

Threshold Concepts: A Review of Related Literature

Helen Burchmore, Naomi Irvine and Patrick Carmichael

Centre for Applied Research in Educational Technologies
University of Cambridge

DRAFT

Please Refer to Authors Prior to Citation

Contents

Section 1: Aims and conduct of the literature review	2
Section 2: Technologies, access and dissemination	9
Section 3: Interpretative Framework and Commentaries	14
Commentary: Context	14
Commentary: Discipline	17
Commentary: Framework	18
Commentary: Methods	20
Commentary: Sector	21
Annex 1: Full Listing of all Keywords Used	24
Annex 2: Full Alphabetical Listing of All Items	25
Acknowledgements	37

This literature review was produced as part of the work of the ESRC/EPSRC Technology-Enhanced Learning Programme Project ‘Transforming Perspectives: Technologies to Support the Teaching and Learning of Threshold Concepts’ (RES-139-25-0361), with support from the Cambridge-MIT Institute ‘Teaching for Learning Network’.



Section 1: Aims and Conduct of the Literature Review

Introduction

‘Transforming Perspectives: Technology to Support the Teaching and Learning of Threshold Concepts’ was a project based at CARET, the Centre for Applied Research in Educational Technologies at the University of Cambridge and was funded for six months (October 2006 - March 2007) under the joint ESRC/EPSRC Technology Enhanced Learning Programme which is part of the Teaching and Learning Research Programme (<http://www.tlrp.org>)

The project emerged from prior research and development work on pedagogic practice in small group teaching within the Departments of Engineering and Plant Sciences at Cambridge University sponsored by the Cambridge-MIT Institute (**Carmichael et al. 2006**)¹. Initial investigation of supervisions within Plant Sciences had discovered concepts which were acknowledged as those that ‘students consistently find difficult’. In parallel work within Engineering, it was found that problematic concepts had often been reified into ‘examples’ or ‘problem sets’. Effective practice on the part of teachers involved diagnostic questioning and interventions to support students in solving complex problems which typically integrated different areas.

It was found on closer examination that approaches to the teaching and learning of these difficult concepts aligned well with emerging theory on threshold concepts, described 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” and being generally characterised as “transformative, probably irreversible, integrative, often troublesome and probably bounded” (**Meyer and Land, 2003**)

The Department of Plant Sciences had provided additional online resources for both staff and students within a Virtual Learning Environment (VLE) to support teaching and learning of these ‘troublesome concepts’, and this demonstrated the potential for technology to be used to support teaching in areas of complexity. The ‘Transforming Perspectives’ project was then established to investigate whether technology had the potential to be helpful in supporting learners in other disciplines ‘through the portal’; what the requirements might be for those technologies; and whether there were specific technologies that addressed those requirements already in existence. The project was envisaged as complementing and extending research surrounding threshold concepts that was building on Meyer and Land’s work and was taking place in disciplines such as economics and physics. A body of case studies exploring how candidate concepts within the disciplines might be regarded as being ‘troublesome’ or ‘integrative’ (**Meyer and Land, 2003; Davies and Mangan, 2005**) allowed increasing refinement of the definition of what a threshold concept might represent, but the discourse was still largely concerned with their identification as part of a drive to improve curricular design.

1 Full citations are included in Annex 2 of this review document.

The aims of the ‘Transforming Perspectives’ project were to establish and support an interdisciplinary network to explore perspectives on the teaching and learning of threshold concepts within a wide range of disciplines and to investigate the potential of technologies to support such teaching and learning activities. In order to fully explore the requirements for a technology to assist in teaching threshold concepts, it was important to know whether they manifested within different disciplines in ways that could be turned into overall requirements for a generic technology, or whether different disciplinary manifestations would require discipline-specific technologies. The first task for the project was then to gather case studies of threshold concepts as conceptualised by practitioners within a wide range of disciplines in order to widen our understanding of disciplinary difference and pedagogic perspective.

Over the course of the six months, three seminars were run within the University of Cambridge with participants from a diverse range of disciplines: initially this included English, Comparative Theology, Engineering, Plant Sciences, Assistive Technology, Sports Science, Social Anthropology, Materials Science and Computer Science. The seminars aimed to engage participants in investigating threshold concepts within their own disciplines, and from both traditional ‘teaching’ and ‘learning’ perspectives where possible. This was followed by two further seminars inviting external views of the wider issues of interdisciplinarity and technology. A final seminar invited graduate students to explore liminality and the generation of individual research agendas as an aspect of ‘graduateness’.

Out of the enthusiastic work of participants at the first series of seminars grew a series of case studies that, although loosely based on ‘the five characteristics’ as identifying features, exhibited a wide range of interpretations of the nature and role of potential threshold concepts, describing ‘integrative’ concepts, ‘transformative’ perspectives and ways of viewing the world and even ways of acting physically within it. The different perspectives of the delegates at these seminars also allowed questions not addressed by the initial threshold concept research agenda to be posed. These included: discussions of whether the concept of liminality was useful in characterising student experience; how best to exploit identified concepts in improving teaching practice; whether threshold concepts, as indicators of contested knowledge within a discipline, were access points to expert discourse and ‘mastery’ within that discipline; and whether more participants from discursive disciplines in which conceptual change teaching was less foregrounded could identify threshold concepts within their repertoire, and what role they then played.

This literature review, intended initially to provide a conceptual background for our own explorations of threshold concepts, evolved during the project to support this practitioner engagement and to form both a community resource and a documentary record of the evolving perceptions of threshold concepts.

Aims of the Literature Review

At the time this review of the literature was started, research was largely being directed into the identification and listing of threshold concepts within different disciplines and educational contexts in Higher Education. Our thinking about the literature review involved exploring a wider context in which to situate threshold concepts and in terms of their specific curricular context, differing disciplinary perspectives, the pedagogical context they occupy and the interpretive framework or lens through which they are studied, communicated and utilised.

We were also interested in the practical applications of the wider viewpoint the initial search has given us; especially how to define, identify and discuss threshold concepts and ultimately how to specify, construct or use technology to support or enhance the teaching and learning of threshold concepts in different disciplines.

Specifically, this review was intended to:

- situate threshold concepts within a broader conceptual framework
- extend the discussion surrounding threshold concepts beyond the process of identification and into their implications for pedagogical practice, teacher and learner identity and assessment
- investigate how threshold concepts arise within a discipline or community, how they are made manifest and how they are then communicated and used within different contexts

This literature review was also intended to support an interdisciplinary network of co-researchers in higher education. As a response to this evolving research agenda, the review became a resource that intended to:

- support the establishment of an interdisciplinary network drawn from a number of disciplines to explore threshold concepts
- document the changing perceptions of threshold concepts arrived at by early reviews of the literature and the research activities of participants engaged through the seminar series
- explore and demonstrate this changed perspective by collating the literature and presenting it in a framework that is easily accessible (both practically and conceptually) to this wider research community.

Conduct of the Literature Review

The varied and evolving aims of the literature review all had implications for its development. The initial aims were to situate threshold concepts in a wider literature, to review literatures relating to learning contexts other than Higher Education and how disciplinary perspectives affected conceptualizations of candidate threshold concepts. These aims shaped the original search strategy, circumscribed the range of resources that were collected initially and was reflected in the original structure of the review. However, as the research activities undertaken within our interdisciplinary

network unfolded, so our search strategies and conceptual frameworks evolved and the technologies used to collate and present the review were altered to reflect some of the history of our thinking.

This process of development of our literature fell into three broad phases:

Phase 1: Reviewing the ‘threshold concepts’ research literature

At the beginning of the review (summer 2006), the notion of threshold concepts was still an emergent research theme, and consequently the use of ‘threshold concept(s)’ as a search term returned only a small and tightly linked set of articles, conference papers and research reports. The majority were associated closely with the Enhancing Teaching and Learning Environments in Undergraduate Courses project (ETL) - such as Meyer and Land’s original report of the notion of threshold concepts (**Meyer and Land, 2003**) or the Embedding Threshold Concepts (ETC) project (**Davies, 2003**; **Davies and Mangan, 2005**; **Davies and Mangan, 2006**). This latter project established threshold concepts as an organizing principle in research into undergraduate learning in economics and worked specifically to refine the processes of identification and understanding of threshold concepts in order to transfer the theory into teaching practice. The ETC Newsletters published between 2005 and 2007 indicate the highlights of their ongoing work and the changing nature of how this particular project developed its conceptualization of ‘threshold concepts’.

Further research on the wider implications of threshold concepts was carried out by an increasing number of groups throughout 2004 and 2005, resulting in a growing number of threshold concept-specific publications. Significantly, some of these studies aligned the threshold concepts research agenda with broader and longer-established research agendas; a good example of this is the work emerged from the ETC project (**Davies and Mangan, 2005**) as they attempted to distinguish different types of threshold concept and align them with Carey’s review of different types of cognitive change (**Carey, 1991**).

These early projects stimulated research into threshold concepts in other disciplines and contexts. The publication of a small number of individual case studies soon followed, dealing with issues of teaching troublesome subjects such as an overview of commercial law to business students (**Allen, 2005**) and ‘caring’ as a threshold concept amongst student health professionals (**Clouder, 2005**). These case studies used the identification of threshold concepts as the starting point for a wider investigation of pedagogic practice within a discipline, opening up a wider context within which threshold concepts could be placed and extending the potential research agenda into other subjects and different learning contexts. However, the majority of the work still remained focussed on higher education and the identification of threshold concepts was characteristically part of a process of staff development or curricular review and reform.

As the ‘Transforming Perspectives’ project began in the Autumn of 2006, two other events contributed to a significantly broadened threshold concepts research agenda. In August 2006, a conference was held at the University of Strathclyde to bring together a wide range of researchers to present case studies of threshold concepts in their disciplines and to discuss the wider implications of their discovery. A book based on the papers presented at the conference is forthcoming. Another book (**Meyer and Land, 2006**) was published in late 2006 with contributions from a wide range of researchers, including work exploring identification of threshold concepts as ‘webs’ of concepts and their role in the integration of new ideas into existing individual belief systems. The authors of the chapters in this book pointed up areas of overlap with other research and offered interdisciplinary perspectives on threshold concepts (although still with little on a number of key issues including technology-enhanced learning and assessment). Even with these new contributions, the small number of publications available meant (and still means, at time of writing) that using ‘threshold concept’ as a search term is a relatively poor indicator of levels of interest in the subject.

Phase 2: The wider context of threshold concepts: ‘troublesomeness’, ‘integration’, ‘transformation’ and ‘boundedness’

As we began to explore threshold concepts within our seminar series involving co-researchers in many disciplines, we began to revisit the conceptual background out of which threshold concepts emerged – that is, to look at their characteristics of troublesomeness, integration, transformation and being bounded or bounding. Each of these characteristics became a basis for searching in its own right, and this produced a more extensive and diverse range of disciplinary and pedagogic perspectives in a range of learning contexts, including secondary schools, workplace learning and professional learning. During this phase of the review, it became apparent that the terms used to characterise threshold concepts aligned with other existing literatures. For example, the idea of a threshold concept being ‘transformative’ aligned well with theories of conceptual change such as described by Carey and others (**Carey, 1991; Carey and Spelke, 1996; Carey, 2000**), while exploring the characteristic of ‘bounded’ revealed obvious similarities with literatures on communities of practice (**Wenger, 1988**) where they related to the negotiation of entry to such communities.

This move beyond Higher Education contexts extended the idea of threshold concepts into the workplace, where they often manifested as areas of tacit knowledge required for gaining expertise in a given profession (**Kennedy, 1987**) or highly contested areas of disciplinary theory or practice that resist being made explicit (**Eraut, 2003**). In this way, each gathered resource became a source of further potential search terms and pointers to other literatures and sources.

