Chapter I

Threshold concepts and troublesome knowledge

An introduction

Jan H. F. Meyer and Ray Land

Introduction

A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress. As a consequence of comprehending a threshold concept there may thus be a transformed internal view of subject matter, subject landscape, or even world view. This transformation may be sudden or it may be protracted over a considerable period, with the transition to understanding proving troublesome. Such a transformed view or landscape may represent how people 'think' in a particular discipline, or how they perceive, apprehend, or experience particular phenomena within that discipline (or more generally). It might, of course, be argued, in a critical sense, that such transformed understanding leads to a privileged or dominant view and therefore a contestable way of understanding something. This would give rise to discussion of how threshold concepts come to be identified and prioritised in the first instance. However, first we require examples.

A simple illustrative example can be taken from the kitchen. Cooking is fundamentally a process of using heat (in various degrees and sources) to effect desired outcomes. In physics one encounters the concept of *heat transfer* and its mathematical formalisation (as an equation) that represents heat transfer as a function of something called the temperature gradient. It is not necessary to have a sophisticated understanding of physics to have this principle quite simply illustrated. Imagine that you have just poured two identical hot cups of tea (i.e. they are at the same temperature) and you have milk to add. You want to cool down one cup of tea as quickly as possible because you are in a hurry to drink it. You add the milk to the first cup immediately, wait a few minutes and then add an equal quantity of milk to the second cup. At this point which cup of tea will be cooler, and why? (Answer is the second cup because in the initial stages of cooling it is hotter than the first cup with the milk in it and it therefore loses more heat because of the steeper temperature gradient.) When the physics of heat transfer is thus basically grasped by

people in terms of things specific to what goes on the kitchen, it will fundamentally alter how they perceive this aspect of cooking, and they might consequently even filter out what to look for (the signified!) when they watch the better class of television cookery programmes; for example, a focus on the pots and pans that are *selected* by the chef in context (the heat source in relation to the cooking process to be applied as a function of time and its regulation to the ingredients) rather than simply on the ingredients and, superficially, the 'method'. So it could be said that, as a stand alone example, heat transfer or, more precisely, controlling the rate of heat transfer, is a threshold concept in cookery because it alters the way in which you *think* about cooking. And, in the special case where barbecuing is the method of cooking (where heat transfer is via radiation) you also have to take into account the inverse square law, which explains why so many people find barbecuing a 'troublesome' notion. We shall return to the notion of troublesomeness later.

Threshold concepts and troublesome knowledge within subject disciplines

Our interviews and wider discussions with practitioners in a range of disciplines and institutions have led us to conclude that a threshold concept can of itself inherently represent what Perkins (1999) refers to as *troublesome knowledge* - knowledge that is 'alien', or counter-intuitive or even intellectually absurd at face value. It increasingly appears that a threshold concept may on its own constitute, or in its application lead to, such troublesome knowledge.

From a *student* perspective let us consider some examples from Pure Mathematics: first that of a *complex number* - a number that is formally defined as consisting of a 'real' and an 'imaginary' component and which is simply expressed in symbolic (abstract) terms as x + /y, where x and y are real numbers (simply put, the numbers we all deal with in the 'real' world; for example numbers we can count on our fingers), and *i* is the square root of minus 1 (V-l). In other words z is a number which when squared (multiplied by itself) equals minus one (—1). So a complex number consists of a real part (x), and a purely imaginary part (zy). The idea of the imaginary part in this case is, in fact, absurd to many people and beyond their intellectual grasp as an abstract entity. But although complex numbers are apparently absurd intellectual artefacts they are the gateway to the conceptualisation and solution of problems in the pure and applied sciences that could not otherwise be considered.

Second, in Pure Mathematics the concept of a *limit* is a threshold concept; it is the *gateway* to mathematical analysis and constitutes a fundamental basis for understanding some of the foundations and application of other branches of mathematics such as differential and integral calculus. Limits, although not inherently troublesome in the same immediate sense as complex numbers,

lead in their application to examples of troublesome knowledge. The limit as x tends to zero of the funct ion f(x)=(sine x)/x is in fact one (1), which is counter-intuitive. In the simple (say, geometric), imagining of this limit is the ratio of two entities (the sine of x, and x) both of which independently tend to zero as x tends to zero and which are also (an irrelevant point, but a conceptual red herring if the threshold concept of a limit is not understood) respectively equal to zero when x equals zero. So the troublesome knowledge here then (based on mathematical proof) is that something which is getting infinitesimally small divided by something else doing the same thing is somehow approaching one in the limiting case.

