study reports on a preliminary analysis of the critical features within epistemic and heuristic dimensions that vary in student conceptions about threshold concept of hypotheses at the early undergraduate stage. Student conceptions of hypotheses vary from hypotheses as representations of facts, to predictive and testable statements, and in the ways that evidence from observations, and univariate and multivariate experiments might be used and judged. These insights into the specific variations in conceptions of hypotheses that students hold provide the baseline for mapping the development of conceptions of hypotheses in the undergraduate curriculum. The next step is to determine how these conceptions change during a semester course which is specifically designed to help students develop skills in hypothesis construction and experimental design. Such studies will enable us to establish the ways in which first year science students understand hypotheses, and how key pedagogies linked to the critical features of hypotheses shape the development of student understanding of this threshold concept as students develop from novices to expert biological scientists.

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Part 5: Threshold Concepts in Professional Development

THRESHOLD CONCEPTS AND PRACTICES IN TEACHER EDUCATION: PROFESSIONAL, EDUCATOR AND STUDENT PERSPECTIVES

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Biographical Note

Dr Ann Devitt, Dr Helen O'Sullivan and Marita Kerin are experienced teachers who share many research interests in the field of education in Ireland particularly in the area of initial teacher education. All teach at the School of Education, Trinity College, Dublin: Ann lectures in Language Education, Helen in Leadership and Marita in Music Education. They all share a strong commitment to the provision of quality education research.

KEYWORDS

Initial teacher education, ontological transformation, teacher identity

ABSTRACT

The metaphor of a programme of professional education as a portal or threshold to a profession is a very apt and powerful one. Professional education programmes are both the gatekeepers of a profession and its door stewards facilitating entry and initiation. The concepts and practices, or ways of thinking and acting, of a profession provide the structure and path for the passageway from novice to initiate within the profession. This paper explores the path to initiation in the teaching profession from the perspective of three actors in this process, the student teacher, the teacher educator and the in-career teacher. Through analysis of interviews with the three groups, the aim is to explore the troublesome and transformative nature of the integration process which is at the heart of student teachers' developing identity as teachers. Our findings would suggest that it is the development of a student teacher's identity as a professional which is of prime importance in negotiating the liminal space of the novice teacher, rather than solely the cumulative acquisition of concrete technical and organisational skills associated with effective classroom teaching.

INTRODUCTION

The metaphor of a programme of professional education as a portal or threshold to a profession is a very apt and powerful one. Professional education programmes are both the gatekeepers of a profession and its door stewards facilitating entry and initiation. The concepts and practices, or ways of thinking and acting, of a profession provide the structure and path for the passageway from novice to initiate within the profession, often governed by requirements of the appropriate professional body. The domain of *Initial Teacher Education* (ITE) in Ireland is currently undergoing radical change with the launch of new requirements for ITE programmes by the statutory professional teaching body, the Teaching Council, and a governmental review of provision of ITE across the country underway. Within this context of change, this paper focuses not on key competencies, skills or knowledge for teaching but rather on ITE as a portal and the nature of the transition and transformation inherent in student teachers' successful negotiation of this portal, from the perspective of the student teachers themselves as well as the profession and teacher educators.

CONTEXT OF RESEARCH

The work described in this paper has emerged from our previous research on transformative experiences during initial teacher education which pointed at a number of concepts in teaching, for example, learner empathy, which seem to be part of a hidden curriculum of teacher education and not explicitly articulated in programme descriptors or statutory requirements (Devitt, Oldham *et al.,* 2011). The learning identified by student teachers was a shift in perspective, an ontological transformation, transforming their view of themselves and their purpose. Upon examination, these concepts fulfilled the criteria for threshold concepts, being transformative, troublesome, integrative and potentially irreversible. While *"beginning teachers typically conceptualise the process of learning to teach as a cumulative acquisition of concrete technical and organizational skills"* (McLean, 1999, p. 59), it is the development of student teachers' identities as professionals which is perhaps more critical to successful negotiation of the liminal space between student and professional within which they find themselves at ITE. It is worth noting that the student teachers carry out their teaching practice alongside attending lectures for the full academic year and so student teachers are continuously moving between

the two roles of teacher and learner for the duration of the ITE programme, existing in both a physical and mental liminal state.

The current study aims to explore the relationship between the ontological and the epistemological change that takes place during ITE, as discussed in Atherton *et al.* (2008). Threshold Concepts (Meyer and Land, 2006) provide a powerful and integrative framework for investigating professional development focusing as it does on transformative aspects of learning (Mezirow and Taylor, 2009), the nature of conceptual change (Carey, 1999), in particular adaptive change entailing changes to belief systems (Heifetz, Grashow *et al.*, 2009) and the importance of communities of practice (Wenger, 1998). The potential for threshold concepts to change not only the learner's knowledge but also his or her consciousness of self and even identity resonates with work on teacher identity and the role of the self in teacher development (Lipka and Brinthaupt, 1999; Day, Sammons *et al.,* 2007). Furthermore, the conditions of the liminal space within a threshold, in particular the notion of mimicry which ties to Brookfield's notion of impostorship for beginning teachers (2006, p. 91), is of key importance in exploring professional learning programmes which function as a rite of passage for Initiands to a profession (Kiley, 2009).

METHOD

This study seeks to answer the questions below, which focus on the troublesome and transformative nature of learning during ITE, with a focus on ITE for the secondary education sector:

- What are the critical moments of learning and/or transformation for teachers along their career path, in particular at ITE?
- What are the conditions, encounters or contexts which generate, facilitate or challenge the integration of this learning?

The study involved eleven student teachers on a postgraduate one-year ITE programme in Ireland, eight teacher educators and six practising teachers (two at early career, two at mid-career and two at late career stages). All participants were drawn from across a range of disciplines taught at secondary level in Ireland to include arts, humanities and science. All participants were volunteers and gave informed consent to participate in the study. Six of the student teachers provided weekly structured reflections for the second semester of their ITE programme and all participated in focus group and/or individual interviews at the end of the programme. The teacher educators and practising teachers participated in interviews which were structured loosely as personal narratives focusing first on individuals' own professional journeys and subsequently relating this to a discussion of ITE. The weekly reflections and post-programme interviews investigated key points of learning for student teachers and the triggering or facilitating events or conditions for this learning. They also addressed specific areas of difficulty experienced or overcome. The interviews with teacher educators and practicing teachers addressed what they had come to believe are the fundamental knowledge and skills underlying good teaching and how this develops, from their own experience and observations and what they felt should or could be achieved at ITE.

FINDINGS AND DISCUSSION

All participants (teachers, teacher educators and student teachers) consistently identified one element as central to the development and integration of professional competence, regardless of the range of competencies and knowledge listed in course requirements for ITE:

> *"a learner-centred perspective generating positive relationships in the classroom".*

This was articulated not in the abstract, as an orientation to establish for effective teaching, but rather in a thoroughly practical and constructive way, as the driving force behind improved exploitation of the teacher's professional toolkit of planning, methods and reflection. For student teachers, this was expressed as the single most important development or point of learning over the course of the year. For early career teachers, this was identified as both the reason for and the product of greater confidence in themselves as professionals since entering the profession. For later career teachers, this was a source of continued motivation and for some developed into an expanded vision of themselves as educators in the broadest sense of the word. Teacher educators expressed this as the single most important outcome of the initial teacher education programme without which student teachers could not progress or sustain their careers.

This shift in perspective, as expressed by student teachers and supported by professionals and educators, was not an epistemological change based on new understandings of how individuals learn and how best to teach them, but rather an ontological change grounded in a new vision of what it meant for them to teach. It entailed an appreciation of their

learners as individuals with their own lives, interests and abilities and also a release of control for them as teachers in their classrooms. Student teachers expressed a changed understanding of the nature of teaching as a social, relational and responsive activity involving not just themselves but all of the individuals in the classroom.

In answer to the question *"what brought about this change"*, student teachers almost uniformly stated that *"being in the room"* with their pupils was the source of this change, getting to know their learners and appreciate them as individuals. On further probing in interviews and in weekly journal entries however, it became clear that while this shift in perspective was experienced as a change in the classroom, the instigating factors were multiple and varied and occurred in school and university contexts, through reflection, dialogue or interaction with theory. The contexts for change included critical incidents with individual students, surprising reactions to new techniques or methods tried at the suggestion of peers, colleagues in the school or teacher educators, awareness raising through interaction with theory in lectures or reading, involvement in extra-curricular activities in school with students. For those undertaking teaching practice in schools in socially disadvantaged areas, it was the shock of learning about the real lives of individual learners that impacted on student teachers conception of what it meant for them to be a teacher.

The path of change was not uniform for all the student teachers. Taking Brookfield's notions of credibility and authenticity, the majority of the student teachers initially focused on establishing their credibility in the classroom, as professionals and experts in their discipline. Over time, then, they came to value the authenticity of their relationships with their students as the core for successful teaching, learning and classroom management. Two of the student teachers experienced a different change over the course of the year. They made the realisation that they valued authenticity of relationships over credibility as classroom teacher. One noted that she did not see herself as a teacher of her discipline but valued her pastoral role as teacher. This may be due to her expressed indifference to her discipline. The second student teacher specified her main priority to be establishing amicable relationships in the classroom. In fact, in a challenging teaching practice supervision, a clash with her supervisor over the degree of authority she needed to enforce reinforced her conviction that she *"did not want to be that kind of teacher".*

This ontological shift, a reconstitution of their identity as teachers, was expressed by some student teachers as the most troublesome aspect of the course. For one student teacher, the change was instigated by a reconsideration of their teaching philosophy as part of an academic assessment. For others it was experienced in the staff room as an amusing or disturbing sense of impostorship (Brookfield, 2006), a disconnect between their real selves and their new teacher persona. The sense of changed or changing identity was noted by all participants but the cause of the change or the realisation that a change was happening was very unique to each individual. Clandinin *et al.* express the varied and very personal nature of catalysts for shifts in teacher identity in a similar way as episodes in teachers' life histories:

> *"…moments where the teacher signalled an instance of heightened awareness, perhaps a moment of tension where s/he was awakened to bumping up against some new possibility in the passing parade … in relation to an encounter with a child or situation on the school landscape, other times they drew on storied experiences from off the school landscape".* (Clandinin, Huber *et al.*, 2006, p. 115)

The underlying ontological threshold or transformation was related in student teachers' accounts to aspects of the threshold concepts for beginning teachers identified by Cove *et al*. (2008). As noted in Atherton *et al*. (2008):

> *"…'cognitive' threshold concepts do not feature much in the experience of the learners, unless and until (we conjecture) they have engaged with the ontological challenges associated with the transformation of identity implicit in taking on a working role".* (Atherton, Hadfield *et al.,* 2008, p. 6)

Whether the ontological change must happen before the other concepts are integrated or the integration of other concepts lead to the change was not conclusive in our study. Both student teachers and early career teachers noted the difficulty in identifying the cause and effect relationship between a stronger learner focus and improved classroom management and more effective deployment of teaching-learning methods and skills. This was expressed as a chicken-and-egg phenomenon by two student teachers. Others felt they were very much moving in tandem with the underlying driving force of mutual respect for everyone *"in the room"* together as part of the learning process. Furthermore, student teachers and teacher educators identified a necessary and perhaps sufficient condition for development of student relations as a level of classroom facility and order within which a student teacher could find the space to consider and develop relationships with students.

In the personal narratives of in-career teachers, the notion of ontological transformation as both the cause and effect of new conceptualisations or knowledge formation over the course of their careers was also very strong. All of the mid to late career teachers spoke of a change in their view of what it meant for them to be a teacher at very specific points in their career. For one this was as a result of taking part in a Masters in education programme. For the others it related to a

change in role within the school which allowed them to view other aspects of their students' welfare and life development than those of which they had been previously aware. For two this was a more pastoral role which broadened their perspective of themselves as teacher to themselves as educator in the broader sense. For the third, this was taking on a final year exam class in a new subject for the first time, which led her to re-evaluate her role with respect to student academic achievement as distinct from their personal development, the reverse of the identity shift of the other teachers.

The aspects of learning which were consistently identified as troublesome by student teachers and on into early career were related to the orchestration of a learner-centred perspective in effective differentiation within the classroom and also on relating the classroom learning to the broader curriculum through long-term planning. While student teachers felt they were better able to observe the different needs and interests within the classroom by the end of the ITE year, they did not feel more able to cope with the demands of this knowledge in terms of planning and implementing variety for the class group. Indeed, this was expressed by all practicing teachers as something which took a number of years to develop. Similarly, the integration of learning in the classroom context to goals of the curriculum was identified as problematic. Both aspects entail both development of skills (planning and implementation) and a further embedding of the learner orientation in terms of what do learners need here and now in order to learn and what and when do they need in order to learn what the curriculum specifies.

CONCLUSION

The study outlined here highlights the interaction between identity and knowledge formation, where in the reconstituted view of the initiate to a discipline or in this case profession, new knowledge is integrated without perceived difficulty. The troublesome process is rather in the reconstitution of the viewpoint which transforms the viewer's subjectivity and their sense of self. The variety of contexts for ontological transformation even in this small study would suggest that the causes of the change are deeply personal, but there does seem to be a predictability in the change occurring. Further work exploring the causal effects of particular encounters with students, peers, colleagues or ideas is required to identify what are the conditions which instigate this change and how best to facilitate them.

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A COMPARACTIVE ACADEMIC/INDUSTRIAL PROFESSIONAL DEVELOPMENT STUDY OF THRESHOLD CONCEPTS IN PROJECT MANAGEMENT

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KEYWORDS

Project management, pattern language, negotiation, complexity, university/industry

ABSTRACT

The threshold concept framework and the *Alexandrian Pattern Language* (APL) framework are compared. The former is examined in a business school postgraduate course on negotiation and the latter in an in-house industrial training course in project management. The APL framework proved to be a valuable aide in the identification of threshold concepts and suggested that a threshold conception in project management is the manager as a social architect.

INTRODUCTION

The threshold concept framework was chosen as one of the underpinning pedagogic approaches in a European Union joint industry-academe project whose aim is the development of a serious game within a virtual world environment for the training of project managers within industry. The few threshold concepts studies in project management (e.g. Dyer and Hurd, 2011; Coughlan and Graham, 2009) are situated in traditional university courses. No matching studies have been reported from industrial professional development programmes where an emphasis on competency profiling often marks them apart from most of their university counterparts. Traditional competency profiling is often structured around a mechanistic approach, 'knowledge management', rooted in monist epistemology, and does not sit comfortably with the threshold concept framework (Kinchin *et al*., 2011; Stacey and Stickley, 2012). Robinson, Sparrow, Clegg and Birdi (2005) in a radical re-examination of competency-based training (CBT) include a recognition that the interdependency of competencies might explain the proliferation of competencies within tables whose generation was predicated on relatively few competencies. This reworking begins to resonate with the integrative characteristic of a threshold concept.

The role of complexity in industrial project management, with the need for "*extreme flexibility in recalibrating when to do what actions on multiple things we have going at one time"* (Allen 2009), has also long been appreciated as a source of barriers to progress in the failure of graduates to perform as effective managers. Industrial professional development courses are faced with the problem of identifying the key nexi within this complexity, not an easy task even given the greater ease of exploiting experiential learning in an industrial environment. In this paper we examine an alternative to CBT adopted by the Siemens Company, an innovative use of Alexander's pattern language framework in the identification of such nexi within an industrial training program. We compare this framework with the threshold concept framework and with the outcomes of a study of threshold concepts in an academic postgraduate course in a matching area as it appears a potentially powerful tool in the identification of threshold concepts.

