Threshold concepts and the troublesome transition from GCSE to A-level: exploring students' experiences in secondary school biology.

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This paper draws on doctoral research exploring the lived experiences of secondary school students during their first year of A-level study, through the theoretical lens of the Threshold Concept Framework (TCF). A longitudinal design frame based on Interpretative Phenomenological Analysis (IPA) is employed, thus providing an original use of this methodology in education research to address the paucity of inquiry exploring the difficulties experienced by students as they transition from GCSE to A-level. In this context, I argue that students' encounters with threshold concepts are significant for them, posing a degree of cognitive and affective challenge which serves to exacerbate the difficulty of transition already caused by increased workload and pressure. The findings offer insights into students' struggles adjusting to shifting identity and membership of communities further intensified by the integrative, discursive and transformative nature of threshold concept acquisition. The longitudinal research design also surfaces positive aspects of growing awareness of the integrative power of threshold concepts. Recommendations are made for further research involving students, teachers and academics to explore threshold concepts in a range of other subjects and settings in secondary schools in the context of recent and significant changes to GCSE and A-level curricula.

Keywords: threshold concepts; secondary schools; biology; transition; A-level.

Introduction

It is broadly acknowledged that the transition from GCSE to A-level study in the UK education system is a 'considerable step up' from GCSEs (NUS, 2014). Recent reforms to A-level qualifications (Ofqual, 2016) have reorganised the structure of these courses from modular to linear, whilst also introducing increased levels of difficulty in the specification content (CIFE, 2018). These changes have resulted in A-levels becoming even harder, potentially exacerbating issues that students experience with transition from GCSE to A-level. Several studies have attempted to investigate difficulties at this transition point from a subject-specific perspective, for example in mathematics

(William et. al., 1999; Mendick, 2008; Hernandez-Martinez et al., 2011; Rigby, 2017), languages (Clark, 1993; Thorogood & King, 1991) and biology (Overton & Reiss, 1990). However, these studies provide limited insight into the issue from the perspective of students' experiences.

This article reports on doctoral research which explored the lived experiences of secondary school students during their first eighteen months of A-level study. Utilising a longitudinal design frame integrating an original application of Interpretative Phenomenological Analysis (IPA) in education research, the study provided opportunities for rich exploration of students' individual journeys. Ethical approval for the research was received from a university ethics committee and informed consent was obtained from all student participants and from the host school. In this paper I argue that these students' encounters with threshold concepts (Meyer & Land, 2003) were significant for them, posing a level of cognitive and affective challenge which served to exacerbate the difficulty of transition already caused by increased workload and pressure. I further argue that providing opportunities to enable students to see the interrelatedness of concepts within these new specifications, through the integrative and transformative nature of threshold concepts, is pedagogically productive. The purpose of this paper is to provide insight into the transformative journey from GCSE to A-level study from a student perspective, whilst also highlighting the benefit of further research into threshold concepts in secondary school curricula.

Threshold Concepts

A defined curriculum within a subject is made up of fundamental concepts, often referred to as 'key concepts' (Davies and Mangan, 2007, p. 713), or 'core concepts' (Meyer & Land, 2003, p. 4). These conceptual building blocks allow students to construct subsequent layers of knowledge within the discipline. In contrast, Meyer and

Land (2003, 2005) introduced the notion of threshold concepts (TCs) as being qualitatively different from 'core concepts', arguing that a TC holds the potential to transform learners' views of their subject, describing such as a metaphorical '...portal, opening up a new and previously inaccessible way of thinking about something.' To support this notion, they posited that a TC is likely to be (Meyer & Land, 2003, p. 4): *transformative, irreversible, integrative, bounded* and *troublesome*. A subsequent paper by Meyer and Land (2005, p. 375) introduced two further features, highlighting the link between identity, thinking and language. They suggested that TCs are *discursive*, in that any shift in perspective resulting from transformation would be hard to imagine without (or as a result of) an extended use of language and a change in discourse, thus triggering a *reconstitutive* effect through the resulting shift in subjectivity brought about by this repositioning of self. Alongside these seven characteristics of a TC, Meyer and Land (2005) also highlighted the notion of *liminality*, a spatial metaphor for the suspended state in the process of learning where students experience a shift in subjectivity (Land, Rattray & Vivian, 2014, p. 1), representing the journey of 'becoming' learners experience through various stages of TC acquisition within a subject (Meyer, 2016, p. 465).

