Threshold Concepts as Focal Points for Supporting Student Learning

Journal Item

Bioscience Education

ISSN: (Print) 1479-7860 (Online) Journal homepage: http://www.tandfonline.com/loi/rhep19

Threshold Concepts as Focal Points for Supporting Student Learning

Katy Jordan, Frances Tracy & Keith Johnstone

Descriptive Account

Threshold Concepts as Focal Points for Supporting Student Learning

By Katy Jordan [1,2], Frances Tracy[3] and Keith Johnstone[1]

[1]Department of Plant Sciences, University of Cambridge, [2]Centre for Applied Research in Educational Technologies (CARET), University of Cambridge, [3]Faculty of Education, Community and Leisure, Liverpool John Moores University

Date received: 28/11/2010 Date accepted: 27/10/2011

Abstract

The Plant Sciences Pedagogy Project conducted research into undergraduate teaching and learning in the Department of Plant Sciences at the University of Cambridge and has translated the research findings into interventions to improve support for student learning. A key research objective for the project was to investigate how teachers within the Department support student learning in small group tutorials. This was undertaken using questionnaires, focus groups and interviews. During focus groups students reported that they valued tutors who were able to anticipate topics that they found difficult to master. The threshold concepts framework provided a medium for discussion about these troublesome areas in this discipline area and a number of threshold concepts were identified by interviewing teaching staff. The topics that emerged from this were used as focal points for development of new online resources for students. As threshold concepts are typically difficult to teach, they are challenging to one's own practice as a teacher. Threshold concepts may provide a good focus for continuing professional development of teaching staff.

Keywords: Threshold concepts, e-Learning, Educational research, Curriculum design

Introduction

The Plant Sciences Pedagogy Project was funded by the Cambridge-MIT Institute (CMI), and employed two dedicated research associates to carry out educational research within the Plant Sciences setting. The project's aims included conducting research into undergraduate teaching and learning within the Department, and producing novel online resources to support student learning.

The design of the project was cyclical in nature, taking inspiration from the description of 'curriculum action research' by Stenhouse (1978) as illustrated in Figure 1. During the first year the focus was on research into student and staff perceptions of various aspects of teaching within the Department and analysis of the findings to enable the development of new resources. In the second year, interventions were made including the deployment of new resources, and their impact and efficacy was assessed.

The project started by exploring how teachers support students' learning. A mixed-method research approach was used to address this question, utilising a combination of semi-structured staff interviews (to explore beliefs about teaching and learning, and also to identify specific topics most appropriate for additional support), alongside focus groups and surveys with students, and video analysis of small-group teaching. These research activities identified the teaching practices that students value most. One of the key aptitudes for teachers was the ability to recognise and address topics that students find particularly challenging to learn (Carmichael *et al*., 2006; Carmichael *et al*., 2007a).