THEORETICAL FRAMEWORKS

This section describes the APL framework and briefly compares it with the threshold concept framework. Christopher Alexander (1977) introduced the idea of a pattern language into architectural design with the intent of capturing ideas

that are archetypical and reusable. It has been adopted by several other disciplines. Alexander (1979) describes a pattern as

> *A three-part part rule, which expresses a relation between a certain context, a problem, and a solution.*
>
> *As an element in the world, each pattern is a relationship between a certain context, a certain system of forces which occurs repeatedly in that context, and a certain [spatial] configuration which allows these forces to resolve themselves.*
>
> *As an element of language, a pattern is an instruction, which shows how this [spatial] configuration can be used, over and over again, to resolve the given system of forces, wherever the context makes it relevant.*

Though the Alexander did not introduce the idea of a pattern language with an emphasis on learning or on identifying troublesome concepts it seems likely, given the above definition, that some archetypical and reusable patterns will coincide with concepts whose grasp is essential in the transformation to a professional manager and hence warrant a comparison with the threshold framework. A pattern is not a solution to a problem but *"a definition of the characteristics that are required for a solution to be effective"* (Christensen, 2004). In this it has some resemblance to a threshold concept which is not a recipe for grasping a transformative concept but a set of characteristics that aide in the identification of a transformative and often troublesome concept. Both are more than a method of identifying key concepts or competencies though both may well assist in that task. Similarly the identification of the pathways leading to a solution of a problem is not necessarily a pattern just as a troublesome concept is not necessarily a transformative threshold concept. The identification of the forces that occur repeatedly in a pattern context and the pattern's reusability echoes both the integrative and bounded aspects of a threshold concept as does Alexander's belief that the interaction between patterns is as important if not more so than the patterns themselves, hence the development of not only a pattern definition but of a pattern language with a vocabulary, a syntax and a grammar (Alexander, 1979). Alexander's use of the word transformation, at one level, reinforces the analogy as, e.g. in structure preserving transformations. These are transformations in which the elaboration of the interacting patterns increases the wholeness, i.e. integrates the parts more effectively into the whole, which Alexander believes to be essential. However, on another level, it is at most a reification, Alexander firmly grounding his patterns in their social milieu with the recognition of his approach by the communities of practice community (e.g. Wenger, McDermott and Snyder, 2002), but it is not directly related to an ontological shift in a learner.

METHODOLOGY

This comparative study involved an APL analysis of fifteen years of an industrial training course in Siemens PSE, Vienna and threshold concept studies within a scenario based postgraduate course in negotiation in the Norwegian Business School (NBS) in Trondheim and within a project management course in NTNU in Trondheim. Thus it has facilitated the adoption of a triangulation approach which comes close to a full multiple triangulation as defined by Denzil (2009). Three of the four basic triangulation types proposed are utilised. Following the strictures of Zelditch (2009) a *between-methods methodological triangulation* has been used involving the use of more than one method to gather data; this study comprises (1) a conventional phenomenographic study involving questionnaires and interviews based on conventionally taught university courses (NTNU), (2) tracking interviews of both staff and students throughout a scenario based university course (NBS) and (3) the identification of troublesome aspects met by learners in industrial training workshops and role playing classes, over fifteen years, supplemented by interviews with the key training staff facilitators. The above and the involvement of multiple closely collaborating researchers in several institutions; lecturers in the Norwegian Business School, lecturers in the Norwegian University of Science and Technology, industrial trainers in Siemens Austria and an educational researcher in UCL, London, satisfies both *investigator triangulation* and *data triangulation.* The fourth basic type, *theory triangulation*, is absent from this study as the authors are not impartial on the existence and value of Threshold Concepts.

SIEMENS' APL STUDY

The APL framework was adopted by the Siemens PSE, Austria, in an analysis of the outcomes of their management training course and in identifying troublesome aspects. The patterns in project management were identified in a fifteen year study drawing on sixty workshops, each of ten to twelve participants with two facilitators, involving ~700 participants, from six countries, mainly from IT and Development divisions, which had a significant emphasis on reflection. The facilitators only classified a particular context, problem and solution as a pattern if they saw forces associated with this context repeated and ranked them on the repeat frequency. Fifty have been examined in detail and classified as such.

The interaction between these has been scrutinised though such a large number precludes an easy presentation of the resultant network plot in this paper. Consequently one subsection, centred on negotiation, will be discussed in this paper. Negotiation was chosen as it allows a fruitful comparison with the outcome of the threshold concept study conducted in the Norwegian Business School at Trondheim in a postgraduate course on negotiation.

NORWEGIAN BUSINESS SCHOOL (NBS) STUDY

Negotiation is seen as a key competence not only in business management but also in social work and has been traditionally and extensively analysed in terms of its constituent capacities and abilities (e.g. MAFF, 2004). It forms an important component the NBS management programme. Table 1 shows the initial candidate threshold concepts identified after the two year study of a scenario based postgraduate negotiation course. The table also shows those patterns, identified in the Siemens APL study, which represented troublesome concepts associated with negotiation.

Table 1: Overlap of initial candidate threshold concepts and APL patterns between the academic and industrial studies

NBS Study	**Siemens PSE Study**
Negotiation as a 'state of flux'	Being prepared for the unexpected
Living with contingency	
Need to understand the other person	Need to step out of one's self ["your glasses"]
Grasping both the overall (big) and the detailed (small) picture	Achieving global and local optimization
Realizing that there is no right or wrong way	Realizing that there is no right or wrong way
Reality versus a model	Reality versus a model
Interest versus position	
Best Alternative To a Negotiated Agreement	
	Distinction between the way and the goal
	Abstraktion

There is a significant but not complete overlap with often near phraseology arising in both studies. As the study progressed to include both an analysis of the interaction of these troublesome concepts and attempts to refine the list to one of transformative concepts the academic/industrial alignment became stronger. The APL study strongly suggested a complex web of cross interactions and a similar conclusion is emerging from the NBS study. The complexity of these cross interactions is shown in Figure 1 in which a subsection of the Siemens APL network centred on negotiation and of the NBS work have been aligned and pooled. The combination of these studies suggests a network of troublesome concepts in project management that may well only be mastered if their interactions are also grasped as Davies and Mangan (2007) first suggested in economics and as Kinchin *et al.* (2011) have suggested in dental education, a vocational discipline in which competency-based teaching is also common. Such a network supports Robertson *et al.* (1987) speculation on the interrelationship of competencies. The resemblance to Davies and Mangan's hierarchical arrangement within a network is even greater as a clear outcome of the overall Siemens study is that the complex interaction of these troublesome concepts leads to the overarching concept that a successful manager must be a social architect. This overarching concept appears very similar to a threshold conception (Land *et al.,* 2005).

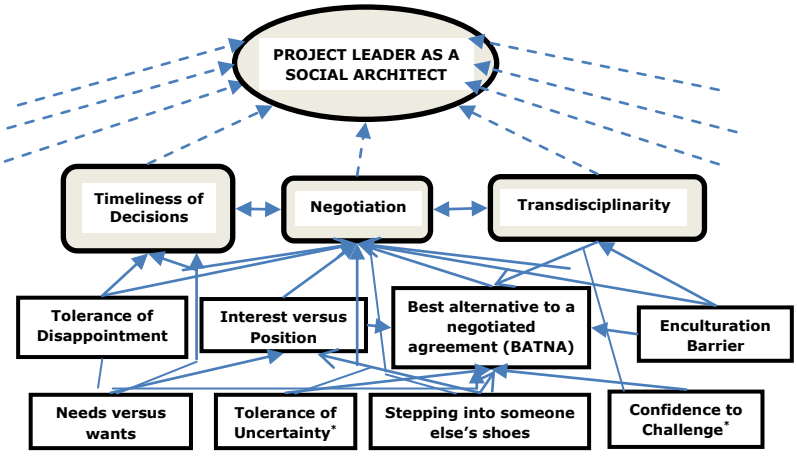

Figure 1: Troublesome concepts associated with negotiation identified in the Siemens PSE Insights and NBS studies. Two (*) were found to be analogous with ones identified in design teaching by Osmond and Turner (2009) and have been given Osmond's descriptors. This scheme represents a fragment of a larger PSE Insights web of pattern language interconnections characterising project management. The square boxes represent basic concepts having many interactions across the whole of the APL matrix. The rounded boxes represent higher level concepts drawing on several basic concepts

CONCLUSIONS

Siemens' migration of the Pattern Language framework to a learning environment has greatly facilitated a retrospective analysis, through a threshold concept lens, of an extensive fifteen year study especially as this study has also included the identification of patterns that may be troublesome and transformative. As commented above the pattern language framework itself does not contain a concept of an ontological transformation but its transfer to an in-house industrial professional development program has provided an excellent opportunity to look for such transformations as the participants may be observed long after they have completed the program. Additionally several cases of participants reporting an apparent 'light-bulb moment' have been observed. The adjective 'apparent' is used as these did not all occur during the workshops but in the work place afterwards which tends to confirm Cousin's observation that "*there is no simple passage in learning from 'easy' to 'difficult'; mastery of a threshold concept often involves messy journeys back, forth and across conceptual terrain"* (Cousin, 2006).

The pattern language approach has proved a powerful aide in the identification of threshold concepts and has facilitated comparison between academic and industrial learners. Not surprisingly there is often a marked difference in the way the academic and industrial learners express their frustration on meeting the same barrier; *"everything is in a state of flux"* (academic postgraduate) contrasted with *"How do you prepare for the unexpected"* (industrial worker). The postgraduate feedback was generally less sophisticated than that of the Siemens participants but, probably more importantly, the differences raise the importance of identity and of the spectre of tacit knowledge. Perkins (2008) has described the interaction between threshold concepts as an episteme and suggests that "*perhaps tacit knowledge is the most pervasive trouble with epistemes".* In this context, for the postgraduates the scenarios within their course in their degree program are the 'real world', for the learners in industry their experience lies in the real 'real world'. Given the extensive overlap of troublesome and potentially transformative concepts with industrial Alexandrian patterns we initially concentrated on these similarities, as they support the emergence of a common set of threshold concepts that if mastered will facilitate the transformation of both academic students and graduates within industry. However it may be as, if not more, fruitful to look at the differences given the problems in converting tacit to explicit knowledge, or at least in analysing this conversion, and in the transition from a 'learner identity' to a 'professional identity'. The differences may reveal hidden constructs that are critical in becoming a successful manager that just would not surface in a postgraduate context and such a study is now in progress.

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SHIFTING IDENTITY IN TEACHER DEVELOPMENT

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KEYWORDS
Identity, autonomy, teacher development, education policy

ABSTRACT
The author seeks to support US teacher candidates' development as instructional decision makers. This proactive disposition runs counter both to their own experiences in highly structured, test-oriented schooling and to increasingly prescriptive policy directives governing their work. Two strategies used in the context of preservice teacher education courses in literacy show promise for supporting candidates in acquiring a self-directed teacher identity while they wrestle with conceptual understanding.

INTRODUCTION
In our work with teachers at every level – from preschool through university, preservice and inservice – one of our greatest challenges is that of helping educators see themselves as capable of orchestrating their knowledge of their discipline with their knowledge of their students in order to make informed instructional decisions and to act on them. This proactive disposition runs counter both to their own experiences in highly structured, test-and-right-answer-oriented schooling (Carmichael, 2010) and to increasingly prescriptive policy directives governing their work. For those who successfully navigate this course, the excursion (Cousin, 2006) is nothing short of transformative (Land *et al.,* 2005). Their language about themselves and about teaching (Meyer and Land, 2005) becomes more active, confident, and authoritative as they reconstitute their identity (Land *et al*., 2010) as 'teacher' and refuse to revert back to being a technician who implements the plans and ideas of others. For many candidates, this rite of passage is troublesome (Perkins, 1999) and very messy, especially when the more compliant, other-directed role is reinforced by administrative policies and/or family or religious influences (Goodman, 2011; Taylor, 2008). The anxiety (Cousin, 2006) attached to this new 'way of thinking and practicing' (Meyer and Land, 2003) as an educator is often most distressing for our strongest students, who have been the most successful over the years in figuring out what their teachers consider 'the right answer', and in producing it. Whether we label it a threshold concept or a threshold conception (Land *et al*., 2005) or something else, the disposition to see oneself as an informed decision maker, and to act on that, is a crucial one in the professional development of teachers (Martin and Crossland, 2000).

In this paper I share strategies and data from my work with pre-service teachers in the US as we have grappled with this phenomenon in the context of elementary teacher education courses. I will describe how two course experiences, the 'Dear Colleen' letter and the self-evaluation portfolio, support students in acquiring a self-directed teacher identity while they wrestle with conceptual understanding. At the same time, my hope is that the relationships I build with my students help them see me as someone *"who can help [them], who [they] can go to"* (Cousin, 2012) not only when they need support themselves, but also as a model for their own teacher/student relationships.

CONTEXT: LITERACY EDUCATION COURSES FOR PRE-SERVICE TEACHERS
One of the courses I teach is *Elementary and Middle School Developmental Reading Instruction*, among the first courses in which prospective elementary, special education, and early childhood education teachers enrol once they are admitted to teacher education at our university. For the elementary teachers, licensure requires a baccalaureate minor and a full-year graduate internship in addition to their baccalaureate degree in an arts and sciences major; when they enrol in the reading class of 20-25 students, it is often the first time their instructor knows their name after freshman and sophomore years of sitting in lecture halls with hundreds of other students (Sperber, 2001). For the past ten years, we have been

required by the Tennessee Department of Education to address a list of 'Reading Standards to Be Integrated into Licensure Standards'. Many of these reading standards are assigned to be taught in this class.

In designing the class experiences, I am of course aiming toward my students' developing deep conceptual understanding of the reading education content knowledge they must have in order to become capable teachers. At the same time, and equally importantly, I want them to develop their identities (Land *et al.,* 2010) as instructional decision makers and begin the life-long process of setting goals for their own professional development. Many of them will teach in school systems that actively work against teacher voice and autonomy and cannot be counted on to support effective professional learning (Evans and Broemmel, 2008). Two of the ways I endeavour to achieve these goals are the 'Dear Colleen' letter and the self-evaluation portfolio.

THE 'DEAR COLLEEN' LETTER

The 'Dear Colleen' letter invites students to talk with me about unfamiliar professional content using more personal discourse. Later, when the content itself is more comfortable, we explicitly translate it into the more formal discourse or jargon in which they will need to be fluent not only in the profession but also if they continue within the university for advanced degree study. In his classic 1985 piece, 'Inventing the University', David Bartholomae wrote

> *"Every time a student sits down to write for us, he has to invent the university for the occasion...The student has to learn to speak our language; to speak as we do, to try on the peculiar ways of knowing, selecting, evaluating, reporting, concluding, and arguing that define the discourse of our community...and he has to do this as though he were easily and comfortably one with his audience, as though he were a member of the academy"* (pp. 134-135).

This essay has generated debate (Bartholomae, 1995; Elbow, 1995) that is still ongoing (Mylnarczyk, 2006); my purpose is not to enter that debate about the rightness, or the appropriateness, of assigning academic writing or not. I propose that in my field – teacher education – a parallel phenomenon takes place when students are asked to write lesson plans or reflections on readings and/or practices as if they were members of the profession when, indeed, they are not. As a teacher of undergraduate and graduate preservice teachers, I face the challenge of asking them to acquire unfamiliar and important content, and it is my experience that when they try to write and speak about these in authoritative discourses, opportunities for genuine engagement are rare.

I have always asked my students to correspond with me about their own learning goals so that I can support them in achieving those. Often in the past, even when I invited personal correspondence, I received some version of an academic essay. In recent years, I have explicitly required students to open these assigned letters to me by writing, 'Dear Colleen', hoping to get them started in a more personal register, and to help them identify with me as a colleague – a fellow teacher (Cousin, 2012). This allows students to draft their thinking in language and formats that are comfortable for them, so that they may concentrate on the unfamiliar content. Later, when the ideas themselves are more firm, we talk about the rhetorical choices they will need to make in other settings and for other audiences – professional, academic, families of their students – to communicate their knowledge and beliefs to others. It has been my experience that Mylnarczyk (2006) is correct when she avers, *"I believe that students cannot write a strong and convincing argument unless they have first grappled with their subject in a deeply personal way"* (p. 23).

Students seem to find it helpful, as Chloe reflected,

> *"The class consisted of some deaf ed people, some special education people, and some ESL education people [in addition to elementary education people]. I was able to experience learning from many different viewpoints and people. I learned to be professional, to share professionally, and to listen in a professional manner".*

In her reflection on our relationships, Maggie wrote,

> *"...I have greatly appreciated a class environment where I can convey my own interpretations of things. And not only is this allowed, but my perceptions are also valued and acknowledged rather than criticized. I am grateful for the way that you modeled constructive criticism against misconceptions. Additionally, you made our learning environment open and safe..."*

Finally, I share Marie's perspective:

> *"I think it is very important to be open to every voice in a classroom. Even though we may not agree with what a person has to say, we must realize that their voice deserves the same protection as anyone else's voice. This*

became very evident to me in observing the small struggles our class had with this. It was a great learning experience to see how this struggle was dealt with in a positive manner".

Maggie's and Marie's observations indicate that students eventually felt safe to share ideas, whether in their 'Dear Colleen' letters, in class, or in meetings with me, even when theirs were unformed-as-yet ideas or 'minority voices'. They seem to find this a productive potential space (Winnicott, 1967) between themselves and the larger cultural environment of schools and teaching in which they will eventually practice (Meyer and Land, 2003).

