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*Supporting students through responding to variation in students' disciplinary learning, developing metalearning capacity, and focusing on the effective teaching and learning of threshold concepts — concepts that transform student understanding.*

# 11

## HELPING OUR STUDENTS: LEARNING, METALEARNING, AND THRESHOLD CONCEPTS

*Jan H.F. Meyer*

### INTRODUCTION

There is much that can be said about student learning (and, more precisely, *variation* in student learning) and the relevance to teaching practice of a knowledge of these matters in a generic sense. Indeed, one advocated “exemplary” form of pedagogy—that of “student-centred teaching”—assumes that teachers have some knowledge of how *their own* students engage learning. The acquisition of such knowledge leads for many teachers to a reconceptualisation of practice, and the desire to be responsive to patterns of variation in their students’ learning in a reflexive manner. It does not require a great deal of effort for university teachers (in whatever discipline) to solicit, interpret, and understand the likely consequences of some of the more common and classic generic patterns of variation. And, in grasping these opportunities, there is variation that can be captured in an empirical learning and teaching “model of engagement” which will be presented further on.

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It is something of a benchmark for teachers to move beyond the comfortable generic metaphors of learning and to actively solicit, and respond to, variation in their students' disciplinary learning. This is a big step forward in terms of reflexive teaching practice. And for teachers to take the next step and help their students become aware of, and take control over, their own learning is an even bigger step because it extends the locus of teaching practice in a most empowering sense for students.

An integrative emphasis on *variation in learning* and developing *metalearning capacity* invites a central rather than a peripheral focus: a conceptual "object of learning." In developing this focus, the analytical framework of *threshold concepts* is introduced as a means to identify transformative "waypoints" in student-learning journeys; a lens that focuses on the learning of concepts that really matter, involving both cognitive and ontological shift.

### A Personal Reflection on Student-Learning Research

This chapter is set against more than three decades of research that tells us much about the student experience of learning in higher education. I have chosen 1976 as the starting point of this reflective, and admittedly subjective, account because it was in that year that Marton and Säljö published their seminal paper on student learning that provided a fresh perspective for thinking about student learning. Unlike preceding work that was grounded in various psychological theories and constructs and their accompanying discourses, this new perspective offered a formalised view of learning as experienced and narrated by students themselves. What Marton and Säljö disturbingly demonstrated was that students differed from one another in their learning intentions in the "reading" of an academic text—a basic learning activity that we assume students can carry out in accordance with our expectations—and that these differences could be conceptually accommodated in terms of the now ubiquitous "deep/surface" metaphor, reflecting a categorisation not of students themselves but rather of the *variability in what they do and why they do it* in terms of learning process and underlying intention.

Simply put, students varied in their understanding of the requirement "to read" in a given expectational context of being prepared to "answer questions" on what they had read. Some focused on extracting meaning from the text while others focused on the features of the text. And these differences mattered, as Marton and Säljö (1976) clearly demonstrated, in terms of an empirical association between the quality of the process, and the quality of the outcome of *reading*. Arguing the case for the conceptually posited directionality of this association in more generic terms was one thing. Empirically determining this directionality in terms of statistical modelling was quite another matter that presented (and still presents)

its own methodological challenges. The intractable problem is that one cannot infer causality from a correlation coefficient. Nevertheless, 30 years on, Richardson (2006)—using a sophisticated path analysis (quantitative) methodology—has plausibly demonstrated “causal efficacy,” whereby variation in various learning processes has a direct effect on marks obtained in assessment. And so we progress in our understanding of the student-learning experience.

The “deep/surface” distinction captured the imagination of many researchers and, given that this distinction was originally discerned in terms of a qualitative analysis of student-interview transcripts, there was an immediate impetus to contemporaneous work already being carried out circa 1976, notably by Biggs and Entwistle. The theoretical contributions of Biggs and Entwistle are reflected elsewhere in this book and it is not the purpose here to summarise, in particular, the subsequent psychometric development of research instruments (student-learning inventories) that sought to both operationalise and extend the originally posited “deep/surface” domain. Richardson (2000) provides a detailed account of this prodigious and evolving work, covering an intervening period of some 25 years that saw a sustained and increasing interest in developing what is now often referred to as the empirically grounded “student experience of learning” (SEL) framework.

Reductionism can be dangerous, but it is worth reflecting on the fact that post-1976 it dawned on many qualitative and quantitative researchers (and their research students) that a new era of educational research had been ushered in by asking students a simple and straightforward set of questions about how they went about learning: what they did, how they did it, why they did it, and so on. In the case of Marton and Säljö, student responses to questions such as these were framed in the context of reading an academic text. Resultant interview data were subjected to an emerging qualitative analytical process—that of phenomenography—that, in the ensuing decades, captivated the minds of hundreds of researchers eager to explore its capacity for revealing, in particular, *qualitative differences* in students’ experiences of learning.

Phenomenography presented a new and relatively simple distinctive analytical “methodology,” with an accompanying terminology and discourse that had an immediate appeal and that was immediately accessible to both researchers and teachers across the disciplines. Virtually anybody could begin researching all manner of student-learning phenomena and, although the transcription and phenomenographic analysis of interview data was time consuming, the start-up costs were modest given the relatively small numbers of students typically involved. Phenomenography did something very special for research into student learning. It provided a compelling and enduring *authenticity* for primary evidence about how students varied in their engagement with learning, and it prompted

categorisations *not of students* but of the patterns of variation in how they went about learning, the likely consequences of which were arguably the concern of *every* teacher.

In a complementary fashion, both qualitative and quantitative studies of student learning reconstituted the simple “deep/surface” metaphor in all manner of contexts and, in terms of accumulating quantitative studies, additionally so in terms of patterns (of variation) of increased multivariate complexity. The net result, which forms the backdrop of this chapter, is that a remarkably consistent body of evidence emanating from a broad landscape of scholarly endeavour began to systematically hammer home a simple truth: that students *varied* in their engagement of learning and that this variation had *explanatory and diagnostic power*.

Teachers who were concerned about the learning well-being of their students began to take this evidence seriously, as did their professional colleagues within the academic-development community. The research base and its application became more embracing and more focused. Teachers started asking questions: If there is evidence of “variation” in general (“deep/surface” + extended) terms of how students engage both the context and the content of learning, what does this evidence represent in practical and ethical terms *for me*? How transferable and amenable to reconstitution in *my* subject or discipline is this “deep/surface” metaphor in terms of specificity and explanatory power? And what are the implications for *my* teaching practice? The point here is that if we know something about how students go about learning in general, how does this help the teachers of particular subjects? And again there are chapters in this book that address these issues.