This raised a new set of issues: rather than being constrained by the limited number of publications which explicitly addressed the issue of threshold concepts, there was now a risk that by trying to map divergent literatures that the emergent theory of threshold concepts seemed to relate to, the review would simply end up repeating the efforts of previous researchers. For example, the rich literature on

conceptual change in secondary school science was clearly relevant, but has already been well-reviewed. Selections were made of the most important and relevant works in these related areas, with the intention of providing a foundation to support the work going on in the seminars rather than creating a definitive listing of every reference. The focus largely remained on papers relevant to threshold concepts and no more than ‘one step removed’ from the core references and concepts identified in phase one of the review.

As the ‘Transforming Perspectives’ project seminars were run and new disciplinary contexts and perspectives at a Higher Education level were explored, the review changed from being an exercise in gathering to one of sharing resources and exposing them to our wider community. The emerging dual role of the review was to provide participants in the seminars with both a conceptual framework explaining and exploring threshold concepts and access to the individual papers. The technology used to fulfil these requirements in itself helped to shape the current literature ‘resource’ and this paper review of the collected literature.

Phase 3: Interdisciplinary perspectives on threshold concepts

The third (and continuing) phase of the literature gathering and sharing took place in a more collaborative fashion, with a wider interdisciplinary research network created by attendance at the TEL seminars. Our co-researchers were able to review areas of the literature review that exposed them to a wider context for their own work, and in turn make suggestions for new papers or even entire areas of interest to review. This led to the inclusion of articles concerned with informal and formal learning contexts (Eraut, 2004) self-efficacy (e.g. Bandura, 1977); innovative business communities (e.g. Nonaka and Takeuchi, 1995); the identification of expert practices, decision making and reasoning strategies (e.g. Bereiter and Scardamalia, 1996; Clement, 1998; Fessey, 2002); and knowledge construction and transfer (Engestrom *et al.*, 1995; Paavola *et al.*, 2004); and the nature of postgraduate learning and research (Leshem and Trafford, 2007).

The growing resource was shared online, with a metadata scheme designed to reflect emerging thinking about threshold concepts. This allowed not only the retrieval of specific items, but also browsing and exploration of the review (further enabled through the development of a novel online interface (described further below).

Resources

As the review proceeded, the sources of information gradually developed, with a transition from reviewing the outputs of specific projects and individual authors to a broader and more ‘grounded’ approach in which seminar contributions drove participants and project members to suggest items for inclusion. With a lack of specific journals in which threshold concepts are a common theme of submissions, a systematic review of selected journals was impossible.

Resources used extensively included:

- Education Resources Information Center (ERIC): <http://www.eric.ed.gov/>
- British Education Index (BEI): <http://www.leeds.ac.uk/bei/>
- JSTOR: <http://www.jstor.org/>
- TLRP Digital Repository: <http://www.tlrp.org/dspace/index.jsp>

Specific projects providing useful starting points, bibliographies and publications included:

- Learning During the First Three Years of Postgraduate Employment (LiNEA):
<http://www.sussex.ac.uk/education/1-4-25-9.html>
- Enhancing Teaching-Learning Environments in Undergraduate Courses (ETL):
<http://www.tla.ed.ac.uk/etl/index.html>
- Embedding Threshold Concepts (ETC):
[http://www.staffs.ac.uk/schools/business/iepr/info/Economics\(1\).html](http://www.staffs.ac.uk/schools/business/iepr/info/Economics(1).html)

Section 2: Technologies, access and dissemination

This section describes the processes by which the literature review process has made use of technology to assist in the gathering, analysis and sharing of resources, and has resulted in a number of linked outputs. The project used a Virtual Research Environment based on the Sakai Virtual Collaboration Environment (<http://www.sakaiproject.org>) for project management, event planning, email list management, resource storage and collaborative writing. Sakai offers an easily-customised and modular platform in which tools and services can be collected together into 'worksites'. The specific instance of Sakai used was 'Camtools', the institutional Virtual Learning/Research Environment used at the University of Cambridge (<http://camtools.caret.cam.ac.uk>).

Through use of the CamTools environment, seminar participants were able to review the developing literature review, and to suggest their own specific additions or areas of literature not yet covered. This online environment also acted as a central repository for other works and supporting materials during our research, and finally was also able to be act as a focus for collaborative sense-making as we came to assess and analyse what we had discovered throughout the project. The shared focus on this site and the feeling of joint ownership it provided allowed the group to develop and maintain an identity².

The literature review was developed and is now accessed within this environment, using combinations of the available tools. initially, results of searches, downloaded documents and URL's of online resources (such as papers on publishers' websites) were stored in the 'Resources' tool' (see Figure 1). Access to these resources was controlled by requiring a registered user name and password and, where appropriate, copyright restrictions were displayed to users before they were able to gain access to the article, forcing them to acknowledge the restriction. Each resource was simply listed in alphabetical order by author name, with the date and a brief title. However, there was no organizing principle underpinning this collection to guide users to a specific resource that might be useful to them, and no way to form a coherent overview of the literature and of emerging conceptual frameworks.

2 The use of the VRE within education research projects has been the focus of another project based at CARET. See Carmichael, P., Procter, R., Rimpilainen, S. and Laterza, V. (2006) 'Sakai: A Virtual Research Environment for Education' *Research Intelligence* 96 (August 2006) pp.18-19, and Laterza, V., Carmichael, P., and Procter, R. (2007 forthcoming) 'The Doubtful Guest? A Virtual Research Environment for Education' *Technology, Pedagogy and Education* 16(3) for further details.

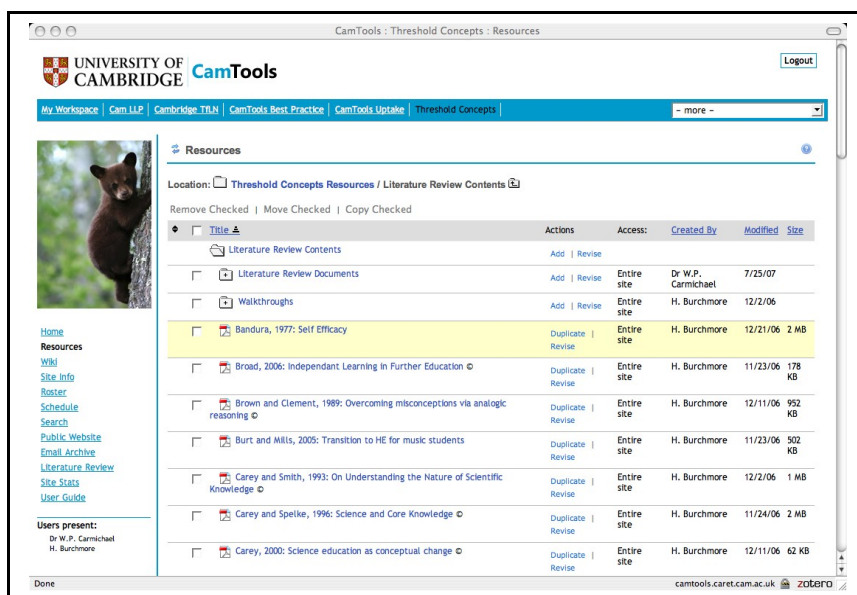


Figure 1: The CamTools worksite for the Transforming Perspectives project, showing the Resources tool with downloadable files. Note the use of © for papers with copyright restrictions.

To this end, the wiki tool was used to develop both interpretative frameworks and to present users with brief overviews of the literature review. The wiki is a read/write web interface, which allows content to be added or amended by any user able to access the VRE, allowing people to make notes, have online discussions over time and to write collaboratively. As such it allowed the cumulation, organization and reorganization of information as conceptual frameworks emerged. An example is a wiki page which was developed early in ‘Phase 2’ of the literature review called ‘10 Must-Read Papers about Threshold Concepts’. This was intended to involve them new participants immediately with the subject matter of the project and the seminar series. While this page has subsequently been superseded, it still provides an important snapshot of the conceptual foundations of the later work of the projects, and for that matter, for the literature review. It has provided a shared background and ‘point of focus’ for the group, giving it purpose and identity. It also illustrated to the network the power of collaborative working using the wiki, and how changing conceptions could be easily captured in order to be shared across the group. The wiki tool was then used to develop the commentaries which form parts of Section 3 of this literature review.

As the literature review developed, it became apparent that a more systematic approach was needed if resources were to be managed effectively. Rather than restrict ourselves to the literature that we could make available through CamTools, we sought out another way of storing our gathered literature that also gave us enhanced flexibility in sharing it with our network. By this point, ‘social software’ designed for sharing resources (such as video, photographs, music and internet bookmarks) with a wide audience (while respecting access restrictions and copyright) was becoming more prevalent. Following a review of ‘bookmarking’ sites such as del.icio.us (<http://del.icio.us/>) and web-based citation managers, such as Cite-u-Like (<http://www.citeulike.org/>), we identified the Connotea Online

Reference Management System (<http://www.connotea.org>) as best matching our requirements (see Figure 2).

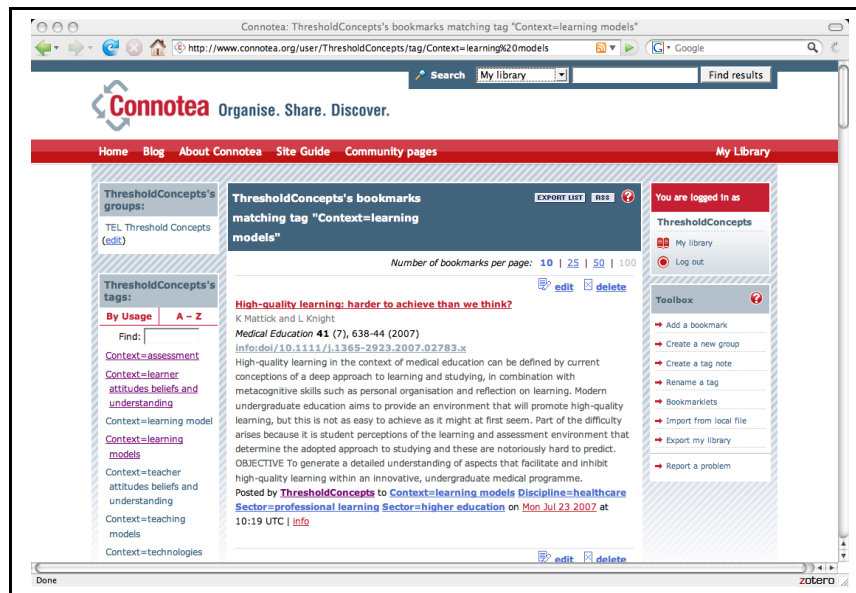


Figure 2: The Connotea Library Interface at <http://www.connotea.org> showing user-defined tags (left); a selected citation and abstract (centre) and tools and functions (right)

Connotea is a free online reference management resource site, established in 2004 by the Nature Publishing Group. Although intended initially for clinicians and scientists to collect and share references such as journal papers and books, the user community has grown in size and expanded into a wide range of other academic disciplines in just a few years. It works much the same way as other social software tools in that it is a metadata management system rather than a digital repository, but is aimed at the meeting the rigorous bibliographic standards of the academic community as well as facilitating the sharing and collective ‘tagging’ by users of citations. It also provides ‘helper’ applications which allow the rapid assimilation of metadata and abstracts from publishers’ websites; ‘import’ and ‘export’ functions making Connotea libraries interoperable with Endnote and BibTex libraries; and, critically, an API (application programming interface) allowing software developers to take Connotea metadata content and reuse it in other applications and services, or to build entirely new interfaces to Connotea content. The project’s Connotea library is searchable (but not editable) by any member of the public, who can identify it in searches as the library of the user: “ThresholdConcepts”.

Following a review of the project’s conceptual framework a metadata vocabulary was established which was then used to ‘tag’ the links to online resources – in addition to keywords and other identifiers provided as part of the metadata ‘packets’ provided by authors and publishers. Each of five themes (interpretative framework; pedagogical context; disciplinary context; methodology; and sector – of which more shortly) became a ‘first level tag’, under which we were able to provide a second level description to give greater granularity. So a resource might be tagged as

“Discipline=Economics, Sector=Higher Education, Methodology=Case Study”. This allows users to search the contents of the project Connotea library; select whether to display citations only or abstracts and annotations; and to export search results in a variety of formats. A full list of tags is included in Annex 1 of this review.