The idea of focusing on what students find difficult in subject disciplines is not new. What makes the notion of TCs of particular interest, however, is the implicit premise that a TC is likely to be transformative, occasioning an ontological and epistemological shift in the learner's view of the world and potentially their own identity (Meyer & Land, 2003, p. 4). Internalisation of TCs allows phenomena to be brought into view that were not formerly perceived, unlocking 'a previously occluded, and integrated, view of subject landscape' (Meyer, 2016, p. 463), thus allowing students to see how TCs and other concepts work together in an integrative way. The resulting

change in perspective may reveal a transformed way of understanding within a discipline which is likely to involve both a conceptual and ontological shift. This transformation may also empower students to think, practise and talk in a transformed way within a discipline, including altered language use, all of which facilitates their entry into a community of practice (Wenger, 2009) within a discipline.

Despite inferring a journey with an intended destination, it is important to note that the Threshold Concept Framework (TCF) does not signify a necessarily rigid or sequential process. Land, Meyer and Baillie, (2010, p. xi) highlighted the 'oscillation' that remains hidden within the recursive nature of TC acquisition, a journey which individuals undertake at varying rates of progress (Meyer, 2016, p. 467). There is likely to be 'deviation and unexpected outcomes' (Meyer, Land, & Davies, 2008, p. 202), involving 'messy journeys back, forth and across conceptual terrain' (Cousin, 2006, p. 5). TCs bring about transformations in perspective once understood (Meyer and Land, 2003), and are thus likely to involve an affective component (Meyer, 2016), relating to feelings, emotions and attitudes. Identification of TCs from a purely cognitive perspective may therefore result in surfacing only content-related concepts (Timmermans and Meyer, 2017, p. 4.), whilst deeper analysis may illicit thresholds involving ontological and epistemological scopes, such as from within the affective domain.

There is now a substantial and increasing international body of literature claiming to offer empirical evidence for TCs across a range of disciplines in higher education and, to a lesser extent, in secondary education, although not without criticism. It has been argued, from a positivist perspective, that demonstrating the existence of TCs is epistemologically difficult due to their reliance on the subjective effects on the learner. O'Donnell (2010, p. 7) referred to this as 'agent-dependence'. In essence, what

is transformative for one student may not be for another, as this will depend on their prior learning and the conceptual schema already in place (Rowbottom, 2007). However, a limitation within one paradigm (normative) may help to shape the theoretical framework of TCs when viewed from an interpretative world-view. In light of this consideration, it is argued here as part of my own conceptual framework that the involvement of students is fundamental to empirical investigation of the impact of encounters with TCs.

Threshold concepts research in biology

Investigations into TCs within the discipline of biology have been conducted by authors in various countries, notably in the UK (Kinchin, 2011; Jordan, Tracy & Johnstone, 2011; Chandler-Grevatt, 2015) and North America (Batzli et al., 2016; Wolf & Akkaraju, 2014). In Australia, various publications by members of the Australian Learning and Teaching Council (ALTC) have reported on the identification of TCs in the discipline (Taylor, 2006), the evaluation of intervention strategies to help address difficulties with the learning of TCs (Ross & Tronson, 2007), how students respond to tasks involving specific TCs (Taylor & Meyer, 2010; Zimbardi et al., 2014) and have generated a matrix of TCs for biology (Ross et al., 2010).

Underlining the importance of the integrative nature of TCs as a defining feature, early observations by Taylor (2006) emphasised the complexity of biology as a discipline, proposing that many of the more difficult concepts to teach in biology stand alone as ‘isolated islands of knowledge’. These concepts remain as such until students are encouraged to make links to a more complex ‘web of composite knowledge and understanding’ (Taylor, 2006, p.89). Relating the structure of the discipline to the reorganised structure of the curriculum representing it, Kinchin (2011, p. 187) found that empowering students to process and synthesise curriculum content through concept

mapping enabled them to visualise the interrelated nature of concepts within the discipline, suggesting that TCs have the potential to transform students' understanding by supporting the integration of disciplinary knowledge.

