Scale: an epistemological exploration of a threshold concept in biology

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Threshold concepts are defined as having a profound effect on the understanding of a subject since they are transformative in nature and involve an integrative approach to learning (Meyer and Land 2003, 2005). As such they have proved constructive, and challenging, as a key component of reviews of teaching approaches and student learning (Davies and Mangan 2005, Taylor 2008, Taylor and Cope 2007).

We have taken up the challenge of defining threshold concepts in biological sciences and have created a matrix of concepts which underlie the ways of thinking, understanding and practising biology (Ross et al 2010). Such concepts tend to be abstract in nature, and thus inherently more difficult to explain, and include: dynamics, temporal and spatial scale, proportionality, and variation. While developing the matrix we also considered the impact of these concepts on 'being a biologist', and the apparent gulf between biologists and their students in this context. Biologists work with tacit knowledge coupled to an ability to integrate ideas and concepts and in a research culture which requires constant questioning and reconceptualising (Entwistle 2005). Students exist in a huge diversity of liminal states and have no conception of the way in which experts work with their knowledge (Martin and Leuckenhausen 2005, McCune and Hounsell 2005).

There has been considerable discussion of teaching sub-microscopic biology (Vass et al 2000, Tretter and Jones 2003, Ross and Tronson 2007) which provides evidence of students' misconceptions and points to difficulties in incorporating *scale* into thinking about cellular processes. We therefore investigated ways to change our teaching, and improve student learning, working with the concept of scale in a first year course. Our initial intervention, with pre- and post-testing, used animations and visualisations of cellular processes, combined with a control, using animations focusing on learning names of processes. We expected that students in the *scale* intervention would perform better on our questions, but this was not the case. Analysis of responses described extensive variation in the critical features of understanding scale, and showed little integration of concepts, confirming that students were still struggling in a liminal phase. A second intervention included key changes to our approach (Tretter and Jones 2003) such that we have made fewer assumptions about prior knowledge and the ability of students to integrate concepts (Martin and Leuckenhausen 2005). In addition, data collection has been extended to allow students to articulate their understanding, using interviews and group discussions in classes. Animations have also become a focus of discussions with students to determine how the visualisation helps to consolidate understanding of scale (O'Day 2007). Finally, we have introduced a cycle of re-conceptualising the thresholds (Duncan and Reiser 2007) into an online module where we can track students' attempts at answering a series of questions on scale.

Our interventions and methods for measuring student understanding of the concept of scale have provided an interesting insight into the difficulties of using appropriate assessment in our curriculum - assessment which will allow students to articulate their understanding (Lutze-Mann et al 2009), particularly when working with such an abstract concept.

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