That mathematicians themselves are aware of issues that surround threshold concepts is evident from the work of Artigue (2001, p. 211) who refers to a Theory of epistemological obstacles' and, by way of summary, gives as a first example of such obstacles: 'the everyday meaning of the word "limit", which induces resistant conceptions of the limit as a barrier or as the last term of a process, or tends to restrict convergence to monotonic convergence.' The idea is then developed by way of more complex examples that, as forms of knowledge, 'epistemological obstacles' constitute 'resistant difficulties' for students.

Within Literary and Cultural Studies the concept of *signification* can prove problematic, even 'subversive' in that it undermines previous beliefs, and leads to troublesome knowledge insofar as the non-referentiality of language is seen to uncover the limits of truth claims. For example, the recognition (through grasping the notion of signification) that all systems of meaning function like signifiers within a language (that is that terms derive meaning from their relationship to each other, rathei than in any direct empirical relationship with a 'reality') leads on to an understanding that there are mo *positive terms.* Hence the basis of many systems of meaning, including positivist science and the basis of many religious and moral systems, falls into question. This can be a personally disturbing and disorienting notion leading to hesitancy or even resistance in learners. Other aspects of post-structuralist practice such as techniques of *deconstruction* for analysing literary texts (with a strong emphasis on the ironic, the contradictory, the ludic) often appear counter-intuitive, looking for *absences,* or what is not there, in order to gain insights into how the text is currently structured by a prevailing set of (occluded or tacit) values or priorities.

One final illustrative example from Economics will suffice, again from the *student* perspective. The concept of *opportunity cost* has been put forward as one of many examples of a threshold concept in the study of economics. Martin Shanahan (as quoted in Meyer and Land 2003, pp. 414—15) assesses the transformative effect of this concept as follows:

> 'Opportunity cost is the evaluation placed on the most highly valued of the rejected alternatives or opportunities' (Eatwell *et al.* 1998, Vol. 3,

p. 719). Fundamental to the discipline of economics is the issue of choice: choosing between scarce resources or alternatives. Economists are interested in how individuals, groups, organisations, and societies make choices, particularly when faced with the reality that resources and alternatives are limited. No-one can have everything, and in most cases the 'constraints' faced by the chooser can be quite severe and binding. People choose, for example, how to allocate their time, their work or leisure; firms choose between different methods of production and combinations of inputs; societies choose between different legal regimes, levels of exports or imports etc. Fundamental to the economic way of approaching the issue of choice is how to compare choices. Thus 'The concept of opportunity cost (or alternative cost) expresses the basic relationship between scarcity and choice' (Eatwell *et al., ibid.);* for this reason it is a fundamental (or threshold) concept in Economics.

Thus opportunity cost captures the idea that choices can be compared, and that every choice (including not choosing) means rejecting alternatives. A student who has a good grasp of this concept has moved a long way toward breaking out of a framework of thinking that sees choices as predetermined, or unchangeable. They have also moved toward seeing 'two sides' of every choice, and in looking beyond immediate consequences, and even just monetary 'costs' towards a more abstract way of thinking.

Thus to quote Eatwell *et al.* for a final time *(ibid.),* 'Opportunity cost, the value placed on the rejected option by the chooser, is the obstacle to choice; it is that which must be considered, evaluated and ultimately rejected before the preferred option is chosen. Opportunity cost in any particular choice is, of course, influenced by prior choices that have been made, but with respect to this choice itself, opportunity cost is *choice-influencing* rather than *choice-influenced'* (emphasis in original). Thus, if 'accepted' by the individual student as a valid way of interpreting the world, *it fundamentally changes their way of thinking about their own choices, as well as serving as a tool to interpret the choices made by others.*

Characteristics of a threshold concept

A threshold concept is thus seen as something distinct within what university teachers would typically describe as 'core concepts'. A core concept is a conceptual 'building block' that progresses understanding of the subject; it has to be understood but it does not necessarily lead to a qualitatively different view of subject matter. So, for example, the concept of *gravity* - the idea that *any* two bodies attract one another with a force that is proportional to the product of their masses and inversely proportional to the distance between them - represents a threshold concept, whereas the concept of a

centre of gravity does not, although the latter is a core concept in many of the applied sciences.