Threshold concepts research in secondary education

Despite their popularity in higher education, studies focusing on TCs in secondary education are still relatively scarce. An exploratory case study in the UK, reported in this journal (Renshaw & Wood, 2011), employed the TCF to develop an approach to learning based on holistic understanding underpinned by central TCs in geography which the authors argued helped students to work through some of the troublesome knowledge identified by the research team (2011, p. 374). Other studies have been conducted overseas in different contexts: in Hong Kong (Pang and Meyer, 2010), Ireland (Sheehan, 2010), the USA (Wolf and Akkaraju, 2014) and Brunei (Haji Bungsu, 2014). Of those taking place in the comparable context of the UK education system (Renshaw and Wood, 2011; Ashwin, 2008, Chandler-Grevatt, 2015), only the latter focused on A-level study in a sixth form college. Involving students (n=70) in their first year of A-level study following courses in sciences, Chandler-Grevatt's (2015) report only discusses findings in chemistry, with the aim of improving transition to higher education rather than from GCSE to A-level.

The current paper is therefore timely in addressing a gap in the literature by proposing an innovative approach with which to explore student experiences of transition from GCSE to A-level. Based on a methodological design frame drawing from the field of Health Care Psychology, the doctoral research reported on here employed an original use of Interpretative Phenomenological Analysis in secondary education research, to explore both the cognitive and affective dimensions of students'

lived experiences of transition through the theoretical lens of the TCF, and presents findings derived from two research questions:

- How do students make sense of the transition from GCSE to A-level study?
- How do students experience threshold concepts in A-level Biology?

Research design and methods

As this study aimed to explore students' experiences of the transition between phases in secondary education, a qualitative approach was adopted which would reconcile a focus on the predefined theory of the TCF with consideration of individual lived experiences. The hybrid methodology employed in this study derives from a synthesis of case study and Interpretative Phenomenological Analysis (IPA). This latter approach originates in healthcare psychology, a field from which others have drawn inspiration for TC research (see Barradell & Peseta, 2014; Hill, 2012; Haji Bungsu, 2014). IPA places a focus on illuminating major life experiences of participants, as well as being employed to illuminate key life transitions, such as having a child, or leaving home (Smith, Flowers & Larkin, 2009, p. 3).

Whilst each author writing about case study offers their own perspectives on the tradition, that of Thomas (2011) aligns most closely with the philosophy and hybrid methodology adopted here. Rather than viewing case study as a method in itself, Thomas argued for 'analytical eclectism' (p. 512), seeing case study as a design frame that integrates a number of methods. Through this approach the *object* in this case study (The TCF and encounters with threshold concepts) is illuminated and explicated (Thomas, 2011, p. 513) by investigations into the *subject's* (biology students) experiences of transition. Integrating IPA methodology into this case study design frame enabled an analytical approach which preserved individual narratives about

transitional journeys, whilst ensuring that cross-case themes could emerge through iterative layers of analysis.

Participants and setting – defining the case

The project was conducted over 18 months in an 11-18 secondary school in rural Lincolnshire with around 900 students on roll. These students were enrolled in the first (AS) year of a modular biology A-level course, prior to the national changes to linear specifications. The participants for this study were selected purposively, consistent with many IPA studies (Smith, Flowers & Larkin, 2009), on the basis that they might provide a perspective on the particular phenomena being studied. In IPA studies a sample size of between five and ten is common (Smith, 2004). Hefferon and Gil-Rodriguez (2011) recommended four to ten data points for professional doctorates, suggesting that 'fewer participants examined at a greater depth is always preferable to a broader, shallow and simply descriptive analysis of many individuals.' (p. 756). In total, six students took part in the project from a biology class of seven, all of whom were from a White British background and one of which was male. Each of the six participants thereby formed an individual case in relation to the IPA-based analysis within the local context of their class.

Methods of data collection and analysis

The methods of data collection and analysis used were:

- *Reflective diaries:* Each student was issued with a reflective diary within which they were encouraged to record thoughts relating to their learning.
- *Semi-structured interviews:* Students were interviewed in the first term to capture their initial perceptions of transition to A-level study. Further open-

ended interviews were conducted throughout the year, triggered by issues noted in the diaries.

- *Individual/group specification analysis:* In the summer term, participants undertook a specification analysis which involved annotation of the course content with TCF-related coding. This analysis was also used to reflect on during the interviews, prompting recall of encounters with TCs.
- *Analytical framework:* Data from interviews were analysed using IPA techniques, involving line-by-line consideration of the experiential dialogue of each participant's responses in turn, through an exploratory examination of semantic content and language use. Emergent themes were then identified and refined through subsequent recursive analysis.

