CHAPTER 6

EMBEDDING WIDER THEORY

Threshold Concepts, Semantic Gravity & Punctuated Learning

INTRODUCTION

The development of concept mapping (unlike many other classroom tools and study aids) is underpinned by a robust theoretical framework, based on the learning psychology of Ausubel's assimilation theory of learning (Novak & Cañas, 2006). After its emergence in the 1970s, concept mapping has been applied to learning in a wide variety of disciplines, and from primary, secondary and higher education to business and military strategy (e.g. Novak, 2010; Rasmussen et al., 2009). During a period of consolidation, stimulated by the release of 'cmaptools' that allowed concept maps to be drawn digitally and shared online followed by a series of international concept mapping conferences, the application of concept maps in teaching has moved from the fringes of education to part of the mainstream (Figure 31).

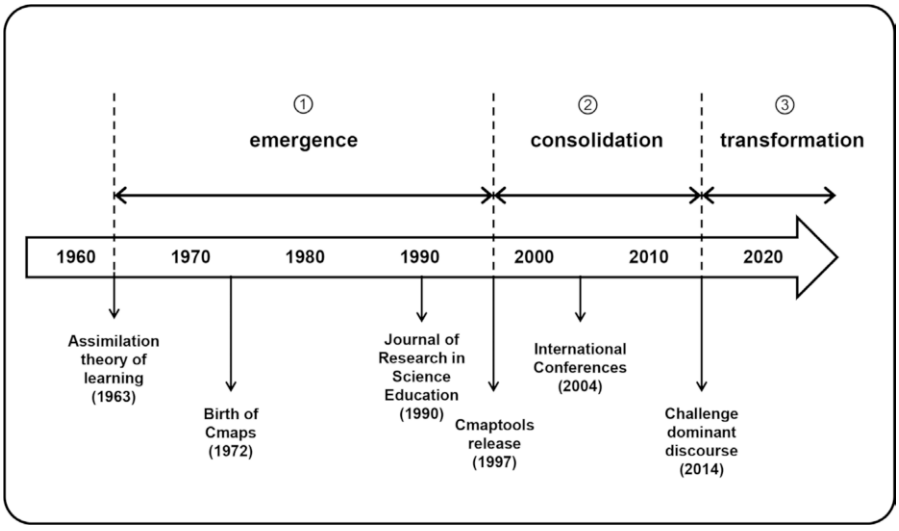

Figure 31. Historical development of concept mapping from the 60s to today (From Kinchin, 2015; redrawn and modified from Cordeiro et al., 2012)

During the 'emergence' and 'consolidation' phases of the evolution of concept mapping, the tool has been used largely to map content rather than to investigate the discourses that underpin the teaching of that content, or in the development of pedagogic theory. As such, concept mapping research has tried to fit in with the dominant discourses in order to gain recognition as providing a credible contribution to the study of student learning. However, it has been suggested more recently that academics should challenge the dominant discourses in education through the application of concept mapping by integrating the tool with contemporary educational theories from both the psychology and the sociology of education. This third phase (transformation) is likely to see concept mapping studies that upset the *status quo* and ask awkward questions about issues that seem to be taken for granted within university curricula (Kinchin, 2015).

VISUALISING THEORY & DEVELOPING THEORY

One of the problems encountered by new entrants into the teaching profession in higher education is the fragmented nature of educational research (coming from various research traditions such as the sociology or psychology of education) and the resulting '*fractured discourses*' that have developed alongside the research (Ashwin et al., 2015). This tends to deter academics in other disciplines from delving into the educational research literature, and so prevents their teaching from benefiting from the latest pedagogic research – despite the ubiquitous claim that universities are engaged in research-led teaching.

Attempts to visualise existing theories through their impact on knowledge structures provides an alternative (or more correctly, a complementary method) to investigating through text alone. The development of concept maps to summarise texts has all the advantages for scholars of teaching and learning that it has for students of biology, geography or history. One of the problems encountered by scholars, which is identical to the problem encountered by students, is that to visualise or to map a problem takes considerable mental effort. It is much simpler to list attributes of a phenomenon than to produce an integrated map of those same attributes. So whilst scholars may use common terms in their discussions, until we 'see' how they link those terms, we cannot be sure that they are all meaning the same thing. Buckley and Waring (2013) concluded that the amalgamation of text and drawings can act as a powerful tool for the dissemination of complex ideas to critical audiences, but that the use of diagrams still seems to be an area of under-explored potential for the development of theory.

