

‘A trend or a Need’ Threshold Concepts in Medicine and Surgery; A Qualitative Synthesis

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Abstract

Information overload, due the enthusiasm of curriculum developers for covering everything, is a grave problem today. In the context of medicine, information load is integral to the discipline because a doctor needs to be knowledgeable in order to identify and treat diseases. It raise a concern about how can students remember and apply this much information when they start their clinical placements? It poses compelling pressures on medical educators to devise ways to manage cognitive load without compromising the knowledge that is transferable to clinical setting which, otherwise, may limit students' time on task to learn threshold concepts and promote rote learning. In this context threshold concept theory seems promising. This review is designed to explore TCs and potential usefulness in medicine and surgery. This qualitative synthesis of literature revealed that there are threshold concepts of knowing and practicing which every student must navigate and master during their training. Though there is growing body of evidence regarding need of adoption of threshold concept framework (TCF) in higher education, further research is needed in the field of medicine and surgery for operationalization of TCF.

Keywords: THRESHOLD CONCEPTS, TROUBLESOME KNOWLEDGE, MEDICAL EDUCATION

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Introduction

The notion of ‘threshold’ concepts is rooted from the project of Enhancing Teaching and Learning Environments in Undergraduate Courses in UK, with vision of Meyer and Land (1). Threshold concept theory argues that within a discipline there are concepts that transform students' understanding and leads to previously inaccessible way of thinking, without which learner cannot progress. Once a threshold concept is internalized, it transforms internal view of the subject matter or the world and this ‘transformation’ represents how people think, perceive, apprehend, and experience particular phenomena in a discipline. Some examples of threshold concepts are ‘Opportunity cost’ in economics, ‘limit’ in mathematics, ‘heat

transfer’ in physics or ‘metabolism’ in exercise physiology (1).

Threshold concepts (TCs) are akin to ‘Jewels’ in the curriculum, but are different from the key topics or core knowledge (2). Neve has argued that TCs are much more than key concepts, the building blocks (3). Likewise, Barradell and Peseta have called TCs as ‘more than Essentials’ and different in having potential of change; change in knowing, doing and being (4). Barry and Littlewood called TCs as subset of core concepts (5). Davies and Mangan have categorized concepts into three types: basic concepts, disciplinary concepts and procedural concepts; wherein, basic concepts are the core topics which are already identified in different subjects; disciplinary concepts are ways of thinking which link with core concepts; and procedural concept are ways of practicing which use both the basic and disciplinary concepts, enabling transformation (6). Hill also endorsed Davies and Mangan’s categorization of concepts

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for identification of the threshold (7). Hill argues that, in prosthetics, integration of disciplinary concepts and procedural concepts can help students grasp why they are learning certain concepts in biomechanics of gait, as internalizing the invisible forces on body during gait is a difficult task (7).

According to Meyer and Land (1), core concepts are building blocks which progress the understanding but doesn't necessarily lead to different view of subject matter. There are some characteristics that differentiate threshold concept from the core or key points. A threshold concept is 'transformative' in that it changes ones way of thinking and practicing; 'integrative' in that it links with previously hidden concepts to develop new understanding; 'irreversible' in that if once internalized cannot be unlearned with ease; 'troublesome' in that it is difficult to grasp; and 'bounded' in that it is specific to that particular discipline or knowledge territory. Threshold concepts are critical holdups which need to be crossed otherwise learner may get stuck in a cognitive state called 'liminality' or 'liminal space' wherein, liminal is derived from Latin word 'limen' meaning 'boundary or threshold'. Liminal space is used as metaphor and akin to stuck places in which students wrestle with troublesome information to develop new understanding (2). They oscillate between understanding and confusion (8). Students, if not engaged well in liminal space, cannot cross that threshold to achieve mastery of that subject matter and may perform in a ritualized way or adopt a form of mimicry which involves attempts at understanding (2). However, students may even pass exam (3). On the other hand, if threshold concept is internalized, it enables students to integrate different aspects of subject for problem solving (9).