Even when they are not speaking explicitly about these identity issues, their language in their 'Dear Colleen' letters (Meyer and Land, 2005) reflects their shifting from a more tentative voice seeking teacher approval to a more confident one who is a teacher determined to make informed decisions. Virginia began her first 'Dear Colleen' letter this way,

"I am not sure, as of right now, what I am concerned about or what I want to know... I do not want to be a boring teacher that makes the students cry every time I stand up in front of them. I think that is one of my major fears... I am honestly completely lost and confused right now. I really can't decide if it's my nerves or if I really don't have a clue as to what I am going to do. I am in desperate need for some guidance..."

but by the time she wrote her second letter, a month later, her increasing confidence was clear:

"I am a lot more comfortable in my shoes after this project! It opened my eyes to how creative and energetic I can be when dealing with assignments to help the children learn. This project was a little harder than I anticipated, but I found it to be fun".

By the end of the semester, she shared that *"I am still nervous about having a classroom full of students that I have to educate, but I am positive that I will do fine".* Yet another student, Lashair, wrote in her final reflection that *"My goal as a professional is to determine which strategies will help specific students in my classroom and to use those strategies to benefit those students",* a big shift from semester's beginning when she expected me to give her a script of specific techniques to carry out. While it is impossible to remove entirely the influence of *"power, tradition, and authority"* (Bartholomae, 1995) always present in assignments for students when an instructor is the audience, the 'Dear Colleen' letter and its follow up help me invite preservice teachers into a collegial space – a 'potential space' (Winnicott, 1967) – where we can reduce their anxiety (Cousin, 2006) and deal with those explicitly and productively.

THE SELF-EVALUATION PORTFOLIO

As mentioned above, there are explicit content standards I am responsible for in this course, and early on (I was one of the creators of this course) I decided that I would ask my students to compose a portfolio demonstrating to me their knowledge of those required standards, rather than giving a formal final examination. The arrangement of the portfolio is left to their discretion, as long as the required standards are included, and the students select artefacts to include as evidence of their learning, along with reflections on these describing how they relate to the standards. This is not only much more interesting for me to evaluate at the end of the course, but also more demanding of understanding and synthesis, i.e. conceptual understanding, on the part of the students in composing it.

Every semester, the students with the strongest academic backgrounds almost panic at this assignment, as they become very anxious (Cousin, 2006) that their previous ways of thinking and producing 'right answers' no longer apply (Meyer and Land, 2003). They want to begin the portfolio right away (despite not having any knowledge yet, in most cases, of reading education), and want me to hand them a template. I meet with them as often as they wish for coaching conversations (Guiney, 2001; Herll and O'Drobinak, 2004; Kise, 2006; Knight, 2009) and have posted on our class's Blackboard site a number of exemplary portfolios from past students. No two of these are the same, to reinforce my intention that students show me how they are making sense of this information by the way they choose to organize it. Final reflections on the portfolio and the process of constructing almost always address issues of identity and efficacy (Land *et al*.; 2005, Land *et al.,* 2010; Meyer and Land, 2005). For example, Liz shared:

"When I first heard about the portfolio assignment, I was terrified. I have never constructed a portfolio before this class, and I was confused on what one was and how I was ever going to learn enough information to be able to put it together. In the beginning, I was worried about getting an A. I thought I was going to have to memorize information and recall it for the portfolio. However, by the end of the semester, the grade was no longer my first priority. I enjoyed making the portfolio. I was more concerned about making sure I could use the articles I read later in classrooms than I was about using them for an assignment... I felt more like I was preparing for my future than doing an assignment for a class".

Cassie's reflection captures something that I hope these preservice teachers will take into their own teaching, when she describes realizing how much she learned by not worrying about passing exams:

> *"The more that I think about it, the more absurd the thought of attaching a number grade to the amount a student learns seems... Doing all of the assigned readings, attending all class periods, and coming to class fully engaged, and ready to participate has helped me maximize my learning potential… While creating my portfolio, I realized that I have learned much more than I had even realized. As I started looking for articles to put under the standards, I found it much easier than I had thought. Because of my high engagement in the class and in the readings, it was easy for me to recall what I had learned".*

CONCLUSION

My teacher candidates leave me to teach in a public school system that is increasingly focused on high-stakes assessments for students (Goodman, 2011; Taylor, 2008) and for teachers (Shakman *et al.*, 2012; Wilson *et al.*, 2011); many districts respond to these assessments by implementing 'teacher-proof' scripted curricula and pacing guides rather than trusting teachers to make instructional decisions (Evans and Broemmel, 2008; Goodman, 2011). My yearning is that in addition to acquiring the content knowledge in reading outlined in our state standards (and pass rates on Praxis II licensure exams indicate success at this), my teacher candidates will cross the border (Jegede and Aikenhead, 1999; Cousin, 2006) into trusting their own voices and capacities for decision making (Holland *et al.*, 1998; Horn and Little, 2010; Urzua and Vasquez, 2008). The 'Dear Colleen' letter and the self-evaluation portfolio are aimed at helping them equip themselves to resist prescriptive policies and to take responsibility (Martin and Crossland, 2000) for creating for their own students opportunities for engaged participation (Guthrie, 2004; Guthrie and Wigfield, 2000; Guthrie *et al.*, 2004; Hickey and Zuiker, 2005) where deep – and possibly even transformational (Land *et al.*, 2005) – learning is the focus, rather than the taking of exams.

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UP CLOSE AND PERSONAL: ENGAGING LEARNERS WITH SERVICE USER KNOWLEDGE

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KEYWORDS

Threshold concepts, social work education, service user knowledge, tangible knowledge

ABSTRACT

This paper reports on the benefits gained from the creation of a high-challenge learning environment within one module of a professional social work degree programme. In a module entitled *Mental Health and Social Work* for final year social work students, the traditional classroom landscape was transformed (and the safety perch of the lecturer-as-expert unseated) when two representatives of a mental health service-user organisation accepted an invitation to audit the module's content and delivery. As part of conducting the audit, the service-users reviewed the module handouts, assignment guidelines and lecture content. They also sat in on all the lectures.

Appreciating the value of the service-user perspective and service-user feedback on service delivery is a threshold concept in social work. It is mandated by law in certain jurisdictions, such as Northern Ireland, that social work degree programmes promote service-user perspectives in the curriculum. Yet, for students it is an elusive and hard-to-grasp concept which can be perceived as ill-defined and ambiguous.

Finding ways to represent the views or the 'voice' of service-users in education of professional disciplines (not just social work but many other professions also) has consequently confronted lecturers and students alike with challenges of definition, conceptual understanding and application. This experimental audit of a module by two mental health service-users threw out the traditional rule-book on boundaries between expert and learner. Students, lecturer and service-users bravely embarked on a journey together into the uncharted territory of service-user involvement in the classroom. This paper reports on the transformative, irreversible, integrative and profoundly knowledge-changing elements of that journey for all concerned….so far.

> *"When people not used to speaking out are heard by people not used to listening, then real changes can be made"* (Western Health Board, 2002, p. 10).

INTRODUCTION

This paper outlines a teaching strategy, developed with reference to threshold concepts theory, which was adopted in a module on mental health social work. Among a number of learning outcomes, the module set out to build student knowledge regarding the benefits of including service user knowledge in healthcare planning and service delivery and to highlight for learners the rich and insightful knowledge that mental health service users hold. Ferguson and Ager (2008, p. 71) refer to 'specific knowledges' carried by service users about their experience and they stress the importance of ensuring that the voices of service users are 'not silenced or excluded' from the assessments and decisions that shape their futures or define their pasts. In order to be able to work inclusively in this way with service users it is essential that social work students appreciate the value of the knowledge, gained from their lived experience, which service users bring into their consultations with professionals. A second aim of the module was to demonstrate, in practical terms, how service user knowledge can be used to inform and improve professional practice.

Viewing service user knowledge through a threshold theory lens unveiled its status as a threshold concept in social work and helped the author, in her role as lecturer, think about the creation of a learning environment in which transformative and integrative learning could take place. By grasping the nature and relevance of service user knowledge, the learner will navigate a conceptual portal (Meyer and Land, 2003) to discover a bigger vista wherein lies the potential for service user knowledge to inform the development of services which are responsive to service user needs. A further consideration for

the social work educator is how service user knowledge as a concept can be rendered "tangible" (Kinchin *et al.,* 2010, p. 83) so that learners can understand it, utilize it and integrate it into their work.

In the sections that follow, this paper deals firstly with the policy and practice arguments which favour the promotion of service user knowledge at all levels of health care planning and delivery. It then outlines the teaching approach adopted in a social work module that aimed to place the knowledge of mental health service users in a central position. It considers how effective the module was at providing the opportunity for transformative, irreversible and integrative learning on service user knowledge.

SERVICE USER KNOWLEDGE IN POLICY AND PRACTICE

Within the literatures on disability rights (Oliver, 1990) and the social model in mental health (Beresford, 2002), there is a call for professionals to incorporate into their work respect for service user knowledge (Beresford and Boxall, 2012; Oliver, 2004). If social workers are to privilege the knowledge of service users in their work, they must first understand its importance, derived as it is from the subjective experiences of individual service users and service user collectives.

At a policy level, the imperative to engage with service user knowledge is articulated across a wide range of policy documents and reports in various jurisdictions (for example, Australian Commission on Safety and Quality in Healthcare, 2010; DoH, 2000; DoHC, 2008). The identified benefits for services that flow from engagement with *service user knowledge* include enhanced quality assurance, improved service performance, greater accountability, better targeted service delivery and better outcomes (McEvoy *et al.,* 2008). As McPhail and Ager (2008, p. 3) suggest, service user knowledge can contribute to enhanced service delivery which they describe as *"more responsive, integrated services for the benefit of service users and carers*".

From a service user perspective, having their views and experiences taken seriously may help improve services but more importantly, it may also help improve their lives by tackling stigma and discrimination (Weinstein, 2010), by influencing resource distribution and by challenging power inequalities (Beresford, 2012; Webb, 1994).

However, in a classroom context, defining and explaining the concept 'service user knowledge' is not straightforward. It takes us into the realm of concrete knowledge, as described by Newman (1874, 1979). For Newman, knowledge derived from experience is distinguishable from notional/abstract knowledge and has important ontological and epistemological qualities that help us better understand the nature of our world. In line with Newman's categorization, the concrete knowledge gained from experience is of the real world, is far from static and comes in many forms. It cannot be reduced to a simple formula. Understanding the deep level knowledge that service users hold requires practitioners to appreciate the ontological and epistemological basis (how we know what we know) of the service user perspective. However, in the language of threshold concept theory, service user knowledge is a 'troublesome' or complex concept (Meyer and Land, 2003, p. 5) because it represents not one singular entity but rather a spectrum of experiences. Helping students engage with it, therefore, stretches educators to steer students through a complex conceptual portal.

TEACHING ABOUT SERVICE USER PERSPECTIVES

To assist learners engage more easily with 'service user knowledge' as a concept, an innovative strategy was introduced into one module in an undergraduate social work degree programme. It entailed two mental health service users[6] acting as auditors of the 'Mental Health and Social Work' module for final year students.

The auditors reviewed all the module documentation (module descriptor, presentations, handouts, assessment outline), observed every lecture and provided feedback on how the module content could be improved. The presence of the auditors in the classroom, of itself, created a high-impact learning environment and the traditional classroom landscape was transformed. It brought mental health service user knowledge centre-stage into the classroom setting – achieving an 'up close and personal' exchange between educator, students and service users.

The auditor role was not a passive one. It was envisaged from the start that the auditors would comment and contribute to the class discussions. Students listened to service users speak with authority on the mental health issues that had affected their lives and how useful (or otherwise) they had experienced professional services and interventions.

[6] In advance of the module, the lecturer consulted a national organisation representing mental health service users and carers, with a view to a joint collaboration. The idea for the 'audit' of the teaching module emerged from this consultation and the organisation nominated two of its members to act as the module auditors.

With the auditors present in each lecture throughout the module, there were many opportunities for gaps in the module content (as designed by the lecturer) to be exposed. Kinchin *et al.* (2010, p. 83) state that:

> *"the adoption of an expertise-based pedagogy requires teachers to have the courage to share their knowledge, and the gaps in their knowledge".*

Of particular note was the difference regarding what module content the lecturer and the service users regarded as important. The auditors identified a number of topics which, from a service user perspective, deserved greater amplification and more in-depth elaboration within the module. For example, the recovery model in mental health (Anthony, 1993) was included in the module but the service users suggested that 'why' the recovery model holds importance for service users deserved extended coverage.

Students observed the interaction between the lecturer and the service users on this and other issues. The involvement of mental health service users in every aspect of the module effectively discarded the traditional rule-book of lecture-based teaching and loosened the boundaries between expert and learner. Ferguson and Ager (2008) cite Evans and Fisher's (1999, p. 63) observation that:

> "*involving service users in teaching social work brings not only immediacy to the learning but a reshaping of the notion of expertise*".

Within the module, students experienced transformation of their own knowledge base but they also witnessed the transformative impact on the lecturer's knowledge base arising directly from the lecturer's openness to engaging with and being informed by service user knowledge.

Students contributed to the class discussions, asking questions or making links between the module content and their own personal or work experiences. The presence of the auditors helped create a bridge between the outside world and the classroom and this provided an integrative learning opportunity. The voice of the service user was in the classroom and students not only had to think about it, they had to engage with it. Students, carrying their own understandings about mental health, were invited to revisit some of the 'truths' they previously held about how mental health difficulties impact on peoples' lives. The service users prompted the students to think again about how well they listen to service users, what they write in case files based on that information, how they evaluate their own practice and how they could better integrate service user knowledge into that evaluation. Furthermore, students' understandings about what service users want from services were among many topics that were unpicked, critiqued or irreversibly deconstructed during class discussion.

As Timmermans (2010) points out, it is not always certain how students have journeyed through the conceptual portals to which they have been introduced. With regard to the module discussed here, anonymous student feedback provided some insight into how the module helped develop student knowledge. Some students reported a shift in how they conceptualized mental health. They found that the module content and the opportunity to engage with service user knowledge in particular, encouraged them to consider the potential of alternative paradigms to the biomedical perspective (which places an emphasis on individual illness and pathology). Some students reported that the distinctions between contrasting paradigms of mental health were clearer for them on completion of the module. Some students reflected on how they would carry forward greater respect for service user knowledge into their work. Students also reported heightened awareness of the difficulties that mental health service users encounter in getting their views heard. Across the feedback, students connected what they had enjoyed or found useful in the module to how it would impact on their future practice as social workers.

CONCLUSION

Students on professional education programmes, such as the one in the case example here, will one day work in a social work role with service users. Farrell (2010, p. 20) reminds us that social work can be more responsive to the needs of service users if it is informed by service user knowledge. A challenge for social work educators is to help students appreciate and understand the importance of listening to service users in the assessments and decisions that affect their lives. However, as Beresford and Boxall (2012) indicate, service users are not a homogenous group and while they may have some shared knowledge they also each have their own unique set of experiences. Therefore, service user knowledge is diverse, varied and multifaceted. It is not something that can be learnt by students in a formulaic way and often for students it appears intangible.

Identifying service user knowledge as a threshold concept, it is concluded, drew the lecturer towards a teaching strategy that acknowledged the complexity of it as a concept and recognized the need to help students 'get it'. It flagged the need

to think pedagogically about how best to make this concept 'tangible' for students. By embedding service user knowledge into the structure and fabric of the module, a transformative and integrative learning environment was created. This environment supported a 'letting go' of previously held beliefs, not only on the part of the students, but also on the part of the lecturer, whose own conceptual framework was developed and enhanced by listening to and being open to the wisdom of service user knowledge.

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THERE'S A RIGHT ANSWER BUT ONLY SOME STUDENTS CAN GET IT: THRESHOLD CONCEPTS IN THE PROFESSIONAL DEVELOPMENT OF PHYSICS LABORATORY DEMONSTRATORS

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KEYWORDS
Undergraduate science, laboratory teaching, professional development, threshold concepts

ABSTRACT
Despite the level of importance often claimed for labs, in Australia first year labs in particular are typically staffed by PhD students with limited teaching experience or training, employed on a casual basis. The ways in which these casual teaching staff conceptualise learning and teaching will inevitably have significant impact on how they view the undergraduate lab environment, and what opportunities for learning they are aware of and facilitate. We report on a study investigating the ideas that physics demonstrators have about teaching, learning and the purpose of undergraduate laboratories at an Australian university. Two candidate threshold concepts were identified: one relating to whether it was more important for students to obtain a particular answer or to use appropriate thinking processes and the other to whether demonstrators and the teaching environment could influence students' thinking processes.