To reiterate: much is known about how students *vary* in their engagement of learning. It is not difficult to solicit this variation from students; that is, externalise it in a manner amenable to observation and estimation for modelling purposes. We also know how to analytically determine and conceptually interpret the dimensionality of this variation. Increasingly we also have a deeper understanding of the association between the dimensionality of this variation and learning outcomes.

But there are those who continue to ask what the point is of all this research on student learning. Well, for a start, it opens up opportunities for *all* teachers to actively address the learning well-being of their students. If reflexive teaching is something to be valued, then here is the means to give expression to that value through actionable theory informed by a knowledge of individual differences in how students conceive, and engage the process of, learning. And since we know so much about student learning, in so many disciplinary contexts, and across a range of institutional and cultural settings, it seems self-evident that we can *and should* use this knowledge to improve the learning and teaching experiences of students. And, as an aside, it can be argued that if the knowledge and

the efficient means exist to do this then it is unethical to deny students these opportunities.

The knowledge referred to is actionable in the most fundamental sense. It can inform teaching at a number of levels, one of which has already been alluded to: What do students understand by our expectations of them “to read?” What exactly does “to read” mean for a student in, say, the context of law, mathematics, programming, or history? Better still, what does *close reading* mean in the analysis of literary text? One generic aspect of actionable theory tells us that the requirement of a learning task, more subtly students’ (often distorted) *perceptions* of what is required of them, influences their *response* to the learning task. In the simplest case we might explicitly “model,” as a teaching strategy, what we require of students in terms of the requirement “to read” a text, or “to write” an essay. Another generic aspect of actionable theory tells us that students’ *conceptions of learning* in a given context has a consequential effect on the learning process(es) they apply to the task. This effect arises precisely because students’ conceptions of learning are couched *in process terms*. And, in general, conceptions of learning are influenced by perceptions of the learning context, and especially of the assessment protocols embedded in it. A third aspect of generic actionable theory tells us that learning processes are controlled by regulation strategies as influenced, for example, by the conception(s) of learning and perceptions of the learning context.

So, as an illustration, we might posit thus: based on a reading of the assessment cues (in lectures) and the “ticky box” multiple-choice test at the end, a student forms a temporal “cram and dump” conception of “learning” that is essentially accumulative. The idea is to get as much factual information into your head so that you can tick the boxes and get the marks. The learning process in this case is essentially a form of mechanical memorising under a strategic form of self-regulation. How do we know this likelihood? This is what students tell us!

I’m more focused on achieving a high mark than I am in gaining more knowledge. If I were to shift more focus towards placing value on the learning in itself, high marks might come as an added benefit... I harbour some resentment towards students who consistently memorise information without understanding it, write it down on an exam without really thinking, and then forget it all afterwards, but I am also guilty of the same practice. (Student D10)<sup>1</sup>

The above scenario invites *in situ* evidence-based teaching responses to *individual differences* in learning. Insofar as such differences are amenable to categorisation and interpretation *beyond* the now limiting “deep / surface” metaphor, we are challenged (in respect of each such category) to consider appropriate teaching responses. The locus of what constitutes “teaching”

now expands to a locus of “learning and teaching.” It is at this level that the “one size fits all” advocacy of managerialist “good practice” becomes less tenable. But it is the case that reconstituting actionable theory based on individual differences remains an indulgent activity for many teachers in higher education. And not everybody is up for it, as we will soon see.

### A Model of Engagement with Variation in Student Learning

A strategy for engaging teachers with the often alien concept of “variation” in student learning is now presented. The context is a graduate-certificate programme that articulates with probationary requirements at a research-intensive UK university. One important and summatively assessed learning outcome of this programme also articulates with an external accreditation requirement: that of demonstrating a theoretically and empirically based interpretive understanding of “how students learn, both generally and in the subject.”

It has already been emphasized that much is known about how students vary in their engagement of learning. This knowledge exists at various levels of conceptual sophistication, and the discursive aspects of some of them are admittedly alien and inaccessible to many university teachers (in science and engineering, for example) who do not have a disciplinary background in higher education and a knowledge of its theoretical perspectives. There is a challenge here to unpack and demystify the required knowledge in a form that is accessible to *all* university teachers, and there are many exemplary examples of how to do this in the standard texts that are used to support graduate-certificate programmes for university teachers, certainly in the UK and Australian contexts with which I am most familiar.

But there is a big gap between reading about, being taught about, reflecting on, and discussing this knowledge of how students learn *in general*, and how they learn *in the subject or discipline*. Part of the problem is that, within the voluminous research literature on student learning, there are relatively few studies that focus on learning within a subject or disciplinary context. Evidence about how learning is engaged in general, as reflected in generic patterns of variation, is dismissed by many teachers as being of little use. This reaction is understandable because they are less interested in reading about how students in general may exhibit a “deep” or “surface” learning engagement and more interested in how, within *their own* subject or discipline, these categorisations may be reconstituted by *their own* students in ways that are of immediate relevance and perhaps quite different from the stereotypes.

The general literature does not, for example, provide any obvious detail about how “deep” or “surface” learning might—and perhaps uniquely so—be characterised in, say, accounting, economics, music, or mathematics. However, studies in these same disciplinary contexts such as those

respectively reported by Lucas and Meyer (2005), Meyer and Shanahan (2001), Reid (2001), and Eley and Meyer (2004) do provide empirical insights that might at least convince teachers in these disciplines that there is something worth exploring here in terms of their own students.

However, teachers themselves also vary in the learning task of soliciting and interpreting variation in their own students' learning. This teacher variation has been captured in an empirical model developed by Meyer (2005) in the context of a graduate-certificate programme on learning and teaching in higher education that articulates with *probationary requirements* for newly appointed university teachers. Participants are required, as part of a summatively assessed assignment, to interview their own students about their learning via a carefully managed and ethically approved protocol. For participants meeting the probationary requirement this is most definitely not an indulgent activity. And there are always those who voluntarily choose to participate outside this requirement.

Resultant interview data then have to be analysed and theoretically interpreted against the research literature, and the findings have to be reflected upon in terms of their implications for the real business of personal rather than hypothetical practice, especially in terms of reflexive teaching and assessment.