Our discussions with practitioners in a range of disciplinary areas have led us to conclude that a threshold concept, across a range of subject contexts, is likely to be:

a *Transformative*, in that, once understood, its potential effect on student learning and behaviour is to occasion a significant shift in the perception of a subject, or part thereof. In certain powerful instances, such as the comprehension of specific politico-philosophical insights (for example, aspects of Marxist, feminist or post-structuralist analysis) the shift in perspective may lead to a transformation of personal identity, a reconstruction of subjectivity. In such instances transformed perspective is likely to involve an affective component - a shift in values, feeling or attitude. In this regard there are correspondences with Mezirow's (1978) work on 'perspective transformation'. A threshold concept may also involve a performative element. Sproull (2002) points out how the gaining of *aquatic confidence* in Sports Science students leads to a dramatically enhanced appreciation of water as a sporting and exploratory environment. This would be an interesting example of an enactive concept in Bruner's sense (Bruner 1966).

b Probably *irreversible*, in that the change of perspective occasioned by acquisition of a threshold concept is unlikely to be forgotten, or will be unlearned only by considerable effort. As a conveniently graphical metaphor, the post-lapsarian state of Adam and Eve after their expulsion from Eden in the Book of Genesis illustrates how new (and in this case troublesome) knowledge, symbolised by the cunning (i.e, 'conynge', knowing) serpent, radically transforms their landscape as they pass through the threshold from innocence to experience (new understanding). They gain freedom, responsibility and autonomy, though this is not a comfortable transition. As they look back to the Gate at the East of Eden their return across the threshold is barred by Cherubim 'and a flaming sword which turned every way' (Genesis 3: 24) to prevent return to the tree of knowledge. Though they have learned, and grown, their transformed state initially feels like loss. Respondents within our study have pointed to the difficulty experienced by expert practitioners looking back across thresholds they have personally long since crossed and attempting to understand (from their own transformed perspective) the difficulties faced from (untransformed) student perspectives.

c *Integrative*, that is it exposes the previously hidden interrelatedness of something. Note that if we re-examine the earlier example of opportunity cost from the novice perspective we may observe that while it satisfies (a) and (b) above, it may not be integrative. Davies (2002) provides the following useful insight:

8 Jan HL F. Meyer and Ray Land

> One way of seeking to identify a threshold concept in economics might be to examine discourse on social and economic policy between economists and non-economists. We might infer that a powerful, integrative, idea used by an economist but not by a colleague from another discipline is characteristic of a community of practice rather than a general level of education. For example, Adnett and Davies (2002) show how non-economists have tended to view parental quest for a 'good education' for their children as a simple zero-sum game whereas an economist would anticipate some supply-side responses and peer effects within and beyond school which make the prediction of game outcomes far more difficult. An economist is working here with a concept of general equilibrium which is not a typical feature of educated common-sense. Ideas like this may be thought troublesome not only because their integrative nature makes them difficult to learn, but also because they make the world appear a more problematic and troublesome place.

Davies (2002) also reminds us, in a salutary fashion, that 'any threshold concept can only integrate so much'.

d Possibly often (though not necessarily always) *bounded* in that any conceptual space will have terminal frontiers, bordering with thresholds into new conceptual areas. It might be that such boundedness in certain instances serves to constitute the demarcation between disciplinary areas, to define academic territories:

> Within the field of Cultural Studies a threshold concept that has to be understood early is the breakdown of the barrier between high and popular culture. This is fundamental to the Cultural Studies approach. This is a significant departure from practice in English Literature where that concept not only doesn't really exist but if it did (i.e. if you crossed that threshold) it would undermine the discipline of Eng. Lit. itself.
>
> (Bayne 2002)

Another respondent, working within Veterinary Sciences, informed us that where students encountered severe conceptual difficulty such areas of the curriculum were quietly dropped. In this sense the conceptual thresholds served to trim the parameters of the curriculum.

e Potentially (though not necessarily) *troublesome,* fo r the reasons discussed below.

