Chapter 8
Helping Learners Through Transitions: Threshold Concepts, Troublesome Knowledge and Threshold Capability Framework in Surgery

Simon Blackburn, Julian Smith, and Debra Nestel

Overview This chapter explores a constructivist theory that can inform the design of surgical education and training programs, especially to address areas of particular challenge. Threshold concepts, troublesome knowledge and threshold capability are introduced and illustrated in paediatric surgical training and transition to cardiothoracic surgical practice. Like other theories in this section, threshold c*oncepts involve transformation of individuals' ways of thinking, movement through a* liminal state. This transformation is often associated with the development of a professional identity and represents an *ontological shift* in how the individual sees themselves and may reflect how others see them too. Learners can, however, sometimes find themselves in a *stuck* place where they can move neither forwards nor backwards. The ideas explored in this chapter may provide insights with which educators can help learners to move beyond their current state, to anticipate and plan for troublesome areas in learning, so that they can successfully navigate transitions.

S. Blackburn (✉)
Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK
e-mail: sblackburn@doctors.org.uk

J. Smith
Department of Surgery (School of Clinical Sciences at Monash Health), Monash University, Clayton, Australia
e-mail: julian.smith@monash.edu

D. Nestel
Faculty of Medicine, Nursing & Health Sciences, Monash Institute for Health and Clinical Education, Monash University, Clayton, VIC, Australia

Faculty of Medicine Dentistry & Health Sciences, Department of Surgery, Melbourne Medical School, University of Melbourne, Parkville, Australia
e-mail: dnestel@unimelb.edu.au; debra.nestel@monash.edu

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8.1 Introduction

The process of becoming a surgeon is a characterised by sustained study and practice over many years. Even after consultant surgeon status is conferred, professional development continues as surgeons adapt to changing technologies and processes of surgical practice. At any point in this development process, surgical trainees or consultants may get "stuck". That is, even with effortful practice they may be unable to advance to the next stage of development. Threshold concepts, troublesome knowledge and threshold capability offer surgical educators guidance in moving the trainee beyond the *stuck place*. This chapter explores these concepts in surgical education and training. We use italics to indicate features of the theoretical notion of threshold concepts.

8.2 Threshold Concepts

An Open University education report on education innovations identified ten new pedagogies and included threshold concepts [1]. In general terms, threshold concepts are "core" concepts/ideas/practices that must be understood (even embodied) before learners can progress. Sometimes these ideas (concepts) may seem counter-intuitive. They are characterised more precisely by the features listed in Box 8.1. For medical students, empathy has been identified as a threshold concept. Students may know what it is and do it (e.g. make empathic statements), but it may not be experienced as empathy by the intended recipient – patients. That is, the patient may experience the student's behaviour as going through the motions or mimicking

Box 8.1 Threshold Concepts Have a Number of Common Defining Characteristics [2–4]

1. *Transformative* – resulting in a sudden or lengthy shift in perception of a subject or discipline; once mastered the threshold concept alters the learner's view of the discipline; an epistemological shift.
2. *Integrative* – exposing and bringing together previously unappreciated interrelatedness within the discipline.
3. *Irreversible* – not being forgotten or unlearned without considerable effort.
4. *Bounded* – defining what is and what is not within a field or certain conceptual space, having a specific and limited purpose.
5. *Discursive* – using an enhanced and extended discipline-specific language in crossing a threshold.
6. *Reconstitutive* – altering a learner's subjectivity, sense of self or identity; an ontological shift.
7. *Troublesome* – see text.

empathy rather than being authentic. Unless the student realises that their empathic behaviour is not experienced by the recipient as such then they may be in a liminal state relative to the concept of empathic care. To illustrate, during a simulated patient-based consultation designed to support students in learning about empathic care, a simulated patient was able to share with a student that his empathic behaviour felt like "one of those drawings children do by joining the dots – it just felt like it was empathy by numbers, by joining the dots without any real commitment from you". This feedback had a profound impact on the student who was able to recognise that empathy in healthcare was much more than "joining the dots"; he had to personally feel committed to it. The student shared that he had experienced challenges in establishing rapport with patients and that he was somewhat *stuck* in developing productive student-patient relationships. This feedback had enabled him to move out of this *liminal* state.