Theories are never more convincing for a researcher than when previously abstract ideas manifest themselves as immediate and concrete evidence. [The assignment] provided compelling, and at times alarming, evidence of what had been up to then, for this learner-teacher at least, the largely theoretical notion of "variation in student learning." In many cases the transcripts illustrated the research-literature examples exactly. For me, this produced a sudden and clear understanding of the literature I had read, and I returned enthusiastically to articles I had previously struggled to assimilate. It was quite rewarding to see that many of the conclusions that I have drawn from these interviews were actually backed by research in the field. The student-learning assignment brought home to me a fundamental truth of student learning; that all students learn differently.

The above quotations, and those that appear further on in this section, are literal extracts from participants' written assessed work or evaluative comments, but are composite (multiple voices present in each set) to protect the anonymity of the sources. The focus here is on the variation exhibited by participants in carrying out this assignment, and this variation is presented below in an adaptation of the model described in Meyer (2005, 363-65):

1. *No initial engagement*: discourse is alien and troublesome.  
I found this assignment difficult to do, because I did not feel that I had any real command of the concepts. All the theory was boring and irrelevant. Theory is a lot of wind.

2. *Descriptive*: there is semantic infiltration, use of extended discourse.  
The approach to studying is a major explaining factor among the multivariate factors causing variation in the learning outcomes. I found evidence of the “paradox of the Chinese learner” during my interviews. The influence of context and locus on student learning is very important. I can pick out the precise moment at which my own approach changed from that of a diligent “surface” learner to that of a “deep” and “transformative” learner ... as my understanding deepened, I was able to put the material together in a different way. It could be categorized [on SOLO] as a shift to “relational” and “extended abstract” levels of understanding.
  
3. *Interpretive*: student-learning constructs and discourse are used for interpretive purposes.  
My teaching practice has been considerably enriched as a direct result of this assignment, in that it convinced me of the value of “repetition as a means of encouraging understanding.” I now have a clear sense of the rationale behind certain traditional language-teaching methods. How the students learned was the key to understanding what they learned.
  
4. *Evaluative*: discourse informs judgments in context, the first stage of reflective practice.  
As a result of these interviews, I radically rethought my teaching. At the most fundamental level, this exercise has awakened an awareness of the variety of ways in which students learn. My experiences ... brought home very clearly what was evident from the literature; different students learn differently. It was evident ... that at least two of the students fell into the classical categories of deep ... and surface ... learners with associated different conceptions of learning. I initially began to reflect without even knowing I was doing it. It is clear ... that superficially similar students possess very different conceptions of learning which relate to their motivations, methods, and intentions.... I now find that I question traditional teaching methods, often, and sometimes unthinkingly, adopted by me in the past. [This exercise] has provided me with an invaluable opportunity to reflect on my teaching: to consider how I teach, why I teach that way, why it works, and how my teaching could be improved.
  
5. *Actionable*: there is informed decision making *in situ*, there is actionable theory underpinning a mental model of *learning* and teaching.  
This exercise has drastically altered my conception of teaching. I have been required to view teaching and learning from the student perspective. This course ... offered information on how to encourage students to adopt an approach that leads to understanding ... allowed me to see how students experienced and perceived my teaching ... adopting the

students' perspective [it is now] much easier to see how I must change my teaching. I have found evidence that suggests that the modifying strategic element employed by deep learners does not always lead to successful learning outcomes. This reinforces the conclusion ... that the way a student approaches a task depends on the perceived rather than actual learning environment. In my consideration, one response would be to attempt to ascertain the students' conceptions of their learning context as the course progresses. My belief was that by making the assessment process more transparent, and allowing the students space to self-assess their learning requirements, their control over the learning situation would increase. I think it [the assignment] will turn out to be a useful tool in diagnosing how Ph.D. students think, why students may be failing or, more generally, why their experience or performance may be unsatisfactory.

What this model demonstrates is that, in varying degrees, it is possible to engage teachers with a learning task focused on the ways in which their own students learn—a task that is generally experienced as a positive and energising experience because the resultant variation in student learning, correctly interpreted, constitutes a manifestation of *personal actionable theory*. There is an immediate foundation on which to reflect and act:

This [assignment] confirmed to me that the distinction between surface and deep approaches to learning is a useful one, and that it might prove to be quite fertile to know the factors that can be employed to encourage a more active and explorative approach in students. My own learning from this exercise is that I now have access to a conceptual framework which I did not have before. I can apply this in lesson designs, and will be less disposed to adopt a “deficit model” of student-learning needs. These interviews showed some factors that were within my immediate power to change ... allowed me to see how students experienced and perceived my teaching. By adopting the students' perspective it became now much easier to see how I must change my teaching. [The students] seemed to scrutinise and adjust their perceptions of learning during the interview itself, and to regard it as an opportunity to learn. I could profitably engage more frequently, and in greater depth, with my students on an individual basis so as to be able to assess and learn from what and how *they* are learning as individuals.

### Metalearning Capacity

Given that a manifestation of variation in student learning can form a foundation of personal actionable theory for teachers invites a further question: Can a knowledge of their own learning also help students to independently form a reflective foundation on which to develop their learning expertise? Yet another generic aspect of actionable theory tells

us that students can vary in their learning engagement of different topics within the same subject, and it is this intra-individual variability that is of interest here. How might students themselves be exposed to this variability and its possible consequences? A theoretical basis for such exposure appeals to the concept of *metalearning capacity* after the work of Biggs (1985)—the capacity of a student to be aware of, and in control of, his or her own learning in some given context. Metalearning embeds a number of constructs; in particular the crucial process aspects of learning and, implicitly, a set of “regulation” constructs that represent the overlapping domains of attribution theory, locus of control theory and, most importantly for present purposes, self-regulation theory after the work of Vermunt (1998). Developing metalearning capacity transcends subject boundaries and represents a fundamental aspect of self-regulation (of learning processes) that is theoretically and empirically linked to the achievement of personal understanding. It is fundamental to any commitment to student-centred teaching, and student learning and well-being. Looked at another way, metalearning capacity also represents a form of personal actionable theory *for students*.

A problem lays in the fact that most entering university students are not likely to have had an opportunity to talk to their teachers (or anybody else) at school about *how* they typically went about learning *in process terms*. For the most part, students have never really thought about themselves in this way and, if asked, they generally experience difficulty, beyond habitual or preferential activities, in describing what *they know about themselves as learners*. They also generally vary in possessing a precise vocabulary to differentiate between contrasting aspects of what they do as learners, as well as a conceptual framework within which to organise and reflect on such contrasts. For some the *repertoire* of learning activities that can be orchestrated in response to learning-task requirements is narrow and difficult to expand. There is a persistency about doing things in certain limiting ways. For others the repertoire is wide, known to self, expandable in light of experience, and allows choice in terms of flexible responses to learning tasks.