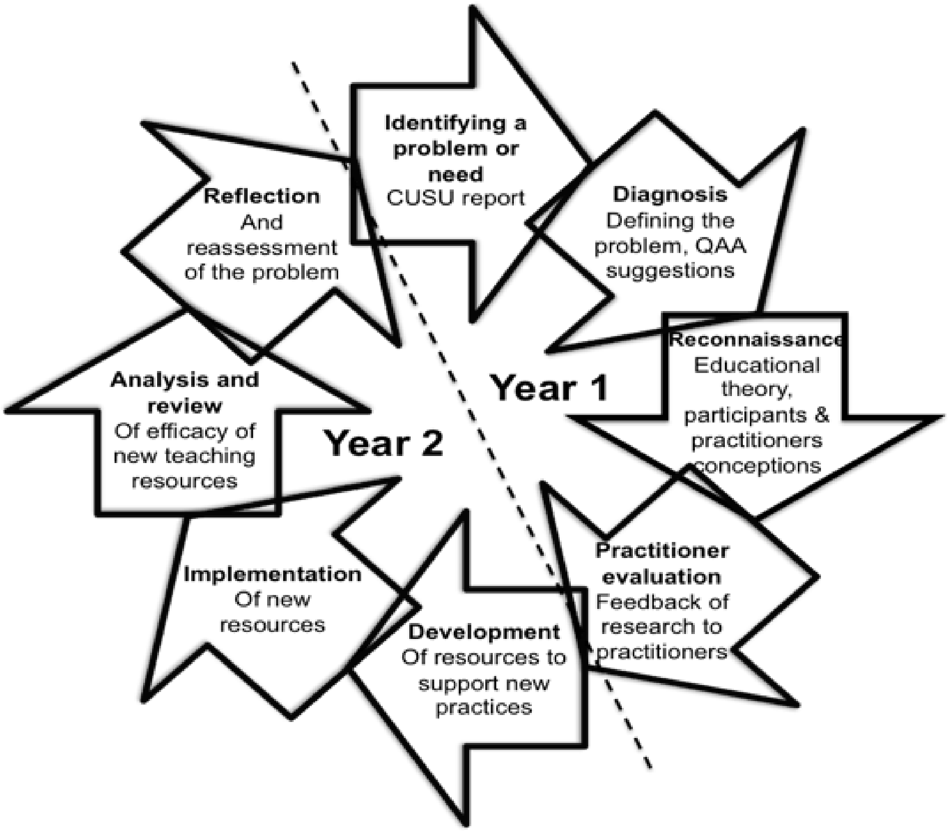

Figure 1 *Plant Sciences Pedagogy Project cyclical research structure. The activities were broadly divided into the academic years indicated. CUSU refers to the Cambridge University Students' Union and QAA to the Quality Assurance Agency.*

This paper follows on from these initial findings, and describes the next stage of the process, identifying areas at which new learning resources could be targeted for maximum benefit. On closer examination, it was found that approaches to the teaching and learning of difficult concepts aligned well with emerging theory on threshold concepts. Threshold concept theory is still relatively young, having been first conceived by Meyer and Land (2003), who described threshold concepts as:

> *'being akin to a portal, opening up a new and previously inaccessible way of thinking about something…represents a transformed way of understanding, or interpreting or viewing something, without which the learner cannot progress'*

Meyer and Land (2003) expanded this description to outline five characteristics, which they considered to typify threshold concepts (but with the caveat that the final two are often, but not always, associated with threshold concepts):

- **Transformative**: Once a threshold concept is understood, it has a transformative effect upon the way the learner views his subject, similar to conceptual change as outlined by Carey (1991).
- **Irreversible**: When that shift of perception has occurred, it is unlikely that the learner could easily return to the initial state.
- **Integrative**: Threshold concepts typically draw upon many different facets of a subject, or subjects, exposing the relationships between previously seemingly isolated information.
- **Bounded**: It is likely, though not essential, that a threshold concept will be bounded within a particular conceptual space, such as a discipline, for example.

- **Troublesome**: A threshold concept may involve an element of 'troublesome knowledge' (a notion adopted from Perkins, 1999), exemplified by counter-intuitive or tacit knowledge.

These hallmarks of threshold concepts afford desirable qualities for determining foci for developing support for students learning. Concentrating on these topics will ensure that newly developed resources are useful for students. This should also be an efficient strategy, as the integrative and transformative aspects mean that facilitating learning around threshold concepts will also illuminate other areas of the course.

Since its inception, most of the work on threshold concepts has focused on the higher education sector (Burchmore *et al*. 2007). One of the largest studies carried out to date is the Embedding Threshold Concepts project at the University of Staffordshire, which has focused on identifying and embedding threshold concepts in teaching within Economics (Davies, 2003; Davies and Mangan, 2005; Davies and Mangan, 2006). Although the topic has been addressed in greatest depth within economics, threshold concepts have also been explored to varying degrees in a diverse range of disciplines; for example, notable case studies include Computer Science (Eckerdal *et al*., 2006); Geology (Miller, 2006); Law (Allen, 2005); and Healthcare (Clouder, 2005).

Threshold concepts have been studied previously in Biological Sciences. Taylor (2006) recognises Biology as a very diverse discipline, and explored candidate threshold concepts across a sample of participants from several sub-disciplines of biology. The threshold concepts that emerged from this approach tended to be fundamental biological principles; further study characterised 'evolution' as a threshold concept (Taylor and Cope, 2007).