Mapping existing terrain also allows otherwise unknown features to come to the surface. In this way, concept mapping may not only be a way of visualising existing theory to enable verification and dialogue, but it may also help new theoretical perspectives to emerge. This is often as a result of identifying links between ideas that had not been previously made, or by viewing known links from a different perspective.

Finally, the application of knowledge mapping does not rely so much on canonical language. It has therefore helped to find useful overlap between different research traditions across the fractured discourses of education. For example, the links between the psychology of David Ausubel and the sociology of Basil Bernstein (who used very different terminology to explain their theories) are only made clear as a result of recognising overlap in graphic depictions of their work.

THE NATURE OF THRESHOLD CONCEPTS

Threshold concepts are seen as more than just important or difficult ideas within a subject. They provide the gateway between being a novice and (potentially) becoming an expert within a discipline. This view is summarised by Meyer and Land (2003: 1):

> A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress. As a consequence of comprehending a threshold concept there may thus be a transformed internal view of subject matter, subject landscape, or even world view.

The identification of threshold concepts within disciplines has proved to be a difficult task in many cases. This is possibly because the overall structure of many disciplines has not previously been made explicit and because there is so much fragmentation and specialisation within disciplines, that few academics have sufficient overview to identify threshold concepts in the curriculum. Meyer and Land (2003) have identified the key characteristics of threshold concepts that disciplinary experts may use to identify threshold concepts in their own subject areas. Threshold concepts are:

a. *Transformative*, in that once understood, they result in a change in perception of the subject that may involve a shift in values or attitudes as well as in understanding. A threshold concept may also involve a performative element as an increase in confidence can lead to an enhanced appreciation of what has to be done. For example, this might be seen in terms of enhanced performance in sports, or increased competence within clinical practice.
b. Probably *irreversible*, in that the change of perspective that results from acquisition of a threshold concept is unlikely to be forgotten. Meyer and Land (2003) consider responses from their studies that point to the difficulty experienced by expert practitioners looking back across thresholds they have personally long since crossed. Attempting to understand (from their own transformed perspective) the difficulties faced from (untransformed) student perspectives is difficult. This links to the comments made by Fontaine (2002) about the need for teachers to maintain a novice's view of their subject in order to be able to teach it in a way that students can access.

c. *Integrative*; exposing the previously hidden interrelatedness of something that may represent a key component of a discourse within a community of practice. As such, the threshold concept may not always appear front-and-centre within a curriculum as it may be seen by the experts within that discipline to be 'a given' that simply underpins everything else. This makes it even more difficult for the novice student to recognise its importance within their studies as it may not be verbalised explicitly, but may form part of the tacit knowledge of the discipline. The nature of a threshold concept may vary depending on the structure of the discipline in question. Within the sciences which are generally seen to develop very hierarchical structure (Donald, 2002), a single threshold concept may be considered for the discipline. So, for example, given his assertion that '*nothing in biology makes sense, except in the light of evolution*', Dobzhansky (1973) seemed to be anticipating the notion of threshold concepts and make a claim for evolution being the leading candidate in the field of biology. Whilst evolution is a key component of the discourse within the community of biologists (often assumed as a 'given' within the discipline), the reach of the concept goes beyond biology and extends into other cultural contexts (Anderson, 2007). In such contexts, the concept may 'lose' its 'threshold' status.
d. Possibly (though not always) *bounded* in that any conceptual space will have terminal frontiers, bordering with thresholds into new conceptual areas. Whilst some subject areas have well demarcated boundaries (e.g. physics), others will have much weaker boundaries (e.g. education, sociology) as they have to overlap with other disciplines and listen to other voices (Wignell, 2007). In order to relate to a variety of other related disciplines, subjects exhibiting weak boundaries may have to accommodate linear and hierarchical models, with the threshold concepts taking on the role of integrating the two. In the case of 'caring' within the clinical sciences (e.g. Clouder, 2005), the concept may link the salient points of the personal perspective (patient-centred discourse) with the biomedical (treatment) discourse (Figure 32).