For students to become *aware* of their learning in a metalearning sense, there has to be a recognition of self in relation to “learning” in some context and a consideration of what, in their own minds, they actually do when they are “learning” in that context. This recognition or initial “knowledge of self” may be well-developed for some students who have reflected upon, and feel comfortable with, themselves as learners. But for the rest, a stimulus is required—something to prompt an empowering initial realisation of self as learner in process terms, the emphasis being on “what am I doing?” rather than “who am I?” This distinction is crucial because empowerment for students begins with the realisation that their learning processes can vary, precisely because they are sensitive to the perceived context in which they are being orchestrated. Indeed, the

processes involved might be a conscious (and perhaps inappropriate, even dissonant) response to the perceptions formed about that context and its learning requirements. The responses can therefore change, under internal self-control preferably, in strategically appropriate ways and across different (subject) response contexts. And, as already mentioned, similarly so *within* a subject context.

There are surprisingly few studies on developing students' metalearning capacity in terms of the Biggs formalisation. Earlier studies by Meyer and Shanahan (2004), and Meyer et al. (2006), have reported on the conceptual architecture of a mechanism—in this case a Web-based interface—that students can log onto in order to generate a *learning profile* of themselves. There is thus an immediate basis for reflection, a representation of self that has in fact been self-constructed and that can literally be gazed upon. This representation of self *should* therefore be recognisable as such, and be further amenable to self-interpretation given suitable guidance.

I feel the learning profile is an accurate snapshot of my approach to learning. (Student D18)

This self-interpretation may in turn be further reflected on, either as a reassuring image of self, or in terms of an opportunity to work on issues *identified by self* as requiring change. Students are quite capable of committing these reflective accounts to paper, via a short essay, for example, that can then form a basis for discussion as part of further teaching support. And it is in the variability of these reflective accounts that one can discern (or not) the second, being "*in control of*" aspect of metalearning capacity.

This metalearning exercise can furthermore be repeated, thus providing evidence, in particular, of the dynamics of change. There is a powerful example of how these dynamics may be captured and interpreted in an empirical (quantitative and qualitative) study by Meyer, Ward, and Latreille (2009). This study also demonstrates quite clearly that a majority of students generally benefit from their metalearning experiences.

*The Learning Profile and its Constructs.* The profile is generated from quantitative response data to a set of statements about learning that traverse the domain of the Reflections on Learning Inventory (RoLI), an instrument grounded in students' self-reported learning experiences that captures variation in students' learning engagement, in particular, in process terms. The detail of the development of the RoLI and its domain can be found in Meyer (2004) and is not presented here. What needs to be conceptualised here is that it is firstly possible to generate, for each student, a set of subscale scores (the subscales embedded in the RoLI that define its internal structure) and, secondly, that this set of scores can be rank ordered and presented visually as a bar chart in which contrasting

aspects of learning are pre-colour-coded for interpretive purposes. So, for example, one RoLI subscale captures variation in terms of the construct of “knowing about learning” and a high score would be interpreted here as an indicator (colour coded green in the bar chart) of knowing something that is likely to support learning. Conversely, a high score on another subscale such as “memorising as rehearsal” (mechanical rehearsal), likely to inhibit learning, would be colour coded red.

I can also see that the red bar for memory as a rehearsal is quite high and I know that this is a big part of my learning and revising style. This may have been inhibiting my learning process so I need to try to stop learning in this way. (Student D20)

The “traffic light” analogy given to students is that they are on a journey by road and are trying to reach a destination (a personal, intended-learning outcome). This (learning) journey may encounter various forms of delays and obstacles along the way, possibly even stuck places (more of this later). Green (go) and red (stop) colours signify elements of learning engagement that are respectively interpreted as supporting or inhibiting progress (in learning) *in the particular response context*, while amber (caution) signifies an aspect of learning that might be delaying, or not, depending on its context-sensitive interpretation.

Overall I need to be aware of what ways of learning are “go” signals, and which are “red” and therefore potentially inhibiting; with this in mind I should be able to have a more distinct graph result and a better outcome to my learning. I need to be able to explain what I know, and know it before I learn it. (Student D5)

Thus conveyed is a spectrum of patterning depending on the “mix” of colours and the degree of conceptual consonance reflected therein. Basically the cleaner the separation between the “greens” and “reds” (with the “greens” scored relatively higher than the “reds”), the better. In contrast, a journey that starts off problematically (relatively high scores on “reds” compared to “greens”) may in fact lead to stuck places.

The profile is intended to engage students in the *first step* of developing metalearning capacity; namely, an *awareness* of their self-reported learning engagement in a particular response context.

I believe that my profile has illustrated both positive and negative features that contribute to my learning.... Learning techniques that I use which have been brought to my attention as negative qualities are “knowledge discrete and factual” and “learning is fact based.” These highlighted areas show that I place certain reliance on learning facts and mistake this as learning. (Student D21)

And some “mixed” patterns of colours can signify a conceptually *dissonant* form of learning (which may be transitional) that may also be generally troublesome in trying to reach the destination.

Mixed patterns of colours (green, amber, and red) tend to show possible troubles when trying to learn and solve problems. This may show my inability to adjust sufficiently quickly to the rapidly changing learning environment that is university. On the other hand, am I particularly concerned? The answer is no. The concept of learning about learning provides the opportunity to sort out any problems. (Student D6)

This basic self-portrait of themselves as learners may be supported in the *second step* in the form of a non-judgemental *guide* on how to interpret their profiles followed by additional activities: a consideration of likely consequences in terms of the quality of personally intended learning outcomes, and whether this is what they comfortably had in mind, and by *learning conversations* conducted by tutors or teachers who have developed an understanding of the underlying conceptual model of (qualitative variation in) student learning that the domain of the RoLI represents. Other forms of support include seminars on student learning in which, as a group, students are presented with a contrasting range of stereotypical examples of learning profiles (together with theoretical interpretations) and invited to thus provisionally “locate” themselves. Discussions and examples of how students can self-initiate change in their own learning are clearly crucial here. And, in many cases, there is also a need for self-initiated private counselling and supportive learning-change management.