Forms of troublesome knowledge

> 'When troubles come, they come not single spies.[9]
>
> *(Hamlet*, IV. v. 83-4)

The notion of a threshold concept might remain merely an interesting issue of cognitive organisation and perspective were it not for the strong indication from our data that such concepts often prove problematic or 'troublesome' for learners. Kennedy's discussion of the concept of 'sampling distribution' in Econometrics appears to identify one such threshold concept that is possibly 'troublesome' for students.

> Upon completion of introductory statistics courses, the majority of students do not understand the basic logic of classical statistics as captured in the concept of repeated samples and a sampling distribution. They know how to do mechanical things such as compute a sample variance, run a regression, and test a hypothesis, but they do not have a feel for the 'big picture'. They have learned a bunch of techniques, but to them they are just that, a bunch of techniques, and they know they can pass the course by remembering how these techniques work. They view statistics as a branch of mathematics because it uses mathematical formulas, so they look at statistics through a mathematical lens. What they are missing is the statistical lens through which to view the world, allowing this world to make sense. The concept of sampling distribution is this statistical lens. My own experience discovering this lens was a revelation, akin to the experience I had when I put on my first pair of eyeglasses - suddenly everything was sharp and clear.
>
> (Kennedy 1998, p. 142)

Given the centrality of such concepts within sequences of learning and curricular structures their troublesomeness for students assumes significant pedagogical importance. How might we best assist our students to gain understanding of such concepts? What might account for the variation in student facility to cope (or not) with these learning thresholds?

Perkins (1999, and with a more recent discussion in Chapter 3 of this volume) has defined troublesome knowledge as that which appears counter-intuitive, alien (emanating from another culture or discourse), or incoherent (discrete aspects are unproblematic but there is no organising principle). He suggests that knowledge might be troublesome for different reasons.

Ritual knowledge

Ritual knowledge, suggests Perkins (1999), has ‘a routine and rather meaningless character’. It feels, he argues, ‘like part of a social Or an individual

ritual: how we answer when asked such-and-such, the routine that we execute to get a particular result’.

> Names and dates often are little more than ritual knowledge. So are routines in arithmetic... such as the notorious ‘invert and multiply' to divide fractions. Whereas inert knowledge needs more active use, ritual knowledge needs more meaningfulness (of course, knowledge can be both inert and ritualized).
>
> (Perkins 1999, p. 7)

Diagrams, which are extensively used in Economics to represent complex relationships may well provide an example of the kind of ritualised knowledge that Perkins identifies here. Though students may have learned with some facility how to plot and represent economic relationships, and may well be able to explain the diagrammatic representation of a model, they may not understand the mathematical functional complexity that lies behind the representation.

Inert knowledge

Inert knowledge, suggests Perkins, ‘sits in the mind’s attic, unpacked only when specifically called for by a quiz or a direct prompt but otherwise gathering dust’. He cites passive vocabulary - words that are understood but not used actively - as a simple example.

> Unfortunately, considerable knowledge that we would like to see used actively proves to be inert. Students commonly learn ideas about society and self in history and social studies but make no connections to today’s events or family life, Students learn concepts in science but make little connection to the world around them. Students learn techniques in math but fail to connect them to everyday applications or to their science studies.
>
> (Perkins 1999, p. 8)

This failure to connect may well relate back to the integrative characteristic of threshold concepts. As Davies (2002) pointed out: ‘ “Integration” is troublesome because you need to acquire the bits before you can integrate, but once you’ve got the bits you need to be persuaded to see them in a different way’

Snroull (2002Ì nrovides an examole of how students find difficulty both in

integrating and in making connections between conceptually difficult topics and 'the world around them'. He reports the way in which *metabolism* acts as a troublesome threshold concept within Exercise Physiology. The function of metabolism, as presented within a standard course text on Exercise Physiology,

apparently proves troublesome for Sports Science students who are often unable to make integrative understandings with the sports-related knowledge, activities and practices that they encounter elsewhere in their programme. In this sense their knowledge of metabolism remains 'inert'. As a bridging device to foster integrative understandings Sproull uses an autobiographical work on running by a Cambridge scientist (Newsholme and Leech 1985) to scaffold and make accessible the concept of metabolism in a sporting context, which then has the transformative potential to open up the understanding of these students in crucial ways in relation to the ways in which human bodies perform in sporting contexts. In this way the inert, superficial, mimetic use of the language of a threshold concept becomes enlivened.