Here 'care' is seen to occupy the space that links caring as a therapeutic intervention (to the left) and caring as the nurse-patient interpersonal relationship (to the right), as described by Morse et al. (1990). This positioning enables the carer and the patient to be active partners in linking the chains of clinical practice with the networks of understanding that relate to the patient's wider needs. The key factor within this model is the 'care' that includes consultation with the patient and carer that allows them to relate the two halves of the model – something that is required for learner agency (Kinchin & Wilkinson, 2016).

THE ROLE OF THRESHOLD CONCEPTS

The central role of threshold concepts opens up a range of possibilities and challenges for teaching in higher education. If the failure to acquire the threshold

concept within a discipline means the learner cannot progress, then this may present a bottleneck for further learning. If students do not really understand what is being presented in a meaningful way, they will have to resort to rote learning, raising the spectre of non-learning as the norm (Kinchin, Lygo-Baker, & Hay, 2008). A further question then arises about the positioning of threshold concepts within the curriculum. Should they be introduced early in the curriculum in order to provide a framework for other ideas, or do they depend on the application of factual knowledge that needs to be acquired in advance. In either case, the position of threshold concepts needs to be considered at an early stage of curriculum design (e.g. Loertscher, 2011).

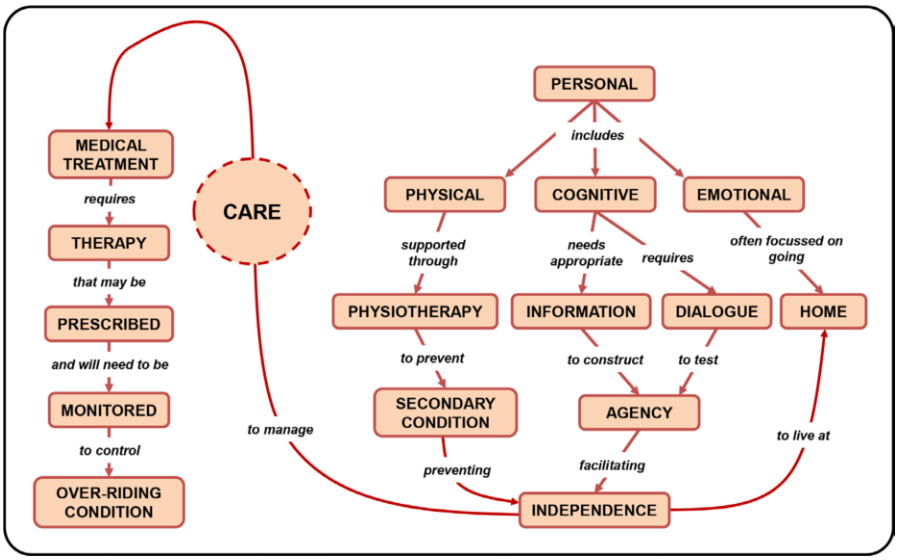

Figure 32. Chain of medical treatment (the health professional focus) juxtaposed against the network of personal understanding (the patient/carer focus). Care is seen to link the two perspectives (From Kinchin & Wilkinson, 2016)

Davies and Mangan (2007) have identified three important implications for teaching that stem from a consideration of threshold concepts:

1. The successful sequencing of threshold concepts requires that students have sufficient related prior knowledge for the threshold concept to have an integrative function. In other words, for integration to happen, students need the appropriate cognitive 'raw materials' to work with. Therefore, the curriculum needs to provide opportunities for segmental and cumulative learning in ways that will allow the two to be complementary (Maton, 2009).
2. The benefits of spending time on integrating prior understanding are likely to exceed the benefits of acquiring new knowledge that may remain isolated and

unconnected. The degree of connectedness is an important issue that needs to be addressed when designing a curriculum to support the students' construction of productive knowledge structures (Kinchin, Lygo-Baker, & Hay, 2008). This provides an argument for not overloading the curriculum with content.