Having insights into students' conceptions of the disciplinary topics has been important for effective curriculum development (10). Practice in medicine demands good knowledge base (11). However, due to overloaded content in subjects, students prefer rote learning over deep understanding (12). In this context, the

ideas of troublesome knowledge, liminality and transformation are considered a way to provide a scaffold to support learning (13). Moreover, it is said that teaching for understanding must be preceded by 'listening for understanding' to know where students are struggling to grasp troublesome (9). Nonetheless, teachers can learn to distinguish candidates showing superficial understanding or form of mimicry and ones showing mastery of the subject matter (13). Hence, understanding where TCs feature in the curriculum may help teacher identify troublesome areas of learning which can guide them where to assign time and activity to facilitate learning.

Though the concept is naïve but the literature in this area has increased quickly (12). There is growing body of research on threshold concepts in disciplines including economics (14), social work (15), engineering (16), nursing (17), management (18), plant sciences (19), occupational health (20-22), and physiotherapy (23). However, dearth of research work persists in the discipline of medical (13, 24, 25) and dental education (26).

Methods

Aim and Research Question

The aim of current pilot review was to critically analyse literature on threshold concepts and to explore its implications for education specifically in the discipline of undergraduate and postgraduate training in medicine and surgery. The questions for this review paper are:

1. What is the current knowledge about TC in medicine and surgery?
2. What are educational implications and related challenges of implementing TCF?

Data Collection

Search Strategy and Inclusion Criteria

In order to avoid duplication of the work, data base was searched to find if there is any previous review article in data pool and what is its scope? A pilot search was done using data base 'google scholar' which generated very

small number of articles using very specific terms. On the basis of initial search, a final search was done using key terms of threshold concepts and troublesome knowledge and without using 'medical education' which otherwise, yielded only one article. The time duration for the review was lasted from August 2018 to December, 2018. Terms of threshold concepts and troublesome knowledge were searched in the titles of abstracts rather than anywhere in the text, to find closely related data. Boolean terms were used and data related to nursing, physiotherapy and occupational therapy, economics, informatics and mathematics were excluded from search. Search was repeated second time (January, 2019) at the end of work to explore if any new research is added to the data base, which added one more article.

The inclusion criteria was journal articles based on exploration of TCs, published in English language. Moreover, studies based on faculty or students' perspective, qualitative or quantitative, single centered or multicentered, undergraduate or post graduate, medical or surgical training were included. To ensure inclusion of good quality research, conference proceeding, letter to editor, interview, poster, reviews, opinion papers and grey literature were excluded. Search also generated articles related to nursing, occupational therapy, physiotherapy, prosthetics, anesthesiology which, though related to health care, but excluded because the focus of this review was to explore work related to undergraduate and postgraduate training in medicine and surgery. After data search, 16 papers were selected which included 14 qualitative and phenomenological studies. The remaining 2 papers comprised of a view point (27) and a discussion paper (28), which were included due to considerable insights regarding TCs. A mutual consensus was developed for inclusion. Bibliography of the selected articles was searched for further addition.

allintitle: Threshold concepts threshold OR OR OR troublesome -Biology -OR -Writing -OR -History -OR -Management -OR -Engineering -OR -Computer -sciences -OR -Economics

-OR -Information -literacy -OR -Maths -OR -nursing -OR -physiotherapy -OR -occupational

Quality Assessment and Justification for Exclusion

Quality assessment of qualitative studies was done according to the criteria of Walsh and Downe (29). Some studies were not conformed to all of those criteria. This could be due to the extensive check list and word limit of the journals. One paper based on short communication by Kobus (30) was excluded due to insufficient details of data collection, data analysis, rigor of methodology. Most of the researchers used source triangulation to bring rigor in data. Two articles did not include comment on triangulation.

Data Analysis

Data was analyzed using technique of thematic synthesis suggested by Thomas and Harden (31). For the analysis of qualitative studies, there are a number of techniques. One group of researchers, in a similar work, used 'through line approach' which connects studies and looks for themes that traverse studies (4). Thematic synthesis across studies was not considered appropriate for this work as the selected studies belonged to different level of training and varied specialty which may involve different TC. Studies were grouped according to level of training as undergraduate and postgraduate. Thematic synthesis was done within groups to find answer to review questions. For qualitative data synthesis, according to the method suggested by Thomas and Harden (31), findings of the selected articles were considered as data to be analyzed. Findings were gathered and read line to line. Data was coded which generated a list of codes. These codes were checked for similarity. Similar codes were merged and labeled. This process generated themes, named as descriptive themes. These themes were more of translation from study findings and were closer to the study finding. Descriptive themes were analyzed to find analytic themes which produced new results. As reviewer, from selected studies, educational implications and challenges were inferred. This