Conceptually difficult knowledge

Perkins argues that conceptually difficult knowledge is encountered as troublesome in all curricula but perhaps particularly in Mathematics and Science. A mix of misimpressions from everyday experience (objects slow down automatically), reasonable but mistaken expectations (heavier objects fall faster), and the strangeness and complexity of scientists' views of the matter (Newton's laws; such concepts as velocity as a vector, momentum, and so on) stand in the way. The result is often a mix of misunderstandings and ritual knowledge: students learn the ritual responses to definitional questions and quantitative problems, but their intuitive beliefs and interpretations resurface in quantitative modelling and in outside-of-classroom contexts. As one Economist reported to us:

> I think data analysis is very, very difficult... You pick up an empirical piece of analysis. There is an immense amount of work involved in getting your head round the data, deciding on the correct estimation techniques - you know, will the estimation techniques actually match to the theory you are trying to test? And I think this is just an incredibly difficult thing to teach undergraduates. The more I think about it - the more difficult I think that is.

Another respondent wondered whether there might be a difference between the relative difficulties of subjects according to their use of threshold concepts, in particular the degree of integration required. He cited as example the perceived contrast in conceptual difficulty between Economics and Business

Alien knowledge

Perkins characterises 'foreign' or 'alien' knowledge as that which 'comes from a perspective that conflicts with our own. Sometimes the learner does not

even recognize the knowledge as foreign' (1999. p. 9). A threshold concept that is counter-intuitive for many novice Physics students is the idea, formalised in Newton's second law of motion, that a force acting on a body produces acceleration rather than simply velocity or 'motion'. Formally put, Newton's second law states that force equals mass times acceleration. That this is 'troublesome knowledge' is reflected in the difficulty that students have in answering a question along the following lines: if a car is travelling along a road at a constant speed (i.e. velocity, or rate of change of displacement with respect to time, is constant over time) then what is the resultant force acting on the car? (Answer is zero.) McCloskey (1983, cited in Perkins 1999) makes a similar point about understanding objects in motion, arguing that 'Leaineis find it hard to accept that objects in motion will continue at the same rate in the same direction unless some force, such as friction or gravity, impedes them. They find it hard to believe that heavier objects fall at the same rate as lighter ones, air resistance aside.'

Tacit knowledge

Perkins suggests that there might be other sources of troublesomeness in knowledge, emanating perhaps from the *complexity* of the knowledge, its seeming *inconsistency* or paradoxical nature or because it contains *subtle distinctions,* such as that between weight and mass. He invites further categories, one of which (not mentioned by Perkins) we would identify as *tacit* knowledge, that which remains mainly personal and implicit (Polanyi 1958) at a level of 'practical consciousness' (Giddens 1984) though its emergent but unexamined understandings are often shared within a specific community of practice (Wenger 1998). The need, for example, for student automotive designers to grasp concepts of 'fluid surfacing', 'double curvature' or other important aspects of spatial and three-dimensional understanding would be examples of threshold concepts that often remain tacit or implicit within the practice of the design community.

Manning (2002) provides a further example from Music, which students within Western musical traditions find troublesome.

> Students who study the art and practice of Western music learn from very early on the concept of *equal temperament,* that is the basic notion of the musical octave and its division thereof into what is perceived as

twelve equal steps in terms of pitch. Thus the interval between two adjacent notes on the keyboard, known as a semitone is logarithmically always the same, no matter what pairing is selected. This process of learning, however, is for the most part implicit, and it is rare indeed for either teacher or student to study this concept in any depth at primary or secondary level. The notion of key s, both major and minor, the function of harmony, and the principles ofmodulation are thus introduced without

any real regard for the reasons why equal temperament has been so axiomatic for the development of classical music, from the 17th century to the present day.