The Connotea API was used to develop a custom Perl application which was then incorporated into the CamTools website. This took the metadata records of the entire library (which are presented in Extensible Markup Language) and used this to generate a ‘cleaner’ read-only interface allowing:

- Browsing of the entire library, sorted by date or author
- Display of further information (such as abstracts or annotations) of individual records with linking directly to downloadable web resources, papers and publishers’ websites
- Display of all currently-used metadata tags (see Figure 3)
- Searching ‘by tag’ to display custom lists of records (see Figure 4)

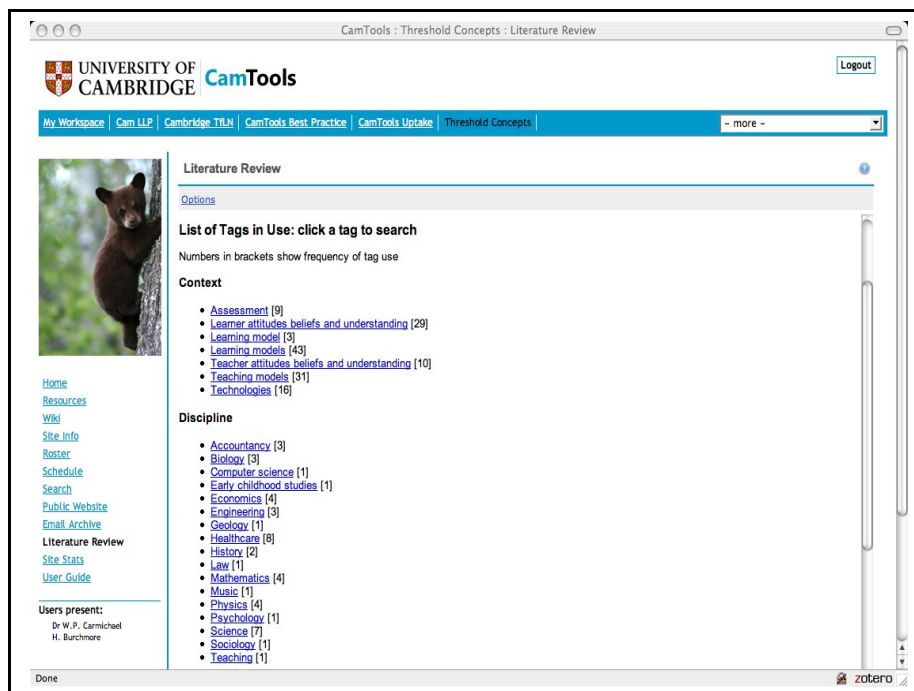


Figure 3: Interactive literature review interface within the project worksite, showing the list of tags. The number in brackets after the ‘tag’ indicates the number of resources with that tag.

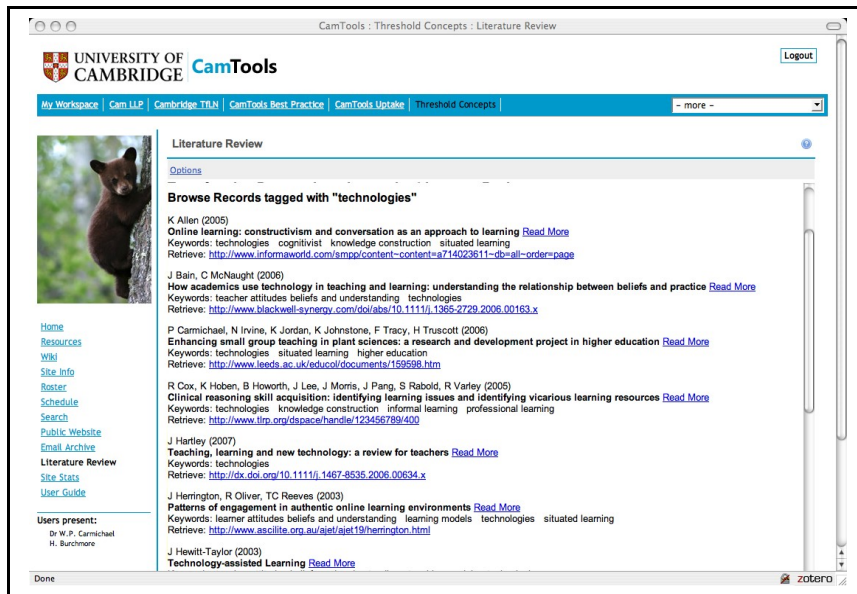


Figure 4: Interactive literature review interface within the project worksite, showing the results of a search with citation details. Users have the option to ‘read more’ - which displays abstract and annotations, or to click a hyperlink taking them directly to the online resource in question.

These features helped to shape the final phase of the literature gathering; using the ‘view by tag’ function, it was possible to gain quick overviews of where literature was richest: this allowed hypothesis generation and testing by subsequent searching of ‘gap’ areas. This work was fed back to the network through seminars and via CamTools, where the interactive literature review complemented and elaborated the emerging themes and interpretative framework developing in the wiki and other project resources. The combination of CamTools, Connotea and some ‘glue’ applications linking them proved to be a very interesting instance of an academic community using combinations of social and collaborative software to create a ‘shared history’ of activity and a foundation for subsequent research, as well as providing a strong sense of shared identity.

The Connotea library is also available as an ‘EndNote’ export file – either directly from the Connotea site, or from the project website at <http://www.caret.cam.ac.uk/tel>.

In summary, then, this literature review is available as:

- A ‘paper’ review, downloadable from the project website
- An ‘EndNote’ export file, downloadable from the project website
- A Connotea library: an online library in a reference management system
- A web service within CamTools, an online space for collaboration and communication

Section 3: Interpretative Framework and Commentaries

The interpretative framework which developed from the literature review and seminar series (and which informed the metadata vocabulary described in Section 2 and set out in Annex 1) involved five themes or dimensions. While these were intended to be independent of each other, in practice distinct patterns and associations were found. The five dimensions were as follows (the ‘short’ version of each used as a metadata tag is in bold):

- **Educational Context**: broad educational setting, agenda or focus, including assessment, technology, teacher and learner beliefs and practices
- **Discipline**: discipline, sub-discipline, subject or course
- **Interpretative Framework**: interpretative framework, theoretical perspective, view of teachers and learners, or of teaching and learning
- **Methodology and Research Approaches**: approaches to the identification and exploration of threshold concepts or to the design and implementation of developments or interventions
- **Sector or Setting**: sector or setting, school, undergraduate, postgraduate, professional and workplace learning

The remainder of this section comprises five commentaries, each addressing one of these dimensions. In each case, they refer to the list of metadata tags or categories in Annex 1 and the full list of citations in Annex 2. In each case, major themes are discussed, key papers are identified and placed in context, and the specific approaches and findings of the Transforming Perspectives project are described.

Commentary: Educational Context

To date, the majority of research into threshold concepts has involved their role in specific disciplines (see Commentary: Discipline), and for the most part these have explore expert teacher perspectives on curriculum design and development. To characterise all work on threshold concepts as ‘curriculum research’ is unwarranted, however, as those who have undertaken these studies have also considered other teacher perspectives and those of students in addition. Added to this are examples of research and development work which are concerned with specific issues and pedagogical contexts.

Teacher Perspectives

The epistemological significance of threshold concepts and conceptual change more generally means that any study of their role must take account of the (often tacit) beliefs held by teachers about learning and about their own role. These have a great impact on the pedagogical strategies they employ (or choose not to), their assessment practices (**Samuelowicz and Bain, 2002; Hativa et al, 2001; McGuinness 2005**), their conceptions of student ability (**Hart, 1998**) and even their use of technology in the teaching and learning environments (**Bain and McNaught, 2006**).

Teacher self-efficacy and self-confidence may also be significant in that it shapes their approaches to teaching within a ‘entangled domain’ where what information or behaviour is required of them is unclear (clearly threshold concepts and troublesome knowledge belong here) with teachers tending to fall back on more embedded teaching and ‘lower stakes’ practices that do not necessarily align with their beliefs (**Pajares, 1992; Samuelowicz and Bain, 2002, Hativa et al, 2001**).

The approaches that students adopt in their studying come to reflect the attitude to teaching they perceive from their teacher, showing a strong relationship between teachers’ approaches to teaching and the learning outcomes of students (**Trigwell et al, 1997; Entwistle et al, 2002**). When attempting to facilitate conceptual change, teachers themselves need to reflect on their instructional methodology (**Silcock, 1994**) and assume new roles (**Posner et al, 1982**), as well as refocusing their assessment strategy (eg. **Watkins, 2003**).

These areas may represent fruitful areas for further, detailed exploration of *how* teachers engage themselves and their students with troublesome knowledge. The parallels with the conceptual change teaching / alternative conceptions movement in school science may be relevant here (this being a literature acknowledged to be important to current work on threshold concepts and troublesome knowledge). This developed through the interrelationship of high-level overviews (such as **Carey, 1991**) and intensive classroom studies focussed on pedagogical practice.

Learner Perspectives

The contribution of students to the discourse of threshold concepts has largely been to highlight areas of the curriculum wherein threshold concepts might lie by indications that they are finding them ‘troublesome’. There is agreement that threshold concepts align with conceptual change, which is ‘extremely difficult to achieve’ (**Carey, 2000**). However, the system within which they are embedded may also present difficulties to students that go beyond the curriculum (**Perkins, 2006**). Often the troublesomeness of a concept lies in applying it in an operational way (**Sfard, 1991**) or the change in learner identity it provokes (**Cousin, 2006; Kennedy, 1987**) and it is at this point that students display ‘surface approaches to learning’ (**Entwistle, 2005**) which may indicate a liminal state (**Meyer and Land, 2003**) and inhibit further progress.

The development of a capacity for critical thinking is often an implicit metacognitive objective in higher education, implying that a student will be able to construct their own epistemological framework from which to regard disciplinary ‘knowledge’ (**Moon, 2005**). Baxter Magolda describes four stages of development towards ‘independent knowing’ a stage of critical thinking where learners engage actively in critical thinking and independent enquiry and encounters with contradictory views are essential part of their development (**Baxter Magolda, 1992**). However, many teachers themselves are not clear on what critical thinking is, how to facilitate its development in students and as curricular

content is often more clearly specified – and linked ultimately to definitive assessment – rely on it emerging as an attribute of ‘good students’ (**Pithers and Soden, 2000**).

Technology

The use of technology in higher education is so new that the evaluation of such usage is still a matter of research interest (**Scanlon and Issroff, 2005**). Several major reviews of the use of technology implemented as ‘e-learning’ have looked at the underlying pedagogies of online learning, often stimulated by a need to transfer courses to an online environment (**Koper, 2001; Williams, 2002; Jaffee, 2003; Herrington, Oliver and Reeves, 2003; Nichols, 2003; Mayes and de Freitas, 2004; Hartley, 2007**). While some of these have considered the potential of technologies to support constructivist and social models of learning, these are often couched in terms of generalised learning designs rather than detailed case studies of technology-enhanced learning guided by conceptual change models, for example.

The role of technology in facilitating reflection has been well documented across a range of contexts including: development of clinical reasoning skills in Speech and Language Therapy students (**Cox et al, 2006**), schoolchildren engaged in collaborative portfolio creation (**Lee, Chan and Aalst, 2006**) and undergraduate students recruited as co-researchers in a new completely online degree course (**Revill et al, 2005**). There remain some interesting challenges (mirroring those in offline environments) with respect to supporting teaching and learning as conceptual change in situations where summative and high-stakes assessment remains in place. Technologies dealing with the assessment of conceptual change or development of expertise remain troublesome to specify, let alone develop (**Spector, 2006**).