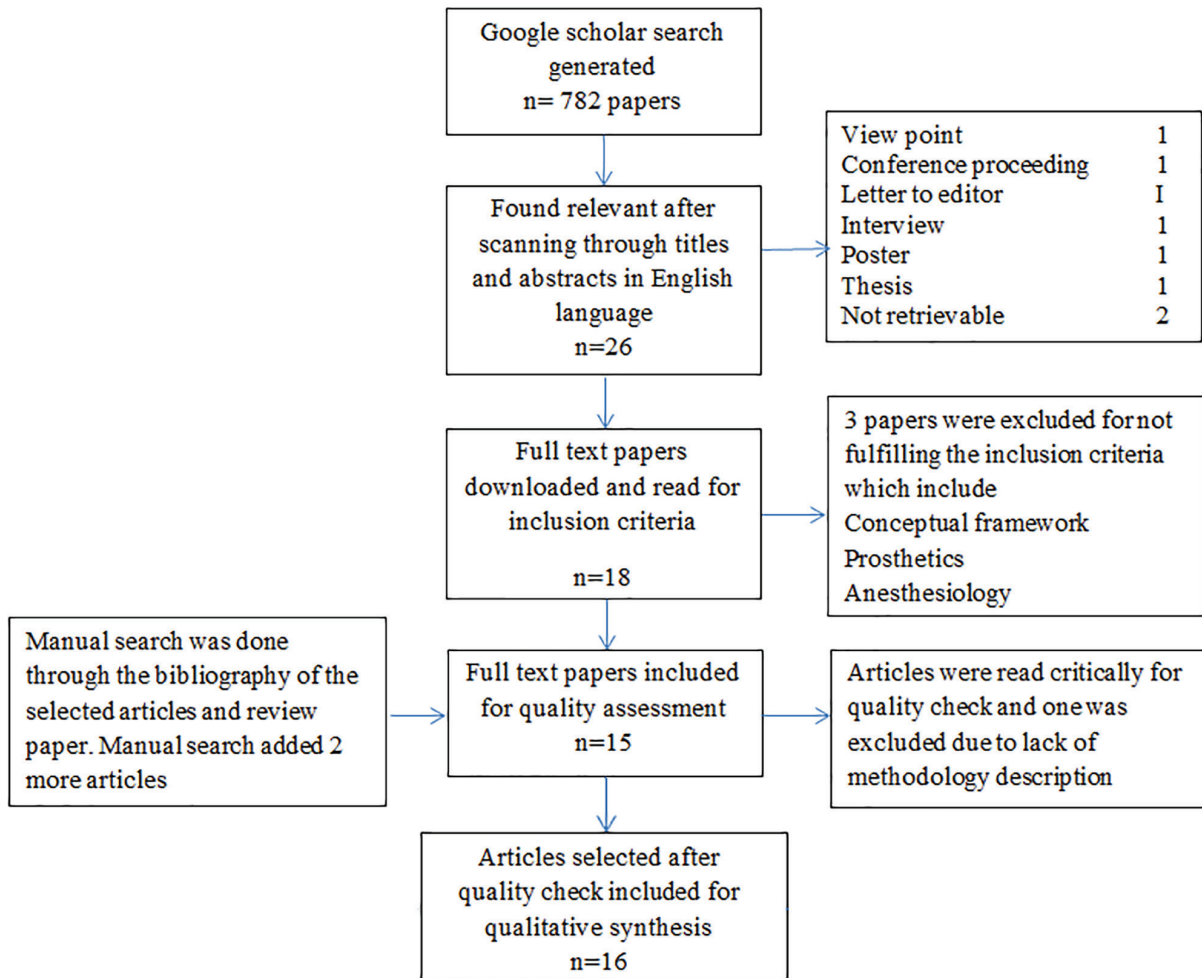


Figure 1: Flow diagram showing studies selection process

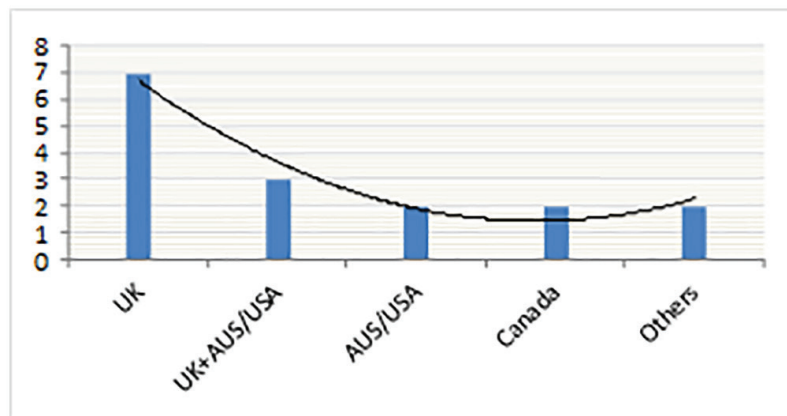


Figure 2: Country of origin of threshold research

process generated analytical themes which are presented as results.

Results

Search Results

Search results are shown in flow diagram

(Figure 1). Summary of methodology and study findings is given in Tables 1 and 2. The educational implications and challenges related to implanting threshold concept framework is given under signpost of discussion. Majority of the studies were originated from UK or in

Table 1: Summary of included Studies

No	Article	Research Aim	Organization/ Country	Type of study	Journal	Study Population	No	Data collection tool	Data Analysis Tool
1	Green & Rasmussen, 2018	To identify threshold concepts in doctor of dental surgery program	School of dentistry University of Alberta Canada	Qualitative Phenomenological	Canadian Medical Education Journal	Dental faculty	10	Focus groups	Phenomenographic analysis
2	Smith et al., 2018	To identify troublesome areas in cardiothoracic surgery training	Monash University Australia Great Ormond Hospital NHS Trust London, UK University of Melbourne Australia	Qualitative Phenomenological	International Journal of Practice based learning in health and Social care	Junior cardiothoracic surgeons	13	Semi structured interviews	Thematic analysis
3	Wilkinson, 2018	To identify threshold concepts that junior doctors face in post graduate training of geriatricians	Surrey and Sussex healthcare NHS trust, UK	Qualitative Phenomenological	International Journal of Practice based learning in health and Social care	Consultants and Postgraduate Trainees	12	Semi structured interviews And questionnaire	Thematic analysis
4	Horrigan, 2018	To identify the threshold concepts in physiology and role of laboratory class	National University of Ireland, Ireland	Qualitative	Advance Physiology Education	Lecturers and students	12 7	questionnaire Interviews	Thematic analysis