Some elements of doubt as to the robustness of this seemingly all-embracing concept may become apparent to more observant students, but it is rare that explanations are either sought or offered. Those who sing in choirs might, for example, notice that a well-tuned chord does not quite accord to the corresponding intervals produced by conventional keyboard instruments and that problems of intonation can prove particularly acute in the case of unaccompanied vocal works that modulate through many keys. It might also occur to string players that the established practice of tuning strings in 'perfect' fifths, such that no beating can be delected when adjacent strings are played simultaneously, also differs from the equivalent keyboard intervals. In the main, however, these discrepancies are merely accommodated within the overall framework of equal temperament.

What is interesting about Manning's account is how it shows that the source of troublesomeness might often be a compounding of the different kinds of knowledge discussed above. 'When troubles come,' Shakespeare warned us, 'they come not single spies, But in battalions' *(Hamlet,* IV v. 83-4). The troublesomeness Manning identifies with students' understanding of equal temperament in music compounds both tacit knowledge and alien knowledge, where what appears counter-intuitive in new knowledge is overridden by existing tacit understanding.

As the study of music becomes increasingly multicultural, possible clues as to the existence of other tuning systems are sometimes encountered, but the tendency to Westernise such cultures in terms of popular music once again asserts the dominance of equal temperament. The chance hearing, perhaps, of an Indonesian gamelan orchestra may lead a student to observe that the gongs appear to be 'out of tune', but it is rare indeed that they recognise the significance of alternative tuning systems in the development of other musical genres in Asia and beyond.

Thus it is that an understanding of tuning methodologies and their evolution through history and across the world becomes a threshold

concept for an advanced understanding of pitch organisation in music. This aspect of music study will be encountered by tertiary level students in the context of: i) the study of late renaissance and early baroque Western music, when the evolution of harmonic structures necessitated the development of tuning systems that could sustain modulation to more remote keys, ii) the study of ethnomusicology, and iii) the manipulation of timbre in the context of electroacoustic music. Recognition that the structure and organisation of music involves acoustic principles

14 jan H. F, Meyer and Ray Land

> that not only are concerned with the different timbres of instrumental and electronic sources but also their associated tuning systems elevates the analysis of music and modes of composition to new levels of understanding of the processes involved.
>
> (Manning 2002)

Troublesome language

Language itself, as used within any academic discipline, can be another source of conceptual troublesomeness. Specific discourses have developed within disciplines to represent (and simultaneously privilege) particular understandings and ways of seeing and thinking. Such discourses distinguish individual communities of practice and are necessarily less familiar to new entrants to such discursive communities or those peripheral to them (Wenger 1998). The discursive practices of a given community may render previously ■familiar' concepts strange and subsequently conceptually difficult. The use of the term 'culture' within first year Social Anthropology, for example, is reported as problematic in this way (Knottenbelt 2002). Moreover, the inherently arbitrary and non-referential nature of language compounds conceptual difficulty through obliging those seeking to teach or clarify concepts to deploy further terms, metaphors and concepts in an endless play of signification (Derrida 1978). 'There is no concept which exists outside systems of thought and language; there is no concept which is not involved in the infinite play of meaning. In order to function socially we do make temporary determinations of meaning but meaning itself is never determinate' (Land and Bayne 1999, p. 738). Eagleton (1983, p. 129) points out that language:

> instead of being a well-defined, clearly demarcated structure containing symmetrical units of signifiers and signifieds, now begins to look much more like a sprawling limitless web where there is a constant interchange and circulation of elements, where none of the elements is absolutely definable and where everything is caught up and traced through by everything else.

As an examnle of such conceptual difficulty Hodskin (20021. discussine

education in the visual arts, reports the difficulty of understanding the concept of'art' itself, locating the concept 'somewhere in the gap that exists between history, scholarship and the feeling of being on the edge of tears'. Reimann (2002) draws attention to the particularly problematic (and complex) example of foreign language learning, where language is also the content.