Results

The findings are presented thematically in two subsections, illustrating how the longitudinal research design surfaced transformation through students' encounters with TCs. The first subsection highlights how students developed their awareness of the integrative nature of knowledge structures within biology, whilst the second explores their transformed discourse alongside a shifting sense of community and identity.

Integrative awakenings - thresholds coming into view

The transition from GCSE to A-level study raised several issues for the students in this research, causing discomfort and surprise as they wrestled with adapting to new ways of working and increased demands. Each of the participants relayed examples of topics, concepts and knowledge that they found difficult to grasp, for different reasons. Some of these examples exhibited characteristics of threshold concepts, particularly in terms of their integrative nature, and how students made sense of the interrelatedness of

concepts within the subject. Anna noted how her awareness of this integration developed when she reflected back over the year:

> It's kind of gradual for me…I have never particularly had those sorts of moments, but I know there has been obviously people that do because they suddenly understand it and you're like…oh okay…it always takes me a while just to get my head around it…but as long as I keep going back to it I can link bits together and different bits of modules and concepts I can say 'ooh' that links to this… when I do that it doesn't leave my head, it will stay in there. (Anna, 3rd interview)

The final part of this account from Anna is indicative of the integrative characteristic of a TC, where she recalls going back to a concept and linking it with other aspects of knowledge. Her account is fascinating in surfacing the excitement she experienced as she recalled discovering that she can link concepts together as part of a fluctuating and messy journey. Development of students' metacognitive awareness is apparent when comparing initial observations with later reflections, as with Liam who began to see the integrative nature of concepts in the subject early on in the year.

> I just kind of saw that there was reactions going on so like the haemoglobin would attach because of an affinity level because there was more oxygen it would attach and then the carbon dioxide has a greater affinity than the oxygen so that would join instead…I can sort of see how things are starting to make sense next to each other, but it's still really hazy. (Liam, 1st interview).

Over time, Liam appeared much more confident and was able to identify how his growing understanding in the subject had allowed him to develop the capacity to make links within his own cognitive knowledge structures:

> It was almost like a three-dimensional jigsaw…I was just putting bits together and I just realised actually that bit can go there, it goes better and I will move that bit somewhere else. It is all just like…one big jigsaw in my mind that I am putting

> together bit by bit and moving bits around to see where they fit. (Liam, 2nd interview)

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

In relation to specific examples of concepts that emerged from the research, Yasmin discusses how the increase in complexity related to cell structure from GCSE presented difficulty for her:

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

In this interview, near the start of the year, Yasmin was seemingly overwhelmed by the volume of content, new language and detail that A-level study required. However, in a later interview, she was able to reflect back on the importance of understanding cell structure as a central concept which integrated many other areas of the subject:

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

This account highlights the importance of cell structure in transforming Yasmin's ability to see links to other aspects of the subject, a feeling shared by other students,

who also pinpointed cells as being central to their understanding of a range of other topics, like Erin, who also began to see how connections were emerging early on in the course:

> The movement of sucrose in the phloem of plants…that's pretty confusing because there's lots of things about active transport and that brings in things we learned about cells so there's a connection…erm…but basically it's…I don't know. (Erin, 1st interview)

When asked to reflect back on her earlier struggles, Erin discussed how she could understand the movement of sugars much more clearly once she had a secure grasp of cell structure and membrane function:

> So, yeah, cells and how they are made up, like the structure of cells…if you don't understand about the plasma membrane then you're not going to get active transport because that's about moving things across the plasma membrane against the concentration gradient, so if you don't know the bare basics…about the thing that you are studying, how are you supposed to understand how substances are transported across it if you don't understand what it is? (Erin, 3rd interview)

Erin's account also highlights the role of the basic understanding of cells in opening up ways of seeing and learning other biological processes. In many ways, she presents this as a foundation of other subject content. However, one of the contrasts to emerge from the findings was how students viewed concepts in biology as a series of linear, or hierarchical 'building blocks' at the start of the course, versus a messier, interconnected network as the year progressed. The following explanation from Yasmin illustrates her reflections on how she perceived the concepts to act in an integrative way:

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

> that. It's more like two or three concepts help you with one hard topic and they overlap. (Yasmin, 3rd interview)