Technologies that have been discussed in a learning context dealing with uncertainty and troublesomeness are more generally termed ‘technology-assisted learning’ and concern the creation of online environments for learning communities, which may include distance or adult learners (**Hewitt-Taylor, 2003**). These spaces generally have a flexible design which arises from and responds to usage patterns; blurs distinctions between ‘learners’ and ‘teachers’; creates a strong sense of shared community and identity, leading to mutual support; and offer flexibility in the choice of embedded features, tools or ways of use. Examples of such online communities can be found in Talk 2 Learn (**Allen, 2005**) and Sakai (**Rimpilainen and Carmichael, 2006**).

One area that may represent a promising avenue for enquiry, capable of supporting both individual and group teaching and learning activities, engagement with complex ‘webs of concepts’ (**Davies and Mangan, 2005**), and potentially also aligning with formative assessment approaches is ‘concept mapping’ technology (**Novak and Canas, 2006**). However, research has shown that while concept maps may work well as an exercise in making explicit the links between concepts, they do not give rise to significant gains in learning unless combined with other practices such as peer collaboration

and discussion (**Bevan, 2004**). This suggests that such mapping tools may offer maximum learning potential when integrated into the kind of learning spaces described above.

Commentary: Discipline

Even though the notion of threshold concepts is offered as an idea with cross-disciplinary relevance, as a new research agenda (and as described in the commentary on ‘Sector’, one that is largely confined to higher education) its reach and impact across the disciplines has, to date, been uneven.

In the course of the literature review we identified articles, papers and other resources either concerned with threshold concepts directly or with closely related topics and ideas in seventeen disciplines, with healthcare, sciences and economics best represented. Initially, the resources collected were mainly case studies relating to threshold concepts where the predominant agenda is the identification of a threshold concept and its rationalisation against the ‘five characteristics’ (see the commentary on ‘Methodology’ for further discussion of this issue).

These case studies included Economics (**Meyer and Land, 2003; Davies, 2003; Meyer and Land 2005; Davies and Mangan, 2005; Meyer and Land, 2006; ETC Project Newsletters 2005-2007**); Computer Science (**Eckerdal *et al.*, 2006**); Geology (**Miller, 2006** and the **Special Edition of Planet journal**, where case studies included ‘time’, ‘sustainability’, ‘spatial literacy’ and ‘climate change’). Other papers, offering a wider examination of threshold concepts and ‘troublesomeness’ within disciplines include a discussion of the reasons why business students find learning commercial law so difficult and illuminating the bounded nature of the legal discourse that itself presents problems to students (**Allen, 2005**) and of the idea of ‘caring’ as a threshold concept for healthcare students, where a personal framework blending personal attributes and professional practice needs to be constructed by students as they work with patients (**Clouder, 2005**). Other studies discuss transitions into professional practice and early career learning: in Music (**Burt and Mills, 2004**); Healthcare (**Fessey 2002; Kell and van Deursen 2002; Clouder and Sellars, 2004**); and across disciplines (**Eraut *et al.* 2004**).

The association of threshold concepts with distinctive ‘ways of thinking and practicing’ (WTP) in the disciplines also led us to include explorations of WTP from a number of disciplines: Biology (**McCune and Hounsell, 2005**); Sociology (**Jones, Jary and Rosie, 2004**); and History (**Anderson and Day, 2005**). The wide literature on conceptual change in science, although largely based on research in schools, has been linked to the threshold concepts literature (by **Davies and Mangan, 2005** in particular, who use **Carey, 1991** as a basis for their elaboration of threshold concepts) and so the literature review also includes work in this area. Some more general work discusses conceptual change within a broader context of individual learning and identity and disciplinary definition, particularly in newer and contested disciplines such as Cultural Studies (**Cousin, 2006**).

Carey looks at school science and theorises that what is troublesome is the ‘alternative conceptual frameworks for understanding’ that children have developed and that are regarded by staff as misconceptions to be eradicated (Carey, 2000). In this respect, the work of **Clement, Brown and Zietsman (1989)**, working in secondary school physics, proves interesting. They realised that the ideas children already had about subjects in physics prevented them from easily learning the ‘correct’ concepts. Preconceptions that were ‘wrong’ were termed misconceptions and discarded, but preconceptions that could be used to ‘anchor a scaffold of ‘bridging analogies’ towards the ‘correct’ concepts. See also **Palmer (1999)** and **Brown and Clement (1989)** for further explanations about troublesomeness in school science and the use of analogy to transform hidden preconceptions into ‘correct conceptions’.

Exploration of these disciplinary differences was at the heart of the activities of the ‘Transforming Perspectives’ project, which aimed to initiate interdisciplinary dialogue as a means to collaboratively better define what threshold concepts might represent across a range of disciplines and how they were manifest in the curriculum or perceived by teachers and students in order to best match technology to pedagogic requirements. This led to the involvement of participants from a science, engineering, social sciences, computer science and arts and humanities, as well as explorations of perspectives on threshold concepts in general from philosophy, psychology, education and social anthropology.

Commentary: Interpretative Framework

A number of writers have offered meta-analytical frameworks in which diverse educational theories, perspectives and practices may be located. These include Watkins’ threefold distinction between ‘learning as being taught’, ‘learning as individual sense-making’ and ‘learning as building knowledge with others’ (**Watkins, 2003**), Sfard’s metaphors for learning, ‘Acquisition’ and ‘Participation’ (**Sfard, 1998**) and Paavola et al’s three metaphors: Sfard’s two plus ‘Knowledge Creation’ (**Paavola, 2004**), and these sources shaped the thinking of participants in the project.

‘Associationist’ or ‘behaviourist’ perspectives on threshold concepts seem rare. At the same time, the dominance of high-stakes assessment in higher education which may be associated with such perspectives in that they are largely concerned with performance against externally-measured norms means that they are of interest, even if only as a potential barrier to the adoption of more constructivist approaches which might be employed to take account of troublesome threshold concepts. There are a number of central papers on threshold concepts and troublesome knowledge (**Davies, 2003; Davies and Mangan, 2005; Perkins, 2006**) which explicitly make the case for seeing threshold concepts as part of a constructivist research agenda, referring back to **Carey (1991)** and drawing parallels with the extensive research literatures on learning in school science and mathematics (for example: **Carey and Spelke, 1996; Clement, Brown and Zeitsman, 1989; diSessa, and Sherin, 1998; Scott, Asoko and Driver, 1991; White and Gunstone, 1989**). Many of these accounts do not advance purely cognitivist arguments; rather they could broadly be described as ‘social cognitivist’ or explicitly relate

their theoretical basis to classroom practices such as ‘conceptual change teaching’. A number of papers which refer to specific practices and approaches, and which frame these in largely cognitivist terms (see for example **Brown and Clement, 1989** and **Clement, 1998** on analogical reasoning and **Zeitsman and Clement, 1997** on ‘extreme case reasoning’) are interesting in that they define expert and learner/novice approaches and capabilities – also a theme in social/situated models of learning.

A specific social/situated learning perspective, and one which would lie entirely within **Sfard’s (1998)** ‘participation metaphor’ would take threshold concepts to represent a particular aspect of the practice of a community. According to the ‘Communities of Practice’ perspective (**Lave and Wenger, 1991; Wenger, 1998; Wenger, McDermott and Snyder, 2002**; see also **Brown and Duguid, 1991**) threshold concepts may lie at a point on a learning trajectory when novice begins to think creatively and reflectively about their practice as an expert practitioner. They may therefore also represent the ‘points of focus’ (**Wenger, 1998**) around which novice-expert discourse may take place, or for that matter be ‘reified’ into processes, procedure or artefacts within the community.

Some accounts attempt to bridge the gap between cognitivist and social models, either using organising principles such as Biggs’ ‘constructive alignment’ (**Biggs, 1996**) to provide overarching frameworks, (other examples include: **Bereiter and Scardamalia, 1996; Chapman, Ramondt and Smiley, 2005**). Meyer and Land, in their various papers on threshold concepts incorporate elements from both cognitivist and social learning perspectives - the ‘transformative’ aspect being closely associated with individual learning while the ‘bounding’ aspect being more concerned with social perspectives (**Meyer and Land, 2003, Meyer and Land 2006**). Other papers on threshold concepts explicitly point up the importance of considering social issues alongside cognitivist ones in relation to significant conceptual changes (e.g. **Cousin, 2006**).

A final group of items in the review deal with themes in innovation and creativity; and the model of learning as ‘knowledge creation’ (**Paavola et al, 2004** characterise the work of **Nonaka and Takeuchi, 1995; Bereiter and Scardamalia, 1993; and Engestrom, 1987** in these terms). While some of these examples are couched in terms of business and technological innovation, others are explicitly concerned with a view of teaching and learning environments as being sites for knowledge creation. The nature of threshold concepts, their potential as disciplinary boundary-crossing objects and their association with the making explicit of tacit knowledge, suggests that they may have an important role in knowledge creation activities.

The Transforming Perspectives project from the outset recognised that TC’s had theoretical significance according to both cognitivist/conceptual change perspectives and those which see learning as a set of social processes and practices – in other words, that they transcended what **Sfard (1998)** calls the ‘two metaphors of learning’. Our engagement (and that of our research participants) with research into knowledge construction and innovation also showed that the concept of TC’s has

meaning within this ‘third metaphor’ (Paavola *et al*, 2004). This has interesting implications for the identification, characterisation and perceived role of TC’s, which, rather than representing individual learning ‘landmarks’ or ‘portals’ take on a discursively constituted role within the working practices of the group, some of which may be well-established to the point of defining disciplinary membership and identity. This aligns them with historically significant conceptual developments (discipline-bounding examples such as heliocentricity, the genetic basis for evolution, the bible as a literary text, or the problematisation of the nature of culture) but, rather than asserting any kind of simple ‘recapitulation’ of historical themes in individual learners, compares like with like – historical models are also seen as discursively constituted, contested and context-laden.

This view of learning as involving or being embedded within discursive practice means that ‘troublesomeness’ is not equated with specific learners having misconceptions while others have achieved mastery; rather it provides a legitimate point of focus for enquiry and reflection (see Irvine and Carmichael, 2007 for a further account of how this was manifest in the work of the project participants). In short, the key question for teachers and learners becomes not ‘why is X hard?’ or ‘Why is this student struggling to achieve X?’ but ‘What is it about X that makes it worthy of further enquiry and reflection?’.

Commentary: Methodology and Research Approach

Our enquiry into research methods used to explore threshold concepts began with the issue of their definition. The original definition of threshold concepts as ‘akin to a portal’ and as ‘transformative, probably irreversible, integrative, often troublesome and probably bounded’ (Meyer and Land, 2003) has been refined through processes of their subsequent identification. Carey’s categories of conceptual change (Carey, 1991) have been used to elaborate and differentiate types of threshold concept: ‘basic’, ‘disciplinary’ and ‘modelling’ (Davies and Mangan, 2005). However, the central definition of what constitutes a threshold concept remains, and has been reinforced by a series of papers from the ETL and ETC projects (Davies, 2003; Davies, 2006; Meyer and Land, 2006; and three Newsletters from the **Embedding Threshold Concepts** project, 2005-2007). The two resources labelled as being concerned with strategies for the identification of threshold concepts (Meyer and Land, 2003; Davies and Mangan, 2005) are in fact a subset of those concerned with definition: highlighting the fact that during this early research phase, definition and identification have proceeded in parallel. This strong correlation between the original definition and the research agenda informing the methods used for identification of potential threshold concepts is one of the strongest themes to run through the literature, the well-established definition shaping and perhaps even circumscribing enquiry and discourse surrounding the central idea of threshold concepts.

A next group of articles and conference papers were case studies of specific threshold concepts or groups of concepts within specific disciplines, this restriction was clear; we found that case studies were generally concerned with an agenda of identification, generally by subject experts using the a

framework derived from the identification-definition literature outlined above to review and suggest revisions to a curriculum (e.g. **Allen, 2005**; **various in the special edition of *Planet journal***; **Miller, 2006**), usually within the originating context of higher education.