3. The devices used by experts to define and interpret problems in the context of their wider understanding often remain implicit in the course of teaching. By making the links explicit between expert understanding and teaching sequences, the process of theorising can be modelled for students, so they can themselves start to think like disciplinary experts.

Barradell and Kennedy-Jones (2015: 538) see threshold concepts as a tool to help academics '*engage more comfortably with the teaching and learning discourse*', whilst Entwistle (2008: 30) has commented that introducing the notion of threshold concepts to teachers seems to '*open up their thinking about the nature of knowledge*' so that '*threshold concepts act as a threshold concept about teaching and learning*'. As such, discussion about threshold concepts can have an integrative and transformative influence on the development of teaching practice, for example helping teachers to view students as producers of personal understanding rather than consumers of accepted information (e.g. Gamache, 2002). In order to open up this thinking, there is an obligation upon discipline specialists to demonstrate their expertise by identifying the threshold concepts in their disciplines. This will then allow an interrogation of the field of study through a critically reflective process, '*to question pedagogical practices, teaching methodologies and domain content to uncover the tacit processes that students must be privy to so that they can 'crack the code' of their learning*' (Behari-Leak & Williams, 2011: 11).

Meyer and Land (2003: 5) comment that '*given the centrality of such concepts within sequences of learning and curricular structures their troublesomeness for students assumes significant pedagogical importance*'. Knowledge is referred to as troublesome for different reasons by Perkins (1999; 2006). It may be seen as ritual knowledge (that forms part of the routine of the discipline, but whose underlying meaning may remain opaque to the novice observer); inert knowledge (that may remain isolated and disconnected from real-world problems); conceptually difficult knowledge (that is hard to grasp and whose acquisition may be impeded by commonly held misconceptions); alien knowledge (which comes from a perspective that is not held by the student and may be counter-intuitive); tacit knowledge that can remain hidden from view and is rarely verbalised, even by experts in the discipline; and linguistically inaccessible knowledge where disciplines utilise specialist terminology, or jargon, to help brevity in communicating complex ideas within the community, but which may exclude 'outsiders' from that community. Evidently, many instances of troublesome knowledge will feature overlap in these forms of troublesomeness, with some characteristics creating more 'trouble' for some students than for others, depending on the nature of the prior knowledge that the student is able to bring to bear on the situation.

FROM CONSUMPTION TO PRODUCTION & TRANSFORMATION – AN ANALOGY

Analogies are often helpful in making a point. Here I describe the learning of photosynthesis as an analogy for the kind of conceptual shift that is required among university teachers to consider the full benefit of the knowledge structures approach to teaching and learning.

Within secondary science education, photosynthesis is known to be a 'troublesome' topic within the curriculum for a whole variety of reasons (see Driver et al., 1994, for a review). Taylor (2006: 90) comments that '*students will memorise details of the process of photosynthesis rather than take the opportunity to think, in a holistic framework, about the significance of photosynthesis*'. Students who have learned details of photosynthesis by rote are able to switch between frameworks to suit the context (Kinchin, 2000b), with students answering an examination question saying that plants make food using sunlight, only to tell you later that in their garden at home, plants absorb food from the soil. The elements that compose photosynthesis and combine to make it a difficult topic for students have been identified, but are considered in a manner that infers equal importance in gaining an overall picture of the topic (e.g. Kinchin, 2000a). In order to fully appreciate photosynthesis, students have to disengage from the common belief that plants fundamentally act like animals and consume food from their environment. The concept of production in photosynthesis is one that needs to be acquired. However, even this is insufficient for the student of biology to appreciate the dynamic role of photosynthesis. Both production and consumption suggest a linear process. Carlsson (2002a, 2002b) has demonstrated how an understanding of photosynthesis in terms of transformation is required to be able to place photosynthesis in context alongside other non-linear environmental processes.