Thus emphasized is how a knowledge of student-learning engagement can be used to help students *to help themselves* develop their metalearning capacity. There really is no excuse for not doing this. The means lie within the grasp of every teacher. In fact, it is possible for universities to create opportunities on a large scale for students to engage in this empowering activity as an *integral* part of the institutional learning and teaching environment. The strategic importance and competitive advantage of creating such opportunities is obvious, particularly at the crucial interface between school and university learning. A further consideration is whether metalearning constructs, in turn, have any role to play in learning and teaching strategies; whether they can be integrated into the learning experiences of students as part of course design and delivery. An example of how this integration may be achieved is provided in the study by Shanahan and Meyer (2003).

### Introducing Threshold Concepts

This section looks afresh at the foregoing discussion on student learning and metalearning, and positions it within the developing theoretical

framework of *threshold concepts*. If there is some excitement and commitment in capitalising, for the benefits of our students, on what is known about student learning and metalearning, and if our energies are going to be accordingly directed, then we might as well focus our attention on the “objects of learning” that really matter. There is much to celebrate here.

“Student learning engagement” is a broad term, and the variation within it can be generally formalised in terms of empirical (or conceptual) “models” of differing multivariate complexity ... [however,] generic models [of learning] are only useful, and indeed “actionable,” up to a rapidly reached point at which they become inadequate proxies for the dynamics of student learning within discipline-specific courses. It is here, at this interface of reached uselessness, that the existence of threshold concepts provides immediate and compelling signposting for avenues along which to solicit variation in student learning and understanding (and misunderstanding) in a far more critical sense. The responsiveness to variation is no longer in the general sense (how are you going about learning?), or even the discipline sense (how are you going about learning subject x?), but is now operating at a critical microperspective level within the epistemology of the discipline itself and its discourse. (Meyer and Land 2005, 380-81)

Thus re-emphasized is that soliciting variation in how students learn in general is of limited value; there is little explanatory power in the response variation. The same is true in respect of metalearning. When the variation reflects a disciplinary or subject-response context, the picture sharpens; there is a finer-grained discernment, and increased explanatory and diagnostic power in the variation for both teacher and student to capitalise on. The former is interested in the reconstitution and extension to practice of generic theory interpretable within a disciplinary discourse, and the latter with insights that can empower self-regulated *expertise in learning*. But there is still, even at this level, a lack of specificity in terms of actionable theory. An even finer-grained view of variation opens up new opportunities here because it can encapsulate those objects of learning represented by threshold concepts which, when successfully internalised, occasion the cognitive and ontological shifts that are the outcomes of transformational learning.

*Distinguishing Threshold Concepts.* We begin with a visual-spatial metaphor that is transportable across subject boundaries:

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). (Meyer and Land 2006, 3)

A frequently asked question is what distinguishes threshold concepts from, say, “fundamental,” “core,” or “key” concepts? This is not a helpful start because many teachers use terms like “core,” “fundamental,” and “key” interchangeably. It is also not helpful to ask what the definition of a threshold concept is. Threshold concepts cannot be described as an essentialist, definitive list of characteristics. The classificatory pursuit of threshold concepts in any scientific sense is a pointless one. It is nevertheless the case that some teachers encountering the notion of threshold concepts for the first time are initially inclined to identify, think, and get excited about them in terms of certain “qualities,” such as “troublesomeness,” that may be foregrounded more than others.

For some, this initial apprehension may be sharper than for others. An indelible recollection springs to mind, that of Phil, an *electrical* engineering colleague, who enthusiastically put up his hand in one of my seminars on threshold concepts and exclaimed: “We’ve got one of those!” On subsequent reflection another one came to mind—that of *reactive power*, *imaginary power*, *wattless power*—without which *real power* cannot be transmitted down a transmission line. And, as Phil later explained to me, when you understand reactive power, “the world looks different.”

An animated conversation in another setting with Michael,<sup>2</sup> an *electronic* engineer from another university, sparked a realisation on his part of an immediate parallel between “reactive power” and the threshold concept of “characteristic impedance.” The latter is fundamental in understanding the complex process of how to transmit information without any reflections. Failure to do so has some simple examples in the everyday phenomena of the “ghosting” of a television picture or “ringing” in an audio system. To appreciate the trouble that lays ahead, keep in mind at this point that a first-year student’s appreciation of “impedance” is very much that of *resistance* (an intuitively easy concept to grasp) as taught at school. Resistance is caused by a conducting material “impeding” the flow of electrons through it. Viewed as such, it’s a basically simple idea. Enough resistance in the element (electrical conductor) of a domestic plug-in kettle causes heat sufficient to quickly boil water. And for a cable (such as a copper transmission line connecting a power source to a load) resistance *increases proportionately with length*.

*Characteristic impedance* (like reactive power) is an equally troublesome threshold concept for engineers looking at the transmission of *information* such as a television signal (rather than power) down a different kind

of transmission line, typically in the form of a coaxial cable. But unlike resistance, characteristic impedance is counter-intuitively *independent of the length of the transmission line* (the coaxial cable) even though its units of measurement are the same, in ohms. (Equally counter-intuitive is that a *vacuum* also has a finite characteristic impedance of 376.7 ohms, in fact.)

However, the two very different transmission lines described above do share a common *equivalent circuit*; that is, an abstraction in which the actual physical systems are represented by a circuit diagram consisting of the simplest possible arrangement of the three key electrical components—the resistor, the capacitor, and the inductor. And now there is more trouble because the resultant abstraction in this particular case *bears little or no physical resemblance* to the actual systems in terms of the appearance, and the clearly defined function, of these components as found by students in their laboratory store room. So, there is plenty of trouble here for students.

But if, on the other hand, reactive power and characteristic impedance thus reflect variation in a commonly shared *critical feature* of transmission-line theory *that is occluded* in the equivalent circuit, then some really provocative teaching questions and opportunities arise. This particular story continues to unfold (Flanagan, Taylor, and Meyer 2010).