The broader view developed by the project, of threshold concepts as aligning with key issues in early professional learning and transitions from HE into workplace learning led to exposure of a more varied range of methods and theoretical frameworks: including explorations of troublesomeness, conceptual change, and transformed learner identities. These include studies of students in healthcare as professional carers (**Clouder, 2005**); the development of clinical fluency in nurses (**Fessey, 2002**); exploration of student coping mechanisms and identities (**Cousin, 2006**) and learner identities over the life course (**Hodkinson, 2005**). A further, extended set of resources were also included in the review because they provided metaphors or meta-level frameworks for describing views of teaching and learning, within which interpretations of the nature and role of threshold concepts could be located. These included accounts of acquisition and participation metaphors (**Sfard, 1998**) and those which interpret learning as knowledge creation or construction (**Paavola, 2002**; **Bereiter and Scardamalia, 1996**).

The ‘Transforming Perspectives’ project was unusual in that, while it involved the construction of case studies within the disciplines, this took place within a broader, cross-disciplinary and interdisciplinary framework, allowing the engagement of participants with threshold concepts from disciplines other than their own and, following from this, the identification of pedagogical and epistemological similarities and differences across the cases (**Irvine and Carmichael, 2007**).

Commentary: Sector or Setting

Current interest in threshold concepts can be largely attributed to work within the Higher Education (HE) sector carried out by ETL, the Enhancing Teaching-Learning Environments in Undergraduate Courses project (<http://www.ed.ac.uk/etl>), and the majority of articles, project reports, book chapters and conference papers collected in this review have continued to concentrate on this sector. Research which is explicitly concerned with threshold concepts and references Meyer and Land’s work (**Meyer and Land, 2003**) directly (rather than being about conceptual change in general, or issues of professional expertise) remains largely based in HE, examples being studies in Legal Education (**Allen, 2005**) and Economics (**Davies and Mangan, 2006**).

One of the intended outputs of the ETL project was to ‘develop more precise ways of thinking about university teaching and learning’ (**Entwistle, 2003**), and since that point, threshold concepts have become established as one of a number of conceptual tools to examine and potentially refocus curricula within some HE disciplines. Within the HE sector, threshold concepts arose as one of a set of conceptual frameworks that might be of use as part of a drive to improve the quality of teaching-learning environments within the sector (**McCune, 2003**; **Entwistle, 2003**). As such, there are

overlaps between work on threshold concepts and other ‘deep learning’ activities involve students being encouraged to look beyond presented curricular concepts and attempting to assemble a comprehensive understanding of the subject.

However, often problems experienced by students are due to the ‘wide disciplinary variations in the nature of the learning outcomes that students are expected to achieve’ (**Entwistle, 2005**). These may include explicitly stated ‘hard concepts’, which the definition of threshold concepts may explain and help to identify within a curriculum, but include also tacit ‘ways of thinking and practicing’ (**Hounsell and McCune, 2004; Anderson and Day, 2005**) that are often implied but not made explicit within formal teaching-learning environments. According to this perspective, threshold concepts might be seen not as clearly defined elements of curricular content, but as part of the evolving repertoire of a legitimate peripheral participant, gradually developing their ‘identity as’ by increasingly taking part in the practices of a learning or disciplinary community (**Lave and Wenger, 1991; Wenger, 1998**). These social dimensions to student learning are multi-faceted and have been explored by SOMUL, the Social and Organisational Mediation of University Learning project (**Houston and Wood, 2005**), including departmental organisation, the self-perception of a discipline as reflected in its curriculum, the conceptions of teaching held by staff (**Akerlind, 2004**) and the students conceptions of learning (**Kell and van Deursen, 2002**). If this is indeed important, then the role of threshold concepts may be closely associated with the perceptions by teachers, learners and broader communities of its role within the HE sector.

This interplay between social role, learner identity and conceptual development (including threshold concepts) is also evident as students move into postgraduate education, where each individual is required to construct their own research agenda and conceptual framework (**Leshem and Trafford, 2007**), but also to display academic and disciplinary professionalism and an ability to ‘make a contribution to knowledge’. Many postgraduates embarking on their PhD studies are reported as find this process daunting and confusing, and often fall back into treating their work as a higher level of undergraduate study (**Trafford, 2007** in press). Postgraduate students at Oxford University are reported to be happier with their overall experience and anticipate better results when the social and intellectual aspects of their work align (**Trigwell and Dunbar-Goddet, 2005**).

Two other sectors which are fairly well represented in related literatures are workplace and professional learning, although there is a great deal of blurring between these two categories, and some also overlap with Higher Education for example where an undergraduate course leads onto a well-established trajectory of further professional development (see **Burt and Mills, 2004** for a discussion of this in the context of musicians). One theme which is evident in studies of workplace and professional learning is that learning becomes more commonly couched in terms of participation (**Sfard, 1998**) and learning practices and outcomes are more tacit. The necessity of effecting a smooth transition from an identity as an undergraduate to that of being a developing professional can

in itself require a transformation that is ‘troublesome’, and in which conceptual change learning may need to be supported by their environment (**Mattick and Knight, 2007**), for example through focused discussion of professional practice in the context of ‘vicarious learning’ activities (**Cox *et al.*, 2005**). When there is a mismatch between the student perceptions of how to go about becoming a professional and the environment they are attempting that within, students often stall in their progress. Identification of interruptions to ‘clinical fluency’ in qualified nursing staff progressing towards proficiency in a surgical specialism allows the isolation of tacit key skills and practices to be learnt and provides useful opportunities to explore ‘newcomer progression’ within surgical teams (**Fessey, 2002**). Although not explicitly couched as such, these interruptions clearly have much in common with threshold concepts.

There exists a large body of research into conceptual change learning in secondary schools, including frameworks explaining conceptual change (**Carey, 1999; Palmer 1989**), reviews of strategies for how conceptual change teaching (especially in the sciences) might be developed (for example **Scott, Asoko, and Driver, 1991**) and how it might be achieved by reframing specific student misconceptions using existing internal cognitive schema as ‘anchors’ leading to ‘correct conceptions’ (**Brown and Clement, 1989**). Broader perspectives on learner motivation have been applied to understanding processes of conceptual change and examining the wider background of conceptual difficulty in secondary schooling and student motivations for overcoming it (**Pintrich, Marx and Boyle, 1993**). The motivation underpinning the conceptual change approach to teaching in secondary schools is a reflection of the necessity to focus scarce resources on curricular design targeted at attaining maximum pupil achievement (leading to Sfard’s characterisation of constructivist approaches as essentially about ‘acquisition’ (**Sfard, 1998**). However, recent research by the TLRP (Teaching and Learning Research programme) within this sector is working to widen the range of learning objectives and assessment to capture learning that appears to be aligned with the threshold concept characteristics of transformation and integration, taking place in more participatory fashion (e.g. **McGuinness, 2005**). While threshold concepts as described by Meyer and Land have not been used to conceptualise learning in the school sector, the combination of conceptual change teaching approaches and studies of learner motivation and agency aligns well with it.

The work of the ‘Transforming Perspectives’ project was largely concerned with teaching and learning in HE, and took as its point of departure work based in the ETL project and its successors (**Meyer and Land, 2003, 2005; Davies and Mangan, 2005, 2006**) and work by participants in project seminar series resulted in the creation of case studies that explored the HE context further, but also included learning in postgraduate biomedical science and coaching in sports science (**Irvine and Carmichael, 2007 forthcoming**). Additionally, as our search began to explore disciplinary differences within HE, we also began to investigate how troublesome, transformative and integrative learning manifested across a broader range of formal and informal learning environments.

Annex 1: Full List of Metadata Keywords Used

Numbers in brackets show number of items with the specific keyword amongst the items in the collection. The majority of items in the collection were assigned multiple keywords.

Context The broad educational setting, agenda or focus of the publication	Assessment [8] Learner attitudes beliefs and understanding [27] Learning models [43] Teacher attitudes beliefs and understanding [10] Teaching models [32] Technologies [14]
Discipline Discipline, subject or course	Accountancy [2] Biology [3] Computer science [1] Early childhood studies [1] Economics [4] Engineering [2] Geology [1] Healthcare [7] History [2] Law [1] Mathematics [4] Music [1] Physics [4] Psychology [1] Science [6] Sociology [1] Teaching [1]
Framework Interpretative framework, theoretical perspective or view of teachers/teaching or learners/learning	Behaviourist [5] Cognitivist [24] Expertise theory [16] Historical studies [1] Innovation theory [6] Knowledge construction [19] Situated learning [38]
Methods Research approaches, methods, instruments or issues	Case study [7] Communication [1] Definitions [5] Identification [2] Metaphors [2] Review [5]
Sector Educational setting or sector	Further education [8] Higher education [44] Informal learning [4] Professional learning [13] Secondary school [4] Workplace learning [9]

Annex 2: Full Alphabetical Listing of Items

G Akerlind (2004)

A new dimension to understanding university teaching

Teaching in Higher Education 9(3) pp. 363-375

URL: <http://www.informaworld.com/10.1080/1356251042000216679>

K Allen (2005)

Online learning: constructivism and conversation as an approach to learning

Innovations in Education and Teaching International 42(3) pp. 247-256

URL: <http://www.informaworld.com/smpp/content~content=a714023611~db=all~order=page>

V Allen (2005)

A reflection on delivering legal education to business students

2005 Annual Conference of the Society for Research into Higher Education

URL: <http://www.ukcle.ac.uk/interact/lili/2006/papers/allen.html>

J Anderson, L Reder, H Simon (1996)

Situated Learning and Education

Educational Researcher 25(4) pp. 5-11

URL: [http://links.jstor.org/sici?sici=0013-189X\(199605\)25%3A4%3C5%3ASLAE%3E2.0.CO%3B2-B](http://links.jstor.org/sici?sici=0013-189X(199605)25%3A4%3C5%3ASLAE%3E2.0.CO%3B2-B)

C Anderson, K Day (2005)

University History Teaching: Disciplinary Distinctiveness, Design and Dialogue

ETL Project: A presentation for the History in British Education Conference

URL: <http://www.ed.ac.uk/etl/docs/HBEpaper.pdf>

J Bain, C McNaught (2006)

How academics use technology in teaching and learning: understanding the relationship between beliefs and practice

Journal of Computer Assisted Learning 22(2) pp. 99-113

URL: <http://www.blackwell-synergy.com/doi/abs/10.1111/j.1365-2729.2006.00163.x>

A Bandura (1977)

Self-efficacy: Toward a unifying theory of behavioral change

Psychological Review 84(2) pp. 191-215

URL: <http://content.apa.org/journals/rev/84/2/191>

M Baxter Magolda, *Knowing and Reasoning in College: Gender-related Patterns in Students' Intellectual Development*. (1992) San Francisco: Jossey-Bass

C Bereiter, M Scardamalia (1996)

Rethinking Learning in: D. Olson and N. Torrance (eds.)

The Handbook of education and human development: New models of learning, teaching and schooling

Cambridge, MA: Basil Blackwell, pp. 485-513.