Threshold concepts are described as being "akin to a portal, opening up a new and previously inaccessible way of thinking about something. They represent a transformed way of understanding, interpreting, or viewing something without which the learner cannot progress" [2]. Threshold concepts are, therefore, by their very nature *transformative*, in that they lead to a change in perception. It is argued that, in certain instances, this change may have an associated shift in identity. Neve et al. (2015) posit that threshold concepts "lead to a qualitatively different view of subject matter and are central to achieving mastery [sic] of a subject" [3]. Threshold concepts are further characterised as *irreversible*, in that, once acquired, the change in perspective or behaviour which has been produced by the threshold concept is unlikely to be unlearned. It may even be difficult to comprehend the state of those on the other side of the threshold who are unable to make meaning of what is happening because they do not understand it [2].

Another characteristic is that threshold concepts are *integrative*, "exposing the previously hidden interrelatedness of something" [2], but they are *bounded*, in that the understanding of one threshold concept is likely only to expose so much, before a new threshold is reached, and a further shift in perspective is required to make progress. See Box 8.1.

Threshold concepts can be challenging to identify [4, 5]. The importance of identification lies in their potential value as an aid to teaching and learning (as in the example above, to work with simulated patients to support the development of empathic care in healthcare students). Approaches to identifying threshold concepts include dialogue between teachers and learners and tools such as semi-structured interviews, questionnaires, surveys, short answer questions, review of old examination papers and observation of class room behaviours [4]. Controversy remains as to how many of the characteristics listed in Box 8.1 are required for a concept to be regarded as "threshold". Some characteristics might be more important than others. One of the theorists originally describing threshold concepts, Land, has stressed the importance of the *transformative* and *troublesome* elements in their definition [6], and these two elements have even been described as non-negotiable [4]. Authors have highlighted definitional problems [7] while others have questioned whether threshold concepts actually exist [5].

8.3 Troublesome Knowledge

Troublesomeness is perhaps the most interesting and relevant feature of threshold concepts. Troublesome knowledge may appear counterintuitive, alien or incoherent to the learner [8]. This feature of difficult learning has also been described as dissonance [9] or disorientating [10]. An important note on the characteristics of threshold concepts is that "all defining characteristics, except for troublesome [ones], describe the aftermath – not the experience – of student's successful acquisition of troublesome material" [11]. To identify threshold concepts in learners engaged in wrestling with them, it is troublesomeness that is likely to provide the clue to their recognition. Seeking areas of learning that are troublesome might point to threshold concepts – areas of learning which could benefit from educational intervention. The original notion of threshold concepts has its roots in university education, based on learning as intellectual understanding rather than learning in a professional, practical context. Meyer and Land (2003) have, however, drawn attention to the potential for the idea of threshold concepts to be applied to more practical disciplines [2]. Several authors have developed the idea in medical education [3, 12].

8.4 Liminal States

Transitional phases in training can be described in terms of *liminality* [13]. This term originates from ethnographic studies of tribal societies in which rituals associated with a transition from one state of being to another involve an *in between* period [14]. In some tribes, this liminal state involves being thrown out into the wild for a period, leaving the community a boy and returning a man. Meyer and Land (2005) argue that several characteristics of this liminal state are of use from an educational perspective. Liminality implies a transformative component; entering the liminal state describes a process of transition from one state of being to another. As a consequence, the individual acquires a new status but must also lose the old one:

> In order to do so, he or she must strip away, or have stripped from them, the old identity. The period in which the individual is naked of self – neither fully in one category or another – is the liminal state. [15]

This transformation may be protracted over time and involve oscillation between states. The other key characteristic of the liminal state is that once it is entered it is almost impossible to revert to the previous role, the old self has been lost but the new self has not been completely taken on. Linking these three ideas, troublesome knowledge may be reasons for a learner's liminality. Threshold concepts then represent changes that are substantive (*transformative* and *troublesome*) in knowledge or in practice that, once understood or achieved, will never be experienced from the same perspective.