Another “quality” of threshold concepts that may vary in its foregrounding is that of *integration*:

We turn now to the question of how to operationalise “integration” and “transformation” in ways that distinguish conceptual change in threshold concepts from conceptual change in other traditions. Practice in these traditions has examined different conceptions of the same phenomenon and the conditions—including those that arise from the learner’s intentions and emotions—in which it is more likely that they will shift from a less complex to a more complex conception of the phenomenon. This focus on conceptions of one particular phenomenon is different from that suggested by “threshold concepts.” Threshold concepts have been suggested as ways of thinking about a wide range of phenomena that fall within the scope of a particular discipline or mode of thought. The transformation that is suggested as an outcome of understanding a threshold concept should be seen in changes in conception of several (perhaps many) phenomena and this way of thinking about conceptual change is different from that suggested by other traditions. (Davies 2010)

In similar vein a new transformational understanding, in the process of being acquired, and once acquired (cognitively or ontologically) will also be *discursive* (exhibiting modes of reasoning and explanation, and how people “think” within a particular discipline):

It is hard to imagine any shift in perspective that is not simultaneously accompanied by (or occasioned through) an extension of the students’ use of

language. Through this elaboration of discourse new thinking is brought into being, expressed, reflected upon and communicated. The extension of language might be acquired, for example, from that in use within a specific discipline, language community or community of practice, or it might, of course, be self-generated. It might involve natural language, formal language or symbolic language. (Meyer and Land 2005, 374)

This is enough to get us started. A comprehensive discussion on these and other “features,” as well as their theoretical underpinning can be found in Timmermans (2010).

*The Threshold Concepts Framework.* There is now an established and expanding literature on the theoretical framework of *threshold concepts and troublesome knowledge* as an Internet search on this term will reveal. A summary of the genesis, and subsequent development and application, of this framework within various disciplines lies beyond the scope of this chapter. The curious reader is simply referred to one version of the seminal paper by Meyer and Land (2003) that can be accessed online. A cross section of the subsequent progression of the seminal ideas contained therein (within various disciplinary perspectives) is compactly reflected in Land, Meyer, and Smith (2008). Another compact collection of more advanced applications, some of which directly address issues of teaching and assessment, can be found in Meyer, Land, and Baillie (2010).

There are many disciplinary perspectives reflected in the edited volumes referred to above, notably in accounting, biology, computer science, cultural studies, history, earth sciences, economics, engineering, law, music, philosophy, and theology. These perspectives provide an accessible entry to the more advanced, peer-reviewed discourses that have been published in specialist journals. Contextualising threshold concepts within interdisciplinary learning environments is also part of the focus of attention (Land and Meyer 2010).

The framework has also been embraced by some within the professional-development community. It has found a place within the formal provision of graduate-certificate programmes in the UK and in Australia.

A word of caution: the threshold-concepts framework is also subversive. It rattles the cage of the managerially efficient “outcomes-based education,” a conveyor-belt model of course design and delivery—a model so deterministic that it requires of teachers in some UK universities the setting of the final-examination paper before the course even commences or the students are known. So let’s forget about individual differences in learning. And let’s give Mager (1975) some credit here for what this model is attuned to. He came up with his version of what is now the fashionable mantra of “intended learning outcomes” (circa 1962).

Learning within a managerialist perspective might be likened to that of students as eggs travelling along the same conveyor belt, being subjected to

various forms of scrutiny, and possible rejection, before reaching the final quality-control check of the graded learning outcomes. (Meyer and Land 2007, 14)

So if an employer needs, say, half a dozen (in UK parlance) “upper second” new accounting graduates, well, there they are ready to go in the egg box! Is this really what “higher” education should be about?

But what if an employer, inspired by *Historical Thinking and Other Unnatural Acts* (Wineburg 2001), seeks a graduate who can “think” like an historian?

Unlike the linear or industrialised model described above, this [threshold-concepts] approach views learning as a form of journey, during which the student not only gains insights great and small, but is also changed as an individual by new knowledge. (Meyer and Land 2007, 14)

What, if anything, might an “upper second” signify in this ontological dimension of variation of transformed learner status and identity and how would it be determined?

*Threshold Concepts and Other Perspectives.* The threshold-concepts framework invites engagement with other perspectives. There is an immediate critical engagement, for example, as Meyer, Land, and Davies (2008) have argued, with pedagogical “theories of variation.” This engagement is a productive one, despite specific reservations expressed about some of the generalisations made in respect of the application of *variation theory* as developed in the phenomenographic tradition.

The threshold-concepts framework presents challenges for assessment that “conveyor-belt” thinking cannot respond to. To begin with, how can one “bring into view” for students a transformative portal that lies *beyond* their ontological horizon? There is no neat taxonomy of objectives in the ontological domain to help us fine tune the outcomes here. One way forward, suggested by the work of Pang and Meyer (2010), rests on the conjecture that students, in varying degrees, may possess some tacit and as yet non-formalised understanding of what a particular portal represents long before it “comes into view” within the technical discourse of the discipline. This study demonstrates that the use of proxy economic scenarios in which school pupils—in this case with no prior formal knowledge of economics or economic language—can locate themselves in interview settings does solicit variation in what has been referred to by Perkins (2006) as an “episteme,” a “way of knowing,” a tacit feel for what the “underlying game” is.

In the absence of economic terminology, a few pupils in Pang and Meyer’s study demonstrated a relatively sophisticated tacit grasp of what was for them the unknown threshold concept of “opportunity cost.”

Furthermore, in talking about how choices may be exercised in what for them was an increasingly abstract sequence of proxy economic scenarios, there was also evidence that some of the pupils *were learning something new* about the concept of “choice” in terms of sacrifice of, rather than selection from, alternatives.<sup>3</sup>

It is worth reflecting on another “bringing into view” example that draws in, integrates, and provides transferable theoretical underpinning for what might otherwise be viewed as an isolated example of an enquiry-based teaching strategy. Consider an example from mathematics. Easdown (2007) below sets the scene in arguing the case for “proof” as a threshold concept in mathematics:

It is common for new students to say that they “like mathematics” but “hate proofs.” For many proof technique is a difficult hurdle to overcome and has all of the hallmarks of a *threshold concept*, in the sense of Meyer and Land (2003, 2005). The ability to understand and construct proofs is *transformative*, both in perceiving old ideas and making new and exciting discoveries. It is *irreversible* and often accompanied by a “road to Damascus” effect, not unlike a religious conversion or drug addiction. The most inspiring mathematical proofs are *integrative* and almost always expose some hidden *counter-intuitive* interrelations. And of course they are *troublesome*: it can take a long time, even years, for students to learn to appreciate proofs and to develop sufficient technique to write their own proofs with confidence. (28)