R Bevan (2004)

From black boxes to glass boxes: the application of computerised concept mapping in schools

5th Annual Conference of the Teaching and Learning Research Programme

URL: <http://www.leeds.ac.uk/educol/documents/00003925.pdf>

J Biggs (1996)

Enhancing teaching through constructive alignment

Higher Education 32(3) pp. 347-347

URL: <http://dx.doi.org/10.1007/bf00138871>

M Bloomer, D James (2001)

Cultures and learning in further education

British Educational Research Association Annual Conference, University of Leeds, 2001

URL: http://www.tlpr.org/dspace/retrieve/542/EX_BR_JMB_DJA_PUB_13.09.01.doc

- J Booth (2006)
On the mastery of philosophical concepts in: Meyer, J.H.F. and Land, R. (eds) *Overcoming Barriers to Student Understanding: threshold concepts and troublesome knowledge* (London: Routledge) pp. 173-181
URL: <http://www.informaworld.com/smpp/content~content=a755535038>
- J Broad (2006)
Interpretations of independent learning in further education
Journal of Further and Higher Education 30(2) pp. 119-143
URL: <http://www.informaworld.com/smpp/content~content=a745950661~db=all~order=page>
- D E Brown, J Clement (1989)
Overcoming misconceptions via analogical reasoning: abstract transfer versus explanatory model construction
Instructional Science 18(4) pp. 237-237
URL: <http://dx.doi.org/10.1007/bf00118013>
- J Brown, P Duguid (1991)
Organizational Learning and Communities-of-Practice: Toward a Unified View of Working, Learning, and Innovation
Organization Science 2(1) pp. 40-57
URL: [http://links.jstor.org/sici?sici=1047-7039\(1991\)2%3A1%3C40%3AOLACTA%3E2.0.CO%3B2-3](http://links.jstor.org/sici?sici=1047-7039(1991)2%3A1%3C40%3AOLACTA%3E2.0.CO%3B2-3)
- D E Brown (1993)
Refocusing core intuitions: A concretizing role for analogy in conceptual change
Journal of Research in Science Teaching 30(10) pp. 1273-1273
URL: <http://dx.doi.org/10.1002/tea.3660301009>
- R Burt, J Mills (2005)
The transition from school to higher education in music: four UK institutions compared
Society for Research into Higher Education Annual Conference, Dec 2005
URL: <http://www.tlrp.org/dspace/handle/123456789/398>
- S Carey (1991)
Knowledge Acquisition: Enrichment or Conceptual Change? In Carey, S and R Gelman (Eds) *The Epigenesis of Mind: Essays on Biology and Cognition*, (1991), Hillsdale, NJ: Erlbaum.
- S Carey, C Smith (1993)
On understanding the nature of scientific knowledge
Educational Psychologist 28(3) pp. 235-251
URL: http://www.leaonline.com/doi/abs/10.1207/s15326985ep2803_4
- S Carey, E Spelke (1996)
Science and Core Knowledge
Philosophy of Science 63(4) pp. 515-533
URL: [http://links.jstor.org/sici?sici=0031-8248\(199612\)63%3A4%3C515%3ASACK%3E2.0.CO%3B2-6](http://links.jstor.org/sici?sici=0031-8248(199612)63%3A4%3C515%3ASACK%3E2.0.CO%3B2-6)
- S Carey (2000)
Science Education as Conceptual Change
Journal of Applied Developmental Psychology 21(1) pp. 13-19
URL: <http://www.sciencedirect.com/science/article/B6W52-3YSXD50-2/2/f73d7ad2b270808fc2894aaf55260691>
- S Carey (2004)
Bootstrapping & the origin of concepts
Daedalus 133(1) pp. 59-68
URL: <http://www.mitpressjournals.org/doi/abs/10.1162/001152604772746701>
- P Carlile (2002)
A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development
Organization Science 13(4) pp. 442-455
URL: [http://links.jstor.org/sici?sici=1047-7039\(200207%2F08\)13%3A4%3C442%3AAPVOKA%3E2.0.CO%3B2-1](http://links.jstor.org/sici?sici=1047-7039(200207%2F08)13%3A4%3C442%3AAPVOKA%3E2.0.CO%3B2-1)

- P Carmichael, N Irvine, K Jordan, K Johnstone, F Tracy, H Truscott (2006)
 Enhancing small group teaching in plant sciences: a research and development project in higher education
 Paper presented at the British Educational Research Association Annual Conference, University of Warwick, 6-9
 September 2006
 URL: <http://www.leeds.ac.uk/educol/documents/159598.htm>
- C Chapman, L Ramondt, G Smiley (2005)
 Strong community, deep learning: exploring the link
Innovations in Education and Teaching International 42(3) pp. 217-230
 URL: <http://www.informaworld.com/10.1080/01587910500167910>
- C Chin, D Brown (2000)
 Learning in Science: A Comparison of Deep and Surface Approaches
Journal of Research in Science Teaching 37(2) pp. 109-109
 URL: [http://dx.doi.org/10.1002/\(sici\)1098-2736\(200002\)37:2%3C109::aid-tea3%3E3.0.co;2-7](http://dx.doi.org/10.1002/(sici)1098-2736(200002)37:2%3C109::aid-tea3%3E3.0.co;2-7)
- J Clement, D Brown, A Zietsman (1989)
 Not all preconceptions are misconceptions: finding anchoring conceptions for grounding instruction on students
 intuitions
International Journal of Science Education 11(5) pp. 554-565
 URL: <http://www.informaworld.com/10.1080/0950069890110507>
- J Clement (1998)
 Expert novice similarities and instruction using analogies
International Journal of Science Education 20(10) pp. 1271-1286
 URL: <http://www.informaworld.com/10.1080/0950069980201007>
- J Clement (1988)
 Observed methods for generating analogies in scientific problem solving
Cognitive Science: A Multidisciplinary Journal 12(4) pp. 563-586
 URL: http://www.leaonline.com/doi/abs/10.1207/s15516709cog1204_3
- L Clouder (2005)
 Caring as a 'threshold concept': transforming students in higher education into health(care) professionals
Teaching in Higher Education 10(4) pp. 505-517
 URL: <http://www.informaworld.com/smpp/content~db=all~content=a723756554~tab=citation>
- L Clouder, J Sellars (2004)
 Reflective practice and clinical supervision: an interprofessional perspective
Journal of Advanced Nursing 46(3) pp. 262-269
 URL: [http://www.blackwell-synergy.com/action/showPdf?submitPDF=Full+Text+PDF+\(77+KB\)&doi=10.1111%2Fj.1365-2648.2004.02986.x&cookieSet=1](http://www.blackwell-synergy.com/action/showPdf?submitPDF=Full+Text+PDF+(77+KB)&doi=10.1111%2Fj.1365-2648.2004.02986.x&cookieSet=1)
- H Colley, P Hodgkinson, J Malcolm (2002)
 Non-formal learning: mapping the conceptual terrain, a consultation report.
 Leeds: University of Leeds Lifelong Learning Institute
 URL: http://www.infed.org/archives/e-texts/colley_informal_learning.htm
- G Cousin (2006)
 Threshold concepts, troublesome knowledge and emotional capital in: Meyer, J.H.F. and Land, R. (eds)
Overcoming Barriers to Student Understanding: threshold concepts and troublesome knowledge (London:
 Routledge) pp. 134-147
- R Cox, K Hoben, B Howorth, J Lee, J Morris, J Pang, S Rabold, and R Varley (2006)
 Clinical reasoning skill acquisition: identifying learning issues and identifying vicarious learning resources
 Teaching and Learning Research Programme Annual Conference, Nov 2005
 URL: <http://www.tlrp.org/dspace/handle/123456789/400>

- P Davies (2006)
Threshold concepts - how can we recognise them? in: Meyer, J.H.F. and Land, R. (eds) *Overcoming Barriers to Student Understanding: threshold concepts and troublesome knowledge* (London: Routledge) pp. 70-84
- P Davies, J Mangan (2005)
Recognising Threshold Concepts: an exploration of different approaches
Embedding Threshold Concepts project: Working Paper 2
URL: [http://www.staffs.ac.uk/schools/business/iepr/info/Economics\(2\).html](http://www.staffs.ac.uk/schools/business/iepr/info/Economics(2).html)
- P Davies (2003)
Threshold Concepts: how can we recognise them?
Embedding Threshold Concepts project: Working Paper 1
URL: [http://www.staffs.ac.uk/schools/business/iepr/docs/etcworkingpaper\(1\).doc](http://www.staffs.ac.uk/schools/business/iepr/docs/etcworkingpaper(1).doc)
- P Davies, J Mangan (2006)
Embedding Threshold Concepts: from theory to pedagogical principles to learning activities
Embedding Threshold Concepts project: Working Paper 3
URL: [http://www.staffs.ac.uk/schools/business/iepr/docs/etcworkingpaper\(3\).doc](http://www.staffs.ac.uk/schools/business/iepr/docs/etcworkingpaper(3).doc)
- P Davies, J Mangan (2006)
Trajectories of students' learning: threshold concepts and subject learning careers
Embedding Threshold Concepts project: Working Paper 4
URL: [http://www.staffs.ac.uk/schools/business/iepr/docs/etcworkingpaper\(4\).doc](http://www.staffs.ac.uk/schools/business/iepr/docs/etcworkingpaper(4).doc)
- A Disessa, B Sherin (1998)
What changes in conceptual change?
International Journal of Science Education 20(10) pp. 1155-1191
URL: <http://www.informaworld.com/10.1080/0950069980201002>
- K Ecclestone, J Pryor (2003)
'Learning Careers' or 'Assessment Careers'? The Impact of Assessment Systems on Learning
British Educational Research Journal 29(4) pp. 471-488
URL: [http://links.jstor.org/sici?sici=0141-1926\(200308\)29%3A4%3C471%3A'CO'CT%3E2.0.CO%3B2-J](http://links.jstor.org/sici?sici=0141-1926(200308)29%3A4%3C471%3A'CO'CT%3E2.0.CO%3B2-J)
- A Eckerdal, R McCartney, J E Mostrom, M Ratcliffe, K Sanders, C Zander (2006)
Putting Threshold Concepts into Context in Computer Science Education
URL: <http://www.it.uu.se/research/group/upcerg/files/EckerdalPuttingThresholdconcepts.pdf>
- A Edwards (2005)
Let's get beyond community and practice: the many meanings of learning by participating
Curriculum Journal 16(1) pp. 49-65
URL:
<http://www.informaworld.com/smpp/section?content=a713734834&fmt=.html&fulltext=713240928&scope=doc>
- Y Engeström (1897)
Learning by expanding: An activity-theoretical approach to developmental research
Helsinki, Finland: Orienta-Konsultit Oy.
URL: <http://www.hcirn.com/ref/refe/engy87.php>
- N Entwistle (2005)
Learning outcomes and ways of thinking across contrasting disciplines and settings in higher education
Curriculum Journal 16(1) pp. 67-82
URL: <http://www.informaworld.com/10.1080/0958517042000336818>
- N Entwistle (2003)
Concepts and Conceptual Frameworks Underpinning the ETL Project
Occasional Report 3, March 2003, Enhancing Teaching-Learning Environments in Undergraduate Courses Project
URL: <http://www.tla.ed.ac.uk/etl/docs/ETLreport3.pdf>

- N Entwistle, V McCune, J Hounsell (2002)
Approaches to Studying and Perceptions of University Teaching-Learning Environments: Concepts, Measures and Preliminary Findings
Occasional Report 1, September 2002, Enhancing Teaching-Learning Environments in Undergraduate Courses Project
URL: <http://www.tla.ed.ac.uk/etl/docs/ETLreport1.pdf>
- N Entwistle (2000)
Promoting deep learning through teaching and assessment: conceptual frameworks and educational contexts.
Paper presented at the TLRP Conference, Leicester, November 2000
URL: <http://www.tla.ed.ac.uk/etl/docs/entwistle2000.pdf>
- M Eraut (2003)
The many meanings of theory and practice
Learning in Health and Social Care 2(2) pp. 61-65
URL: <http://www.blackwell-synergy.com/doi/abs/10.1046/j.1473-6861.2003.00045.x>
- M Eraut, S Steadman, J Furner, F Maillardet, C Miller, A Ali, C Blackman (2004)
Early Career Learning at Work
TLRP Conference Paper, Cardiff 2004
URL: <http://www.sussex.ac.uk/usie/linea/CardiffTLRPpaperNov2004.doc>
- K Evans, N Kersh (2004)
Recognition of tacit skills and knowledge: Sustaining learning outcomes in workplace environments
Journal of Workplace Learning 16(1/2) pp. 63-74
URL: <http://www.emeraldinsight.com/Insight/viewContentItem.do?contentType=Article&contentId=882312>
- C Fessey (2002)
The development of clinical nursing capability: an analysis of progression towards individual clinical and role skills in a surgical ward
Learning in Health and Social Care 1(4) pp. 202-217
URL: <http://www.blackwell-synergy.com/doi/abs/10.1046/j.1473-6861.2002.00032.x>
- J Gallacher, B Crossan, T Mayes, P Cleary, L Smith, D Watson (2006)
Expanding our understanding of the learning cultures in community based further education
BERA 2006
URL: [http://brs.leeds.ac.uk/cgi-bin/brs_engine?*ID=13&*DB=BEID&*DD=Document:%206%3CBR%3E&*TH=BEIT&*TX=Y&*HI=N&*UZ=000163261\[DOCN\]&*QX=~~%40DENT%3E%2220070318%22](http://brs.leeds.ac.uk/cgi-bin/brs_engine?*ID=13&*DB=BEID&*DD=Document:%206%3CBR%3E&*TH=BEIT&*TX=Y&*HI=N&*UZ=000163261[DOCN]&*QX=~~%40DENT%3E%2220070318%22)
- H Gardner, T Hatch (1989)
Educational Implications of the Theory of Multiple Intelligences
Educational Researcher 18(8) pp. 4-10
URL: <http://edr.sagepub.com/cgi/reprint/18/8/4>
- D Gentner (1983)
Structure-Mapping: A Theoretical Framework for Analogy
Cognitive Science 7(2) pp. 155-170
URL: <http://www.cogsci.rpi.edu/CSJarchive/1983v07/i02/p0155p0170/MAIN.PDF>
- P Hager (2004)
The competence affair, or why vocational education and training urgently needs a new understanding of learning
Journal of Vocational Education & Training 56(3) pp. 409-433
URL: <http://www.informaworld.com/10.1080/13636820400200262>
- J Hartley (2007)
Teaching, learning and new technology: a review for teachers
British Journal of Educational Technology 38(1) pp. 42-42
URL: <http://dx.doi.org/10.1111/j.1467-8535.2006.00634.x>