5	Bhat et al., 2018	To identify TCs in internal medicine clinical rotation and explore their relationship to PIF and performance	Schulich school of medicine and dentistry, Western university Canada	Qualitative	Medical Education	Clinicians and junior doctors	13 17	In depth Interviews	Grounded theory analysis
6	Randall et al., 2018	To identify threshold concepts in pediatric clerkship	Uniformed University of Health Sciences Bethesda	Qualitative	MedEduPublish	3rd year pediatric clerks		Reflective essays	Grounded theory analysis

7	Howden, 2018		University of Dundee UK	Discussion paper	International Journal of Practice based learning in health and social care	Newly graduating health and social care practitioners	-	-
8	Hyde et al., 2018	To explore relationship of TC curriculum and reflective practice tasks	School of dentistry and health sciences, Charles Sturt University Australia	View point	European Journal of Dental Education	Applicable to undergraduate dental students	-	-
9	Neve et al., 2017	To identify threshold concepts related to professionalism and understand factors might help students get those concepts	Plymouth University Peninsula school of medicine and dentistry, UK	Qualitative	Teaching in Higher Education	Tutors Students	6 16	Reflective audio diaries Thematic analysis
10	Collett, 2017	To identify TCs in non-biomedical sciences that are closely relevant to medicine	School of medicine and dentistry, Plymouth University UK	Qualitative Phenomenological	Practice and Evidence of Scholarship of Teaching and Learning in Higher Education	Medical Students from year 1 -5	16	Reflective audio diaries After clinician lead small group activity Thematic analysis
11	Moeller and Fawn, 2017	To identify TCs in EEG learning and explore teachers' perspective on barriers to learning EEG	Yale school of medicine, USA University of Edinberg, UK	Qualitative	Medical Teacher	Neurologists (EEG Experts)	12	Semi structured interviews Thematic analysis
12	Bowman, 2017	To identify challenges faced by year 1 dental students as independent learners and to explore strategies adopted during transition to self regulated learners	School of Dentistry University of Leeds UK	Qualitative	European Journal of Dental Education	Year1 dental students	35 1	Questionnaire pair interview Thematic analysis