How might the construction of a proof be “brought into view” for students? Sandefur (2005) summarized failed attempts to teach students how to construct a proof, concluding that “... one of the most important reasons that we failed is that none of us really knew how students learn to solve problems” (2). In turning his attention to remedying this situation, he describes how, as a pure mathematician, he observed over a period of several years how students varied in their attempts to construct a proof and how this knowledge has been used to develop a learning and teaching strategy that effectively models this process. One of the keys used to unlock the variation involved is what he refers to as videoed “think alouds”—recorded observations of students verbalising what they are thinking in attempting to construct a proof. There are two interesting things about his account: the use of variation, and the fact that he provides no apparent theoretical underpinning for his methodology. What he perhaps unknowingly describes is a powerful example of the application of *self-explanation theory* after the work of Chi et al. (1994) and earlier work by Chi and colleagues that, according to Meyer and Land (2010), should be capable of generating explanations of the variation reflected in reaching an understanding (or not) of threshold concepts. The final point here is that Sandefur’s work, like that of Pang and Meyer, and that of Flanagan, Taylor, and Meyer mentioned earlier, signals the means

to identify, *from the student-learning perspective*, variation in the “critical features” of threshold concepts. There is much that can be done with a knowledge of this variation. It has been demonstrated:

... that it is possible to derive pedagogical principles from the idea of threshold concepts and that activities that are devised on the basis of these principles are distinctive when compared to other approaches to teaching and learning which at first sight are quite similar. (Davies and Mangan 2008, 48)

## TAKING STOCK

What has been discussed in this chapter is a celebration of progress. It is exciting to explore new ideas and practices that progress our understanding of how our students vary in their learning engagement, and how we might reflexively respond to that variation as teachers. For example, it is clear from the work of Meyer, Ward, and Latreille (2009) that variation in student learning, and developing students’ metalearning capacity, can *simultaneously* be focused on at the level of discrete threshold concepts—the very concepts that for many students represent the troublesome stuck places in their learning journeys. It is also clear from this study that it is possible to statistically model changed or changing metalearning capacity in the learning of a threshold concept. And what this modelling also reveals are the dimensions of the dynamics of change so crucial to our understanding of the critical learning episodes that really matter.

We need to let go of some old, tired, and worn-out formulaic ideas about teaching practice. Conveyor-belt thinking is not going to help our students internalise threshold concepts or our capacity to assess the dynamics of their transformational learning journeys. We need to move on and develop, and respond to “... a coherent analysis of the problems facing learners” (Davies and Mangan 2008, 48). What is being advocated here is *not* a tired restatement of the general position that, insofar as variation in learning can be neatly categorised, we should look for an appropriate teaching response to each category (assuming such a theoretically justified response exists). The threshold-concepts framework generates *new sources* of variation in the cognitive and ontological shifts in students’ learning journeys, and within different uncharted modes of liminality. And what is becoming clear is that the patterns of variation emanating from these new sources are not amenable to “categorisation” in terms of the old metaphors. We need to take our eyes off the rear-view mirror and look ahead.

This chapter began with a reflective account of some of the classic ideas that have helped us to better understand our students’ learning, and it ends with the observation that *integrated* thinking about variation

in student learning, metalearning, and threshold concepts opens up a new landscape for us as teachers. There is a powerful triangulation synergy of ideas here to help *us* to help our students, and for students to *help themselves*.

## NOTES

<sup>1</sup> Note that this quotation, and following quotations attributed to students with D-numbers, are anonymised verbatim extracts from reflective essays written by students about their learning as part of a study by Meyer, Ward, and Latreille (2009).

<sup>2</sup> Michael Flanagan has since gone on to develop a definitive website on the status of some threshold concepts that are relevant to his own disciplinary interests (electronic engineering and computing), including links to mathematics, physics, and statistics as supporting disciplines. His website is being expanded in 2010 to cover other disciplinary contexts and is well worth visiting (at <http://www.ee.ucl.ac.uk/~mflanaga/thresholds.html>).

<sup>3</sup> The contrast here is between the “cost” of a choice as seen in terms of the cost of what has been sacrificed, rather than the cost of what has been selected. The definition of “opportunity cost” does not emphasize the sacrifice of alternatives (plural) but of the *best* alternative foregone.

This is one of the most fundamental concepts in economics. It is a *threshold concept*: once you have seen its importance, it affects the way you look at economic problems. When you use the concept of opportunity cost, you are *thinking like an economist*. And this may be different from thinking like an accountant or from the way you thought before. (Sloman 2006, 8)

It is remarkable that some of the school pupils interviewed in the Pang and Meyer (2010) study were able to demonstrate a tacit inclination to in fact *begin* “thinking like an economist.” The significance of this observation lies in the conjecture that, were these same pupils to choose to study economics in the future, they would do so *having already made* a preliminal ontological shift such that when they encounter the formalization of “opportunity cost” they might say “OK, I think like this anyway but now it has a name” rather than getting stuck trying to comprehend a definitional way of analytical thinking that is alien and counter-intuitive.

## REFERENCES

- Biggs, J.B. 1985. The Role of Metalearning in Study Processes. *British Journal of Educational Psychology* 55(3):185-212.
- Chi, M.T.H., N. de Leeuw, M.-H. Chiu, and C. LaVancher. 1994. Eliciting Self-Explanations Improves Understanding. *Cognitive Science* 18(3):439-77.
- Davies, P.I. 2010. Transforming Knowledge Structures: A Procedure for Developing Students’ Understanding of Threshold Concepts. Paper to be presented at the 3<sup>rd</sup> Biennial Threshold Concepts Symposium, University of New South Wales, 1-2 July.