Why is it that effective teaching practices that have been identified through educational research are not more widely implemented? Regardless of discipline or level of education, one can find evidence in the literature that certain approaches to teaching (see for example Biggs (1999), Elliott (1991)) result in better student learning and greater student engagement. And yet these approaches are not universally used.

One possible explanation is that there are threshold concepts (Meyer and Land, 2003) in academics' understandings of teaching and learning. If such concepts exist, they could present barriers to professional learning and development, since deep understanding of purpose and potential is required for effective implementation of strategies. We investigate this idea by applying a threshold concepts analysis to conceptions of teaching held by demonstrators in a first year physics laboratory.

INQUIRY ORIENTED STUDENT LABORATORIES

The student laboratory is a feature of most undergraduate science courses. In large first year courses, direct teaching is frequently left to casual staff, known as demonstrators in Australia, who work under the guidance of a lab coordinator. In the university described in this paper, as is common in many others, the lab coordinator designs experiments, writes student instructions and develops assessment tasks and marking criteria. Demonstrators are responsible for teaching groups of 12-20 students in the laboratory. They are also responsible for assessing student work and providing feedback throughout the semester.

As in the current study, demonstrators are frequently young and inexperienced, often concurrently undertaking PhDs in physics. They are thus in a transitional phase, no longer undergraduate students engaged in structured coursework but also not yet identifying as professional academics. They are unlikely to have had much formal training in teaching and may have had little or no engagement in preparing the curriculum they are effectively responsible for delivering.

This leads to a potential disjuncture between planning and implementation. It seems likely that students will learn most effectively when the coordinator and demonstrator hold similar views regarding teaching and learning. When the coordinator wishes to make fundamental changes to the laboratory program, they face a similar challenge to that faced by education researchers: persuading others to adopt the new approach. Laboratory coordinators have a number of advantages over education researchers: they control the experiments that students carry out, and they formally supervise

the demonstrators and so may meet regularly with them over the course of the semester in order to ensure that their vision is being implemented. Therefore, any aspect of the modified teaching that demonstrators continue to struggle with is likely to be a particularly troublesome concept for that mode of teaching.

The specific reform of laboratory teaching relevant to this paper is the move away from directed experiments toward more open-ended inquiry oriented experiments. Traditionally, laboratory instruction manuals provided students with explicit, step by step instructions leading students through the experiment and toward the expected answer. Concerns have been raised that this both failed to develop students' ability to think scientifically and presented students with a disengaging experience of doing science (Hoffstein and Lunetta, 1982).

This has led to many physics departments moving to towards more open-ended or inquiry based approaches to laboratory design. In such programs, students are intended to develop scientific thinking by carrying out experiments where they do not already know the expected answer (Olson and Loucks-Horsley, 2000). Such experiments focus on the thinking processes students use, rather than the answer they ultimately arrive at. We use the term thinking processes to emphasise the importance of the thinking and understanding behind a particular action, rather than simply the ability to perform that action, which we refer to as a skill. Table 1 gives some examples of skills and related thinking processes that may be developed in student laboratories.

Table 1: Skills and Thinking Processes

Skill	**Related Thinking Process**
Keep accurate records in provided format	Decide what needs to be recorded and then record accurately
Calculate uncertainties using formula	Identify appropriate way to estimate uncertainties, calculate and interpret appropriately
Remember physics concept	Make conclusions about validity of concept from experimental result, apply concept to carrying out experiment

THIS STUDY

This paper reports on a study examining how demonstrators in a first year physics laboratory at an Australian university understand their teaching in context. Over a number of years, the laboratory program in which the demonstrators worked had been reformed to become more inquiry oriented. The demonstrators were paid to prepare for each experiment and met with the lab coordinator a number of times during the semester to discuss the aims of the program and their role as demonstrators. Eleven demonstrators were interviewed prior to the start of semester and ten of these demonstrators were re-interviewed at the end of semester. Nine of these demonstrators were new to the role.

The interviews explored interviewees' ideas about the purpose of labs and their role as demonstrator, and their experiences of laboratory teaching both as a student and demonstrator. The interviews were semi-structured, centred around a series of planned questions but allowing flexible follow-up seeking elaboration or clarification. Both direct and indirect questioning was employed. For example, in the first interview, demonstrators were directly asked *"What do you hope students will get out of doing the labs?"* and *"What do you think the role of the demonstrator is?"* The additional question, *"If you were the lab coordinator, how would you run the labs?"* indirectly allowed clarification of ideas raised in response to earlier questions, particularly allowing demonstrators who felt constrained by decisions made by the lab coordinator to explain what they would do differently and why. This allowed them to distinguish between ideas about how teaching and learning should occur from strategies adopted to make the best of a bad situation.

Meyer and Land (2003) originally described threshold concepts as likely to be transformative, integrative, troublesome, irreversible and bounded. In this work, we wish to identify threshold concepts that may be critical in the professional development of demonstrators working in inquiry-oriented laboratory programs. With this in mind, we sought concepts emerging from the interviews that were bounded in the sense that they related closely or uniquely to demonstrating in this environment. We also sought concepts that simultaneously had a transformational effect on demonstrators' approaches to teaching, opening up new ways of seeing student learning in labs and their role in promoting or facilitating it. Finally, we sought the subset of bounded, transformational concepts that appeared to be troublesome, in that some demonstrators showed no signs of acquiring them, since these should prove useful foci for professional development activities. Concepts that satisfied these criteria were analysed to determine whether they also functioned to integrate elements of demonstrators' knowledge and/or practice. Given the timescale of the study, it is not possible to determine whether the candidate threshold concepts we identify are irreversible.

In presenting the analysis, we built on the more recent work of Land *et al.* (2010), who describe the acquisition of threshold concepts as a journey through pre-liminal, liminal and post-liminal spaces. In the pre-liminal space, individuals first encounter troublesome knowledge that may cause them to question their prior understandings. In the liminal space, individuals attempt to integrate the troublesome knowledge into their existing understanding, a process that requires both ontological and epistemic shifts and is typically troublesome. In the post-liminal space, the integration has been completed and the individual possesses a transformed understanding.

Two candidate threshold concepts were identified from the interviews: the primacy of process over content and the idea that teaching can influence students to develop new ways of thinking. These concepts, and their correlation with reported approaches to teaching, are discussed in more detail below.

THRESHOLD CONCEPT I: THINKING PROCESSES ARE MORE IMPORTANT THAN CORRECT ANSWERS

The interviews discussed a number of aspects of laboratory education, including: overall purpose, judging which students succeeded, deciding how to interact with students and judging whether experiments were running successfully. Definitions of success were deliberately left unstated in order to elicit individual demonstrator understandings. The conceptions of successful outcomes for labs that emerged from the interviews can be described in terms of four categories, which exhibit an increasing emphasis on thinking processes over correct answers. These categories are illustrated in Table 2.

Table 2: Threshold Concept I: Thinking Processes are More Important than Correct Answers

	Pre-liminal		**Liminal**	**Post-liminal**
What is most important?	Correct Answers			Thinking Process
Emphasis	Defined by Course Coordinator	Facts and skills	Thinking process leads to correct answers	Answering questions leads to improved thinking processes
Example of conception	*"…and we spend so much time [at demonstrator meetings] on discussing the problem but why not just solve it and say that okay, this is the answer, this is what we're after".*	*"Their (lab designer's) goal firstly is that they want student to understand some basic concepts".*	*"…just the whole grading and everything, it's like summer camp from my point of view…Well I do get the point that they wanted them to learn the experience of working in a lab and finding out things for themselves".*	*"An experiment can vary from time to time and just because you know the formula and the answer, it doesn't mean that they are going to follow and you have to force the data is going to be different… The data is the data here is what you see, you say in what you see. If it is not what you expected say it is not what is expected".*
Example of actions	[To student] *"I just try and help you to finish this and get a good mark so do it".*	*"Most of them don't really understand the pre-labs and I have to go through like an hour and a half to actually get them to understand first. We spend the rest of the time to do the labs".*	*"In the end, I tended more to give them more like a recipe so that they would do things little bit better".*	*"I said I could be wrong. So I was just kind of joking with them to make them go back like to think… And there was that arguing bit so they talk to themselves again and at the end that group kind of had an answer that isn't what I sort of jokingly tell them and that was good".*

Two distinct categories in the pre-liminal space were identified. In category A, correct answers are seen as defined by the coordinator: the demonstrator's role is to help students obtain them. In category B, demonstrators develop their own correct answers: specific facts, understandings of particular topics or skills that the demonstrators believe students should gain from doing the experiment.

Responses in category C display aspects of liminality. Demonstrators consider both the students' answers and the thinking processes they use to arrive at them as important and show signs of feeling conflicted as to which is more important. When forced to choose, the demonstrators make decisions that indicate they still consider correct answers to be more important, indicating they have not yet acquired the threshold concept.

Category D represents a qualitatively different conception of success. In this category, the purpose of the lab is seen as being to provide students with an opportunity to improve their thinking processes. Thus although both categories C and D address thinking processes, only in category D is the development of ways of thinking understood to be the intended outcome of participation in the lab program.

Only the responses corresponding to category D align with the coordinator's intentions in designing an inquiry-based program. The data indicate that some demonstrators maintain quite different conceptions of the intended outcomes of the program, even after a semester of teaching and interacting with the coordinator. This suggests that the transition from focusing on correct answers to focusing on thinking processes is a difficult, troublesome one.

That the focus on thinking processes is transformative can be seen from the differences in reported teaching strategies associated with each category. Reported teaching strategies demonstrate the transformative effect the threshold concept has on demonstrator's actions. When the focus is on correct answers, demonstrators use transmission strategies and focus the students on obtaining passing marks. When the focus is on thinking processes, demonstrators report interactions with students designed to promote thinking and discussion between students. Close to the threshold, demonstrators report using a mix of strategies: trialling a more open approach, but reverting to more explicit instructions if students were unsuccessful or time was short. Such conflict and oscillation is typical of being trapped in the pre-threshold liminal space described by Meyer and Land (2010).

THRESHOLD CONCEPT II: DEMONSTRATORS AND EXPERIMENTS INFLUENCE THE THINKING PROCESSES STUDENTS USE

A second threshold in understanding of teaching and learning relates to the role of the demonstrator and experiment design in the learning process. When it came to learning facts and skills, all demonstrators agreed that the experiment design and explanations from demonstrators were important: a bad explanation from a demonstrator could confuse students further or an experiment trying to cover too much would not give the students enough time to perfect any of the skills. However when it came to thinking processes, a number of different beliefs were identified. As shown in Table 3, a qualitative shift was evident between those demonstrators who believed that the thinking processes used by students reflect the ability of the student alone, and those that recognised a contribution from the demonstrator or experimental design. This idea is bounded since the improvement of students' thinking processes is a key intention of inquiry-oriented lab programs: demonstrators must believe the lab program can influence students' thinking processes in order to contribute to this goal.

Table 3: Threshold Concept II: Demonstrators and experiments influence the thinking processes students use

	Pre-Liminal	**Liminal**	**Post-Liminal**
What influences student's thinking processes?	Student Ability		Demonstrator/Experiment
Focus	Explicit statements of fixed student ability	Reliance on student ability in explanations, despite stating that some students can improve their thinking processes	Demonstrator and experiment make significant contribution in addition to student ability
Example	*"I think that most people aren't born to be experimentalists. Q. What are they lacking? A. Well, it has to be – the ability to be curious of the physical aspects of life, the universe and everything, and to actually want to play with equipment to see what you get out of it".*	*"I think it's the students. I mean, the lab is pretty self-explanatory. I mean, if you read the notes, everything's there. They just need to read the notes and do it properly. It shouldn't be a problem".*	*"...maybe the way that I heard them and spoke to everybody and I noticed some of the students were switching off and that's not working. So I'm going to try next week to talk to people in terms of on each table and I can engage and make it more a group discussion than a lecture and those kinds of things".*

In the pre-liminal category, demonstrators believed that only some students had the ability to perform the thinking processes characteristic of experimental physicists. Even when inquiry-based laboratories fitted more closely with their experiences of being an experimental physicist, demonstrators did not believe that all or even most students could cope. This resulted in the belief that an inquiry-based program was not appropriate for first year students (a belief which is completely at odds with the intentions of the program being delivered).

In the liminal category, demonstrators suggest that (at least some) students are able to improve their thinking processes, or that they have observed students to do so. However, they retain some of the actions and biases associated with the student ability conception. For example, the demonstrator quoted in table 3, who had previously described students in his group acquiring new ways of thinking, ascribes failure to do well in one particular experiment to poor preparation alone. It does not occur to the demonstrator that their own actions might contribute to the students' success or failure.

In the post-liminal category, demonstrators have integrated the belief that their actions influence student learning with their professional practice. This can be seen in the response in the Demonstrator/Experiment category of table 3. The demonstrator has identified an aspect of student performance they are unhappy about and is considering the ways their actions may have been influential and possible future changes.

The habit of critically reflecting on one's teaching performance and identifying areas of improvement is widely accepted as being key to continued improvement as a teacher (see for example Rowland (2000), Ramsden (1991)). However, if the teacher does not believe their actions influence student learning, such reflection will seem pointless. The second sub-category focusing on student ability shows that it is not enough to agree that teachers influence student learning in an abstract sense, the idea must be used to reflect on concrete examples of their teaching. This illustrates both the transformative and troublesome nature of this threshold concept. If a teacher considers their contribution to student learning every time they reflect on their teaching, significant improvement in teaching practice will likely follow. However, this requires the belief to be so well integrated into the teacher's ideas about learning that it is triggered every time they reflect.

CONCLUSIONS AND IMPLICATIONS

We have identified two candidate threshold concepts that were of particular relevance to demonstrators working in inquiry oriented student laboratories:

- Thinking processes are more important than correct answers (key to the philosophy of inquiry oriented labs)
- Demonstrators and experiments significantly influence the thinking processes students use (key to demonstrator engagement in ongoing professional development and personal reflection)

These threshold concepts proved troublesome to many demonstrators, despite working in an environment in which they were paid to prepare for their demonstrating and met regularly with the lab coordinator, who had designed a lab program specifically intended to develop thinking processes and who saw the role of demonstrators as facilitating that development. This indicates the demanding nature of demonstrating in an inquiry oriented laboratory. This should be recognised by the university when setting expectations and payment: demonstrators should be expected and paid to prepare for their role and participate in professional development.

The difficulty encountered by this lab coordinator was that they had not identified these threshold concepts as being key to the demonstrators' role. They assumed that when they talked in meetings about the different thinking processes used in an experiment and the different approaches to demonstrating that could be used, the demonstrators would interpret these discussions in the way the lab coordinator intended. However, this was not the case: demonstrators who saw their role as helping students get the correct answer saw these discussions as a waste of time. Other demonstrators struggled to reconcile conflicting ideas.

We therefore propose that professional development for demonstrators working in inquiry-oriented lab programs needs to be explicitly designed to address these threshold concepts. The lab coordinator should create opportunities to listen to demonstrators' current understanding of each of the threshold concepts and give the demonstrators' feedback on their ideas. This strategy could take many forms. In demonstrator meetings, demonstrators could be asked to work in groups to discuss ways a particular thinking process is used, both in the laboratory experiments and in the demonstrators' experience. The groups can then report their discussion to the rest of the group, with the lab coordinator commenting on their responses. When talking to demonstrators individually, the lab coordinator can ask questions that encourage the demonstrator to think about the threshold concept. If the demonstrator is talking about their experiences with a

particular lab, the lab coordinator could ask about what they demonstrator did, and whether different responses might result in different outcomes. The lab coordinator could also share examples of how other demonstrators have approached the same situation differently and obtained different outcomes.

A key aspect of the above strategies is the opportunity to hear the ideas of other demonstrators; even when talking to demonstrators individually, the lab coordinator can still promote this idea sharing by passing on good ideas they have heard. Hearing that other demonstrators have other ways of thinking, use different approaches and have had a different level of impact on student learning, despite working on the same course and experiments is troublesome knowledge. As noted by Meyer and Land (2010), an encounter with troublesome knowledge is an important trigger that may lead individuals to re-examine their existing understanding.