13	Evgeniou et al. 2015	To identify threshold concepts in learning microsurgical skills	Derriford Hospital Plymouth UK Staffordshire NHS trust, UK Imperial college London. UK	Qualitative	Journal of Reconstructive Microsurgery	Microsurgical Trainers Microsurgical Trainees	4 5	Semi structured interviews	Thematic analysis
14	Loercher et al. 2014	To identify TCs in Biochemistry	Seattle University Western Australia University of south Florida USA	Qualitative	Life Sciences Education	Faculty students	77 56	Consensus workshops of faculty & Student Focus groups	Thematic analysis
15	Blackburn and Nestel, 2014	To identify threshold concepts applied to pediatric surgical training and explore knowledge and skills that surgical trainee find troublesome	Imperial college London, UK Monash University Australia	Qualitative	Journal of Surgical Education	Trainees in pediatric surgery	8	Interviews	Thematic analysis
16	Meyer and Land, 2011	Surgery	UK	Qualitative	Book chapter	surgeons	-	Interviews	Thematic analysis

Table 2: Summary of descriptive themes of Threshold concepts mentioned in the selected studies

Article	Specialty	Threshold concept characteristics examined	Threshold concepts	Limitations
Green and Rasmussen, 2018	Dentistry	Transformative Integration Troublesome Irreversible Bounded	Dealing with whole patient Accountability You may not always know everything Problem solving and adapting	Sample size Students perception Selection bias
Smith et al., 2018	Cardiothoracic surgery	Troublesome	Ultimate responsibility of unsupervised surgery Designing a career Navigating new work environment Managing relationship with colleagues Coping with technical challenges Managing the unexpected Coping with adverse events Change as a person as a surgeon	Lack of representation of female surgeons
Wilkinson, 2018	Geriatric medicine	Troublesome	Frailty Multidisciplinary team working Patient centered care Inquisitiveness Pragmatic investigation Seeing the bigger picture	
Horrigan, 2018	Physiology	Troublesome	Measurement of action potentials Observation of muscle contraction, muscle fatigue, twitch, summation and tetanus. Measurement of respiratory volumes, capacities, air flow, oxygen consumption, resting metabolic rate, peak flow. Calculations of concentrations with equation of physics, Drawing and interpretation of graphs of action potentials and muscle contractions. Understanding hanging pressures in the lungs as a dynamic process Ventilation perfusion matching. Making connections in physiological phenomena Integration of concepts in mind	Small response rate may not be the representation of whole class
Bhat et al., 2018	Internal medicine	Considered all five descriptors Mainly focused on Transformative Troublesome	Active learning Burden of responsibility Plurality of role Uncertainty Purposeful action Contextual care Patient centeredness Collective competence Documentation as essential practice	Not meant to generate extensive list of TCs Trainees at different level of crossing TC

Randall et al, 2018	Pediatrics	Transformative & Troublesome	Being smart is not enough Its about patient Life is not fair Sometimes there isn't a right answer You cannot save everyone Learning is lifelong Medicine is not black and white	Conducted at one medical school at one point of time Some codes might not be labeled as themes
Howden, 2018	Interprofessional Education		Client centered practice Interprofessional learning critical reflection Role as non-judgmental, Respect for interprofessional partnership Dealing with uncertainties Developing identity, Multi layered communication language as a professional tol	Research based Educational enquiry
Hyde et al. 2018	Dentistry	Transformative Troublesome Integrative, Irreversible, Bounded, Discursive, Liminal	Treatment decision at individual stages in removable prosthodontics	Personal opinion
Neve et al.,2017	Undergraduate medical training	Transformative Troublesome Integrative Liminality Did not find elements of irreversibility and boundedness in the identified TC	Becoming a part of a professional culture, Consider the whole person I don't need to know everything Considering the bigger picture We have to work with uncertainty People have different expectations Emotional intelligence	Due to involvement of small cohort from one medical school, findings cannot be assumed to be generalizable to other educational setting Due to participants from different academic years, relationship between year of training and threshold crossing was not established
Collett, 2017	Softer sciences relevant to medical practice	Transformation Integration Troublesomeness Liminality Found only few examples of irreversibility and boundedness in students' accounts	A good doctor Professionalism Benefitting society Uncertainty in medicine Patients' expectation of a doctor Prescribing medicine as an art Responsibility Stress management Saying I don't know to patient Applying theoretical models in ethical dilemma Fairness and equality Being limited by ethics Medicine is not black and white Moral position of doctor	Findings do not represent all students Lack of consideration of trajectory of students' learning across years