This shift in ecological understanding from a consumption model to a production model is troublesome for many students, but once grasped is transformative, not only of plant nutrition but also of the wider understanding required to appreciate the energetics of ecosystems. This is analogous with a shift in teachers' perspectives from students as consumers to students as producers, and eventually to students as transformers of knowledge. The concept of dynamic transformation may provide a threshold to the understanding of photosynthesis and other biological processes as well as of learning processes. Dynamic transformation is not a concept that would immediately spring to the minds of most biology teachers. The tacit nature of many threshold concepts is predicted by Ross et al. (2010: 170) who emphasise that '*while academics and teachers identify content knowledge as troublesome or problematic, the threshold concepts which underlie the difficulty receive the least attention in teaching*'. Similarly, the transformation of knowledge receives little consideration in the typical university curriculum, in which 'students-as-producers' is still seen as an innovative pedagogic stance. Moving from the linear consumer-producer dichotomy towards a non-linear 'student-as-transformer' model will require continued effort, and will challenge the commodification of education (Land, 2016).

CHAPTER 6

SEMANTIC GRAVITY

One of the most well-developed conceptual frameworks for the generic consideration of the variation in knowledge structures is that based on Bernstein's sociology of education (Bernstein, 1999, 2000). Bernstein describes '*horizontal knowledge structures*' and '*hierarchical knowledge structures*'. When elaborating upon horizontal knowledge, Bernstein (2000: 159) refers to a '*segmental organisation*' in which '*there is no necessary relation between what is learned in different segments*'. This resonates with the recognition of rote learning of content without understanding. In contrast to horizontal structures, Bernstein (2000: 161) sees hierarchical knowledge structures as attempting '*to create very general propositions and theories, which integrate knowledge at lower levels and in this way show underlying uniformities across an expanding range of apparently different phenomena*'. This resonates with the view of integrated expert knowledge structures that are often hierarchical in structure (Bradley, Paul, & Seeman, 2006).

Bernstein's work has been developed by Maton (2009) to consider how '*curriculum structures play a role in creating conditions for students to experience cumulative learning, where their understandings integrate and subsume previous knowledge, or segmented learning, where new ideas or skills are accumulated alongside rather than build on past knowledge*'. The segmented learning described by Maton equates to a surface approach that on its own would result from the serial acquisition of knowledge chains, ultimately leading to cycles of non-learning (Kinchin, Lygo-Baker, & Hay, 2008). The cumulative learning that is described by Maton equates to the meaningful learning espoused by Novak (2010) that is typically represented by integrated knowledge networks. The combining of hierarchical and linear knowledge structures has been described as a fundamental problem in education (Novak & Symington, 1982) and is considered necessary to develop expertise (Kinchin & Cabot, 2010). Making links between these complementary knowledge structures is therefore a major issue in curriculum design and delivery.

Within this framework, Maton (2014) has developed the concepts of semantic gravity and semantic density which resonate with the knowledge structures approach. Semantic gravity (SG) refers to the '*degree to which meaning relates to its context*' (*ibid*: 129). This may be seen to be relatively stronger (+) or weaker (–) along a continuum. Therefore a concrete example of something tied to a particular context may be seen to exhibit a stronger semantic gravity (SG+) than a more abstract generalisation that may be derived from it (SG–). Importantly, the dynamic nature of semantic gravity needs to be acknowledged so that oscillations between theory and practice, or between principles and examples, can be referred to in terms of weakening (SG↓) or strengthening (SG↑) semantic gravity, depending on the direction of travel. So for example, analysis of political theory followed by description of the practicalities of voting in local elections would be an example of SG↑, whilst fieldwork looking at patterns of banding in snail shells followed by a lecture on the principles of natural selection would be an example of SG↓. Repeated

oscillations back and forth in this way are described by Maton as semantic waves (see Figure 38).

The concept of semantic density (SD) refers to '*the condensation of meaning*' (Maton, 2014: 129) that may be determined by socio-cultural practices, symbols, terms, concepts, phrases, gestures, actions etc. Within specialist texts or practices of a discipline, there are highly nuanced and detailed meanings that are embedded. These are recognised by 'insiders' but may be overlooked by novices who fail to pick up on the appropriate cues. For novices to start to gain access to the richness of understanding, some 'unpacking' is often necessary so that students can make links to at least some parts of the wider body of disciplinary knowledge. This is also complicated where some terms cross into everyday discourses. So from the ecological analogy given above, the everyday use of 'plant food' has a low semantic density, however, in the more scientific context of photosynthesis, 'plant food' can be further unpacked to reveal understanding about soluble minerals and their active transport across cell membranes that allows them to fulfil their role in the biochemical processes of photosynthesis. So in the right context, the term has greater semantic density.