Since approaching a selection of 'biologists' yielded general threshold concepts, this raises the question of whether or not threshold concepts are likely to exist with different levels of granularity depending on the degree of focus on specific topics. For example, would the same concepts emerge if the sample were limited to 'Plant Scientists'?. As a result, we felt it was worthwhile to explore threshold concepts within the Plant Sciences course, to see if threshold concepts unique to this field could be identified, as focal points for development of online resources to enhance and support students' learning of these topics.

Method

Interviews with teaching staff were held over the course of one academic year, each staff member being interviewed within a fortnight of finishing teaching activities on their module for that year. In total, thirteen members of teaching staff (including lecturers, and also graduate students and postdoctoral researchers engaged in delivering tutorials) were interviewed. A semi-structured interview format was used, typically lasting from 30 minutes to one hour, including a component asking teaching staff to identify the questions frequently asked by students in tutorials, year after year. It was expected that the topics that tutors find themselves explaining most frequently would be the topics which students find most 'troublesome'; it was these topics that we hoped would include threshold concepts. Some of the common students' questions identified by staff were different approaches to essentially the same topic, and were combined. These 'frequently asked questions' were pooled and ranked to yield a list of thirteen commonly 'troublesome' topics.

Being troublesome alone does not warrant being considered a threshold concept, however, and the list included topics ranging from a simple confusion between two similar enzymes to topics, which are entire research fields in their own right. At this point, the most common frequently asked questions were mapped each against the definition provided by Meyer and Land (2003); that is, the extent to which each was likely to be transformative, irreversible, integrative, bounded and troublesome was evaluated. The topics which emerged from this analysis as threshold concepts included photoprotection, water potential, electrical potential, the gene-for-gene hypothesis, circadian rhythms and species area curves. The concepts identified tended to be troublesome for students either due to issues of being counterintuitive (photoprotection, gene-for-gene hypothesis, circadian rhythms) or difficulties in making the link between the abstract concept and wider context (water potential, electrical potential, species area curves). The necessity of photoprotection can seem counterintuitive, having been taught that light is essential for plants' survival and photosynthesis increases in proportion to light, that excessive light levels can have deleterious effects may initially seem jarring but the change in conception of photosynthesis required to understand photoprotection is essential to understanding the chemical basis of photosynthesis. Similarly, plants having mechanisms which induce their own cell death may seem too harmful to be a protective strategy but once understood open up a new perspective on the complexity of plant defence.

It is interesting to note that, although the scale at which we looked for threshold concepts is very different (at the specific department level compared to the whole of the biological sciences), some of our findings do mirror those of Taylor (2006). For example Taylor (2006) identified osmosis, and scale (with regard to ecological sampling) as threshold concepts, which show parallels with our identification of water potential, and species-area curves, respectively. An additional point often associated with the threshold concepts during interviews with teaching staff was that a large proportion of difficulty encountered by students with a topic was concerned with placing the threshold concept in context. For example, students could understand or even just memorise the equations associated with water potential as an isolated concept quite easily, but the threshold identified was to realise its full implications at the whole plant level and in different contexts within Plant Sciences.

Results and Evaluation

Once a set of threshold concepts had been identified within the course, we developed resources to support student learning of these topics using technological solutions. In approaching resource development, we drew upon themes which emerged from focus groups with students. Students identified that a particularly valuable aspect of tutorials was having the opportunity to listen to expert explanations of difficult topics explained in a variety of different ways as an alternative to the one explanation that they experienced in lectures. Students also highly valued having tutorials given by the lecturer of the course topic, but due to time constraints it is not possible for every student to be tutored by the particular 'expert' for every topic. To address this, we worked with lecturers to produce screencasts of explanations of the threshold concepts as electronic narrated animations or videos recorded using Camtasia software (http://www.camtasiastudio.com). The screencasts were then integrated into the student virtual learning environment for the course, so that any student on the course could access the lecturers' explanation and replay it several times if required. An example of one of the explanations created using Camtasia is shown in the screen capture below (Figure 2).