- Davies, P. and J. Mangan 2008. Embedding Threshold Concepts: From Theory to Pedagogical Principles to Learning Activities. In *Threshold Concepts within the Disciplines*, ed. R. Land, J.H.F. Meyer, and J. Smith, 37-50. Rotterdam and Taipei: Sense Publishers.
- Easdown, D. 2007. The Role of Proof in Mathematics Teaching and *The Plateau Principle*. UniServe Science Symposium proceedings. Science Teaching and Learning Research including Threshold Concepts. The University of Sydney, 27-28 September.
- Eley, M.G. and J.H.F. Meyer. 2004. Modelling the Influences on Learning Outcomes of Study Processes in University Mathematics. *Higher Education* 47(4):437-54.
- Flanagan, M.T., P. Taylor, and J.H.F. Meyer. 2010. Compounded Thresholds in Electrical Engineering. In *Threshold Concepts and Transformational Learning*, ed. J.H.F. Meyer, R. Land, and C. Baillie. Rotterdam: Sense Publishers. In press.
- Land, R. and J.H.F. Meyer. 2010. Threshold Concepts and Troublesome Knowledge (6): Issues of Interdisciplinarity. Paper to be presented at the 3<sup>rd</sup> Biennial Threshold Concepts Symposium, University of New South Wales, 1-2 July.
- Land, R., J.H.F. Meyer, and J. Smith. ed. 2008. *Threshold Concepts within the Disciplines*. Rotterdam and Taipei: Sense Publishers.
- Lucas, U. and J.H.F. Meyer. 2005. "Towards a Mapping the Student World": The Identification of Variation in Students' Conceptions of, and Motivations to Learn, Introductory Accounting. *The British Accounting Review* 37(2):177-204.
- Mager, R.F. 1975. *Preparing Instructional Objectives*, 2<sup>nd</sup> edition. Belmont: Fearon Publishers.
- Marton, F. and R. Säljö. 1976. On Qualitative Differences in Learning. II – Outcome as a Function of the Learner's Conception of the Task. *British Journal of Educational Psychology* 46(2):115-27.
- Meyer, J.H.F. 2004. An Introduction to the RoLI. *Innovations in Education and Teaching International* 41(4):491-97.
- Meyer, J.H.F. 2005. Closing the Gap between Educational Research and Educational Development: A Model of Engagement. In *Improving Student Learning 12 – Diversity and Inclusivity*, ed. C. Rust, 360-76. Oxford: Oxford Brookes University.
- Meyer, J.H.F. and R. Land. 2003. Threshold Concepts and Troublesome Knowledge: Linkages to Ways of Thinking and Practising within the Disciplines. In *Improving Student Learning. Improving Student Learning Theory and Practice – 10 Years On*, ed. C. Rust, 412-24. Oxford: Oxford Brookes University. Also separately published earlier as accessed 5 January 2010 at <http://www.tla.ed.ac.uk/etl/docs/ETLreport4.pdf>
- Meyer, J.H.F. and R. Land. 2005. Threshold Concepts and Troublesome Knowledge (2): Epistemological Considerations and a Conceptual Framework for Teaching and Learning. *Higher Education* 49(3):373-88.
- Meyer, J.H.F. and R. Land, eds. 2006. *Overcoming Barriers to Student Understanding: Threshold Concepts and Troublesome Knowledge*. London and New York: Routledge.
- Meyer, J. and R. Land. 2007. Stop the Conveyor Belt, I Want to Get Off. *Times Higher Education* 17(August):14.
- Meyer, J.H.F. and R. Land. 2010. Threshold Concepts and Troublesome Knowledge (5): Dynamics of Assessment. In *Threshold Concepts and Transformational Learning*, ed. J.H.F. Meyer, R. Land, and C. Baillie. Rotterdam: Sense Publishers. In press.
- Meyer, J.H.F., R. Land, and C. Baillie, eds. 2010. *Threshold Concepts and Transformational Learning*. Rotterdam: Sense Publishers. In press.

- Meyer, J.H.F., R. Land, and P. Davies. 2008. Threshold Concepts and Troublesome Knowledge (4): Issues of Variation and Variability. In *Threshold Concepts within the Disciplines*, ed. R. Land, J.H.F. Meyer, and J. Smith, 59-74. Rotterdam and Taipei: Sense Publishers.
- Meyer, J.H.F. and M.P. Shanahan. 2001. A Triangulated Approach to the Modelling of Learning Outcomes in First-Year Economics. *Higher Education Research and Development* 20(2):127-45.
- Meyer, J.H.F. and M.P. Shanahan. 2004. Developing Metalearning Capacity in Students – Actionable Theory and Practical Lessons Learned in First-Year Economics. *Innovations in Education and Teaching International* 41(4):443-58.
- Meyer, J.H.F., M. Shanahan, L.S. Norton, D. Walters, S. Ward, and H. Hewertson. 2006. Developing Students' Metalearning Capacity: A Grounded Assessment Framework. In *Improving Student Learning 13 – Improving Student Learning Through Assessment*, ed. C. Rust, 248-66. Oxford: Oxford Brookes University.
- Meyer, J.H.F., S.C. Ward, and P. Latreille. 2009. Threshold Concepts and Metalearning Capacity. *International Review of Economics Education* 8(1):132-54.
- Pang, M. and J.H.F. Meyer. 2010. Modes of Variation in Pupils' Apprehension of a Threshold Concept in Economics. In *Threshold Concepts and Transformational Learning*, ed. J.H.F. Meyer, R. Land, and C. Baillie. Rotterdam: Sense Publishers. In press.
- Perkins, D. 2006. Constructivism and Troublesome Knowledge. In *Overcoming Barriers to Student Understanding: Threshold Concepts and Troublesome Knowledge*, ed. J.H.F. Meyer and R. Land, 33-47. London and New York: Routledge.
- Reid, A. 2001. Variation in the Ways that Instrumental and Vocal Students Experience Learning Music. *Music Education Research* 3(1):26-40.
- Richardson, J.T.E. 2000. *Researching Student Learning: Approaches to Studying in Campus-Based and Distance Education*. Buckingham: Open University Press.
- Richardson, J.T.E. 2006. Investigating the Relationship between Variations in Students' Perceptions of their Academic Environment and Variations in Study Behaviour in Distance Education. *British Journal of Educational Psychology* 76(4):867-93.
- Sandefur, J. 2005. Problem Solving: What I Have Learned from My Students. A paper presented at the Kaist International Math Education Conference. Accessed 28 January 2009 at <http://www9.georgetown.edu/faculty/sandefur/ProofPaper.pdf>
- Shanahan, M. and J.H.F. Meyer. 2003. Measuring and Responding to Variation in Aspects of Students' Economic Conceptions and Learning Engagement in Economics. *International Review of Economics Education* 1(1):9-35.
- Slovan, J. 2006. *Economics*, 6<sup>th</sup> edition. Harlow: Pearson Education Limited.
- Timmermans, J. 2010. Changing Our Minds: The Developmental Potential of Threshold Concepts. In *Threshold Concepts and Transformational Learning*, ed. J.H.F. Meyer, R. Land, and C. Baillie. Rotterdam: Sense Publishers. In press.
- Vermunt, J.D. 1998. The Regulation of Constructive Learning Processes. *British Journal of Educational Psychology* 68(2):149-71.
- Wineburg, S. 2001. *Historical Thinking and Other Unnatural Acts: Charting the Future of Teaching the Past*. Philadelphia: Temple University Press.