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

> Well, I know they all link together …sort of…I can see that already, like how we did the fluid mosaic model, which I still don't understand. It's like the cell membrane and how it's made and what it's made of and like there's loads of things that go in it, like there's channel proteins, and there's cholesterol on it and there's all these different things, glycoproteins, glyco…something else and it's…what all of them do. But I guess I thought it would be more of a steady learning curve, like one thing would follow another. (Anna, 1st interview)

In the final interview, Anna was asked to reflect back on her early thoughts about her expectations that her understanding would be more progressive and linear:

> So I guess it's more messy like a load of things all stirred up together. But I think that's just the nature of this course, having like the mess, the way everything links into each other. (Anna, 3rd interview)

Anna's description of the relationships between concepts conjures up images of a bowl of spaghetti, all stirred up and messy, with links being made which are hidden from view until they become uncovered by digging into them. These accounts demonstrate growing awareness of the structure of knowledge and relationships between concepts within the discipline.

The interrelated nature of concepts across disciplines was also apparent within the findings: all three students who were not studying chemistry identified the biochemistry aspect of biology as a particularly troublesome aspect of the course, whilst the others highlighted it as integrative, but only one suggested that it was troublesome. The reasons for this appear to lie in how specific concepts covered in chemistry played a key role in helping them to make sense of biological knowledge structures:

> I think especially how haemoglobin attaches itself and all of this conversion. That knowledge kind of helped me understand other knowledge. Cos I kind of never related reactions going on in biology and after looking at that I kind of understood the bonding because of chemistry. (Liam, 1st interview)

Liam demonstrates here a growing awareness of how concepts link across disciplines. In a similar way, Erin highlighted just how important an understanding of chemical bonds was to allow her to more easily grasp the concept of cohesion tension theory:

> The cohesion tension theory is about like…you have got massive trees in the rainforest…how does the water get to the leaves?...Knowing about water from chemistry helps…obviously as water evaporates from the leaves on the trees all of the water is joined together because of the polar bonds between the molecules…which are permanent, so the delta-positive and delta-negative charges of the hydrogens and the oxygens as they attract each other then all the water gets joined together in a chain so as it evaporates at the top, it pulls all of it in a stream…all the way from the roots. They lose water at the top, but replace it at the bottom, through the roots. It's clever! (Erin, 2nd interview)

She was keen to explain this particular example and explain how she had come to realise the importance of the integration of knowledge across subject divides. For those who did not study chemistry as well as biology, this awareness was not evident in the interviews, but Yasmin, who did study both subjects, was able to explain how that integrative prior knowledge had allowed her to generate a deeper understanding, rather

than just accepting it at face value:

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

Transformed identity and disciplinary language

Throughout the year students alluded to experiencing a shift in their identity, initially being aware of becoming part of the Sixth Form. Within this, growing awareness of community membership of the biology group emerged from discussions. This response from Liam surfaces strong feelings of collaboration:

> We work quite well together as a group. We are quite a small class and we have to help each other out. I would like to say we are kind of doing the A-levels as a team instead of just doing them yourself…other people would start walking off because they didn't know what we were saying. It sort of makes you realise you are part of that group and you all have something in common that they don't have or…understand. (Liam, 1st interview)

As Liam exemplifies, when asked about what makes such strong bonds between members of the biology group, students identified language as a key feature which defined the boundaries of membership and created a feeling of belonging that other students could not achieve. This resonates with the discursive nature of TC acquisition and the development of transformed language use. Community membership also appeared to be accompanied by a strong affective dimension. Here, Erin summarises of her experience of talking to her friend about biological processes:

> For her it was really just like a foreign language where you know some of the words but a lot of them just mean absolutely nothing [laughs]. And it makes you

> feel really…clever I guess 'cause you understand it and they don't. But then it can be a bit isolated when you need to talk to someone about it. (Erin, 2nd interview)

She alludes to a feeling of superiority and satisfaction at realising she has knowledge that others do not possess, but also acknowledges how isolating this can be. In this respect, membership of a community of practice can both empower but also alienate from others who are outside that community. Disciplinary language presented as troublesome for all of the students, for different reasons. Anna highlights here how the similarity of scientific words caused her issues initially:

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

Later in the year it was clear that Anna had come to terms with the prevalence of troublesome language and found coping strategies. However, she also discussed how she felt more confident in her understanding of the science behind the terms. The following extract suggests that Anna's developing understanding of scientific discourse is interdependent with her increasingly integrated knowledge structure.

