Solving Cordelia’s Dilemma: threshold concepts within a punctuated model of learning

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Introduction

The idea of Cordelia’s Dilemma (Gould, 1993) is taken from Shakespeare’s King Lear in which Lear’s daughters, Goneril and Regan, attempt to gain their father’s favour by proclaiming their love for him in increasingly false and enthusiastic tones. Lear’s third daughter, Cordelia, refuses to play the same dishonest game of offering false praise for financial gain, and so says nothing in the belief that her silence would indicate that her love for her father was deeper than any verbal expression could convey. However, this is misinterpreted by her father who cuts her off of his inheritance. While Cordelia’s response (silence) was technically appropriate, it was interpreted by Lear as no response at all. Her dilemma was therefore, either to respond inappropriately to placate her audience or to respond appropriately, but be misinterpreted as the audience was working within a different framework. This idea has been applied to the workings of the scientific community:

“Cordelia’s Dilemma arises in science when an important (and often predominant) signal from nature isn’t seen or reported at all because scientists read the pattern as ‘no data’, literally as nothing at all.” (Gould, 2002: 765)

Cordelia’s Dilemma was discussed by Gould (1993, 2002) as part of his explanation for the ‘textual silence’ exhibited in the palaeontology literature in its neglect of the widely observed phenomenon of stasis within the fossil record. The lack of documented commentary on stasis was interpreted by the community as an indication of the idea’s lack of significance.

This status of ‘hidden in plain sight’ that Gould describes for the stasis that exists within the fossil record is also applicable to the periods of conceptual stasis within student learning. While there is extensive discussion in the literature that describes students’ reluctance to relinquish misconceptions (see Carmichael et al. 1990, Dreyer et al. 1994, Plumb and Dunn, 1994, Wandersee et al. 1994, for reviews), this is typically framed in terms of students’ failure to grasp accepted views rather than as a necessary part of their learning journey. The literature focuses on the comparatively brief moments of change rather than the longer periods of stasis, as it is seen as a more interesting story to tell.

Gould comments on the similarities between his work on the development of the concept of punctuated equilibrium in evolutionary biology with his observations in the nature of human learning:

“Only years later … did I conceptualise the possibility that plateaus of stagnation and bursts of achievement might express a standard pattern for human learning” (Gould, 2002: 957).

This has been developed into a punctuated model of conceptual change by Mintzes and Quinn (2007):

“… conceptual change in science is most probably not a steady, gradual, and regular phenomenon, but instead it is marked by long periods of stasis and/or
Threshold concepts

There is an emerging theoretical framework, supporting a review of educational research and practice, that considers some key concepts within a discipline as threshold concepts that need to be passed before a student can develop his/her understanding beyond a novice level (e.g. Lucas and Madenovic, 2007, Entwistle, 2008). Meyer and Land (2006) consider a threshold concept to be:

“...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.”

Meyer and Land offer a number of characteristics of threshold concepts that distinguish them from other important ideas within a discipline. Threshold concepts are likely to be;

- Transformative: they result in a change in perception of a subject and may involve a shift in values or attitudes.
- Irreversible: the resulting change is unlikely to be forgotten.
- Integrative: it exposes a previously hidden ‘interrelatedness’ of other concepts within the discipline.
- Bounded: it serves to define disciplinary areas or to define academic boundaries.
- Potentially troublesome: students may have difficulty coping with the new perspective that is offered.

Threshold concepts within biology are still to be charted. The nature of these concepts and the relationships between them is likely to be the subject of debate as the curriculum is reconsidered in terms of ‘thresholds to be crossed’ rather than ‘content to be covered’ (Mintzes and Quinn, 2007). It is also likely that threshold concepts will start to be recognised as constructing a web within the discipline (Sousa Davies and Mangan, 2007) that will emphasise the interconnectedness between elements of the subject. Some of these threshold concepts will then be seen as subordinates to others (Figure 2).