- N Hativa, R Barak, and E Simhi (2001)
 Exemplary University Teachers: Knowledge and Beliefs Regarding Effective Teaching Dimensions and Strategies
The Journal of Higher Education 72(6) pp. 699-729
 URL: <http://www.jstor.org/view/00221546/di020052/02p0005u/0>
- J Herrington, R Oliver, TC Reeves (2003)
 Patterns of engagement in authentic online learning environments
Australian Journal of Educational Technology 19(1) pp. 59-71
 URL: <http://www.ascilite.org.au/ajet/ajet19/herrington.html>
- J Hewitt-Taylor (2003)
 Technology-assisted Learning
Journal of Further and Higher Education 27(4) pp. 457-464
 URL: <http://www.ingentaconnect.com/content/routledg/cjfh/2003/00000027/00000004/art00008>
- C Hoadley, P Kilner (2005)
 Using technology to transform communities of practice into knowledge-building communities
SIGGROUP Bull. 25(1) pp. 31-40
 URL: <http://portal.acm.org/citation.cfm?id=1067705>
- H Hodgkinson (2005)
 Learning as becoming, in changing experiences of work throughout life
 4th International Conference on Researching Work and Learning (Dec 2005)
 URL: <http://www.tlrp.org/dspace/handle/123456789/393>
- D Hounsell and C McCune (2004)
 Ways of thinking and practicing in biology and history: disciplinary aspects of teaching and Learning Environments
 Paper presented at Higher Education Colloquium, Centre for Teaching, Learning and Assessment, Teaching and Learning within the Disciplines,
 URL: <http://www.tla.ed.ac.uk/etl/docs/BioHistWTP.pdf>
- M Houston, E Wood (2005)
 Biosciences: An Overview of Undergraduate Studies in the UK
 What is Learned at University: The Social and Organisational Mediation of University Learning
 URL: http://www.open.ac.uk/cheri/pdfs/somul_biosciences_subject_overview_report.pdf
- S Hsiao-Ching (2004)
 Fostering radical conceptual change through dual-situated learning model
Journal of Research in Science Teaching 41(2) pp. 142-142
 URL: <http://dx.doi.org/10.1002/tea.10130>
- D Jaffee (2003)
 Virtual Transformation: Web-Based Technology and Pedagogical Change
Teaching Sociology 31 (2), 227-36
 URL: <http://www.jstor.org/view/0092055x/sp050007/05x0136f/0>
- R Jones, D Jary, A Rosie (2004)
 Sociology: An Overview of Undergraduate Studies in the UK
 What is Learned at University: The Social and Organisational Mediation of University Learning
 URL: http://www.open.ac.uk/cheri/pdfs/somul_sociology_subject_overview_report.pdf
- C M Kell, R W M Van Deursen (2002)
 Curricular influences on academic belief systems
Learning in Health and Social Care 1(2) pp. 86-93
 URL: <http://www.blackwell-synergy.com/doi/abs/10.1046/j.1473-6861.2002.00002.x>
- M Kennedy (1987)
 Inexact Sciences: Professional Education and the Development of Expertise
Review of Research in Education 14pp. 133-167
 URL: [http://links.jstor.org/sici?sici=0091-732X\(1987\)14%3C133%3AISPEAT%3E2.0.CO%3B2-F](http://links.jstor.org/sici?sici=0091-732X(1987)14%3C133%3AISPEAT%3E2.0.CO%3B2-F)

- R Koper (2001)
Modelling units of study from a pedagogical perspective: the pedagogical meta-model behind EML
First Draft (Version 2)
URL: <http://eml.ou.nl/introduction/docs/ped-metamodel.pdf>
- J Lave (1988)
Cognition in Practice: Mind, Mathematics and Culture in Everyday Life
Cambridge: Cambridge University Press
- J Lave, E Wenger (1991)
Situated Learning: Legitimate Peripheral Participation
Cambridge: Cambridge University Press
- E Y C Lee, C K K Chan, J Van Aalst (2006)
Students assessing their own collaborative knowledge building
International Journal of Computer-Supported Collaborative Learning 1(1) pp. 57-57
URL: <http://dx.doi.org/10.1007/s11412-006-6844-4>
- S Leshem and V Trafford (2007)
Overlooking the Conceptual Framework
Innovations in Education and Teaching International 44 (1), 93-105
URL: <http://www.informaworld.com/smpp/content~content=a770380742~db=all~order=page>
- J Malcolm, M Zukas (2001)
Bridging Pedagogic Gaps: conceptual discontinuities in higher education
Teaching in Higher Education 6(1) pp. 33-42
URL: <http://www.informaworld.com/10.1080/13562510020029581>
- K Mattick, L Knight (2007)
High-quality learning: harder to achieve than we think?
Medical Education 41(7) pp. 638-644
URL: [http://www.blackwell-synergy.com/action/showPdf?submitPDF=Full+Text+PDF+\(469+KB\)&doi=10.1111%2Fj.1365-2923.2007.02783.x](http://www.blackwell-synergy.com/action/showPdf?submitPDF=Full+Text+PDF+(469+KB)&doi=10.1111%2Fj.1365-2923.2007.02783.x)
- T Mayes, S De Freitas (2004)
JISC e-Learning Models Desk Study: Stage 2: Review of e-learning theories, frameworks and models
URL: [http://www.jisc.ac.uk/uploaded_documents/Stage%202%20Learning%20Models%20\(Versio%201\).pdf](http://www.jisc.ac.uk/uploaded_documents/Stage%202%20Learning%20Models%20(Versio%201).pdf)
- V McCune, N Entwistle (2000)
The deep approach to learning: analytic abstraction and idiosyncratic development
Paper presented at the Innovations in Higher Education Conference, September 2000, Helsinki, Finland
URL: <http://www.tla.ed.ac.uk/etl/docs/mccune2000.pdf>
- V McCune, D Hounsell (2005)
The development of students' ways of thinking and practising in three final-year biology courses
Higher Education 49(3) pp. 255-255
URL: <http://dx.doi.org/10.1007/s10734-004-6666-0>
- V McCune (2003)
Promoting High-Quality Learning: Perspectives from the ETL Project
Norwegian Network in Higher Education 14th Conference on University and College Pedagogy, Fredrikstad, Norway
URL: <http://www.tla.ed.ac.uk/etl/docs/McCune03.pdf>
- C McGuinness (2005)
Behind the acquisition metaphor: conceptions of learning and learning outcomes in the TLRP
The Curriculum Journal 16 (1), 31-47
URL: <http://www.ingentaconnect.com/content/routledg/rcjo/2005/00000016/00000001/art00003>

- J Meyer, R Land (2006)
 Threshold Concepts and Troublesome Knowledge: an introduction
 Meyer, J.H.F. and Land, R. (eds) *Overcoming Barriers to Student Understanding: threshold concepts and troublesome knowledge* (London: Routledge) pp. 19-32
 URL: <http://www.informaworld.com/smpp/content~content=a755535080>
- J Meyer, R Land (2006)
 Threshold Concepts and Troublesome Knowledge: issues of liminality in: Meyer, J. and Land, R. (eds) *Overcoming Barriers to Student Understanding: threshold concepts and troublesome knowledge* (London: Routledge) pp. 3-18
 URL: <http://www.informaworld.com/smpp/content~content=a755535193>
- E Meyer, R Land (2003)
 Threshold Concepts and Troublesome Knowledge : Linkages to Ways of Thinking and Practising within the Disciplines
 Occasional Report 4: Enhancing Teaching-Learning Environments in Undergraduate Courses Project
 URL: <http://www.leeds.ac.uk/educol/documents/142206.pdf>
- J Meyer, R Land (2005)
 threshold concepts and troublesome knowledge (2): Epistemological considerations and a conceptual framework for teaching and learning
Higher Education 49(3) pp. 373-388
 URL: <http://dx.doi.org/10.1007/s10734-004-6779-5>
- J Mezirow (2000)
 Learning as Transformation: Critical Perspectives on a Theory in Progress
 The Jossey-Bass Higher and Adult Education Series
 URL:
http://eric.ed.gov/ERICWebPortal/custom/portlets/recordDetails/detailmini.jsp?_nfpb=true&_ERICExtSearch_SearchValue_0=ED448301&ERICExtSearch_SearchType_0=eric_accno&accno=ED448301
- W Miller (2006)
 Planet: Special issue on threshold concepts and troublesome knowledge
Planet 17, Higher Education Academy Subject Centre for Geography, Earth and Environmental Sciences.
 URL: <http://www.gees.ac.uk/pubs/planet/p17/p17.pdf>
- J Moon (2005)
 We seek it here...a new perspective on the elusive activity of critical thinking: a theoretical and practical approach
 ESCalate Discussion Series
 URL: <http://escalate.ac.uk/2041>
- M Nichols (2003)
 A theory for eLearning
Educational Technology & Society 6(2) pp. 1-
 URL: <http://ifets.ieee.org/periodical/6-2/1.html>
- I Nonaka (1994)
 A Dynamic Theory of Organizational Knowledge Creation
Organization Science 5(1) pp. 14-37
 URL: [http://links.jstor.org/sici?sici=1047-7039\(199402\)5%3A1%3C14%3AADTOOK%3E2.0.CO%3B2-G](http://links.jstor.org/sici?sici=1047-7039(199402)5%3A1%3C14%3AADTOOK%3E2.0.CO%3B2-G)
- I Nonaka, H Takeuchi (1995)
 The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation
 Oxford: Oxford University Press
- J D Novak, A J Canas (2006)
 The Theory Underlying Concept Maps and How to Construct Them
 Technical Report IHMC CmapTools 2006-01
 URL: <http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConceptMaps.pdf>

