Using cognitive load theory as a framework for designing a set of integrated multimedia modules to assist in the teaching of a threshold concept

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Introduction

The present paper reports on a work in progress undertaken by an educational multimedia developer working in collaboration with a high school biology teacher in order to create a set of integrated multimedia resources to assist student understanding of homeostasis. The resources are designed to not only align with evidence-based guidelines of cognitive load theory (Sweller 2005) but also incorporate course design and evaluation considerations that pertain to threshold concepts such as those raised by Land, Cousin, Meyer and Davies (2006). Although cognitive load theory is particularly enlightening in terms of creating discrete learning objects, it does not as yet demonstrate how to deal with the complexity of threshold concepts as suggested by their 'hidden interrelatedness' (Meyer and Land 2006). To this extent a discipline specific model is posited in terms of a set of integrated multimedia modules that can be further developed through a process of feedback and evaluation.

Why multimedia?

Students accessing online multimedia resources are not bound by time and place, whilst also being able to engage with the learning activities in an interactive and self-paced manner. Properly designed resources can function as high-quality re-usable learning objects that are optimised for purposes of dissemination and uptake.

With respect to threshold concepts, multimedia resources provide the ideal medium for facilitating recursiveness, visualising scale-related phenomena, mapping of base to target domains in the employment of analogies, and incorporating appropriate delivery modalities suited to pre-liminal or post-liminal levels of expertise. Through a combination of segmenting, sequencing and user-control multimedia resources can provide an ideal platform for purposes of scaffolding.

Structured as a set of integrated multimedia modules they can serve to reflect the 'hidden inter-relatedness' inherent in many threshold concepts. This complex networking of resources can be further developed to include supporting or transitional material for activities with a 'hands-on' or 'real-world' component and eventually approach the type of rhizomorphic structure as suggested by Land et al. (2006).

What is the connection between Cognitive Load Theory and Threshold Concepts?

Threshold concepts are likely to be of particular interest to cognitive load theorists because of their inherent difficulty (i.e., their high intrinsic cognitive load), whereby the efficiency of the instructional design is more critical than when dealing with subject matter that is less challenging. There are a number of striking parallels and similarities between the two research disciplines that suggest cognitive load theory may provide a 'light in the tunnel' as to how some of the design and evaluation considerations relating to threshold concepts such as those mentioned above may materialise in the form of effective learning resources.

For example, recursiveness (Land et al. 2006) can be optimally designed by combining segmentation and user-control, both of which are topics of investigation by cognitive load theorists (Bertrancourt 2005). Figure 1 shows how thumbnails are used as visual indicators of re-playable segmented sections within the study of homeostasis. The student is encouraged to internalise the concepts in a self-paced, recursive manner by selecting, comparing, and integrating different examples to infer important features.