8.5 Threshold Capability Framework

A further development in this field is the *threshold capability framework*. This framework provides an approach to dealing with previously unseen situations in professional, social and personal lives. Capability theory is concerned with the ability of learners to act effectively in future professional roles – of being able to deal with circumstances that cannot be specified in advance [16]. This theory, which has the potential to lead to the design of curricula to enhance a learner's transformative and capability building experiences, has had limited but promising applications [17]. It has particular appeal in surgery for its anticipatory nature, application to professional practice and the qualitative nature of *capability*.

8.6 Transitions in Surgery

We now shift our discussion to surgical education and practice. The personal development of surgeons traverses a number of important states: from medical student -> pre-vocational doctor -> surgical trainee -> consultant surgeon (Fig. 8.1). Through each state there will be an altered identity or sense of self where the individual feels that in some particular respect they are now thinking and practicing a little more like a surgeon [18]. Failing to address threshold concepts and troublesome knowledge encountered during each state may significantly impede learning and subsequent progression to the next state. There are particular challenges for newcomers to each state.

8.7 Threshold Concepts and Troublesome Knowledge in Surgery

Land and Meyer [18] explored ontological shifts across the careers of a small number of surgeons in London. They describe the threshold concept of *uncertainty* for surgical training – referring to the many surgical practices that are enacted to reduce, to manage and even to embrace uncertainty as part of the ontological shift in becoming a surgeon. They report surgeons' efforts during training of making sense of anatomy from a textbook relative to the patient on the operating theatre table. *Letting go* of learning anatomy from 2D textbooks requires an epistemological shift. The ability to deconstruct procedural practice was considered essential – this task analysis being key to error reduction. Surgical expertise is, of course, much more than the assemblage of the component parts; it requires integration, the achievement of which comprises an epistemological shift.

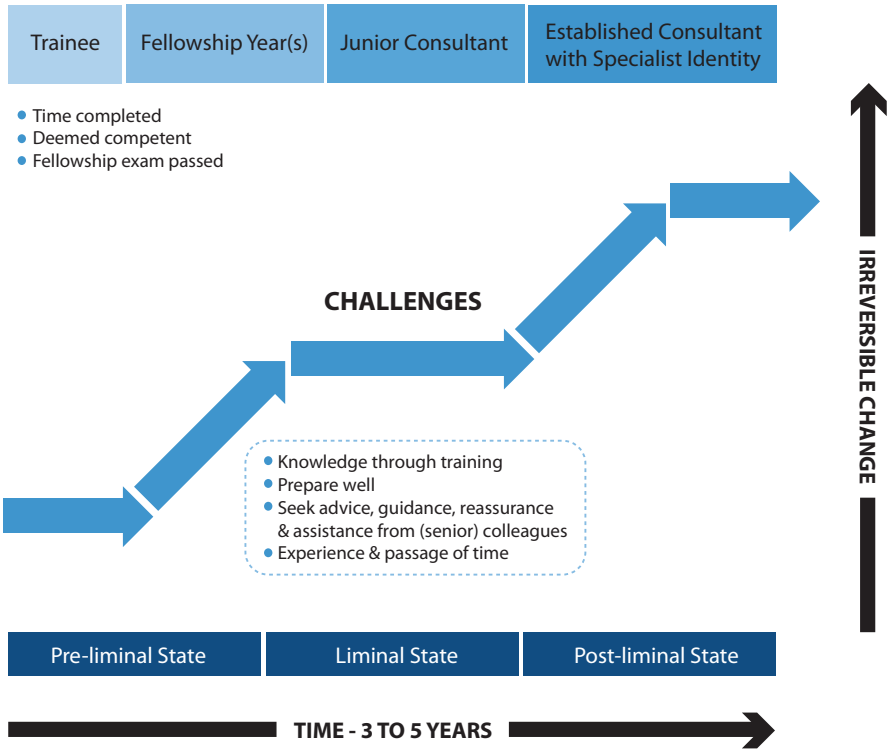

Fig. 8.1 Transition from trainee to an established consultant with a specialist identity via a state of liminality

We now share two examples from our research with study features summarised in Box 8.2. Both studies involved individual interviews with learners – in the first example, paediatric surgical trainees in the United Kingdom and, in the second example, junior cardiothoracic surgeons establishing themselves in consultant practice in Australia.