It seems likely that a similar approach to identifying threshold concepts would assist with the dissemination of education research. In established academic disciplines, the majority of communication occurs between experts, who have already acquired the threshold concepts of their discipline and will therefore interpret new results in similar ways. This is not the case for education researchers, who are frequently discussing their work with teachers who have little experience of education research. Audience members may therefore be at a loss to understand the reason for investigating the topics in question, just like the demonstrators who were frustrated by the lengthy discussions on different ways to approach the experiments. By being aware of the threshold concepts underpinning their approach, education researchers may be better able to communicate both the relevant threshold concepts and the ways these concepts relate to their research.

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A BROADER THRESHOLD: INCLUDING SKILLS AS WELL AS CONCEPTS IN COMPUTING EDUCATION

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KEYWORDS
Threshold concepts, threshold skills, professional education, practice

ABSTRACT
We propose 'threshold skills' as a complement to threshold concepts. The definition of threshold concepts assumes that theoretical knowledge is paramount: gaining the understanding of particular concepts irreversibly transforms the learners.

Mastering computing, like many disciplines, however, requires learning a combination of concepts and skills. Mathematicians learn to do proofs, musicians learn to play their instruments, and martial artists learn to make moves by doing these activities, not just intellectually understanding them. We propose some characteristics for threshold skills and outline implications for teaching and for future work.

INTRODUCTION
The theory of threshold concepts has been applied to computing by a number of authors: (Shinners-Kennedy, 2008); (Sorva, 2010) and (Zander *et al.*, 2008) for example (see also Rountree and Rountree (2009) or Flanagan (2012) for more). These have identified a number of potential threshold concepts, many having to do with learning to program.

One of the features of programming is that it requires skill as well as conceptual understanding. Things like writing recursive functions, object-oriented modeling, and debugging improve with practice, even after students have learned them. Moreover, when we interviewed students about learning concepts, they often discussed skill acquisition as an important (and difficult) aspect of their learning.

With this in mind, we re-analyzed a collection of interviews (about threshold concepts in computing) in the light of skills instead of concepts. What this analysis suggests is that skills as well as concepts can be 'thresholds' for our students. One of our interviewees pointed the way:

> *"There's just some aspects to (programming) that just seem to remain kind of mysterious to me at the programming level. Not the concept level, not the theory level, not the technology level, but at the kind of code nuts and bolts level... I sense from our conversations that you (as a teacher) feel you have more problem in getting the concepts across".*

This student was explicitly telling us that we were looking for concepts, but that for her the concepts were not the problem, the 'doing' was. Thus, we argue that in computing, and possibly other disciplines, skills as well as concepts need to be considered as thresholds.

Section 2 of this paper examines theories of knowledge. In section 3 we report on how the threshold concept characteristics are manifested in the context of skills, and discuss similarities and differences between threshold concepts and threshold skills. This section further shows parallels from other disciplines. Section 4 discusses implications for learning and curriculum of threshold skills.

KNOWLEDGE: CONCEPTS AND SKILLS

Philosophers and educators have long noted that knowledge comes in different forms. In discussing student learning, Entwistle (2003, p. 3) writes:

> *"In the student learning literature, there has been an emphasis on conceptual understanding to represent high quality learning, but this had to be broadened to cover additional skills and ways of thinking, both academic and professional".*

Dewey argued that theory should be the foundation of professional education (discussed in Shulman (1998)), but also pointed to the need for 'intelligent practice' (Dewey, 1910, p. 125). He rejected theory without deep understanding as well as practice learned as procedures removed from their meaning. This is in line with what is generally accepted in computing: a successful professional needs to master both theory and practice, and both aspects can be difficult to learn (du Boulay, 1988).

Ryle (1945) and Norman (1990, pp. 57-58) discuss notions of 'knowing what' and 'knowing how'. Ryle discusses this from a philosopher's standpoint:

> *"When a person knows how to do things of a certain sort (e.g. make good jokes, conduct battles or behave at funerals), his knowledge is actualized or exercised in what he does… When a person knows how to do things of a certain sort (e.g. cook omelettes, design dresses or persuade juries), his performance is in some way governed by principles, rules, canons, standards or criteria… But his observance of rules, principles, etc., must, if it is there at all, be realized in his performance of his tasks"* (Ryle, 1945, p. 8).

Norman discusses similar concepts in the context of engineering design where he writes that 'knowledge of', declarative knowledge, is easy to write down and to teach while 'knowledge how', procedural knowledge, is *"difficult or impossible to write down and difficult to teach. It is best taught by demonstration and best learned through practice".* For both of these authors, procedural knowledge is reflected in actions.

In research on professional education, the terms 'theory', 'conceptual', and 'knowing what' are at one end of a spectrum; and the terms 'practice', 'procedural', and 'knowing how' are at the other, with the understanding that a professional needs to master the whole spectrum.

We will refer to these two sides of knowledge as 'concepts' and 'skills' while being aware that these may not be the most nuanced terms and also recognizing that skills and concepts, to varying degrees, depend on each other.

CHARACTERISTICS OF THRESHOLD SKILLS

We propose the following characteristics for threshold skills, derived from threshold concepts but manifested somewhat differently and one new one, the importance of practising. This discussion is based on an empirical analysis of student interview data, described in detail in Sanders *et al.* (2012). Threshold skills:

Are transformative: Mastering a threshold skill transforms what students can do – and their vision of what they can do. It is empowering and, as a result, often accompanied by an increase in confidence. Contrast this with threshold concepts, where mastery transforms how students see their discipline.

Are integrative: Once a threshold skill is attained by applying it to one task, students see other potential applications. Rather than unifying different concepts (as threshold concepts can do), a threshold skill broadens the list of tasks students can perform or enables them to perform them in a new way.

Are troublesome: Skills can be complex, demanding, and time-consuming to learn and maintain. They may seem alien at first (like the linear, step-by-step thinking required to debug a program). They may even be counter-intuitive.

Are semi-irreversible: Unlike threshold concepts, threshold skills degrade over time with lack of use. They do not completely go away, however. Students who have acquired a threshold skill stay transformed and know where the skill applies, but may need to review or practice.

Must be practiced: Part of the definition of a skill is that it is attained or learnt through practice, where practice is *"repeated exercise in or performance … so as to acquire or maintain proficiency"* (Oxford English Dictionary Online, 2012).

True mastery of a skill means it becomes almost automatic. One computing student noted that after he acquired a particular skill, *"it's almost like it's a tool and you don't even think about using it. You say I need to do this. Okay, done".* In foreign language learning, the equivalent might be the point at which you begin thinking in your new language and no longer need to translate mentally before speaking.

Learning to converse in a foreign language may be a good example of a threshold skill. Learning vocabulary lists and grammar rules are not enough; you need to practice speaking the language. Being able to converse is transformative: you can communicate with people you would not have been able to talk to before. It's integrative: once you've learned one language, it's easier to learn the next. It's troublesome: real fluency in any language typically takes years of work to achieve. Moreover, elements of foreign languages can seem strange and counter-intuitive at first. (Children are neuter and chairs are masculine? Verbs have gender?) Finally, the skill is semi-reversible and needs to be practiced. If you learn a language and then don't use it for several years, you'll become rusty, but will re-learn much more quickly than if you were learning it for the first time.

In areas generally thought of as skills there are also concepts. For instance, learning martial arts includes a theoretical side, understanding how applying different forces affects the opponent's movement. This is not enough, however; there is also a need to practice the skills of doing the proper movements so that it is possible to perform the movement automatically with speed and accuracy. While it is easy to understand the necessity of both theory and practice in martial arts, it is still a problem to teach this to novices. Many martial styles teach novices basic movements (skills) without emphasizing the concepts. As the novices progress, they are expected to learn more about the concepts behind the movement. Giving the students all the theory at once does not result in good martial arts practitioners, neither does unnecessary practice of movements – both aspects need to be learned in relation to each other. Advanced practitioners still need to practice and hone their skills, but more emphasis is put on the theoretical side (Greger *et al.*, 2006).

We suspect that a similar dynamic is at play in other practical disciplines, and even in those that are more traditionally academic. From mathematics education, Worsley *et al.* (2008) propose that the technique of substitution and solving ordinary differential equations are candidates for threshold concepts. They might, however, be examples of threshold skills. Similarly, in physics laboratories, instruction helps students connect theory to practice (von Aufschnaiter and von Aufschnaiter, 2007).

In research on professional education, the terms 'theory', 'conceptual', and 'knowing what' then, may be considered to be at one end of a spectrum; and the terms 'practice', 'procedural', and 'knowing how' are at the other, with the understanding that a professional needs to master the whole spectrum.

IMPLICATIONS AND FUTURE WORK

The idea of threshold skills has implications for both research and teaching. In computing, for example, textbooks have relatively few exercises at the end of each section (compared to, say, mathematics books). In recent years, many introductory programming classes have added what are called 'closed labs': class time during which students work on modifying and/or writing programs with supervision. Much attention has been given to how students should work with each other during these labs, but little to the actual assignments that are given. As threshold concepts have the potential to organize a curriculum, threshold skills can focus and organize the activities and assignments we give our students.

As with threshold concepts, there is a question of granularity. Is the threshold skill learning to speak a foreign language, or certain parts of that process, for example, being willing to make mistakes? Are all the martial arts moves thresholds, or are some of them stumbling blocks while others are not? These are questions for future investigation.

Another important question is the relationship between skills and concepts. For some computing concepts, the threshold might include both a concept and a skill, tightly connected together. Practicing the skill leads to deeper understanding of the concept, this in turn leads to increased skill (Eckerdal, 2009).

Some effort has been made in computing education research to consider the dependencies between concepts akin to threshold concepts (Mead *et al.*, 2006; Pedroni *et al*., 2007). This seemed to work relatively smoothly for algorithmic concepts like selection (and hence for procedural programming built up from them), but the authors found object-oriented problems to be much more difficult (Mead *et al.,* 2006). It was not the concepts of object-oriented languages but rather the pragmatics of using those concepts that presented the problem. We believe that this illustrates that when we consider threshold skills rather than concepts we need to be more aware that students may reach mastery by following different routes through the material – we need to be more flexible in our presentation, approaching thresholds from several directions.

In Computer Science, problem solving is a highly valued activity and ability and is what the educated professional is expected to do for a living. Problem solving, however, is neither a purely procedural activity, nor conceptual. It is not about having the conceptual knowledge itself, it is the ability to put pieces of knowledge and various skills into action in a structured and creative manner. But problem solving is also known for being hard for students to master. In the light of this, perhaps textbooks and teachers are often too keen to give students (too hard) problems to solve – (too soon) before the students have acquired the skills needed (by practice). We hypothesize problem solving in programming may contain many threshold skills.

The present work has discussed how skills, and not only concepts, can be threshold in students' learning. There is further need to investigate the role of skills that act as threshold: how do students best learn these skills? What does 'intelligent practice' mean in relation to threshold skills? How do we balance threshold concepts and skills? What does the community of professional practitioners value in terms of these kind of skills?

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VOICE, VISION AND ARTICULATION: CONCEPTUAL THRESHOLD CROSSING IN ACADEMIC WRITING

Gina Wisker, University of Brighton

Biographical Note

Gina Wisker is head of the centre for learning and teaching at the University of Brighton, UK where she is professor of higher education and contemporary literature. Gina is a national teaching fellow and extraordinary professor at the University of Stellenbosch, South Africa, and Associate Professor at the University of Bergen, Norway. Gina's specialist areas are in doctoral learning and supervisory practices, supporting and enabling writing for academic publication, and contemporary women's Gothic literature. Gina lives in Cambridge and works in Brighton.

KEYWORDS
Threshold concepts, vision, voice, threshold skills, professional education, practice

ABSTRACT
Most research into the development and acquisition of threshold concepts concentrates on development among undergraduate students. More recent work has focused on conceptual threshold crossing among postgraduates suggesting that at various stages in their doctoral work postgraduates begin to work at or settle into working at levels which can enable them to produce conceptual critical and creative work in their own projects, in their own discipline. Recent work (Wisker and Savin Baden, 2009) has concentrated on overcoming stuck places in the writing process and using liminal spaces to move writing practices forward, another example of conceptual threshold crossing. Research and practice shared here explores how academics and researchers on writing courses for professional development cross conceptual thresholds in the development of voice, ownership of their writing projects, authenticity in their argument and expression, confidence in their writing and writing practices.

Respondents on the programmes have constructed metaphors and other creative ways of expressing the moments of enlightenment, breakthrough, learning leaps or conceptual threshold crossing when they find they can achieve confident expression in their own writing, voice, and a sense of a repertoire of good writing habits. These metaphors I describe as vision/visions while the confident managed diversity of expression dependent on project, discipline, context and the sense of knowing what to say and how to say it I am describing as 'voice'.

BACKGROUND AND INTRODUCTION

Most research into the development and acquisition of threshold concepts concentrates on undergraduate students. Recent work focuses on conceptual threshold crossing among postgraduates (Kiley and Wisker, 2009, 2012) suggests that at various stages in their doctoral work postgraduates can begin to conceptualise their research and its contribution to knowledge at a sophisticated and more complex level, and gain fuller ownership of their work. This enables them to settle into working at levels which can enable them to produce conceptual, critical and creative work in their own projects, in their own discipline. During the Higher Education Academy National Teaching Fellowship funded 'Doctoral Learning Journeys' research project (Wisker, Morris *et al*., 2010) many respondents' statements identifying such conceptual threshold crossings indicate a close link between ontology, i.e. self and being in the world, academic identity, and epistemology, the construction and ownership of knowledge. For several respondents, moments of communication in writing, engagement with and adding to the dialogue in the literature were identified as significant.

Recent research (Wisker and Savin Baden, 2009) has concentrated on overcoming stuck places in the writing process and using liminal spaces to move writing practices forward, another example of conceptual threshold crossing, in writing.

Research and practice shared here builds on insights from both these two previous research projects with a new exploration of writing and conceptual threshold crossing. It explores how academics and researchers on writing courses for professional development cross conceptual thresholds in the development of voice, ownership of their writing projects, authenticity in argument and expression, confidence and articulacy in their writing and writing practices. I argue that while there are numerous useful theories and practices which help us to understand writing development, the awareness of breakthrough moments in articulacy in writing is particularly vehicled and understood by the notion of conceptual threshold crossings.

Respondents on the courses have constructed metaphors and other creative ways of expressing moments of enlightenment, breakthrough, learning leaps or conceptual threshold crossing when they find they achieve confident expression in their own writing, voice, and a sense of a repertoire of good writing habits. These metaphors I describe as vision/visions while the confident, managed diversity of expression dependent on project, discipline, context and the sense of knowing what to say and how to say it I am describing as 'voice' and 'articulation'.

This essay shares small scale research with colleagues on a 'writing for academic publication' module and other short courses for writing for academic publication – against a background of previous research with writers. It theorises the moments of breakthrough or conceptual threshold crossing moments in writing which lead to and evidence voice and articulation, both a development of the writer's being (ontology) and their ability to express their contribution to knowledge construction (epistemology). In so doing the research begins to explore ways in which support and development practices in the module are perceived to move colleagues forward in their writing so that they cross conceptual thresholds and achieve voice, good habits, confidence and articulation of their work**.**

1. how conceptual threshold crossing is identified by writers, particularly participants on writing for academic publication courses;
2. where, how and why it seems to take place – and how they can tell that happens;
3. what strategies we can use as writers, supervisors, and colleagues to 'nudge' the conceptual threshold crossing, the voice, vision and 'articulation' in our own writing and that of others.

(NB Here because of space I focus on 1 and 2, strictly conceptual threshold crossings, breakthroughs not blocks. Extended work emphasises all three.)

LITERATURE REVIEW

This research is based on literature on conceptual threshold crossings, threshold concepts, and literature on academic writing practices. Conceptual threshold crossing (Wisker, Kiley, Robinson, 2006; Kiley and Wisker, 2008, 2010) developed from the theorising of threshold concepts in the disciplines (Meyer and Land, 2005). Our earlier work focuses on the identifying and 'nudging' of 'learning leaps' or conceptual threshold crossings in the stages of doctoral students' research and writing. The Doctoral learning journeys research (UK based, HEA funded, Wisker, Morris, Robinson, Trafford, Lilly, Warnes, 2010) and the 'parallel project' (international based, Wisker, unpub.) focused on identifying stages when doctoral students work more conceptually, critically and creatively, ways supervisors can 'nudge' this, and where and how examiners recognise it in students' work, both written and in the viva.