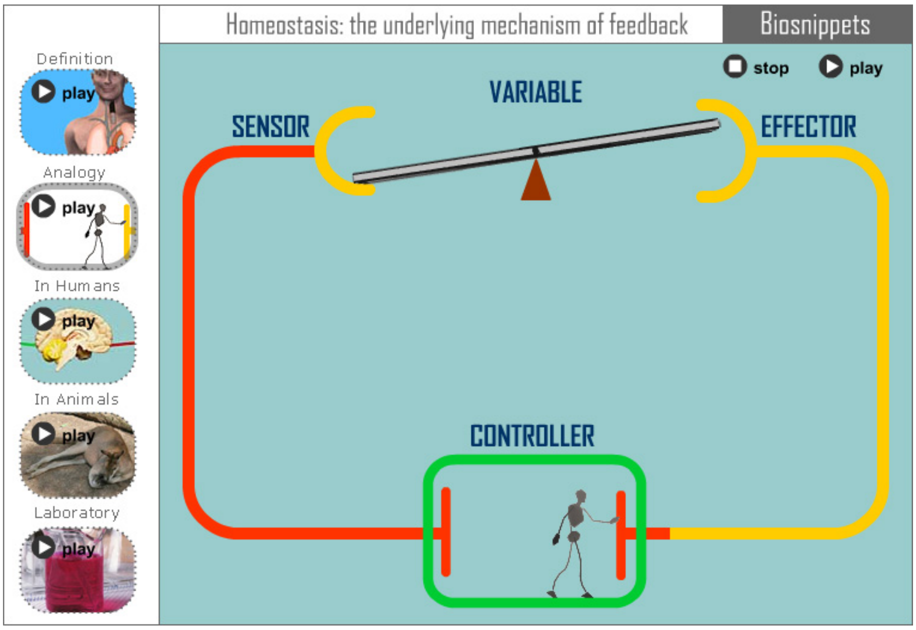

Figure 1. Screen shot from *BIOSNIPPETS* (http://www.phys.unsw.edu.au/biosnippets), a collaborative project between Ms Lynne Joslyn and the author to assist high school students with the topic of homeostasis. The thumbnails are used as visual indictors of re-playable segmented sections which encourages students to internalise the concepts in a self-paced, recursive manner

Future research might assess whether such 'self-administered' internalisation results in less disjunction and minimization of the obstruction to learning of troublesome knowledge (Meyer and Land 2006). Can a self-paced multimedia approach be construed as a 'self-help' approach akin to providing aid by 'helping them to help themselves' and as such provide better outcomes in terms of the students sense of self-esteem and identity?

Another area of interest related to both fields of research is the difficulty that experts face when confronted with teaching novices. Land et al. (2006) refer to this issue as addressing pre-liminal variation within the novice population by cultivating a third ear that performs the function of 'listening for understanding'. Related to this consideration in the field of cognitive load theory is the 'Prior Knowledge Principle' (Kalyuga 2005) in multimedia learning which suggests that multimedia design principles should be different for novices and experts. For example, whilst novices integrate narration and pictures better than text and pictures, experts show the reverse trend (Low and Sweller 2005). Such information is of critical importance for an expert trying to relate difficult concepts to a novice in an effective and engaging manner.

These examples illustrate the type of meaningful inter-relationships that can be found between the two research fields and the subsequent applicability to course design. However, threshold concepts also raise larger issues relating to their integrative nature, liminality, student identity, communities of practice, and so forth.

A set of integrated multimedia resources designed for a discipline-specific model of teaching

Many disciplines of science e.g., biology, physics, chemistry have traditionally taught with a combination of lectures, tutorials and laboratories. An integrated approach as modelled in Figure 2 below presents a collection of resources that mirrors this process through the use of multimedia resources but with the following distinctive features:

1. The barriers of time and place are not present i.e. there are no issues of asynchronicity such as when a student arrives at a laboratory prior to attending the lecture. The student can control the order and pace of the relevant modules. A cognitive load theorist may view this in terms of providing spatial and temporal contiguity and thus reducing the cognitive load.
2. The integrated resources are intended to deal with specific threshold concepts and not cover the entire curriculum i.e., money and time is invested in studying the ‘jewels of the curriculum’ (Land et al. 2006).
3. The resources must be carefully ‘scripted’ in an integrated manner much like a mystery novel where all the pieces fall together at the end i.e.. where mastery is accomplished at the laboratory level. The design of tutorial problems can benefit by adherence to both the ‘Split Attention Principle’ (Ayres and Sweller 2005) and the ‘Worked-Out Examples Principle’ (Renkl 2005). Initially, the science educator needs to determine what authentic science activities would confirm that the student has mastered or excelled in his understanding of the threshold concept. The presentation and tutorial problems should then be carefully scaffolded towards achieving this outcome in the ‘laboratory’ stage.
4. The resources are carefully constructed on current understanding and using available resources. Student feedback and a phenomenographical analysis may reveal weaknesses in the model which is then modified or amplified in a ‘rhizomorphic’ manner (Land et al 2006) to broaden its scope and strengthen its effectiveness.