> If 'foreign' knowledge is troublesome, will learning foreign languages, including knowledge and insights about foreign cultures ('otherness'), always be troublesome? Does this perhaps contribute to the reputation of

> languages as difficult subjects? Also, in foreign language learning, issues of content and of language merge. The language *is* the content. Students get very disconcerted when they come across ways of expressing familiar concepts in a different way, for example numbers. Surely saying *eighty-four* is more 'natural' - better than *quatre-vingt-quatre* or *vierundachtzigl* Is this particularly troublesome?

Here we see the notion of alien knowledge compounded with the inherently problematic nature of language itself - another instance of troubles coming not as single spies.

Ways of thinking and practising

Threshold concepts would seem to be more readily identified within disciplinary contexts where there is a relatively greater degree of consensus on what constitutes a body of knowledge (for example Mathematics, Physics, Medicine). However, within areas where there is not such a clearly identified body of knowledge it might still be the case that what might be referred to as 'ways of thinking and practising' within a discipline also constitutes a crucial threshold function in leading to a transformed understanding. One of our respondents identified the threshold function of a way of thinking and practising within the teaching of Economics:

> we have to instill in students a kind of acceptance of modelling which is quite fundamental to the way in which we approach most of our analysis ... we want our students to start to think about problems, issues. You get them to formulate, if not explicitly at least implicitly, some kind of formal analytical structure or model that simplifies things but then allows someone to think through a problem in a very structured way. That's something fundamental I think.

Another economist from a large modern English university offered a similar view:

> Within Economics I sense that sometimes students see abstract models as abstract models and don't see the link between them and the real world, so that students would be quite happy talking about problems of inflation, unemployment and so on, but as soon as you say 'Good, let's have a look at the model', they sort of switch off. They think that's a completely separate issue. T don't want to do the model, I just want to talk about inflation or unemployment.' So the idea that models which look abstract -can be looked at abstractly - actually talk about the real world, perhaps that is a crucial factor. I mean they tend to put models into one box and then the discussion about the policy issues in another box. They don't

> necessarily see that the two must be linked. Perhaps that's a threshold issue.
>
> (Respondent 3)

And finally we may consider än extract from a book on the teaching of undergraduate Economics:

> When the dust settles, most students leave the introductory course never having fully grasped the essence of microeconomics. Thus the opportunity cost concept, so utterly central to our understanding of what it means to *think* like an economist, is but one among hundreds of other concepts that go by in a blur.
>
> (Frank 1998, p. 14, emphasis added)

Conclusion

The intention of this chapter has been to open up discussion of threshold concepts as an important but problematic factor in the design of effective learning environments within disciplines and to indicate the linkages to ways of thinking and practising within these disciplines. It is our contention that where threshold concepts exist within curricula there is a likelihood, owing to their powerful transformative effects, that they may prove troublesome for students. Difficulty in understanding threshold concepts may leave the learner in a state of *limmality* (Latin *limen* - 'threshold'), a suspended state in which understanding approximates to a kind of mimicry or lack of authenticity. Palmer (2001), in a discussion of liminality and hermeneutics, reminds us that the insights gained when the learner crosses the threshold might also be unsettling, involving a sense of loss: 'The truth or insight may be a pleasant awakening or rob one of an illusion; the understanding itself is morally neutral. The quicksilver flash of insight may make one rich or poor in an instant' (Palmer 2001, p. 4).

A further significant issue İs that threshold concepts might be interpreted

as part of a 'totalising' or colonising view of the curriculum. Such a view would point to the effects of power relations within curricula with threshold concepts serving to provide a measure, and exert a 'normalising' function in the Foucaldian sense (Foucault 1979, 1980). *'Whose* threshold concepts?' then becomes a salient question. These are non-trivial concerns and merit further consideration.