In this project we discovered links between ontology: being in the world, self, and epistemology: ways of knowing and construction of knowledge, largely through respondents' explicit statement of how their sense of self, identity and voice were linked to their contribution to knowledge. In terms of writing, the conceptual threshold crossing stages and moments are what I call 'breakthrough moments' when writing blocks are overcome and academic writers find their voice, articulate their ideas, arguments and interpret data in a coherent, well-argued, articulate piece of writing. For doctoral students this writing appears in the thesis and for other academic writers in publications. There is much research literature on academic writing support, mainly focused on undergraduate or international student writing. Previous work on writing for doctoral students and academics writing for publication, including our own (Wisker and Savin Baden, 2009; Elbow, 1973; Sword, 2009; Kamler and Thomson, 2006; Murray, 2005) largely focuses on support for that writing rather than the writers' own perception of breakthrough moments. Our ongoing work suggests the writing process can be enabled and vehicled by structured courses.

CONTEXT

The main context is the Writing for Academic Publication (WAP) MA module/course at the University of Brighton, an online Masters in Professional writing from another university, and the experiences of academic writers known to the author and specifically contacted with the same questions. WAP contains:

- Two day face to face workshops
- Critical friend ongoing groups
- Three x 2 hour bring back sessions responding to progress and troubleshooting– encouraging sharing and confidence building/maintaining
- Feedback on drafts

It is argued that both face-to-face and on-line environments are appropriate for integrating models of academic writing support. Face-to-face workshops encourage practice, working out of ideas and sharing of experiences in public. Individual on-line tutoring or mentoring, informal blogging in writing groups, and on-line conferencing, encourage skills, socialisation and academic literacies.

METHODOLOGY AND METHODS

In the previous studies (above) we defined conceptual threshold crossing moments in writing. When I consider the breakthrough or conceptual threshold crossing moments in my own writing I think of liminality, grey spaces, clarifications, images and sounds, something feeling cleverer than me, then appearing: it's the inspiration and then emergence of the words. I wanted to discover how other writers experience such moments and what language they use to express both those moments and the writing articulacy which follows.

In this research and essay I consider writers' perceptions of the exact 'breakthrough' moments in inspiration and expression. Respondents focused precisely on such moments, how the writer feels, what happens, what is produced, what they learn and how they know their work is enhanced and their skills improved, how they feel about this, what evidence they have of it and what they perceive nudges them into such breakthroughs, conceptual threshold crossing moments.

The sample of academic writers for this study includes doctoral students, other academics and academic related colleagues undertaking writing for academic publication courses at two UK universities, and academic writers known to me. I sought participants' perceptions of their own breakthrough moments of crossing conceptual thresholds in their writing, and their sense of what helped or nudged writing breakthroughs and the sustaining of effective writing practices. I wanted to look at the course and its effectiveness and to ask writers about their breakthrough moments, to capture the moment, find out how it feels, what the signs are, what nudges the writing into shape.

Data includes responses to direct questions, extracts from logs and blogs produced as part of the course and evaluative responses noting developments following feedback.

The main issue and context, which introduced the specific questions to participants was built on feedback responses from previous courses and so presented to colleagues as a comments turned into a set of question prompts, explicitly requiring thought and response. The comment followed by the questions asked for open reflection and discussion of experience, to enable responses which were as full and varied as possible. Respondents could of course also indicate that they had not had such experiences:

> *"several people have talked about a specific moment when the writing process became clear for them, when they knew what they needed to do to move on, when the particular piece they were writing fell into place – if you have had one or more of these 'conceptual threshold crossing' or breakthrough moments (making a leap in your work and understanding of your writing processes or that particular piece of writing) please could you share it?"*

QUESTIONS FOR ACADEMIC WRITERS:

1. Have you had breakthrough or conceptual threshold crossing moments in your own writing? If so how did this feel?
2. What nudged it?
3. What do you do?
4. Did it change your writing practices and processes?
5. Did it change your feelings about yourself as a writer?
6. As an academic writer what do you find useful to support your writing development and breakthroughs?

All participants in the research were asked for informed consent; all data and details have been kept confidential.

FINDINGS

The data and findings from this research have been broken into sections based on their responses. Many began by identifying blocks to writing, then talked about breakthroughs, what nudged them, how they experienced these and what feelings and behaviours followed.

1 Blocks and feelings about them
2 Breakthroughs

BLOCKS

1a Systems and processes: time, overload of work, access to sources, data, technology, space

1b Behaviours and beliefs: procrastination, inner saboteur, outer saboteur, identity, lack of confidence

1c The writing: understanding, complexities, articulation

Blocks are not the focus of this essay, which focuses on breakthroughs. Further work will report the nature of and feelings about the writing blocks noted by respondents.

BREAKTHROUGHS (THE MAIN SUBJECT OF THIS ESSAY)

2a Systems and processes:

2b Behaviours and beliefs:

2c The writing: from i) conceptualisation to ii) articulacy

2A SYSTEMS AND PROCESSES

Respondents talk of: managing time, organising work, access to sources, data, technology, space, support.

"[I]Feel exhausted by the end of the few days dedicated to the paper – interesting that I had always thought that I needed to create big 'chunks' of time to be able to progress this paper, but then when I do have that space, I find it stressful, exhausting and unproductive. As teaching quietens down over the next few weeks, will try a 'little but often' approach" (C) (managing time, organising)

"For me, the best part about these last two days was the information which de-scarified the article-writing process. The afternoon of the first day was really the point where the motivation kicked in. I desperately wanted to go and write" (T) (space and support)

"If I recognise a writing interlude in there, I try to make sure everything is in place to accommodate it. But the process of doing that can often destroy it. I have to wait for another. I can't manufacture writing moments. I need to find a beautiful clever woman and move somewhere I really want to be – that would make me really productive" (A2) (space and support)

2B BEHAVIOURS AND BELIEFS

They talk of*:* overcoming procrastination, inner saboteur, outer saboteur, positive sense of identity, confidence, build on success, critical friends, seeking and using feedback, behaviours like walking, multitasking, reading – on topic, not connected – to push ideas and articulacy forward or let it come in to the space then work on it:

"…no writing, but lots of reading... I must demonstrate a certain amount of knowledge about my subject area, but when can/does this stop? Where is the boundary? Or am I using reading (and gathering information) as a block?" (C) (procrastination, saboteurs)

"…worthwhile writing can also happen in short bursts at opportune moments waiting for meetings, at train stations etc. – just be open to it! Critical friends, managing time balance between structure and automatic writing" (K) (managing time, critical friends).

2C THE WRITING FROM I) CONCEPTUALISATION TO II) ARTICULACY

They talk about: recognising and seizing the breakthrough thinking; using metaphors; instinctive, visionary ideas and hints, images, words, turning into expression; moving through liminality to praxis; managing the writing energy; multitasking; breakthroughs using mimicry, patchwork-time and writing management , identity.

"Now I am really getting into this project, I feel a sense of returning into the 'loop' of my field and returning to who I am" (K) (identity)

"Well, having come from a family of 'automatic writers' in the psychic sense, I can't say it is quite like that for me. Automatic writing comes from elsewhere whereas I am very aware of what I am writing and I know it's coming from somewhere deep inside me. There comes this moment when the backlog of 'stuff' bursts through in the right order and it is a feeling of joy. I certainly did experience the Eureka moment – that delightful aperçu when you know it's all going to be

OK. I think I even said 'Yes' out loud. On the other hand, I do go into a kind of Zen mode where I am typing as fast as I can because the piece has already been written in my head and I need to release it. Once again, this is really enjoyable" (A) (visionary)

"Most of the time I 'feel' little breakthrough, but then...ping...a knowing leap. I have encountered more of these in the last two years than ever before. Often it is through the processes of writing back, drawing back to myself and a combination, as in the jester writings for example. They become an enabler... Do you want this to refer to academic, or 'creative writing', or poetry, artistic, drafts/journal writing... For me they all link in an holistic way." (C) (managing the energy, instinctive)

"If it creeps up on me and I can't engage with it I go slightly bonkers because life is getting in the way. It rarely creeps, but leaps into my lap. Well, the truth is it's there permanently on sleep mode. Just needs me to touch the space bar" (A2) (managing time, energy)

"I did some 'automatic' writing while waiting to go into a meeting. Fantastic! Identified the main relationships and their 'characters' within the writing that I wanted to do. The first draft occurred on a long train journey 'up north', with scribbled notes and drawings in my late father's notebook" (S) (instinctive, liminality)

THEMES EMERGING

Comments on the course processes and breakthroughs involve the legitimating of the writing process and the licensing of the voice – the space to write in and the structure of it, then models, and critical friends. Whether talking about turning an engineering piece out or turning a client brief over – respondents are as much engaged in the inspirational, articulation, and structure issues as the photographers and artists who worked together and paced round the kitchen writing on white boards, took photos outdoors, putting the work out in cyberspace to capture its dimensions. The importance of having something to say which matters – gives them the right to write. They read to find the right voice, noting the 'tumbling' out of words.

They talk of a mixture of insights, creativity, flair, 'something' and – management, planning, structure, good habits, developing sound writing practices that work for them, helping to scaffold, structure, nurture writing, engaging with their own voice for confidence and articulation. Participants recognise moments of blockage and moments of vision, harnessing the breakthroughs and recognising the patterns to build on, editing, and 'licensing the creativity.'

CONCLUSIONS

Moments of conceptual threshold crossing, of breakthrough and articulation are important in successful academic writing in all disciplines. Early research here considers academic writers' perceptions of their 'breakthrough' moments as conceptual threshold crossing moments, when their writing becomes more conceptual, critical, creative, more organised and coherent, articulate and inspired. Some of these moments are described in metaphors indicating a kind of visionary breakthrough while others are the clear result of focused, organised, managed, supported, consistent hard work enabled in structured courses through taught face-to-face and online support, critical friends, assessment and feedback. This early work suggests that academic writers are and could be made aware of and supported in capitalising on breakthrough moments in their writing. Academic writing courses, reflective practice, self-awareness, emotional resilience and tenacity also help these processes of breakthrough and articulation.

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Part 6: Posters

ENGAGING STUDENTS WITH THRESHOLD CONCEPTS

1. Teaching Students to Think the Unthinkable
Bradley Bowers, Barry University, Florida

2. Engaging University Students in the 21st Century Classroom: The Creation and Implementation of Meaningful Multi-Dimensional Learning Spaces
Janet Hamnett, Mount Royal University

3. Evidencing Graduating Competency in Occupational Therapy: Resources and Thresholds to Evidence Competence
Carol Hills, Susan Ryan, Catherine Studdert, University of Newcastle, Australia; and Kim Nguyen, Hunter New England Heath, NSW Australia

4. Scientific Thinking as a Threshold Concept in Nursing Education: Transforming Avoidance into Engagement
Sarah List, University of South Australia

5. Will an m-Learning Technique Promote Student Understanding of Problematic Knowledge and Key Threshold Concepts?
William Lyons, Dundalk Institute of Technology

6. Personalised E-Learning: Facilitating Students' Understanding and Mastery of New Concepts
Eileen O'Donnell, Trinity College Dublin

7. Exploration of the Use of Handheld Personal Response Systems with First Year Accountancy Students for Deep Learning and Understanding
Muireann O'Keeffe, Dublin Institute of Technology

8. Using Assessment Activities to Engage Students with Threshold Concepts
Liz Springfield, University of Queensland

(Click here for hyperlinked poster folder)

INTERDISCIPLINARY THRESHOLD CONCEPTS

9. Welcome to My House! Enter Freely of Your Own Free Will!: Literary Experience and Threshold Concepts
Richard Hayes and Catherine Lowry-O'Neill, Waterford Institute of Technology

10. The Same but Different: Troublesomeness when Students' and the Lecturer's Disciplines Do Not Match
Sophie Hill, Oslo and Akershus University College of Applied Sciences

11. Separating the Chaff from the Wheat: Threshold Concepts in Higher Education Assessment
Louise Lutze-Mann, University of New South Wales; and Marie Northcote, Avondale College of Higher Education

12. Crossing Subject Specific Threshold Concepts via Short Story Writing: Law Students Demonstrate an Increased Understanding of Human Rights
Alyson Morris, Coventry University

13. Innovation synapses: transgressive movements in working with knowledge
Lorraine White-Hancock, Monash University

(Click here for hyperlinked poster folder)

THRESHOLD CONCEPTS IN PROFESSIONAL DEVELOPMENT

14. Using a Professional Community to Support the Identification of Threshold Concepts: A Physiotherapy Example
Sarah Barradell, La Trobe University

15. Hard Fun as a Threshold Concept in Problem-Based Learning
Terry Barrett, University College Dublin

16. Embracing Threshold Competencies and Concepts as an Educational Model for the Professional Development of PhD Students
Barbara Bender and Monica Devanas, Rutgers University

17. Transforming the Practioners: An Exploration of the Application of Threshold Concepts to a Multidisciplinary Professional Development Masters Course in Christian Leadership
Kerry Greer, Deirdre Ryan, Aoife McLoughlin, Eugene Duffy, Mary Immaculate College, University of Limerick; and Amalee Meehan, CEIST

18. The Process and Lessons Learned in Developing Interdisciplinary Threshold Concepts
Jody Horn, Oklahoma City University

19. Crossing the Threshold into Reflective Practice
Pauline Joyce, Royal College of Surgeons in Ireland

20. Bringing the Discipline into Generic Professional Development Programmes: Open Materials for Exploring Disciplinary Ways of Thinking and Practising
Helen King, University of Bath

21. Evidence-Based Practice in Nursing Education: Exploring Learning and Practice Thresholds
Linda Martindale, Lorraine Walsh, University of Dundee; and Ray Land, Durham University

22. Threshold Concepts and Troublesome Knowledge in the First Year Curriculum at a UK Medical School
Sarah Meek and Susan Jamieson, University of Glasgow

23. Threshold Concepts in a TEE (Teaching English in English) Context
David Moroney, Trinity College Dublin

24. Prospective Mathematics Teachers' Development of Understanding of the Threshold Concept of a Function
Kerstin Pettersson and Max Scheja, Stockholm University

25. Identifying and Addressing Threshold Principles in the Study of Classical Voice
Reid Spencer, Mount Royal University

26. Creating an Occupational Therapy Student-Centred Website and e-Portfolio using a Threshold Level Framework to Evidence Competence and Professional Development
Catherine Studdert, Susan Ryan, Caroline Hills, University of Newcastle, Australia, and Kim Nguyen, Hunter New England Health, NSW, Australia

27. Threshold Concepts and the Social Professions
Mark Taylor and Perry Share, Institute of Technology, Sligo

28. Threshold Concepts in Search Expertise
Virginia Tucker, Christine Bruce, Sylvia Edwards, Queensland University of Technology; and Judith Weedman, San Jose State University

29. Expectation Failure and the Pedagogy of Threshold Concepts
Brad Wuetherick, University of Saskatchewan

(Click here for hyperlinked poster folder)

Part 7: E-publication papers*[7]

[7] Please note that the following papers have been accepted for the e-publication, but have not undergone a peer review process organised by the editors.

TROUBLESOME THRESHOLDS AND LIMITING LIMINALITY: ISSUES IN TEACHING IN VOCATIONAL EDUCATION

James Atherton, Peter Hadfield, and Peter Wolstencroft, University of Bedfordshire

In the UK, much vocational education outside the university sector is undertaken according to curricula prescribed by national awarding bodies. This paper will use the discourse of threshold concepts and liminality (and communities of practice) to explore the epistemological and pedagogic assumptions and values contained in several such curricula and the ways in which they contribute to (or hinder) the formation of a sense of practitioner identity and ways of thinking and practising within an occupation.

Building on research undertaken for a previous presentation (Atherton, Hadfield and Meyers, 2008) with in-service students teaching within this area, we shall show how external influences, from funding mechanisms to assessment regimes, conspire to militate against effective engagement with threshold concepts on such courses, and particularly shy away from allowing learners to experience liminality. We also recognise the difficulty of prescribing how the transformation inherent in crossing the threshold might or even should be managed.

Against this background, we shall discuss strategies for enabling teachers to recognise threshold opportunities within their disciplines and to capitalise on them within the constraints of their curricula, and evaluate our own efforts in this field, with particular reference to Perkins' (2010) framework of moving concepts from "object" to "tool" to "frame".

Link to paper

ADDRESSING DIVERSITY AS ASSET: USING SOCIAL JUSTICE VIGNETTES FOR TRANSFORMATIONAL CHANGE IN TEACHER PREPARATION

Joan Barnatt and Mary Knight-McKenna, Elon University

This presentation describes a study utilizing social justice vignettes designed to challenge prospective teachers in identifying troublesome knowledge concerning diverse learners, consider beliefs and dispositions, and acknowledge the dissonance between their own life experience and that of their students. Teacher candidates are also asked to consider adjustments to practice based on independent examination of these issues and small group discussions fostered by the scenarios. Through the experience, participants are pressed toward transformational change in adopting an asset perspective in their interactions with diverse learners.