The relative strengths of semantic gravity and semantic density can vary independently along continua of strengths to form what Maton refers to as a semantic plane (Figure 33). Here the semantic plane has been annotated to suggest the types of knowledge that might be plotted within the quadrants. Practical knowledge (SD– SG+) relates to the competencies that are often described within the disciplines that are tied to a given context (when you see x, you do y) and can be summarized by a linear protocol. This is often the kind of knowledge that is learned in practical exercises that students are then required to link to the theoretical knowledge, (SD+ SG–) that they have obtained from their books and lectures. The successful combination of conceptual and procedural (SD+ SG+), may be seen as the hallmark of professional knowledge in which the links between theory and practice become second nature to the disciplinary expert. The stages of expertise development have been traced against the semantic plane by Shay and Steyn (2016), who see the novice-beginner occupying the top left quadrant and the expert-master occupying the bottom left quadrant of the plane. As a teaching tool within the knowledge structures approach, this becomes more useful if we can visualise the structural arrangements of knowledge that are likely to be found populating the quadrants (Figure 34).

Extending the applicability of this tool beyond its sociological origins, Blackie (2014: 468) has applied the use of the semantic plane to the teaching of Chemistry. By applying the knowledge needed to understand examples such as the dissolution of sodium chloride in water, she has been able to increase her consciousness of the '*kinds of complexity that different sections of chemistry require*' and the '*extent of the leap required by the students at any particular stage*'. The process emphasises the importance to the teacher of moving from the comfort of the top right quadrant of the plane (SG– SD+), which may be a comfortable place for the subject expert, but an intimidating arena for the subject novice. Navigating the semantic plane in this

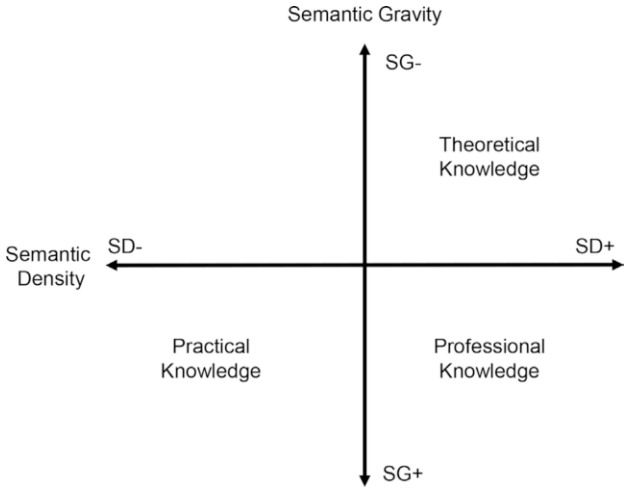

Figure 33. The semantic plane indicating the types of knowledge that may populate the quadrants (After Maton, 2014)

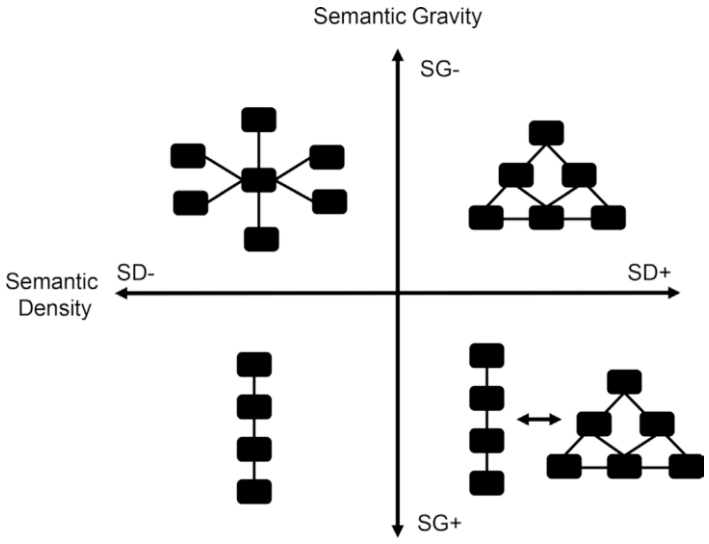

Figure 34. The semantic plane indicating the typical knowledge structures that are likely to populate the quadrants

way provides teachers with a '*way to make the organising principles of knowledge visible to students through explicitly teaching discipline-specific language resources that create and shape the knowledge of their disciplines*' (Macnaught et al.,

2013: 61). As such, it may provide a route for the navigation of threshold concepts within a discipline.