Although it was not intended to quantify the impact of these new resources upon student learning of these topics, their popularity with students has been borne out both by questionnaire responses and by site usage data. An online questionnaire was circulated to students at the end of the academic year, to elucidate student opinions on various novel components of their virtual learning environment, including the threshold concepts explanations. Part of the questionnaire asked students to rate different components as to how 'useful' they perceived them to be on a scale of 1 ('not useful at all') to 5 ('very useful').

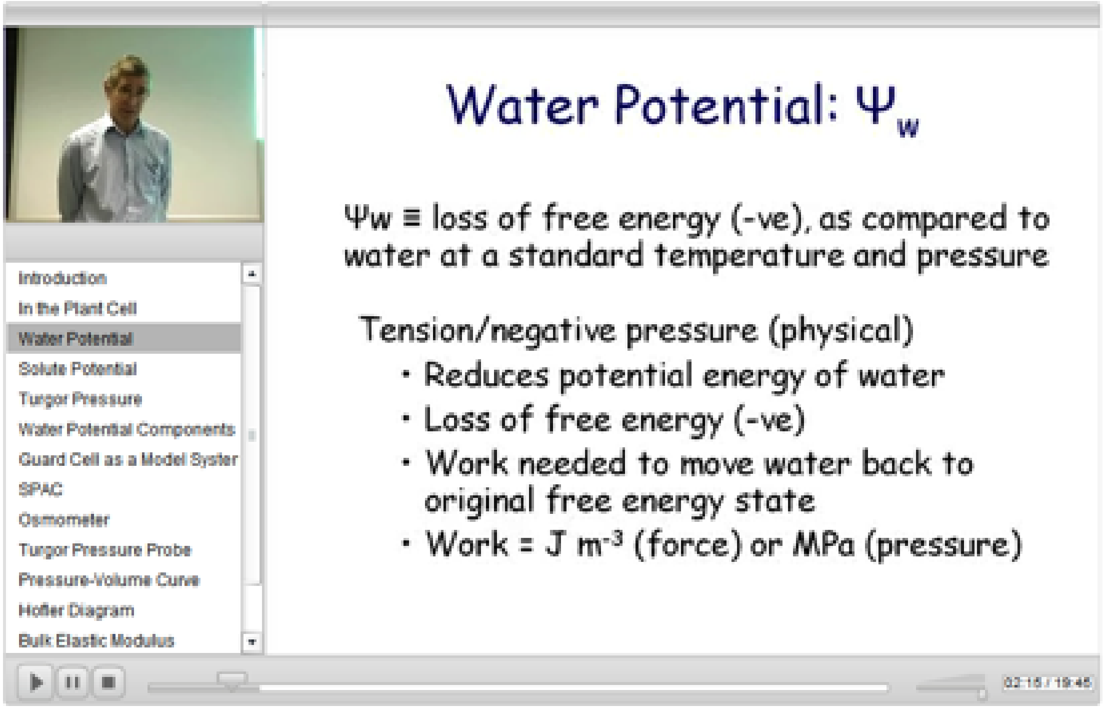

Figure 2 *Screen capture from an explanation of the threshold concept of water potential created using Camtasia.*

On this basis, the explanations were perceived to be the third most useful aspect of the virtual learning environment, out of a total of nine novel types of learning resource; 74% of the respondents rated the explanations a 4 or 5. Several students also volunteered praise for these resources in a free text box, including:

> *"Really like the videos! Like the gene for gene one for example."*
>
> *"[Online] Tutorials are excellent."*

Since the Camtasia explanations were hosted within an online virtual learning environment (VLE), it was also possible to determine whether students chose to use these resources in practice. The student VLE automatically logs information about how frequently files hosted on the site are accessed. From this log, information about the frequency with which the pages with Camtasia videos embedded within them were accessed was derived. 88% of students had accessed two or more of the explanations on more than one occasion. This re-use suggests that students did find them genuinely useful, and valued the ability to replay and re-visit the explanations as many times as they liked. However, only 23% of students watched all of the explanations provided, which may reflect the specific design of these resources. Since not all student learners are identical and do not necessarily share the same prior experiences, perspectives or motivation for studying a topic, it is likely that there is a personal factor relating to the difficulty or ease with which a student passes through the conceptual gateway of a threshold concept. The patterns of use seen here probably reflect this, with each student 'dipping in' to the new resources related to the selection of topics which proved particularly troubling to them.