8.7.1 Example 8.1 Exploring Threshold Concepts in Paediatric Surgical Training [19]

Troublesome areas of paediatric surgical training are listed in Box 8.2.

Box 8.2 Summary of Our Studies Exploring Threshold Concepts

Paediatric surgery	Cardiothoracic surgery
Trainees in United Kingdom	Junior consultants in Australia
8 individual semi-structured interviews	13 individual semi-structured interviews
Purposively sampled surgical trainees across all years of the training programme	Purposively sampled cardiothoracic surgeons within 10 years of completing speciality training
Participants invited to consider technical skills, clinical judgement and knowledge derived from Intercollegiate Surgical Curriculum Project (ICSP, 2016)	Participants invited to consider theoretical and practical knowledge associated with cardiothoracic surgery including technical skill, clinical judgement, uncertainty, surgical complexity, etc.
Thematic analysis of transcribed interviews	Thematic analysis of transcribed interviews
Troublesome areas included:	Troublesome areas included:
1. Knowledge	1. Taking responsibility for patient care such as
2. Clinical judgement	a. Clinical judgement
3. Access opportunities for developing technical skills	b. Decision-making
4. Transitions between roles (including validation as a paediatric surgeon)	c. Unsupervised operating
5. Relationships with colleagues, especially consultant trainers	2. Career design
6. Impact of negative experiences	3. New work environments
	4. Relationships with colleagues, trainees and other team members
	5. Technical challenges
	6. Managing the previously unseen or unexpected
	7. Coping with adverse events
	Uncertainty associated with handling each of these challenges was the most prominent threshold concept

8.7.1.1 Knowledge

The breadth of paediatric surgery as a specialty was identified as a source of difficulty. This was compounded by the rarity of some conditions encountered, particularly when neonatal surgery was considered. Specific topic areas were most notable by their absence from the discussion, although some areas of basic science were identified as difficult. Applied knowledge, the "know-how" of paediatric surgery, was perceived as being much more troublesome by participants:

> Well, there's what's written in the textbook and people know that there's an inner textbook. [Participant 3]

8.7.1.2 Access Opportunities for Technical Skills

There were few examples of technical operative skills that were identified as troublesome. Rather, accessing opportunities to operate sometimes proved troublesome.

8.7.1.3 Clinical Judgement

Developing clinical judgement, and recognising and reflecting on incorrect judgement, was a commonly occurring theme. Trainees often reflected on developing an ability to tolerate diagnostic doubt and the fact that their judgement had developed from experience. Clinical judgement was also an area in which the expectations of more junior trainees (of themselves) differed from those of more senior trainees. Paradoxically, junior trainees had an expectation that their own judgements should be independent, a different view from that expressed by more senior participants:

> I think, as a ST3 [Senior trainee] it's very difficult to make an independent decision about anything because everything is so overwhelming… [Participant 5]

Junior trainees moved from a position of expectation about their ability for independent clinical judgement to one expecting and accepting the shared nature of clinical judgement.

8.7.1.4 Transitions Between Roles

The transition to a higher surgical trainee was marked by an increased level of challenge; this was expressed in a perception of increased responsibility, increased expectations of technical skill and the demands placed by the fact that those being looked after are children. Associated with this increase in technical demand and responsibility, several trainees described difficulty with the sudden remoteness of support, with the consultant on call often at home and away from the hospital. Interestingly, this fear of seeking help seemed not to be recognised or recalled by the more senior trainees.

8.7.1.5 Validation as a Paediatric Surgeon

Alongside this transition in role, trainees described a desire to prove themselves, reflecting a lack of validation as a paediatric surgeon, one responded to a discussion about technical skills by saying:

> Yes, if you're a bit clumsy you'd be shown a better technique then that happens, but that's the default of the training pathway as opposed what is actually difficult for you as a trainee in those stages, the fact that you don't have any self-belief [Participant 1]

Some participants reflected on the importance of external support, particularly from their consultants, to their feelings of self-belief.