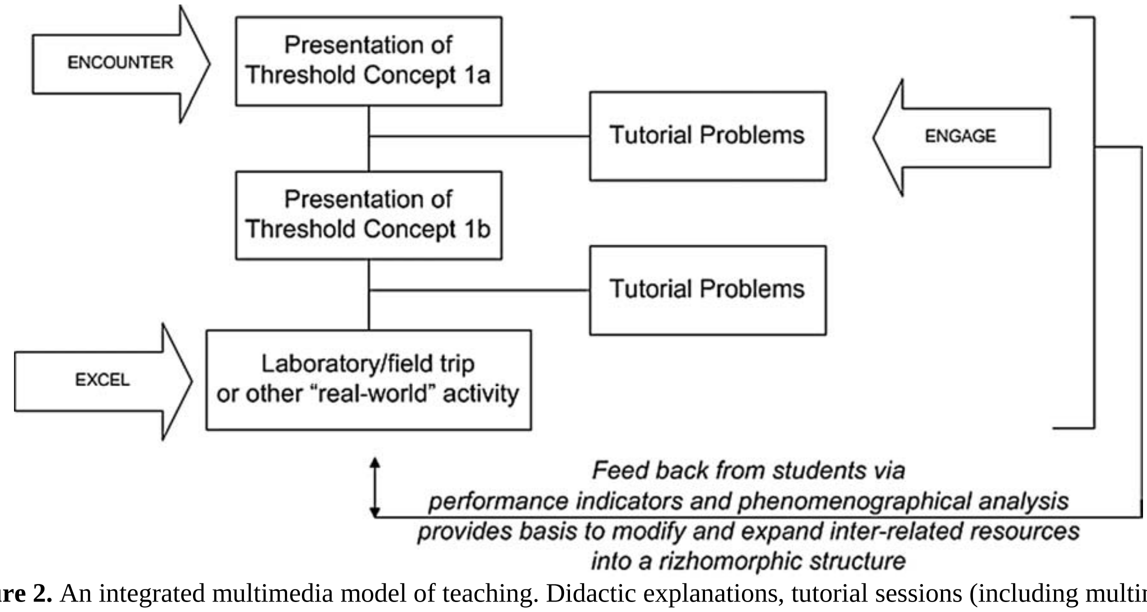

Figure 2. An integrated multimedia model of teaching. Didactic explanations, tutorial sessions (including multimedia modules) and ‘real-world’ activities are integrated to allow students to internalise threshold concepts.

An early example of this integrated multimedia model can be viewed at http://www.phys.unsw.edu.au/biosnippets. Although not complete it demonstrates:

- presentation and tutorial material as precursors to a ‘master lab’;
- using transitions to map the base domain to the target domain when using analogies; and
- segmentation, user-control, the modality principle and other guidelines associated with minimising the cognitive load.

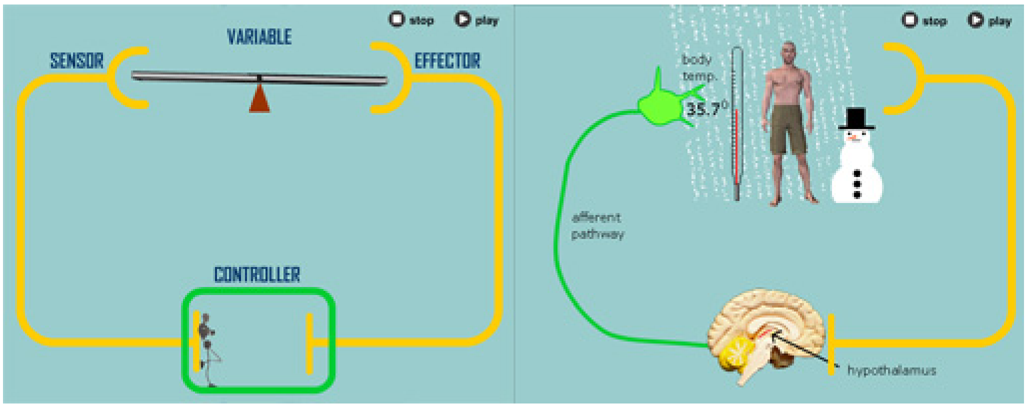

Figure 3. Screen shots from *BIOSNIPPETS* showing how analogy domains can be mapped successively over time. In this case the variable, sensor and controller have been mapped to real world symbols whilst the discussion and mapping of the effector is not as yet mapped. Note that the mapping occurs as a succession of transitions that are accompanied by an audio narration.

Note: Research is still pending as to whether homeostasis can be considered a threshold concept (Taylor 2006) however, discussions with colleagues suggest it is a candidate.

Conclusion

The challenge of ensuring that education theory materialises in the classroom is of particular concern to educators. Curriculum designers working in the field of threshold concepts can optimise the effectiveness of their learning resources by incorporating evidence based guidelines relating to cognitive load theory. Within the disciplines of science the traditional model of lectures, tutorials and laboratories/field trips may be a starting point for developing a set of integrated multimedia resources that not only reflect the complexity of the subject matter but provide ancillary material for more authentic hands on activities.

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