Implications for teaching

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
   - 1.1 The disciplinary threshold – evolution
       When Theodosius Dobzhansky made his much cited comment that “nothing in biology makes sense except in the light of evolution” (e.g. Dobzhansky, 1973), he seems to have anticipated the notion of a threshold concept as one that both transforms and integrates the understanding of other ideas in biology. We can consider evolution against the criteria for threshold concepts given by Meyer and Land (2003, 2006), that they should be transformative, irreversible, integrative, bounded and troublesome. The idea that the living world is a dynamic and changing system is at once transformative and troublesome. For many evolutionary theory appears to conflict with other culturally held beliefs (i.e. religious beliefs), and may also be seen as counterintuitive – running against everyday experience – for example because of the timeframes involved in evolutionary change. Evolution has an integrative function in biology. An understanding of evolution brings the discipline together at all levels of focus from biochemistry to ecology. The criterion of boundedness may be more problematic than the other criteria of a threshold concept. The limits of Biology can be set as that which is physically influenced by evolution. However, the cultural context for understanding evolution requires that it interacts with ideas beyond the scope of biology (Anderson, 2007). At the macro level of the entire discipline of biology, it would seem that evolution is the disciplinary threshold concept that enables individuals, whatever their specialism, to think as biologists.
   - 1.2 A subordinate threshold – the concept of photosynthesis
       Photosynthesis is known to be a troublesome topic within the secondary curriculum for a whole variety of reasons (see Driver et al, 1994 for a review).
       “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, 2008b), with students answering a GCSE 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 comprise 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 for fully to appreciate photosynthesis, students have to disengage from the common belief that plants fundamentally act like animals and so must 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 environmental processes. This shift in 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 energetics of ecosystems. The concept of dynamic transformation may, therefore, provide a threshold to the understanding of photosynthesis and other biological 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) 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”.

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 excessive disconnectedness is an important issue that needs to be addressed when designing a curriculum to support the students’ construction of productive knowledge structures (Kinchin, Kyo-Baker and Hay, 2008). This provides an argument for not overloaded the curriculum with content.
There is an increasing recognition of the significance for student learning of the interactions between complementary knowledge structures in the development of expertise, creative thought and problem-solving abilities (e.g. Kinchin and Cabot, 2010; Vance, Zell and Groves, 2008; Hunter et al., 2008). 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, 2009). 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 notional ‘threshold concept’ within the horizontal structure (Bernstein, 2001: 101, 137). Horizontal knowledge structures as attempting “to create very general propositions and theories, which integrate knowledge at lower levels and in this way show underlying uniformity across a range of apparently different phenomena”. This resonates with the view of integrated expert knowledge structures that are often hierarchical in structure (Bradley, Paul and Seeman, 2008).

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 segment 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 and 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. Combining hierarchical knowledge structures has been described as ‘threshold concepts’ education (Novak and Symington, 1982) and is considered necessary to develop expertise (Kinchin and Cabot, 2010)

Conclusions
One of the strengths of the threshold concepts perspective is that it places subject specialists at the centre of curriculum enquiry (Cousins, 2008) and may therefore help to provide a safe trading zone between disciplinary (biological) discourses and educational discourses. Indeed, JBE 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 and learning’. As such, consideration of threshold concepts in biology may help to have an integrative and transformative influence on the development of the subject. It is also anticipated that biologists familiar with the complexities of punctuated equilibria in evolutionary theory will help to scaffold the conceptual jump to a punctuated model of conceptual change – rather as it appeared to do for Gould (2002).

A consideration of threshold concepts at different levels of resolution (macro and micro) suggests that students need to have crossed many of the macro level thresholds before moving the transition to higher education. These macro threshold concepts are likely to be the core of the secondary school curriculum. The connection of threshold concepts as a web helps to construct an overall structure for the discipline with the concept of evolution forming the overarching connection. Acknowledgement of such a web of thresholds may help to establish greater disciplinary continuity for students moving from secondary school to university.

Threshold concepts provide part of the solution to Cordella’s Dilemma. The thresholds create moments of transformative change whilst the periphery of conceptual change, rather than being ‘nothing’, are required to assemble the structure. Indeed, Wall’s (2006) comment 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 and learning’ is echoed. As such, consideration of threshold concepts in biology may help to have an integrative and transformative influence on the subsequent integration. In non-learning scenarios on the other hand, there is never any explicit intent to facilitate such change and so only the context-specific segmental structures are activated – the complementary hierarchical/ cumulative structures are absent so that students are hindered in their development from novices towards experts.

Cerinically a consideration of threshold concepts will challenge the ways in which we think about learning and teaching biology (Ross et al., 2010), and will have implications for curriculum design and assessment procedures. No doubt there will be considerable discussion and disagreement in the coming years about the nature of threshold concepts in biology, and the candidate concepts will fill the spaces that are currently blank in Figure 2. It may also prompt discussion about the links that can be made between secondary and higher education, in order to ease student transition from school to university.

References