Moeller and Fawn, 2017	EEG, Neurology	Transformative Integration Troublesome Irreversible Bounded Discursive	Polarity Pattern interpretation clinical significance	Lack students' representation
Bowman, 2017	Dentistry	Troublesome	Learning how to learn from multiple resources rather than one text book Learning how to organize information Coping with heavy workload Knowing what to expect from exams and coursework	Constraint of generalizability due to small scale study
Evgeniou et al., 2015	Plastic Surgery	Troublesome Transformative	Practical skills Patient selection Preoperative decision making for flap Expect the unexpected Ability to recognize and manage post op complications	Doesn't provide generalizable evidence about threshold concepts
Loertscher et al. 2014	Biochemistry	Troublesome And one of the Transformative Integration Irreversible Did not included bounded	Steady states Biochemical pathway regulation, Physical basis of interactions, Thermodynamics of macromolecular structure formation Free energy	Dynamics and
Blackburn and Nestel., 2014	Pediatric surgery	Troublesome	Clinical judgement Transition between roles Relationship with seniors Dealing with negative experiences	
Meyer and Land, 2011	Surgery	Transformative Troublesome Liminal	Decision making Acquisition of surgeons' identity Attitudes of perfection Change in subjectivity Thinking out of books Managing the unpredictable Tolerating uncertainty	Small sample size

collaboration with UK organizations (Figure 2). The objective of the included studies was not to produce extensive list of threshold concepts except one study by Loertscher et al (32). They explored TC in biochemistry in undergraduate courses by involving big number of staff and students and produced extensive list of TC. The current review reveals that there are two types of TC; one is discipline specific and second is related to ways of practicing (Tables 3, 4). In the former category, examples of threshold concepts include measuring action potential or ventilation perfusion match in physiology

laboratory work (33), thermodynamics or free energy in biochemistry (32), technical skills in surgery (34, 35), understanding complexity of the care of old in geriatric medicine (36), polarity and pattern of EEG in neurology (37) etc. Threshold concepts can be fundamental to the subject. Horrigan (33) argued that understanding changing pressures in the lungs as a dynamic process is a fundamental concept of ventilation perfusion matching but it is often articulated as troublesome. Likewise, in biochemistry, Loertscher et al. (32) reported a list of TCs including steady states, biochemical pathway

Table 3: Subject specific threshold concepts

Subject Specific Threshold concepts in Undergraduate medical and dental education		
Level of training	Category; Analytical Themes	Threshold concepts; Descriptive Themes
Undergraduate Medical Education	Biochemistry	Steady states Biochemical pathway Dynamics and regulation, Physical basis of interactions, Thermodynamics of macromolecular structure formation Free energy
	Physiology Lab	Measurement of action potentials Observation of muscle contraction, muscle fatigue, twitch, summation and tetanus. Measurement of respiratory volumes, capacities, air flow, oxygen consumption, resting metabolic rate, peak flow. Calculations of concentrations with equation of physics, Drawing and interpretation of graphs of action potentials and muscle contractions. Understanding changing pressures in lungs as dynamic process Ventilation perfusion matching. Making connections in physiological phenomena Integration of concepts in mind
	Dentistry	Treatment decision at individual stages in removable prosthodontics
Post graduate Medical Education	Reading and interpreting EEG in neurology	Polarity Pattern interpretation clinical significance of EEG
	Understanding complexity of caring in geriatrics	Complexity of care of old Contextual care Holistic nature of care
	Discharge planning in geriatrics	Decision making in discharge planning
	Technical skills in surgery	Technical challenges Practical skills Patient selection
	Ability to identify and tackle complications in surgery	Coping with adverse events Ability to recognize and manage post op complications Dealing with negative experiences

dynamics and regulation, physical basis of interactions, thermodynamics of macromolecular structure formation and free energy. These five concepts, according to them, are not only integral to deep understanding but also fundamental to the subject matter.