United States teacher preparation programs are being challenged to provide opportunities to address beliefs and conceptions of practice that limit effective instruction in increasingly diverse classrooms (Darling-Hammond and Bransford, 2005), considered broadly here as including differences in ethnicity, race, culture, social and linguistic background, learning modalities, and academic abilities. This requires the generally homogenous pool of teacher candidates in US schools – largely made up of white, middle class women – to see beyond their own life experience in developing an asset perspective to diversity as they form positive interpersonal connections with families, deepen and broaden cultural understandings, develop high expectations for all students, and effectively differentiate in support of student learning. Further, there is an increasing expectation that teacher candidates move beyond reflection on beliefs to transformation of practice, though few promising formats have been identified to facilitate transformative experiences (Gay, 2010). The vignettes utilized here offer a means for teacher candidates to identify and struggle with real life situations, toward this end. The format also provides potential for other disciplines in addressing these sorts of sensitive issues.

The presentation will describe the vignettes, as well as findings from use with teacher candidates from a US teacher preparation program.

Link to paper

'THRESHOLD CONCEPT LITERACY': HELPING LEARNERS DEVELOP WRITING SKILLS AND ACQUIRE THRESHOLD CONCEPT UNDERSTANDING THROUGH EXAMINING ASSOCIATED TRANSFORMATIONS IN DISCOURSE

Graham Barton, London South Bank University

The workshop will first report and comment on the outcomes of preliminary explorations into the application of threshold concepts theory undertaken in collaboration with learners and subject lecturers at a large central London university. In

particular, the outcomes of one pilot case study will be used to illustrate how these collaborations might inform approaches to developing student writing, as well as engaging learners with threshold concepts in potentially generative ways.

Participants in the workshop will then be encouraged to undertake a number of activities that mirror these explorations. At various points in the workshop, I will describe approaches that seek to encourage learners and subject lecturers to use text analysis to investigate not only the language features of threshold concepts and ways of thinking in their disciplines, but also the associated transformations in discourse that arise from threshold concept understanding (Land and Meyer, 2003; 2005). The purpose of this approach is threefold: to facilitate conceptual, paradigmatic change in learners; to develop their ability to engage with, and participate in, disciplinary discourses; and to inform Threshold Concept research and practice.

The language features of discourse shifts associated with threshold concepts acquisition appear under-researched outside of the discourse analysis proposed in Land and Meyer's 2003 paper (p.4). Similarly, the undertaking of literacy development practices through the lens of threshold concepts is under-reported. Threshold Concepts as a field of enquiry and practice might therefore be successfully informed by text and discourse analysis methods developed in the fields of Applied Linguistics, Academic Literacies and Academic Writing. Importantly, the possibility that learners might acquire threshold concept understanding through certain methods of discourse or text analysis (as vehicles for learning) remains under-researched. The implications for pedagogic practice and perspectives on developing student writing will be concurrent themes of the workshop.

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Link to paper

EMBEDDING THRESHOLD CONCEPTS INTO HIERARCHICAL CONCEPT STRUCTURES

Michael A. Bedek and Albert Dietrich, Graz University of Technology

The meaning of a concept is constituted by its extension, which is defined as the set of objects or instantiations belonging to the concept, and its intention, the set of attributes or characteristics those objects possess. The meaning can be enriched by embedding the concept into a web or hierarchical structure, whereby the sub-supra concept-relation plays a prominent role. There are several definitions of concepts which share the same or similar attributes of Threshold Concepts (e.g. Anchor Concepts). We apply the Formal Concept Analysis (Wille, 1982) to establish a hierarchical structure which delivers sub-supra concept-relations and attribute-implications. The Formal Concept Analysis focuses on the Formal Context which is defined by the set structure K := (G, M, I) with G as the set of objects, M as the set of attributes and I as a binary relation, connecting objects with attributes. We consider Threshold-, Anchor-, Foundational-, Central-, Core- and Key Concepts as well as Fundamental Ideas as objects and their characteristics established from literature as attributes. The formal context provides all information necessary to establish a concept lattice B(K), which can be visualized by a structured graph. Such a graph is a readably visualization of sub-supra concept-relations and attribute-implications. As an example, Anchor Concepts are defined as being transformative and integrative (Mead *et al*, 2006). These attributes are a subset of Threshold Concepts attributes, and thus, Anchor Concepts are supra-concepts of Threshold Concepts. With respect to attribute-implications, the attribute transformative implies that the concept is also irreversible. Such attribute-implications provide the opportunity of adaptive procedures to examine which attributes a concept possess. In addition, a concept hierarchy with well described sub-supra concept-relations delivers the foundation for pedagogically sound recommendations by means of deductive and inductive reasoning.

Link to paper

SERIOUS PLAY: THRESHOLD CONCEPTS, INFORMATION ENGAGEMENT AND GAME DESIGN

Margaret Blackmore and Pam Freeland, University of New South Wales

In 2010, librarians at the UNSW Library worked together to identify places where students commonly encounter problems whilst attempting to engage with information at university. Based on their many years of experience, the librarians identified a number of different "troublesome" areas where students regularly get stuck, then analysed these to uncover the "ways of thinking" that help students to transcend such problems. These "ways of thinking" were then employed to identify particular threshold concepts that need to be understood if students are to most effectively engage with information at university.

The impetus for this work came from our reading of the research literature on threshold concepts, in particular Meyers and Land, (2006), Land, Meyer and Smith (2008) and Meyer, Land and Baillie, (2010).

Since 2010, consideration of the identified threshold concepts has opened opportunities for innovating library support for university learning and teaching. We are now looking beyond traditional competency based approaches to focus more on the inherent understandings enabling skill acquisition. This has led to a re-imagining of the ways these understandings might be experientially enabled, for example, through the use of interactive games.

This paper will report on an on-going Library and faculty collaboration with a game development course in which students respond to a library creative brief to create game designs to promote understanding of the threshold concepts. Learning outcomes from this collaboration are greater than the sum of any games produced. Librarians have learned about the difficulties involved in presenting abstract ideas through creative briefs, game design students are learning about threshold concepts and sometimes overcoming unhelpful beliefs about information engagement. Both Library and faculty are learning more about students' incidental learning (learning about content when designing games to teach it). It is perhaps proof for that old adage, "to better understand something, teach it!"

Link to paper

DESIGNING TASKS TO AID UNDERSTANDING OF FUNCTIONS

Sinead Breen, St Patrick's College, Drumcondra, and Ann O'Shea, NUI Maynooth

The concept of a 'function' can be viewed as a threshold concept in Mathematics. To properly understand functions and to work with them in diverse areas of mathematics, students should be able to conceive of a function as an action, as a process and as an object in its own right. In fact, some authors have claimed that successful mathematical thinking lies in moving flexibly from one interpretation to another. However, most students find the transition of thought involved in progressing to view a function as an object troublesome. Once such 'reification' has taken place, it is unlikely to be forgotten, previously inaccessible means of thinking about many different mathematical concepts are opened up, and students' conceptual understanding is transformed. The key role played by functions in Mathematics justifies paying significant attention to the teaching of functions and to the types of tasks assigned to students to support their learning.

Traditionally undergraduate courses in Mathematics tend to be described in terms of the mathematical content and techniques students should master and theorems they should be able to prove. Moreover, recent studies have shown that many sets of mathematical tasks produced for third-level students emphasize lower level skills, such as memorization and the routine application of algorithms or procedures, rather than endeavouring to develop students' understanding of the underlying concepts. In this talk, we will describe a set of tasks designed by the authors to help students develop a comprehensive understanding of functions and to move flexibly between different interpretations and representations of functions. The design of tasks drew on a number of frameworks, such as those of Swan and Mason, adapted for use with undergraduate students.

Link to paper

INTERDISCIPLINARY THRESHOLD CONCEPTS: AN ONTOLOGICAL AND EPISTEMOLOGICAL ANALYSIS

Monica R. Cowart, Merrimack College

Multiple examples of disciplinary-specific threshold concepts already exist within the academic literature and additional disciplinary-specific threshold concepts continue to be added to this growing list (Land, Meyer and Smith, 2006). However,

less attention has been devoted to both the identification and understanding of those key threshold concepts that hold such a level of importance that they cross over into multiple disciplines. I maintain that these discipline-crossing threshold concepts require a more complex analysis. Specifically, one must ask: how are interdisciplinary threshold concepts able to retain their core nature while seemingly transforming to conform to the demands of distinctly different disciplines? This paper will be devoted to answering this question by offering a preliminary analysis of the epistemological and ontological nature of interdisciplinary threshold concepts. To further illustrate this emerging theoretical analysis, the interdisciplinary threshold concept of psychological trauma is isolated and discussed in relation to the various disciplines that claim it. Finally, I discuss how the lessons learned from this examination will aid in the identification and understanding of additional interdisciplinary threshold concepts.

Link to paper

LOCKED DOORS: THRESHOLD CONCEPTS AS GUARDIANS

Jason Davies, University College London

Threshold concepts are typically treated as doors into the understanding of a discipline yet, just as doors can be open or closed, so too threshold concepts can be important as guardians of a discipline's character and workings. It might be said that what is distinctive about any discipline is precisely its threshold concepts. Thus many attempts to explain what a particular discipline 'is' – such as subject centre formulations – depend on its practitioners articulating some (but disguising others) of their threshold concepts.

Teaching a particular discipline is therefore not just about initiating students into critical threshold concepts but also about equipping them to defend the discipline from threshold concepts that might re-construct and re-describe those concepts. At times this is obvious (so obvious that they are hard to describe, such as 'deity' and science) and at others, invisible from a distance and requiring specialist knowledge to explain (indeed, the threshold concepts themselves).

Teaching in a multidisciplinary and interdisciplinary setting requires some dexterity in this regard: the teaching of threshold concepts can be accompanied by an explicit discussion of how and why one set should be privileged over another. This can be tantamount to advocating (even evangelising) the deployment of a particular discipline for particular questions – a difficult and even politically sensitive task for many disciplines in the current climate.

This talk will explore some examples taken from a range of specialist fields (classics, history, anthropology) as well as considering broader brush examples (e.g. Chemistry, Chemical Engineering). Addressing these issues deliberately as part of teaching can inculcate a more reflective type of teaching and learning and potentially create a different set of relationships between disciplines which in turn can be a driver and facilitator for interdisciplinary work within the university.

Link to paper

WHAT CONCEPTS UNDERPIN SKILLS TRAINING IN COMMUNITY SERVICES IN VOCATIONAL EDUCATION AND TRAINING

Rhonda Fuzzard and Margaret Kiley, Australian National University

Many students enter community service courses in vocational education believing life experiences and motivation to ‘help’ or ‘give back’ are the basis for additional skill development, so they can graduate as good workers. However, the literature argues that workers in these fields must have more than skills training and their own unexamined life experiences to be effective workers in a demanding environment (Sercombe, 2010).

Experts from the field have understandings of skills required by students on graduation, and national training packages define the skills to be taught. Skills “are intimately tied up with values and knowledge” (Ife, 2002, p. 227), yet we do not fully understand the concepts that underpin those skills; so this is the focus of this study; to identify the threshold concepts that professional experts agree are key to community services training.

Six experts from the field agreed to participate in identifying concepts they believe are essential to understanding community services work. Using the Delphi method (Skulmoski, Hartman, and Krahn. 2007), results were integrated then forwarded back to the participants who then ranked the top five concepts.

These concepts were then analyzed against the criteria for a threshold concept. From the analysis, several of those identified by the experts are argued by the researchers to be Threshold Concepts. These will be discussed during the

session, it is anticipated that initial data from the subsequent study will be available to support these early findings. The subsequent study aims to seek from classroom teachers what skills and behaviours they can identify in students, that signify who have, or have not crossed these important thresholds?

Link to paper

'PLAYING' SO HARD WE FALL OUT OF OUR HEADS: THRESHOLD CONCEPTS AND TROUBLESOME KNOWLEDGE IN EXPERIENCES OF EXPERIENTIAL KNOWLEDGE ACQUISITION IN HIGHER EDUCATION ACTOR TRAINING

Sam Grogan, Liverpool Institute for Performing Arts

This paper discusses and reflects upon the writer's experience of delivering key aspects of Level 4 (year 1) undergraduate actor training at Bath Spa University during 2009-2011.

Adopting the position of a 'tutor-guide' with the students through the training the student actors are asked to revisit territory previously felt to be familiar. The nature of the interaction with this territory during the experience of training causes them to necessarily adopt a fundamentally altered perspective in relation to their view and embodied understanding of this knowledge and territory. In attempting to attain this perspective and also in attempting to maintain and implement the embodied knowledge the perspective contains, the student necessarily encounters these aspects of training as a Threshold Concepts and as Troublesome Knowledge.

Within this experiential setting this paper focuses particularly on the idea of 'play' as espoused by Winnicot and Huizinga amongst others, as a paradigm for engaging in the act of acting. The paper also uses Csikszentmihalyi's notion of 'flow' as an 'optimal' psychological state linked by Csikszsentmihalyi to notions of creativity and discovery. As embodied in studio and performance practice this playful state is commonly referred to by the students as 'letting go'.

This paper positions Meyer and Land's Troublesome Knowledge and Threshold Concepts firstly as 'embodied knowledge-as-experience', and secondly as a playful state of being involving interaction with an altered state of consciousness on the part of the student actor similar to those states associated with 'flow'.

This paper examines the practical strategies of the particular training undertaken by students at Bath Spa University during this time in order to facilitate a habitual implementation of transformation and change within the work of the student actor. In doing so I reference the work and thinking of Gunduz Kalic, from whose practice these particular processes and approaches stem.

Link to paper

INTEGRATING THRESHOLD CONCEPTS PEDAGOGY INTO A MARKET-VALUE EDUCATION SYSTEM TO REDUCE THE "PLAGIARISM EPIDEMIC"

Corrine Hersey, St Thomas University

This paper argues that: 1) the current market-value model of education reduces real learning and the student`s connection with knowledge thereby encouraging plagiarism, and 2) that the implementation of a Threshold Concepts pedagogy increases real learning and the student`s connection with knowledge thereby decreasing plagiarism. Plagiarism is fundamentally associated with market-influenced education that operates in terms of supply and demand, profitability and a means to an end. Knowledge becomes commodified in terms of human capital (Giroux, 1997) and universities engage in "academic capitalism" (Slaughter and Rhoades, 2004). The plagiarism industry thrives under policies and practices that consider "knowledge and education a commodity, students consumers, faculty entrepreneurs and university managers corporate executives" (Calvert and Kuehn, 1993, p. 116). This framework begins early in the school years and encourages the acquisition of minimal amounts of bits of information – enough to pass to the next level. Students come to post-secondary education on a career path, and ill-prepared for in-depth learning and understanding complex concepts. Student dependence on online information has exploded under these conditions and with anonymous, immediate and cheap access to the Internet. The Threshold Concept model stresses "a transformed way of understanding" (Meyer and Land, 2003, 2006), making meaning of knowledge (Meyer, Land and Baillie, 2010) and participation rather than acquisition (Irvine and Carmichael, 2011). Expanding their first theory of a more discipline-specific model, Meyer, Land and Baillie move to an integrative model of Threshold Concepts. It is not only the discipline-specific model that can move students into that area of transformational learning, but the integrative model of moving

them into a transformational way of understanding, using knowledge and "being in the world" (O'Sullivan *et al*, 2001, p. 11). This paper proposes that under this model, plagiarism and learning cannot coexist.

Link to paper

EMBEDDING THRESHOLD CONCEPTS IN A STUDENT LEARNING COMMUNITY

Jody Horn, Oklahoma City University

Threshold concepts are embedded in a Student Learning Community (SLC) as an entryway to the discipline and for student engagement. This paper presents data from assessment of these threshold concepts. The SLC (created and realized based on best practices for learning communities) is required for first semester students in three majors (Sociology, Justice Studies-Criminology, and Justice Studies-Peace & Conflict) in one department (Sociology and Justice Studies). Students are introduced to the four threshold concepts (i.e., restorative justice, victim-offender dyad, sociological imagination, and self-authorship) through interesting autobiographies, films, and discussions. Data reveal 80% of the students experience transformative learning upon completion of the SLC. They are able to reconstruct and integrate these threshold concepts in the real world. The evidence is made visible through written narratives on these concepts – moving from the concrete recognition in books and films to the more abstract and deeper understanding of threshold concepts and their connection to everyday life.