8.7.1.6 Relationships with Trainers

All participants made reference to the importance of their relationship with their consultant trainer. The impact of this relationship was described across the domains of practice discussed and was seen to have an impact at all levels of training. Within this setting, trainees commonly remarked on the problems presented by frequently changing training consultants, who might have rather different views on the best way to perform a procedure.

8.7.1.7 Impact of Negative Experiences

All participants described the impact on learning associated with *negative experiences*: situations where trainees had experienced an adverse outcome or had made a misjudgement. The emotional language associated with negative experiences was more marked in the interviews with junior trainees. The majority of the trainees were able to describe a specific instance in which a mistake or misjudgement on their part had led to a significant emotional response and also a process of reflection leading to a change in behaviour.

One participant summarised his understanding of this process in this way:

> I'd say it almost feels like the cerebral, cognitive part comes first…
> …then the emotional part helps to impress it on you. [Participant 2]

The emotional response to negative situations was quite marked, with trainees describing a profound impact on their sense of self as a consequence of negative experiences. The use of emotional language in the interviews was striking, with the term "cognitive scar" used by all trainees to describe their memory of such experiences.

Despite the profound emotional impact of these experiences, one interesting feature of the trainees' descriptions was that the eventual impact on learning was thought to be positive.

8.7.1.8 Movement from Epistemological to Ontological Understanding

The impact of negative experiences on trainees was clear, and the descriptions obtained were very rich. There seemed to be a clear pattern of the response to these experiences having both emotional and cognitive components. The emotional aftermath and subsequent cognitive rationalisation were key points at which change occurred, with several trainees describing changes in their behaviour as a consequence of these experiences. This response could be viewed as a key event in development, analogous to a threshold.

The early stages of training in this study were characterised by a lack of self-belief and a feeling of a lack of validity as a paediatric surgeon, with some participants describing an abject fear of making mistakes. Some participants viewed the transition from their previous role into that of a higher surgical trainee as the greatest source of troublesomeness they had encountered. This moves the model of a threshold from an epistemological obstacle, where cognitive understanding is a key component, to a more complex process involving an ontological component, in which a change in identity is important. Emerging from this state, it might be argued that trainees acquire a "mature specialist identity" [20].

8.7.2 Example 8.2 Exploring Threshold Concepts in Cardiothoracic Surgeons (Junior Consultants)

Using similar methods to those in Example 8.1, threshold concepts and troublesome areas in the transition to consultant cardiothoracic practice were identified (Box 8.2). Knowledge acquired in preparing for the fellowship examination and the experience gained during local or international fellowships greatly assisted the transition from trainee to consultant. Successfully addressing some or all of the threshold concepts resulted in change as a person and as a surgeon that positively influenced each consultant's sense of worth and identity as a cardiothoracic surgeon:

> Well, I think I have moved on. I think I have an understanding now completely different from the beginning when I came out. I have matured. I have become more confident, comfortable dealing with a variety of routine or complex situations in cardiothoracic surgery. [Participant 1]

8.7.2.1 Negotiating Threshold Concepts as a Junior Consultant Surgeon

In general, the threshold concepts and the associated challenges especially with respect to the actual conduct of cardiothoracic surgery were handled through having the requisite theoretical knowledge, preparing thoroughly for any challenging procedure and by seeking the advice, assistance or reassurance of experienced surgical colleagues. The accumulation of experience and reflection upon this experience over time resulted in a successful transformation in learning:

> I can actually do this job, you know, maybe I am actually all right, you know, as a surgeon; and I guess it gives you some confidence. [Participant 10]

8.7.2.2 Uncertainty in the Operating Theatre

Faced with uncertainty in the operating theatre, the surgeons' response was to slow down, to move from a routine mode of practice to one that is more effortful and to recruit additional cognitive resources in a fashion previously described by