- J Nussbaum (1989)
Classroom conceptual change: philosophical perspectives
International Journal of Science Education 11(5) pp. 530-540
URL: <http://www.informaworld.com/10.1080/0950069890110505>
- S Paavola, L Lipponen, K Hakkarainen (2002)
Epistemological Foundations for CSCL: A Comparison of Three Models of Innovative Knowledge Communities
Proceedings of CSCL 2002 pp. 24-33
URL: <http://www.tml.tkk.fi/Opinnot/T-110.556/2003/Materiaali/CSCL2002.pdf>
- S Paavola, L Lipponen, K Hakkarainen (2004)
Models of Innovative Knowledge Communities and Three Metaphors of Learning
Review of Educational Research 74(4) pp. 557-576
URL: <http://rer.sagepub.com/cgi/reprint/74/4/557>
- F Pajares (1992)
Teachers' Beliefs and Educational Research: Cleaning up a Messy Construct
Review of Educational Research 62(3) pp. 307-332
URL: [http://links.jstor.org/sici?sici=0034-6543\(199223\)62%3A3%3C307%3ATBAERC%3E2.0.CO%3B2-8](http://links.jstor.org/sici?sici=0034-6543(199223)62%3A3%3C307%3ATBAERC%3E2.0.CO%3B2-8)
- F Pajares (1996)
Self-Efficacy Beliefs in Academic Settings
Review of Educational Research 66(4) pp. 543-578
URL: [http://links.jstor.org/sici?sici=0034-6543\(199624\)66%3A4%3C543%3ASBIAS%3E2.0.CO%3B2-N](http://links.jstor.org/sici?sici=0034-6543(199624)66%3A4%3C543%3ASBIAS%3E2.0.CO%3B2-N)
- D H Palmer (1999)
Exploring the link between students' scientific and non-scientific conceptions
Science Education 83(6) pp. 639-639
URL: [http://dx.doi.org/10.1002/\(sici\)1098-237x\(199911\)83:6%3C639::aid-see1%3E3.0.co;2-o](http://dx.doi.org/10.1002/(sici)1098-237x(199911)83:6%3C639::aid-see1%3E3.0.co;2-o)
- R Pea (1993)
Learning scientific concepts through material and social activities: Conversational analysis meets conceptual change
Educational Psychologist 28(3) pp. 265-277
URL: http://www.leaonline.com/doi/abs/10.1207/s15326985ep2803_6
- D Peel (2005)
Peer observation as a transformatory tool?
Teaching in Higher Education 10(4) pp. 489-504
URL: <http://www.informaworld.com/smpp/content~db=all~content=a723756553~tab=citation>
- D Perkins (2006)
Constructivism and troublesome knowledge in: Meyer, J.H.F. and Land, R. (eds) *Overcoming Barriers to Student Understanding: threshold concepts and troublesome knowledge* (London: Routledge) pp. 33 - 48
URL: <http://www.informaworld.com/smpp/content~content=a755535038>
- P Pintrich, R Marx, and R Boyle (1993)
Beyond Cold Conceptual Change: The Role of Motivational Beliefs and Classroom Contextual Factors in the Process of Conceptual Change
Review of Educational Research 63 (2), 167-99
URL: <http://www.jstor.org/view/00346543/ap040294/04a00050/0>
- R Pithers, R Soden (2000)
Critical thinking in education: a review
Educational Research 42(3) pp. 237-249
URL: <http://www.informaworld.com/10.1080/001318800440579>
- G Posner, K Strike, P Hewson, and W Gertzog (1982)
Accommodation of a scientific conception: Toward a theory of conceptual change

Science Education 66(2): 211-227

URL: <http://www3.interscience.wiley.com/cgi-bin/jissue/112768699>

A Raddon (2006)

Absence as opportunity: learning outside the institutional space and time

Journal of Further and Higher Education, 30(2) pp. 157-167

URL: <http://www.ingentaconnect.com/content/routledg/cjfh/2006/00000030/00000002/art00004>

G Revill, I Terrell, S Powell, I Tindal (2005)

Learning in the workplace: a new degree online

Innovations in Education and Teaching International 42(3) pp. 231-245

URL: <http://www.informaworld.com/smpp/content~content=a714023609~db=all~order=page>

J T E Richardson, R Edmunds (2007)

A cognitive developmental model of university learning

What is Learned at University: the Social and Organisational Mediation of University Learning: Working Paper 4

URL: http://www.open.ac.uk/cheri/pdfs/somul_wp04.pdf

S Rimpilainen and P Carmichael (2006)

Sakai: An Environment for Virtual Research

Ennen & Nytt (2)

URL: http://www.ennenjanyt.net/2006_2/rimpilainen.pdf

K Samuelowicz, J Bain (2002)

Identifying Academics' Orientations to Assessment Practice

Higher Education 43(2) pp. 173-201

URL: [http://links.jstor.org/sici?sici=0018-1560\(200203\)43%3A2%3C173%3AIAOTAP%3E2.0.CO%3B2-8](http://links.jstor.org/sici?sici=0018-1560(200203)43%3A2%3C173%3AIAOTAP%3E2.0.CO%3B2-8)

M Savin-Baden (2006)

Disjunction as a form of troublesome knowledge in problem-based learning in:

Meyer, J. and Land, R. (eds) *Overcoming Barriers to Student Understanding: threshold concepts and troublesome knowledge* (London: Routledge) pp. 160-172

E. Scanlon and K. Issroff (2005)

Activity Theory and Higher Education: evaluating learning technologies

Journal of Computer Assisted Learning 21 (6), 430-9

URL: <http://www.blackwell-synergy.com/doi/abs/10.1111/j.1365-2729.2005.00153.x>

A H Schoenfeld (1983)

Beyond the purely cognitive: Belief systems, Social cognitions and Metacognitions as driving forces in intellectual performance

Cognitive Science 7(4) pp. 329-363

URL: <http://www.cogsci.rpi.edu/CSJarchive/1983v07/i04/p0329p0363/MAIN.PDF>

P H Scott, H M Asoko, R H Driver (1991)

Teaching for Conceptual Change: a Review of Strategies

Research in Physics Learning: Theoretical Issues and Empirical Studies. Proceedings of an International Workshop. R. Duit, F. Goldberg, H. Niederer (Eds.) March 1991

URL: <http://www.physics.ohio-state.edu/~jossem/ICPE/C5.html>

A Sfard (1991)

On the dual nature of mathematical conceptions: Reflections on processes and objects as different sides of the same coin

Educational Studies in Mathematics 22(1) pp. 1-1

URL: <http://dx.doi.org/10.1007/bf00302715>

A Sfard (1998)

On Two Metaphors for Learning and the Dangers of Choosing Just One

Educational Researcher 27(2) pp. 4-13

URL: [http://links.jstor.org/sici?sici=0013-189X\(199803\)27%3A2%3C4%3AOTMFLA%3E2.0.CO%3B2-0](http://links.jstor.org/sici?sici=0013-189X(199803)27%3A2%3C4%3AOTMFLA%3E2.0.CO%3B2-0)

- P Silcock (1994)
The Process of Reflective Teaching
British Journal of Educational Studies 42(3) pp. 273-285
URL: [http://links.jstor.org/sici?sici=0007-1005\(199409\)42%3A3%3C273%3ATPORT%3E2.0.CO%3B2-I](http://links.jstor.org/sici?sici=0007-1005(199409)42%3A3%3C273%3ATPORT%3E2.0.CO%3B2-I)
- J M Spector (2006)
A methodology for assessing learning in complex and ill-structured task domains
Innovations in Education and Teaching International 43(2) pp. 109-120
URL: <http://www.informaworld.com/10.1080/14703290600650368>
- J Tapper (2004)
Student perceptions of how critical thinking is embedded in a degree program
Higher Education Research and Development 23(2) pp. 199-222
URL: <http://www.ingentaconnect.com/content/routledg/cher/2004/00000023/00000002/art00006?crawler=true>
- K Trigwell, P Ashwin (2003)
Undergraduate Students' Experience of Learning at the University of Oxford
Oxford: Institute for the Advancement of University Learning
URL: <http://www.learning.ox.ac.uk/files/OLCPFfinal.pdf>
- K Trigwell, M Prosser, F Waterhouse (1997)
Relations between Teachers' Approaches to Teaching and Students' Approaches to Learning
Higher Education 37(1) pp. 57-70
URL: [http://links.jstor.org/sici?sici=0018-1560\(199701\)37%3A1%3C57%3ARBTATT%3E2.0.CO%3B2-X](http://links.jstor.org/sici?sici=0018-1560(199701)37%3A1%3C57%3ARBTATT%3E2.0.CO%3B2-X)
- K Trigwell, S Shale (2004)
Student learning and the scholarship of university teaching
Studies in Higher Education 29(4) pp. 523-536
URL: <http://www.informaworld.com/10.1080/0307507042000236407>
- K Trigwell, H Dunbar-Goddet (2005)
The Research Experience of Postgraduate Research Students at the University of Oxford
Oxford: Institute for the Advancement of University Learning
URL: <http://www.learning.ox.ac.uk/files/PGRreport.pdf>
- P Tynjala, J Valimaa, A Sarja (2003)
Pedagogical Perspectives on the Relationships between Higher Education and Working Life
Higher Education 46(2) pp. 147-166
URL: [http://links.jstor.org/sici?sici=0018-1560\(200309\)46%3A2%3C147%3APPOTRB%3E2.0.CO%3B2-%23](http://links.jstor.org/sici?sici=0018-1560(200309)46%3A2%3C147%3APPOTRB%3E2.0.CO%3B2-%23)
- S Waite, B Davis (2006)
Collaboration as a catalyst for critical thinking in undergraduate research
Journal of Further and Higher Education 30(4) pp. 405-419
URL: <http://www.informaworld.com/10.1080/03098770600965417>
- C Watkins (2003)
Learning: a sense-maker's guide
London: Association of Teachers and Lecturers
URL: http://www.atl.org.uk/atl_en/images/ATL%20Learning%20a%20sense-maker's%20guide_tcm2-1682.pdf
- E Wenger (1998)
Communities of Practice: Learning, Meaning and Identity
Cambridge: Cambridge University Press
- E Wenger, R McDermott, W Snyder (2002)
Cultivating Communities of Practice
Harvard: Harvard Business School Press
- R White, R Gunstone (1989)
Metalearning and conceptual change
International Journal of Science Education 11(5) pp. 577-586

URL: <http://www.informaworld.com/10.1080/0950069890110509>

C Williams (2002)

Learning On-line: a review of recent literature in a rapidly expanding field

Journal of Further and Higher Education 26(3) pp. 263-272

URL: <http://www.informaworld.com/10.1080/03098770220149620>

A Zietsman, J Clement (1997)

The Role of Extreme Case Reasoning in Instruction for Conceptual Change

Journal of the Learning Sciences 6(1) pp. 61-89

URL: http://www.leaonline.com/doi/abs/10.1207/s15327809jls0601_4

Acknowledgements

We would like to acknowledge the role of ESRC/EPSRC in funding the ‘Transforming Perspectives’ project and the Cambridge-MIT Institute’s Teaching for Learning Network (TfLN) for initial ‘pump-priming’ funding of the literature review in the early stages and for continuing support.

Dr. Patrick Carmichael was the Director of the Transforming Perspectives Project; Co-Directors were Dr. Keith Johnstone and Prof. Peter Robinson. Researchers were Dr. Naomi Irvine (ESRC/EPSRC) and Helen Burchmore (TfLN).

We would also like to acknowledge the enthusiasm and input of our seminar participants, who researched their own disciplinary practice; committed to attendance to at least two seminars; produced posters detailing their work with students, colleagues and their own reflection; enthusiastically raised and debated issues with the theory and in the process contributed a great deal to the project’s understanding of threshold concepts in practice and to the shape of this literature review:

Fran Tracy	Keith Johnstone	Katy Jordan	Clare Folkes
Richard Procter	Aidan Reilly	Hugh Hunt	Dan Sheppard
Lee Wilson	David Leitner	Christopher Burlinson	Lucy Taylor
Keith Macaulay	Andrew Brown		

Additionally seminar contributions were made by:

Jane Heal	Robert McCormick	Kate Plaisted	Deborah Youdell
Nicky Solomon	Uma Patel	Laurence Solkin	William Billingsley
Kate Taylor	Catherine Howell	Robin Boast	Harriet Truscott
Kirsten Hoben	Ray Land	Diana Laurillard	Tom Boyle
Vernon Trafford			

The support staff responsible for the Connotea online reference system provided full, friendly and timely answers to queries, and encouraged us to ‘test the boundaries’ of what Connotea could do for us. Our tiered “attribute/value” tagging system is now listed as a future development to roll out across their service, as is support for a wider range of publication types. Finally, thanks go to our colleagues in CARET for their support over the period of time this literature review was being carried out.