These four threshold concepts open the door and interdisciplinary connection among all three majors. The first two concepts: restorative justice and victim-offender dyad are particularly troublesome for the students, as well as essential to the Justice Studies students. Since Justice Studies is in a sense a critical outgrowth of criminal justice many of the students enter the major with preconceived retributive and law and order mind sets. However, Justice Studies critiques the criminal justice system, focusing on social justice and potentials for justice. Thus, the first two threshold concepts; one, centering on harm not punishment and the other questioning whether the offender is really the victim, disrupt students preconceptions and facilitates their critical thinking in the disciplines.

Link to paper

USING LANGUAGE TO TRANSFORM JUDGEMENTAL ATTITUDES

Charity Johansson, Elon University

Two Threshold Concepts are identified in the initial course of a physical therapy doctoral program:

The clinician's role is not to judge patients, simply to inform and assist them.

Language is a professional tool that both reveals and shapes a clinician's attitudes toward patients.

Patients who feel respected rather than judged have better clinical outcomes. Judgment is often unconscious, however, and difficult to examine. Language can be purposefully used to bring hidden judgments to light.

Course activities are designed to:

- increase awareness of judgmental attitudes and communications
- allow students to suspend judgment, creating space for reflection and choice
- facilitate on going self-awareness and growth

In particular, activities interweaving the two Threshold Concepts are designed to disrupt students' habits of thinking and speaking and push them to create new ways of communicating. For example, students must go 24 hours without saying "should," stripping their statements of implied judgment and restating their thoughts in purely informational terms. Similarly, students are directed to change judgment-laden "why" questions to factual "what" questions during patient interviews.

The concept of non-judgment and the revelatory nature of language are inherently troublesome. Although students initially agree that judging patients is inappropriate, knowing and being able to tell patients what they "should" do often represents the culmination of their educational goals. When their own everyday communications are challenged, students often fail to see judgments inherent in them. The idea that they may be expressing unconscious judgmental attitudes that are partially responsible for patients' poor clinical outcomes is difficult to accept.

These Threshold Concepts are not unique to healthcare. Any professional education program must wrestle with the shift from a practitioner-centered to a client-centered approach and with the fundamental influence of language on their clients, all within the time constraints of mandatory content mastery.

Link to paper

DON'T FEAR THE ENGINEER: SOCIAL SCIENCE STUDENTS EXPLORING A LIMINAL SPACE WITH ENGINEERING STUDENTS

Jens Kabo, Chalmers University of Technology; and Caroline Baillie, University of Western Australia

Engineering students learning, in interdisciplinary courses, to consider the social context of their work, need to learn how to think in ways more familiar to social scientists. In our previous work we have shown that this can cause concern and potential trouble as they traverse a liminal space (Kabo and Baillie, 2010). However, we have found that there are just as many, albeit different, thresholds to cross for social science students taking the same class.

During two iterations of the course we conducted interviews with students and analysed their critical self-reflections. During this analysis it became apparent to us that most of the social scientists in the class had no or little actual understanding of what engineering really entails and often had quite negative perceptions of it. For these students, the course offered an opportunity to work with engineering students in a constructive manner that in many cases resulted in the breaking down of (negative) stereotypes of engineers and engineering. This is an important first step toward grasping any positive potential engineering has to offer. Some social science students moved beyond the breaking down of negative stereotypes to the realisation that engineering can play a positive role in the creation of viable alternatives to current practices and that engineers possess skills and ways of thinking that complement those of social scientists in a potentially beneficial way. Our findings indicate that understanding engineering and engineers can serve as a threshold that social scientists students working in an interdisciplinary context with engineering students need to cross for the possibility of true interdisciplinary, rather than multidisciplinary, collaboration to take place. A central aspect of this crossing is to negotiate together with engineers what engineering means and can mean.

Link to paper

THE EXPERIENCE OF INTERDISCIPLINARITY IN DOCTORAL RESEARCH: THRESHOLD JOURNEY

Jeffrey Keefer and Gale Parchoma, Lancaster University

There is a rather widely held perception that doctoral students begin their formal studies in a foundational discipline and then continue in it throughout their academic careers. It would then follow that their doctoral supervisors would share their supervisees' home discipline. Supervisor-supervisee pairs would research and teach in the same discipline, would share an interest in specialized topic area, and perhaps even engage in a preferred methodological approach. However, evidence from applied research fields, including educational research, suggests this pattern may not consistently be the case, with the effect of traditional disciplinary blurring leading to unanticipated doctoral research and supervisory challenges. An extended literature review was conducted, after which a research design was developed to explore the central question, "How can supervisors support their postgraduate students to work through threshold crossings if they come from different foundational disciplines, even if they are working within a clearly delimited field of study?"

This paper reports findings from a resultant qualitative, small scale study of fourteen applied research doctoral supervisors from ten universities in five countries. Using a grounded theory-informed strategy, interview transcripts were individually coded and then discussed between both researchers to develop and agree upon shared themes. A series of disciplinary challenges, opportunities, and questions surfaced. Questions around disciplinarity were found to be especially pronounced when influenced by a need for methodological pluralism to investigate complex, contextualised problems, which most often occurred when divergent academic backgrounds introduced tensions between supervisors and supervisees. This paper discusses a broad set of challenges, opportunities, and questions around transdiciplinary integration and problematises threshold concepts and crossings in applied doctoral studies.

Link to paper

CROSSING A THRESHOLD CONCEPT IN BIOLOGY: VARIATION IN STUDENT LEARNING

Eileen Kennedy, University of New South Wales

A threshold concept has been described as troublesome knowledge negotiated through a conceptual gateway that transforms the learners understanding and develops the ability to integrate it with related areas of learning (Meyer and Land 2006). Many areas of Biology are troublesome and also more complex than expected [Taylor in Land et al (eds) 2008].

A threshold concept in Biology involving chromosome strands (within chromosomes) and chromosome pairs (between chromosomes) has previously been identified (Kennedy 2010). Subsequent investigation, described here, supports this identification. The use of hands-on models together with facilitator discussion was found to be helpful in promoting transformation and integration within this troublesome area of knowledge (Kennedy 2010).

Meyer and Land suggest that once a conceptual gateway has been successfully negotiated, the understandings that have been achieved are irreversible (unlikely to be forgotten). They also suggest that transformation may be sudden or may be protracted over a considerable period of time (Meyer and Land 2003). Research (using analysis of exam questions and surveys) following the use of models has supported this in revealing variation between students. Those who have mastered the concept clearly show their new understandings whereas others may still have not travelled "through the portal (gateway)". The latter group, once identified, may benefit from further co-inquiry via the model/discussion learning scheme. The frequently overlooked factor of discursiveness (linguistic skill or absence of it) was also identified.

Link to paper

THRESHOLD CONCEPTS IN LIBERAL EDUCATION

Bruce MacKay, University of Lethbridge

This paper presents findings on Threshold Concepts in an integrative liberal education program at the University of Lethbridge, Canada. Liberal education involves the acquisition of a broad range of interdisciplinary and integrative knowledge and skills, the exposure to a diverse range of perspectives, and the development of abilities in critical and creative thinking and expression. A liberal education, in the words of Martha Nussbaum, “liberates the mind from the bondage of habit and custom, producing people who can function with sensitivity and alertness as citizens of the whole world." Student transformation from rote learners, holding positions of what William Perry has termed “basic duality,” to independent critical thinkers and writers, holding positions of “committed relativism”, involves crossing a number of troublesome thresholds. This paper will discuss and reflect on the results of interviews with selected students who identified thresholds which proved to be troublesome and transformative in their acquisition of the skills and integrative interdisciplinary perspectives of a liberal education.

Link to paper

THE INTEGRATIVE NATURE OF THRESHOLD CONCEPTS IN FINANCIAL ACCOUNTING – AN EXPLORATION OF THE INTERDISCIPLINARITY OF ONE THRESHOLD CONCEPT

Sonia Magdziarz, Paul Myers, and Sheila Bellamy, RMIT University

The notion of threshold concepts developed by Meyer and Land (2006) has been explored in the area of Introductory Accounting but not in Financial Accounting. In financial accounting, my experience has shown that many students have difficulty being able to understand and apply accounting principles and techniques and resort to rote learning and leave the course with a superficial understanding of accounting. Semi-structured interviews with accounting academics were used to explore the identification of threshold concepts in financial accounting in higher education. One of the threshold concepts identified was the duality of transactions. It is a troublesome concept that requires students to integrate knowledge about the business world and society; features of the economy a business operates in and/or trades with; the impact legal regulation has in the form of taxes and laws as well as accounting regulation in the form of accounting standards and the conceptual framework; and the impact of different business structures and operations on the accounting function in an entity in profit and non-profit sectors. This threshold concept goes beyond the content of the accounting discipline as it requires a student to adapt knowledge and thinking from different disciplines and relate this to

the accounting discipline. The interdisciplinary nature of duality is normally covered very superficially early in a business program but its identification as a threshold concept and a more detailed understanding of its importance can help inform the context of learning and frame how financial accounting is taught in higher education. This paper explores the views of accounting academics on the interdisciplinary nature of accounting threshold concepts.

Link to paper

THRESHOLD THEORY, ACTION RESEARCH, AND TEACHER LEARNING: AN EXPLORATION

Sarah Noonan, University of St Thomas

The author provides a proposed model of action research, called REAL, combining threshold theory (Meyer and Land, 2003, 2005) with scholarly research on action research and teacher learning. The REAL model illustrates a struggle with threshold concepts and the importance of experimentation and reflection to improve practice in action research to grow in professional learning, and expertise. Featuring the 'action' in action research, the REAL model shows a progression of professional engagement from awareness and inquiry to changes in practice to address and resolve challenges. Interviews conducted with five expert teachers show how encounters with threshold concepts and learning and the adoption of an 'informal' teacher-led model of action research led to substantial changes in professional knowledge and identity. The integration of threshold theory with action research illustrates the relationship between the nature and experience of some challenges (threshold concepts) and their resolution through action research.

Link to paper

I HATE MATHS AND MATHS HATE ME! ANALYSING THE DEVELOPMENT OF THRESHOLD CONCEPTS AND ATTITUDES IN PRESERVICE MATHEMATICS TEACHER EDUCATION

Maria Northcote, Avondale College of Higher Education

The process of learning to become effective mathematics teachers of young children can be impeded by preservice teachers' anxiety about mathematics or phobia of mathematics (Kargar, Tarmizia and Bayat, 2010; Johnson, Smith and Carinci, 2010). Ingrained attitudes to mathematics, often reinforced by stereotypical societal and popular values, must be acknowledged before the preservice teacher can begin the journey to becoming a skilful mathematics teacher. Although some research has been conducted on the mathematical threshold concepts developed during the study of tertiary level mathematics (Jooganah, 2010) and the attitudes of preservice teachers' attitudes to mathematics (White, Way, Perry, and Southwell, 2005, 2006; Prescott and Cavanagh, 2006; Perry, 1996), the area of how threshold concepts and attitudes are connected in primary mathematics education is an under-researched field.

This paper reports on the first stage of a longitudinal study, designed to investigate the development of both attitudes and troublesome threshold concepts of mathematics education in a cohort of preservice teachers. In order to gain access to the student voice, narrative methodologies have been used to gather and analyse data gathered during this study. Narrative analyses of these stories have been employed to: 1) determine how students' attitudes to teaching mathematics develop; and 2) to identify the threshold concepts that students develop about mathematics education. To triangulate the data gathered from the students' stories, the cohort was also invited to complete an attitudinal questionnaire which will provide quantitative evidence of their attitudes to mathematics at the beginning and the end of the semester.

As well as contributing to the reasonably new study of threshold concepts, began in 2005 by Land and Meyer (2003), the findings of this study adds to the growing research on the importance of analysing the threshold concepts developed by preservice teachers, especially in association with attitudinal and emotional issues.

Link to paper

ACADEMIC NUMERACY: CHALLENGING THINKING DISPOSITIONS TO ENABLE STUDENTS TO ENTER AND CROSS THE LIMINAL SPACE

Rebecca LeBard and Rachel Thompson, University of New South Wales, and Rosanne Quinnell, University of Sydney

The thresholds concepts framework was used to identify the underlying dysfunctional attitudes and stances students may adopt that can preclude them from engaging in our discipline practices. In the sciences numeracy skills are integral to the

professional practice of data handling, data presentation and interpretation. We have found that students lacking in numerical confidence are more hesitant to engage in these activities, which impacts of their learning of the discipline by directly inhibiting how well the students tackle threshold concepts with numeracy elements.

While mathematics can be enabling, we postulate that the transfer of numeracy skills can be inhibited by a transfer in "maths anxiety", a "transferable anxiety", that doesn't appear unique to a particular discipline. In the classroom, this often translates to a hierarchical standoff: "I can't do maths" versus "they can't do maths". Students who default to this position are at risk of not engaging in our practice as they have adopted a thinking disposition where a lack of depth in understanding has been previously legitimised i.e. if they retain the static position long enough, the educator will eventually offer a worked solution.

We have identified and compared inclinations and assessed students' abilities across three disciplines within science. We have been able to map these onto the Perkins *et al* (1993) framework of "triadic thinking dispositions" and offer descriptions of the sensitivities, inclinations and abilities that place students "at risk" of not engaging in numeric activities. We have designed a diagnostic tool to help students understand and self-challenge their level of confidence in numeracy. We postulate from the tool's evaluation, on the success of this learning activity in helping students cross the liminal space and also posit how this might improve our students' ability to transfer their numeracy skills and confidence more readily across disciplines.

Link to paper

CREATING OPTIMAL DISTANCE EDUCATION ENVIRONMENTS FOR THE EMERGENCE OF THRESHOLD CONCEPTS

Kristi Archulta-Frush and Candy Sebert, University of Central Oklahoma

This highly interactive workshop is focused on strategies to create optimal distance learning environments for threshold concepts to emerge. In recent years, technology has brought about numerous changes in the design and delivery of educational programs (Bishop and White, 2007). Administrators and instructors are challenged with communication at a distance and potential barriers of the intersection of culture and technology.

As global interaction and cultural diversity became more prominent, the issue of cultural competence received more attention, and how to treat people from different backgrounds considerately and equally has become a pivotal issue (Chang, 2007). Online courses can be an ideal environment for rich dialogue exchange between learners as well as between learners and instructors of many varied backgrounds. Yet, according to McCoy and Garten (2008), the issues of diversity and multiculturalism are present in distance education. Thus, in order for the setting to be constructive for all learners, course designers and instructors will need to create the conditions for respectful communication to occur.

Questions that will be addressed include: What are the conditions that need to occur for threshold concepts to emerge; How can the necessary communication occur for threshold concepts to transpire a distance; How can culture difference impact the creation of the optimal conditions for threshold concepts; What is the link between respect, trust and threshold concepts.

Link to paper

HELPING STUDENTS TO 'THINK HISTORICALLY' BY ENGAGING WITH THRESHOLD CONCEPTS*[8]

Paul Sendziuk, University of Adelaide

In 2005 Lee Shulman urged scholars to conceptualise and define was he called "signature pedagogies" rooted in the theory and practice of individual disciplines. These were skills and concepts that were unique to, or at least uniquely applied by, scholars of specific disciplines, which set them apart from other disciplines. Teacher historians took up the challenge with relative gusto. Lévesque (2008) and Andrews and Burke (2007) have posited that 'thinking historically' involves an appreciation of change over time, context, empathy, and the recognition that the 'past is a foreign country' (to borrow a phrase from Hartley) and that the people who live there are not like us. Others such as Wineburg (2001), Pace (2004), Pace *et al* (2008) and Calder (2006) applied cognitive science to identify the mental tasks that practicing historians routinely perform, tasks such as drawing connections, corroborating, and (often unconsciously) applying a sceptical interrogation of sources of evidence. But while the appreciation of these concepts, and performance of these tasks, is

[8] This paper has undergone peer review organised by the author.

second nature to practicing historians, this is rarely the case for students, especially those new to the study of history. Yet without grasping their significance, it is nigh impossible for students to unlock the secrets of the past. In effect, they constitute the primary "threshold concepts" (Meyer and Land 2003) of the discipline that teachers must help students navigate. A case can be made that too much time is spent in academic history courses on teaching content (i.e. about people and events of the past) rather than facilitating the acquisition of the skills and conceptual understandings required for students to make sense of the past (Calder 2006). This paper explains why concepts such as empathy and viewing the past as a foreign country constitute "threshold" understandings, and how History courses can be redesigned to focus on student engagement with threshold concepts (and thus promote life-long learning skills) rather than just the mastery of historical narratives and facts.

Link to paper