Moulton et al. [21]. On occasion, junior consultants would un-scrub, phone a colleague for advice or request a colleague come to the operating theatre to assist or take over. Factors influencing how they responded were both cognitive (e.g. heuristics, fatigue and distractions) and sociocultural (e.g. surgical culture, socialisation, hidden curriculum). How the junior surgeons sat within the social context of the cardiothoracic team had an impact on their clinical judgement and their intraoperative decision-making [22]. Positive relationships between junior consultants and their senior colleagues meant that there were few impediments in asking for help. Establishing trusting relationships with senior colleagues was important in managing uncertainty that cut across several of the troublesome areas. Effective socialisation within the cardiothoracic team combined with the successful completion of a demanding technical task, with a satisfactory patient outcome, provided the junior consultants with a huge boost in confidence. The self-belief to complete a task generated further successes in a positive feedback loop of self-efficacy. A balance was eventually reached between confidence, coping with uncertainty, personal image and technical performance [22]. It seemed apparent that this accumulated experience was a threshold through which the junior consultants passed and would never go back to seeing their work in the same way – an ontological shift.

8.7.2.3 The Previously Unseen or Unexpected

The junior cardiothoracic surgeon is constantly challenged by the uncertainty associated with previously unseen or unexpected situations:

> Certainly there are operations that you do when you're a consultant, but which you've never done as a registrar. [Participant 2]

Some of the strategies employed (and the influences underpinning them) to address these have been described above. The linking of threshold concepts with capability theory to create threshold capabilities [23] provides a framework for the design of a training programme aimed at preparing the surgeon to deal with previously unseen or unexpected circumstances. This theory recognises that in experiencing variation the surgeon develops the knowledge capability to deal with unexpected circumstances. Threshold capability theory has not, to our knowledge, been applied in surgery but the findings of this study suggest that such a theory would have significant appeal.

8.7.2.4 Coping with Adverse Events

Surgical complications and poor patient outcomes provoked a strong emotional response from the participants:

> ….. you see it all through your training, but it sort of just bounces off you emotionally until it happens to you, and you almost need grief counseling for the next few days. [Participant 4]

Sensations of being traumatised and strong grief reactions were common:

> The adverse outcomes traumatise you and they shake your confidence. [Participant 2]

They described to varying degrees the four phases identified by Luu et al. (fall, kick, recovery, long-term impact) following adverse events that relate to possible or actual surgeon error [24, 25]. There was also significant cognitive rationalisation especially when the adverse event was expected rather than unexpected. These experiences and responses to them were "troublesome" and were addressed through broad discourse with the cardiothoracic team and through being reflective (productive learning) and occasionally defensive (unproductive learning).

Schwartzman (2010), in proposing a theoretical foundation for threshold concepts, provides an explanation of these responses to adverse events as *rupture of the meaning frame* – "structures which embody the categories and rules that order new experience, shaping how we classify our encounters with the world: what we take in and how we act" [11]. Learning fills the meaning frame with content, whereas troublesome knowledge represented by the adverse event ruptures the meaning frame. A reflective response leads to reforming the meaning frame promoting transformative learning. A defensive response, however, preserves the existing meaning frame and limited if any learning occurs from the adverse event [11]. The attraction of this latter response could lie in the avoidance of cognitive dissonance [9]. Fortunately, the junior consultants saw adverse events as a positive learning experience, particularly in the context of discussions at morbidity and mortality meetings.

8.7.2.5 Liminality in the Transition to Consultant Cardiothoracic Surgical Practice

Each of the participants reported challenges in the transition from trainee to consultant.

> I don't think anything quite prepares you for consultant life. [Participant 5]

> The learning curve is so steep. [Participant 4]

> It's not a pleasant transition because there's always a degree of uncertainty. [Participant 9]

This transition commenced with the satisfactory completion of training (by achieving the requisite competencies) and with passing the Fellowship Examination. In preparing for consultant practice, the majority of consultants spent 1–3 years in a local or international Fellowship position to provide them with additional experience prior to commencing as a consultant. Time spent in this pre-liminal space [26] greatly assisted the participants in overcoming the uncertainty of responsibility (particularly in unsupervised operating) and of technical complexity. Upon appointment as a consultant the liminal space was entered and gradually traversed over

several years. The anxiety and uncertainty of responsibility (particularly in decision-making), technical complexity (including the speed of operating), their place in a new institution and having adverse outcomes were overcome, and the consultants became confident, validated and more secure in their role. Successful patient outcomes from complex technical procedures were a major contributor to this ontological shift. Oscillations in and out of a liminal state, thereby creating a "provoked liminality", could occur even in the more experienced surgeons when previously unseen or unencountered technical complexities were faced. The overall process is shown in the Fig. 8.1.