These issues notwithstanding, conversations with colleagues in various disciplines have suggested that the idea of a threshold concept remains a powerful one to the extent even of being used to benchmark curricula. It appears, however, that threshold concepts might be more readily identifiable in some disciplines (such as Physics) than in others (such as History). Wherever present they constitute an obvious, and perhaps neglected, focus for evaluating

teaching strategies and learning outcomes. This chapter has drawn primarily from the perspectives of teachers in higher education. A research question is also opened up on the degree to which threshold concepts, as perceived by teachers, are experienced by students, and with what *variation.* If it is accepted that threshold concepts represent experiential entities in the minds of students, might threshold concepts usefully provide a micro-perspective for examining learning environments? These questions will form the basis of subsequent chapters in the second part of this volume which draw on the perspectives of both students and teachers in a variety of disciplines in higher education.

References

Adnett, N. and Davies, P. (2000) 'Education as a positional good: implications for market-based reforms of state schooling', *British Journal of Educational Studies,* 50(2): 189-202.

Artigue. M. (2001) 'What can we learn from educational research at the university level?' in Holton, D. (ed.) *The Teaching and Learning of Mathematics at University Level,* Dordrecht: Kluwer Academic Publishers.

Bayne, S. (2002) Personal communication, Queen Margaret University College, Edinburgh.

Bruner, .1. (1966) *Toward a Theory of Instruction,* Cambridge, MA: Harvard University Press.

Davies, P. (2002) Personal communication with the authors, University of Staffordshire.

Derrida, J. (1978) 'Structure, sign and play in the discourse of the human sciences', cited in Lodge, D. (ed.) (1988) *Modern Criticism and Theory,* London: Longman.

Eagleton, T. (1983) *Literary Theory: An Introduction,* Oxford: Blackwell.

Eatwell, J., Milgate, M. and Newman, P. (eds) (1998) *The New Palgrave. A Dictionary of Economics,* London: Macmillan.

Foucault, M. (1979) *Discipline and Punish: The Birth of the Prison,* Harinondsworth: Penguin.

Frank, R.H. (1998) 'Some thoughts on the micro principles course', in Walstad, WB. and Saunders, P. (cds) *Teaching Undergraduate Economies: A Handbook for Instructors*, Boston, MA: Irwin/McGraw-Hill, pp. 13-20,

Giddens, A. (1984) *The Constitution of Society*, Cambridge: Polity Press.

Hodgkin, H. (2002) Annual Edinburgh Festival Lecture, University of Edinburgh.

Kennedy. P. (1998) 'Using Monte Carlo studies for teaching econometrics', in Becker, W. and Watts, M. (eds) *Teaching Economics to Undergraduates. Alternatives to Chalk and Talk*, Cheltenham, Northampton/MA: Edward Elgar.

Knottenbelt, M. (2002) Personal communication, University of Edinburgh.

Land, R. and Bayne, S. (1999) 'Computer-mediated learning, synchronicity and the metaphysics of presence', in Collis, B. and Oliver, R. (eds) *ED-MEDIA 1999: Proceedings of 11th Annual World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Charlottesville, VA: American Association for the Advancement of Computing in Education.

McCloskey, M. (1983) 'Naive theories of motion', in Gentner, D. and Stevens, A.L. (eds) *Mental Models*, Hillsdale, NJ: Erlbaum (cited in Perkins 1999).

Manning, P. (2002) Personal communication, University of Durham.

Meyer, J.H.F. and Land, R. (2003) 'Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines', in Rust, C. (ed.) *Improving Student Learning Theory and Practice - 10 Years On*, Oxford. OCSLD, pp. 412-24.

Mezirow, J. (1978) 'Perspective transformation', *Adult Education*, 28(2): 100-9.

Newsholme, E. and Leech, T. (1985) *Runner: Energy and Endurance*, fourth edition, Roosevelt, NJ, Oxford, London: Walter. L. Meagher.

Palmer, R.E, (2001) *The Liminality of Hermes and the Meaning of Hermeneutics*, MacMurray College, http://www.mac.edu/~rpalmer/liminality.html (last modified 29 May 2001).

Perkins, D. (1999) 'The many faces of constructivism', *Educational Leadership*, 57(3), November.

Polanyi, M. (1958) *Personal Knowledge*, London: Routledge.

Reimann, N. (2002) Personal communication, University of Durham.

Sproull, J. (2002) Personal communication, University of Edinburgh.

Wenger, E. (1998) *Communities of Practice: Learning, Meaning and Identity*, Cambridge: Cambridge University Press.