> So if you don't understand what they are by just remembering it you can kind of get it by working out by what the word is saying…so like…glycogenesis…genesis is creation, glyco is glycogen, therefore…creation of glycogen. I sort of do that in my head really quickly now, it's all part of getting better at biology and…but you can't do that until you know what the different parts are…what they mean and how they link. I couldn't do that at the start, I had to just learn them. (Anna, 3rd interview)

Whereas in the early stages of transition students indicated they were aware of becoming part of the sixth form community, later in the year it was apparent that they were not only adapting to the change but were starting to look ahead, considering their

futures and the transition to university and careers. When asked specifically about how far along they saw themselves in this journey, links with the literature on communities of practice began to emerge, specifically relating to becoming a scientist.

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

For some students, like Liam, the prospect of evolving into this new identity was a clear possibility, whilst for others, the thought of specialisation was a step too far, even at the end of the year. However, despite most of the group stating that they were a long way from entering a scientific community of practice, there was an emerging feeling that they were starting to think like scientists as the year progressed:

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

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

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

Along with the notion of joining and transitioning between communities of practice, it

also emerged from the interviews that students had developed skills and ways of thinking and practising that had instigated a perceived transformation in their identity, such as becoming a scientist and starting to think like a scientist:

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

Liam's experience was not unique in the group, and other students also highlighted changes in ways of thinking and practising as a result of their transformed view of the subject. Erin started the year feeling overawed by the thought of ever being a scientist, suggesting that this was '…not gonna happen, I am just talking gibberish all the time' (Erin, 1st interview). Her development over the 18 months of the study was quite remarkable, illustrating how changes in understanding and knowledge structures, accompanied by transformed use of scientific language gave her confidence, when asked to revisit her understanding of cells and cell membranes from the first interview:

> You mean the plasma membrane…yeah, it's a partially permeable membrane because small things can pass through it like gases via diffusion or water by osmosis…but active transport is when energy is needed to force things through it basically. And the energy comes from mitochondria within the cells producing ATP to transport things like nitrate ions when you've got transport of sucrose into the phloem…they use energy to actively transport the nitrate ions into the…erm…centre of the phloem…into the cytoplasm…but then that lowers the water potential of the cell. But when water moves because of osmosis it moves from areas of high water potential to areas of low water potential…just like when you've got a diffusion gradient it's from areas of high concentration to low concentration. So with osmosis…if you're actively transporting the nitrate ions in…lowering the water potential in the cell then the water from the outside of it will move in by osmosis…wow, do I sound like a scientist or what? [laughs]. (Erin, 3rd interview)

Discussion

Meyer and Land posited that a TC can be seen as a '...portal, opening up a new and previously inaccessible way of thinking about something.' (2003, p.1). Some consideration has been given in the literature to the theoretical notion of students' initial perceptions and apprehension of this portal (Pang & Meyer, 2010), as well as variation in the starting points of students' knowledge (Land & Meyer, 2010). However, the longitudinal research design employed in this study provides insight into students' lived experiences as they negotiated their way through the liminal space in real-time.

Whilst the increase in difficulty of work clearly came through from students' responses, two of the students needed longer to grasp this, and realisation did not really set in until they were tested under examination conditions, indicating variation in each student's transitional experience, an interesting feature of the longitudinal approach to data collection. Throughout the study, there was also a sense of students' shifting perceptions of where they fit within the group, the wider school community, and their own aspirations for education and future career. In the early days and weeks of study the findings indicated that these students perceived they were becoming A-level students, part of a defined community of practice (Wenger, 2009), within this occupying a micro-community they identified as the biology class itself.

As the year progressed, students acclimatized at different rates, exhibiting transformed ways of perceiving their own position with regard to shifting from member of one community to another, whilst also gaining membership of multiple communities (for example, A-level student, biology student, degree student, scientist or biologist). The changes in identity expounded by students in this study was perceived as arising from changes to ways of thinking and practising within biology, resonating with the assertion of Davies and Mangan (2007. p.712) that these changes shape not only

identity in relation to the current academic community, but in relation to past communities and future communities which individuals may aspire to join.