Impact Beyond Plant Sciences

In addition to providing a practical focus for undergraduate teaching, consideration of threshold concepts also shows promise as a good process for encouraging practitioners to think in a reflective way about their teaching. Since these topics are intrinsically difficult to teach, they challenge teaching staff to think about their own practice and identity as a teacher. Common frequently asked questions were discussed and related to the idea of threshold concepts during interviews with teaching staff. The idea of threshold concepts resonated strongly with all of the interviewees and they could all relate to a concept that they themselves had once struggled with, leading to a personal 'eureka moment'. In some cases, staff demonstrated a great deal of enthusiasm for the concept, and a determination that there 'had to be' at least one threshold concept within the topics they taught, whether or not this proved to be the case. More importantly, the discussion of threshold concepts itself had sparked practitioner reflection upon their own teaching.

It is also becoming evident that the resonance of the idea of threshold concepts is not limited to Plant Sciences teaching staff. In the wake of this initial work in Plant Sciences, identifying and supporting threshold concepts in student learning was taken up by members of the Teaching for Learning Network at Cambridge, a higher education initiative which facilitates brokerage and co-interpretation of educational research findings between disciplines (Carmichael *et al*., 2007b). In the Department of Engineering, the idea of threshold concepts proved to be a very effective way of engaging Engineers in practitioner research (Carmichael *et al*., 2007ca). A comprehensive account of the interdisciplinary discourse evoked by threshold concepts in the wider Teaching for Learning Network and their potential as a focus for continuing professional development is provided by Irvine and Carmichael (2007; 2009).

In conclusion, threshold concepts are a useful point of focus to facilitate student learning of troublesome knowledge in Plant Sciences. Once identified by teachers, this may influence how such concepts are taught within the lecture context as well as becoming points of focus within tutorials, which can become a conversation about troublesome learning between generations. In addition it is relatively straightforward to produce effective e-learning resources to develop student understanding of threshold concepts which can be deployed within a virtual learning environment.

Summary

In this study, we have identified threshold concepts within an undergraduate Plant Sciences course, and shown that they can be useful focal topics for provision of extra resources to support student learning. We have also found that the idea of a threshold concept travels well between educational researchers, practitioners and disciplines, and as such shows promise as a good starting point for initiating practitioner research or interdisciplinary discussion.

Communicating author: Katy Jordan, Centre for Applied Research in Educational Technologies (CARET), University of Cambridge. Klj33@cam.ac.uk

Acknowledgements

We would like to acknowledge the contributions of members of the Teaching for Learning Network and CARET staff including Helen Burchmore, Patrick Carmichael, Naomi Irvine and Harriet Truscott (CARET); Timothy Hill and Paul Millett (Classics); Aidan Reilly, Hugh Hunt and Hugh Shercliff (Engineering); and all of the Plant Sciences teaching staff and students. We gratefully acknowledge the Cambridge-MIT Institute for funding the project that made this work possible, and the Technology-Enhanced Learning (TEL) initiative of the Teaching and Learning Research Programme for funding the associated project "Transforming Perspectives: Technology to Support the Teaching and Learning of Threshold Concepts" (grant RES-139-25-0361).