8.7.2.6 Implications for Surgical Education

Trainees or consultant surgeons seldom discuss, either formally or informally, the uncertainty and troublesomeness associated with the commencement of surgical practice. These troublesome areas need to be acknowledged and addressed by curriculum designers with respect to instruction and assessment. All participants stated that they were poorly prepared for consultant practice. The Royal Australasian College of Surgeons Preparation for Practice Course [27], which principally addressed the logistic aspects of career design (e.g. private practice), was attended by some but was deemed to be of limited overall value.

Each of the seven troublesome areas could serve as a curriculum target within surgical education. Workshops covering surgical decision-making, the various relationships in new work environments and handling the emotional impact of adverse events, for example, would be welcome. Robust discussion of these issues amongst senior trainees and junior consultants within cardiothoracic surgery and across other specialties would highlight many of the unseen or unspoken issues. Some of the transcripts analysed in this study could even form part of the educational materials for these workshops.

e-Learning [28] and simulation-based education [29] have been proposed as aids to the teaching and assessment of approaches to dealing with threshold concepts particularly uncertainty. Kneebone emphasised that the complexities of handling uncertainty must not be oversimplified during the simulated experience. In addition, it has been recognised that more senior surgeons soon forget the uncertainty and troublesomeness associated with commencing practice and simulated activities that have an "expert-centred focus with a learner-centred perspective" which could reconnect them with the transformative process being experienced by their junior colleagues [29].

Once in practice the junior cardiothoracic surgeons paid tribute to the advice, assistance and reassurance provided by their more senior colleagues. It is likely that a more formal mentoring programme might further enhance the interaction between junior and senior cardiothoracic surgeons.

8.8 Conclusions

Threshold concepts, troublesome knowledge and threshold capability all offer surgical educators a lens through which to view the complex pathways to becoming a surgeon. In our studies of paediatric surgical trainees and consultant cardiothoracic surgeons, the impact of negative experiences and coping with adverse effects had profound impact on the trainees and consultants, respectively. Learning to manage uncertainty usually resulted in some transformation of identity. Ensuring that negative experiences, coping with adverse events and managing uncertainty lead to learning is important so that trainees or consultants do not find themselves in a *stuck place*. Some suggestions have been proposed (e.g. e-learning, simulation, etc.), but these are unlikely to change individuals' ways of thinking as single events. Whole curriculum approaches that acknowledge threshold concepts that privilege their discussion between trainees, trainers and consultants, together with enactment of a range of strategies, are likely to support learners through these transitions.

Resources
The following website is an excellent resource for research and other resources associated with threshold concepts.

https://www.ee.ucl.ac.uk/~mflanaga/thresholds.html

References

1. Sharples, M., et al. (2014). Innovating pedagogy 2014. In *Open University Innovation Report 3*. Milton Keynes: The Open University.
2. Meyer, R., & Land, R. (2003). Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines, In *ETL Project*. Coventry: Universities of Edinburgh.
3. Neve, H., Wearn, A., & Collett, T. (2015). What are threshold concepts and how can they inform medical education? *Medical Teacher,* 1–4.
4. Barradell, S. (2013). The identification of threshold concepts: A review of theoretical complexities and methodological challenges. *Higher Education, 65*, 265–276.
5. Rowbottom, D. P. (2007). Demystifying threshold concepts. *Journal of Philospophy of Education, 41*, 263–270.
6. Land, R. (2011). There could be trouble ahead: Using threshold concepts as a tool of analysis. *International Journal for Academic Development, 16*, 175–178.
7. O'Donnell, R. (2010). *A critique of the threshold concept hypothesis and an application in economics. Working paper 164*. [cited 2014 October 5th]. Available from: http://www.finance.uts.edu.au/research/wpapers/wp164.pdf
8. Perkins, D. (1999). The many faces of constructivism. *Educational Leadership, 57*, 6–11.
9. Festinger, L. (1957). *A theory of cognitive dissonance*. Stanford: Stanford University Press.
10. Mezirow, J. (2000). *Learning as transformation: Critical perspectives on a theory in Progress*. New York: Wiley.
11. Schwartzman, L. (2010). Transcending disciplinary boundaries. A proposed theoretical foundation for threshold concepts. In J. H. Meyer, R. Land, & C. Baillie (Eds.), *Threshold concepts and transformational learning* (pp. 21–44). Rotterdam: Sense Publishers.