As we have seen in the earlier chapters, practical knowledge is often dominated by chains of practice, whereas theoretical knowledge is more likely to be structured as an integrated network of understanding. The professional knowledge that is needed to function as an expert in many fields requires the individual to oscillate between the chains and networks (Figure 28), allowing an apparently simultaneous access to theory and practice. It may therefore be more 'correct' to say that these expert individuals oscillate between the practical and theoretical quadrants, but as structural shorthand here, it makes practical sense to consider the professional knowledge to exhibit high semantic density and high semantic gravity, as appropriate. The region of the plane that describes low semantic density (relatively little information held), and low semantic gravity (not linked with a particular context) to describe the novice who has not yet gained any degree of competence in the discipline. This is most likely to be depicted by a spoke – type concept map. I have to acknowledge that these are extreme structural types and most of the maps that are observed will tend to offer mixtures of the main morphological types shown here.

LEARNING AS CHANGE

In learning, it is the change, the dynamism between knowledge structures that is of greatest interest. Therefore, the transitions between structures as learning progresses and as the student moves between learning contexts should be the focus of attention. The cycles between the linear and the hierarchical (described by Novak & Symington, 1982) and the movements across the semantic plane (Maton, 2014) resonate with the cycle of experiential learning developed by Kolb (1984). Kolb described a cycle of experiential learning in which the abstract conceptualisation creates hierarchical knowledge structures and concrete experience creates linear structures. The passage between these two complementary structures would be undertaken through periods of active experimentation and reflective observation.

Kolb's cycle has been particularly popular within the educational literature and its simple visualisation appears to make it accessible to many who are embarking upon scholarly reflections of their teaching. Engeström and Sannino (2012: 49) consider the frequency of this continual reproduction and simplification to '*testify to a widespread wish to find genuinely dynamic process models of learning*.' I am happy to support this goal and the simplification of Kolb's cycle in Figure 35, may be a starting point for many before considering the more complex double Kolb cycle presented in Chapter 1. However, a limitation of this cyclic view is that it suggests that learning proceeds at an even and gradual pace as the student makes the transitions around the cycle. In practice, this is often seen not to be the case, with learning observed to occur in fits and starts.

The importance of change is emphasised by Dall'Alba and Sandberg (1996: 422) who consider the development of competence for professional practice to require

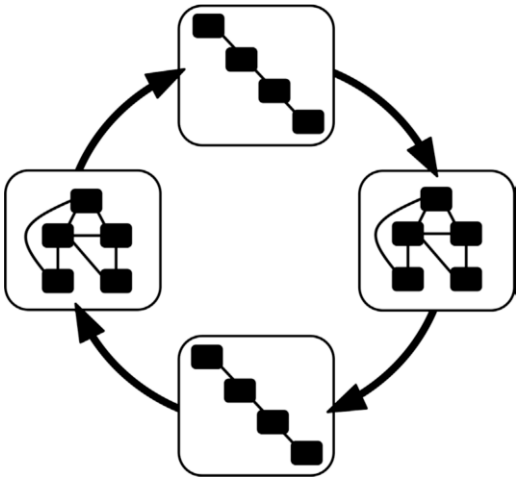

Figure 35. A typical learning cycle in which the learner passes through repeated episodes of linear and hierarchical knowledge construction

more than just the acquisition of new knowledge, but '*change in the structure of meaning*' so that the practice evolves as learning progresses. This change can be visualised by concept mapping the evolution of hierarchical structures through cycles of learning (Figure 35).