References

Allen, V. (2005) A reflection on delivering legal education to business students. *Paper presented at the Annual Conference of the Society for Research into Higher Education, University of Edinburgh.*

Burchmore, H., Irvine, N. and Carmichael, P. (2007) Threshold concepts: A review of related literature. *Teaching and Learning Research Programme Technology-Enhanced Learning Phase.* Available at: http://www.caret.cam.ac.uk/tel/downloads/tel_literature_review.pdf (accessed 28 November 2010)

Carey, S. (1991) Knowledge acquisition: Enrichment or conceptual change? In S. Carey & R. Gelman (Eds.) *The epigenesis of mind: Essays on biology and cognition,* Hillsdale, NJ: Lawrence Erlbaum Associates

Carmichael, P., Irvine, N., Jordan, K. Johnstone, K., Tracy, F. and Truscott, H. (2006) Enhancing small group teaching in Plant Sciences: A research and development project in Higher Education. *Paper presented at the annual BERA Conference, University of Warwick*.

Carmichael, P., Irvine, N. and Tracy, F. (2007b) The Teaching for Learning Network: A research and development initiative in Higher Education. *Paper presented at the annual BERA Conference, Institute of Education, London*

Carmichael, P., Johnstone, K., Jordan, K., Tracy, F. and Truscott, H. (2007a) Developing evidence-informed practice in undergraduate teaching and learning at the University of Cambridge. In D. Good, S. Greenwald, R. Cox and Goldman, M. (eds.) *University Cooperation for Innovation: Lessons from the Cambridge-MIT Institute*, Rotterdam: Sense Publishers

Carmichael, P., Johnstone, K., Tracy, F. and Burchmore, H. (2007c) Threshold Concepts: an emerging interdisciplinary research agenda in Higher Education research. In D. Good, S. Greenwald, R. Cox and Goldman, M. (eds.) *University Cooperation for Innovation: Lessons from the Cambridge-MIT Institute*, Rotterdam: Sense Publishers

Clouder, L. (2005) Caring as a 'threshold concept': transforming students in higher education into health(care) professionals. *Teaching in Higher Education* **10** (4): 505 - 517

Davies, P. (2003) Threshold Concepts: how can we recognise them? *Embedding Threshold Concepts project: Working Paper 1* Embedding Threshold Concepts Project

Davies, P. and Mangan, J. (2005) Recognising Threshold Concepts: an exploration of different approaches. *Embedding Threshold Concepts project: Working Paper 2* Embedding Threshold Concepts Project

Davies, P. and Mangan, J. (2006) Embedding Threshold Concepts: from theory to pedagogical principles to learning activities. *Embedding Threshold Concepts project: Working Paper 3* Embedding Threshold Concepts Project

Eckerdal, A., McCartney, R., Moström, J. E., Ratcliffe, M., Sanders, K. and Zander, C. (2006) Putting threshold concepts into context in computer science education. *Proceedings of the 11th annual SIGCSE conference on Innovation and technology in computer science education*, 103–107

Irvine, N. and Carmichael, P. (2007) Initiating and supporting practitioner research in Higher Education. *Paper presented at the annual BERA Conference, Institute of Education, London*

Irvine, N. and Carmichael, P. (2009) Threshold concepts: A point-of-focus for practitioner research. *Active Learning in Higher Education* **10** (2): 103–119

Meyer, E. and Land, R. (2003) Threshold concepts and troublesome knowledge: linkages to ways of thinking and practising within the disciplines. *ETL Occasional Report 4*, Enhancing Teaching-Learning Environments in Undergraduate Courses Project

Miller, W. (2006) Planet: Special issue on threshold concepts and troublesome knowledge. *Planet* 17, Higher Education Academy Subject Centre for Geography, Earth and Environmental Sciences

Perkins, D. (1999). The many faces of constructivism. *Educational Leadership*, **57** (3): 6–11

Stenhouse, L. (1978) Case study and case records: towards a contemporary history of education. *British Educational Research Journal*, **4** (2): 21–39

Taylor, C. (2006) Threshold concepts in biology: Do they fit the definition? In J. H. F. Meyer & R. Land (Eds.) *Overcoming Barriers to Student Understanding*, Routledge

Taylor, C. and Cope, C. (2007) Are there educationally critical aspects in the concept of evolution? *Proceedings of Uniserve, University of Sydney, Sydney.* Available at: http://www.sydney.edu.au/science/uniserve_science/pubs/procs/2007/21.pdf *(accessed 28 November 2010)*