12. Wearn, A., O'Callaghan, A., & Barrow, M. (2016). Becoming a different doctor: Identifying threshold concepts when doctors in training spend six months with a hospital palliative care team. In R. Land, J. Meyer, & M. Flanagan (Eds.), *Threshold concepts in practice*. Rotterdam: Sense Publishers.
13. Meyer, J., & Land, R. (2005). Threshold concepts and troublesome knowledge (2): Epistemological considerations and a conceptual framework for teaching and learning. *Higher Education, 49*(3), 373–388.
14. Gennep, A. V. (1960). *The rites of passage*. London: Routledge & Kegan Paul Ltd.
15. Goethe, R. (2003). *Ritual and liminality (NCSS theme: Culture) – purpose, background, and context*. Available from: http://www.uiowa.edu/~socialed/lessons/rituals.htm
16. Bowden, J. (2004). Capabilities driven curriculum design. In C. Baillie & I. Moore (Eds.), *Effective teaching and learning in engineering* (pp. 36–47). London: Kogan Page.
17. Male, S., et al. (2016). Students' experiences of threshold capability development with intensive mode teaching. In M. A. Davis & A. Goody (Eds.), *Research and development in higher education: The shape of higher education* (pp. 192–201). Hammondville: HERDSA.
18. Land, R., & Meyer, J. (2011). The scalpel and the 'Mask': Threshold concepts and surgical education. In H. Fry & R. Kneebone (Eds.), *Surgical education: Theorising an emerging domain* (pp. 91–106). London: Springer.
19. Blackburn, S., & Nestel, D. (2014). Troublesome knowledge in paediatric surgical trainees: A qualitative study. *Journal of Surgical Education, 71*(5), 756–761.
20. Rees-Lee, J., & O'Donoghue, J. (2009). Inspirational surgical education: The way to a mature specialist identity. *Journal of Plastic, Reconstructive & Aesthetic Surgery, 62*(5), 564–567.
21. Moulton, C. A., et al. (2007). Slowing down when you should: A new model of expert judgment. *Academic Medicine, 82*(10 Suppl), S109–S116.
22. Jin, C. J., et al. (2012). Pressures to "measure up" in surgery: Managing your image and managing your patient. *Annals of Surgery, 256*, 989–993.
23. Baillie, C., Bowden, J. A., & Meyer, J. H. (2013). Threshold capabilities: Threshold concepts and knowledge capability linked through variation theory. *Higher Education, 65*, 227–246.
24. Luu, S., Leung, S. O., & Moulton, C. A. (2012). When bad things happen to good surgeons: Reactions to adverse events. *The Surgical Clinics of North America, 92*(1), 153–161.
25. Luu, S., et al. (2012). Waking up the next morning: Surgeons' emotional reactions to adverse events. *Medical Education, 46*(12), 1179–1188.
26. Meyer, J. H., & Land, R. (2005). Threshold concepts and troublesome knowledge (2): Epistemological considerations and a conceptual framework for teaching and learning. *Higher Education, 49*, 373–388.
27. RACS. (2014). *Preparation for practice*. [cited 2014 October 5th]. Available from: http://www.surgeons.org/for-health-professionals/register-courses-events/professional-development/preparation-for-practice/
28. Evgeniou, E., & Loizou, P. (2012). The theoretical base of e-learning and its role in surgical education. *Journal of Surgical Education, 69*, 665–669.
29. Kneebone, R. (2009). Perspective: Simulation and transformational change: The paradox of expertise. *Academic Medicine, 84*, 954–957.