These findings reflect those of Haji Bungsu (2014), who's participants identified as being on a journey to becoming agriculturists. However, whilst the findings of that research suggested students were beginning to 'feel' like farmers, in my own study, participants mostly reported awareness of becoming scientists with relation to knowledge and language, specifically starting to think and talk like a scientist. This difference may be due in part to the difference in phase, with participants in Haji Bungsu's study being nearer to employment. Figure 1 illustrates my interpretation of the journey for students in my own study through the notion of nested communities and micro-communities, membership of each forming part of a journey within a journey. This diagram also reflects aspects of Wenger's (2009, p.212) social theory of learning, in terms of identity (learning as becoming), but also community (learning as belonging), which surfaced in the findings in relation to feelings of 'isolation from' and 'belonging to' a group.

[Figure 1 near here] - Nested communities and journeys within a journey

At a surface level, language played a key aspect in this feeling of transformed identity early on in the year, as students were establishing their identity as sixth form students and members of the biology class. However, whilst initial encounters with disciplinary language were troublesome, due mainly to the complex nature of biological terms, the longitudinal design also illuminated findings showing development in metacognition and ability to make links between aspects of disciplinary knowledge leading to transformed use of language, and confidence in becoming a scientist. These developing knowledge structures and awareness helped students to make sense of words

and underlying meaning, as well as playing a role in establishing the boundaries of their community.

Cousin (2010, p.2) argued that the true nature of TCs manifests itself through altered behaviour, and that 'we are what we know'. Barradell and Peseta (2014, p.263) considered the transformed behaviour exhibited by learners as inherently linked to the bounded nature of a TC and therefore the subject content and curricula which defines and demarcates a community. Whilst I agree with this assertion in that each micro-community is defined to some extent by the body of knowledge within the subject, I would argue that TC learning involves not only understanding of knowledge, but also an altered way of viewing knowledge in the subject landscape (Meyer, 2016), as a result of developing cognitive awareness of the interrelatedness of disciplinary knowledge. The integrative nature of disciplinary concepts linked together by TCs, and students' growing awareness of these networks of interrelated knowledge played a key role in their transformative journeys. Furthermore, the findings presented here also highlight how students were aware of the importance of knowledge structures from other disciplines, such as chemistry, in supporting their development of understanding within biology.

The findings also build on the work of Hernandez-Martinez et al. (2011), who argued that the transition from GCSE to A-level was a question of developing social and academic identity. They posited that their participants saw difficulties with transition as a challenge to be overcome, allowing them to move on, even if this meant realigning their career aspirations and identity. My own research presents similar findings, highlighting social bonds within the micro-community and transformations in students' academic and social identities. The notion of journeys within a journey frames the initial transition from GCSE to A-level as the students embarked on the first year of

study and were increasingly aware of 'becoming'. What these findings therefore contribute to the literature is an original body of evidence which explores the experiences of students through this transitional journey in a secondary school at a very personal level. The findings also support my argument that the transition to A-level was a challenging one for these students, exacerbated by ontological discomfort brought about through the transformative nature of their journey through liminal space and TC acquisition. Evidence of the integrative nature of concepts in biology also surfaced particular concepts as being potential TCs, such as *cell structures*, which all students at some point suggested was pivotal to their understanding in the subject. Whilst initially causing discomfort, acting as an isolated island of knowledge (Taylor, 2006), grasping this particular concept opened up new ways of seeing and understanding other areas of the subject, highlighting the potential of TCs to enable subject mastery and altered ways of viewing disciplinary knowledge structures through their integrative characteristic.

Conclusion

In this paper I have illustrated how the transition from GCSE to A-level can be highly problematic for students, as they grapple with increased workload and pressure alongside shifting notions of identity and community membership. Most significantly, I have argued that encounters with TCs may serve to exacerbate the troublesome nature of their journey through a combination of cognitive and ontological discomfort. The transformative and integrative nature of TCs appear to act as key determinants in how powerfully this discomfort may surface whilst students traverse the liminal space. Grasping the interrelatedness of concepts within and across disciplinary boundaries also acted as an enabler for students. The findings from this small-scale exploratory study, prior to recent GCSE and A-level curricula changes, suggest that there is scope for further research utilising the TCF and the longitudinal design frame employed here to

investigate the existence and impact of TCs in the latest iteration of A-level specifications. Exploring and identifying these networks of disciplinary threshold concepts by teachers and academics has the potential to yield pedagogically productive insights into knowledge structures within A-level specifications. Externalising and sharing these networks with students may well be the key to easing the troublesome nature of their transitional journey from GCSE to A-level.

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