PUNCTUATED LEARNING

The punctuated pattern of student learning has been hiding in plain sight. Whilst curriculum documentation seemed to assume that student learning occurs in an even and gradual manner, it is evident to anyone who has worked in a classroom that there are periods where students don't seem to be making any progress and short bursts of activity where progress is rapid (Figure 36). The term 'punctuated' is borrowed from evolutionary biology, where Gould (1993; 2002) explains the textual silence in the world of palaeontology around the evolutionary stasis that was evident to anyone examining the fossil record. The palaeontology literature tended to focus on the comparatively brief moments of change that could be documented, rather than the longer periods of stasis, as it is a more interesting story to tell. Similarly, the educational research literature on conceptual change is extensive, but there is almost nothing documenting the occurrence of conceptual stasis or what happens 'beneath the surface' during these periods.

Gould (2002: 957) comments on the similarities between his work on the development of the concept of punctuated equilibrium in evolutionary biology with his observations on the nature of human learning, '*only years later ... did I*

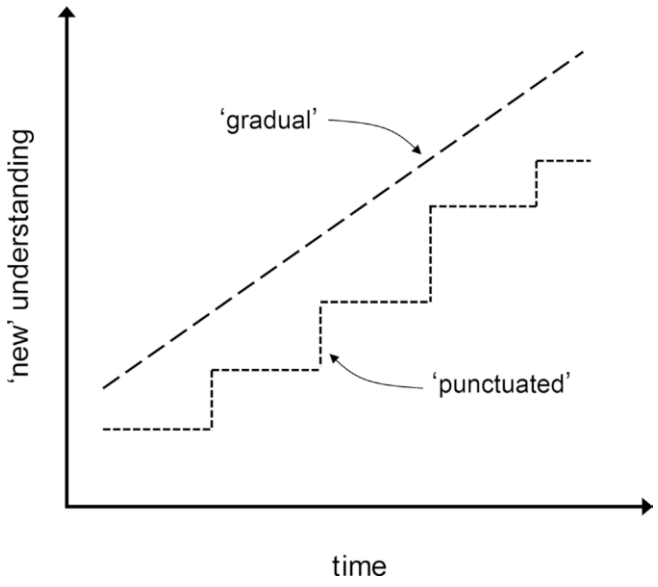

Figure 36. Patterns of learning (gradual vs. punctuated), in which long periods of conceptual stasis are punctuated by brief moments of insight

conceptualise the possibility that plateaus of stagnation and bursts of achievement might express a standard pattern for human learning.' This has been developed into a punctuated model of conceptual change by Mintzes and Quinn (2007) who have recognised the long periods of stasis that are punctuated by explosive bursts of knowledge construction. Because of the focus on conceptual change within the research literature, we know relatively little about what goes on in the minds of students during the periods of stasis. We can only speculate at the moment that at least some of the time whilst the students are experiencing conceptual stasis, students are acquiring information that may contribute to an emerging knowledge structure.

Mintzes and Quinn (2007: 303) have identified a number of characteristics of a curriculum that acknowledges the role of punctuated learning:

1. It would be founded on the principle that significant strides in learning are highly individualistic and idiosyncratic.
2. It would acknowledge significant differences among students in the structure of their prior knowledge.
3. It might offer different benchmarks for different students.
4. It would emphasize meaningful learning, knowledge re-structuring and conceptual understanding rather than 'covering material'.
5. It would emphasize formative and diagnostic assessment rather than evaluation of student performance at pre-determined times for the purposes of 'accountability'.

A number of these ideas have been explored in the literature, but usually in isolation. In order for these factors to be researched effectively in an ecologically valid environment, they need to be considered as interrelated factors which offer a combined curriculum view.

IN CONCLUSION

The ideas of threshold concepts, semantic gravity and punctuated learning combine to reinforce each other and to inform the knowledge structures approach that enables us to visualise the development of the expert student (Figure 3). Some parts of a student's knowledge structure are more important than others and it is crucial that these are identified within the curriculum so they may receive appropriate attention. Rather than seeing the theoretical perspectives explored here as isolated, the knowledge structures perspective employs them as complementary in the way that can inform the emerging adaptive expertise of university teachers and a basis for academic faculty development – explored further in Chapter 8.

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