Howden (28) reviewed literature related to threshold concepts and found a relationship with the core competences required of inter professional practice. Howden (28) emphasized the importance of learning at workplace as a place to encounter thresholds related to being interprofessional. He propounded that research informed by TCF may advance the understanding

of how students learn and what are barriers or facilitators of threshold crossing.

In postgraduate medical education, practical or technical skills are articulated by trainees as troublesome. However, Evgeniou et al. (34) argued that the reason for troublesomeness related to technical skills was lack of opportunity to operate, not by nature of threshold concept and that, the practical skills can be attained with time with more focused training. Some threshold concepts may be tacit in nature. Wilkinson (36) identified ‘understanding care of the old’ as threshold concepts that postgraduate trainees encounter during their

Table 4: Threshold concepts of practicing

	Categories	Analytical themes	Descriptive themes
Threshold concepts in Undergraduate medical and dental education	Developing as individual Agency	Being professional	A good doctor
			Professionalism
			Applying theoretical models in ethical dilemma
			Fairness and equality
			Being limited by ethics
			Moral position of doctor
			Responsibility
			Accountability
			Learning how to learn and organize information
			Learning how to learn from multiple resources
Threshold concepts in Postgraduate training	Developing as individual Agency	Understanding clinical application of theoretical knowledge	Learning how to organize information
			Understanding relevance of theoretical knowledge to dentistry
			Applying theoretical knowledge in clinical practice
			Coping with heavy workload
			Learning to manage overcrowded curriculum
			Stress management
			Knowing what to expect from exams and coursework
			Prescribing medicine is an art
			Uncertainty in medicine
			We have to work with uncertainty
Threshold concepts in Postgraduate training	Developing as individual Agency	Self-Regulation	I don't need to know everything
			Saying I don't know to patient
			Medicine is not black and white
			You may not always know everything
			Critical thinking
			Problem solving and adapting
			Being a Doctor
			Becoming a part of a professional culture
			Benefitting society
			Considering the bigger picture
Threshold concepts in Postgraduate training	Developing as individual Agency	Art of prescribing	Consider the whole person
			Dealing with whole patient
			Patients' expectation of a doctor
			People have different expectations
			Active learning
			Relearning with new perspective
			Learning Is lifelong
			Burden of responsibility
			Ultimate responsibility of unsupervised surgery
			Attitudes of perfection
Threshold concepts in Postgraduate training	Developing as individual Agency	Dealing with uncertainty	Uncertainty in medicine
			Dealing with uncertainty
			Sometimes there isn't a right answer
			Medicine is not black and white
			Managing the unexpected
			Life is not fair
			You cannot save everyone
			Being smart is not enough
			Managing the unpredictable
			Tolerance of unexpected
Threshold concepts in Postgraduate training	Developing as individual Agency	Ability to deal with uncertainty	Expect the unexpected

	Managing multiple identities	Acquisition of surgeons' identity Plurality of role Change in subjectivity Transition between roles Change in cognitive understanding of surgical community
Cognitive skills	Selecting career trajectory	Deciding career path
	Mindful practice	Pragmatic investigation Purposeful action Thinking out of books
	Clinical judgment	Clinical judgment Tolerating diagnostic doubt
	Decision making	Decision making Critical decision making Preoperative decision
Being a member of communities of practice	Developing relationships with colleagues Collaboration	Developing collegial relationships Relationship with trainers Collective competence
Patient as core of interest	Client centeredness	Patient Centeredness Its about patient Good surgeon should be good physician

training of being geriatrician. According to Wilkinson, it is considered a tacit phenomenon and is troublesome, but once experienced, lead to a transformed identity, that of geriatrician. Through this work, the importance of complexity of the care of old and nurturing care has been brought into lime light for the attention of supervisors and curriculum developers.

Threshold Concepts of Practicing

Second type of TCs was more related to ways of practicing rather than knowing. These include five categories; developing as individual agency, developing social capital, patient centeredness, developing cognitive skills and becoming part of community of practice.

Developing as Individual Agency

In the category of developing as individual agency, undergraduate students feel difficulties in being able to be professional, being able to learn and organize information, being able to deal with uncertainty, being able to regulate oneself, and being able to apply theory in practice; whereas, for postgraduate interns, concepts of being active learner, being responsible, dealing

with uncertainty, managing multiple identities and selecting career trajectory were identified as thresholds (Table 4).

There are some similarities in TC identified by undergraduate and post graduate trainees, for example, self-regulation was voiced by both. However, level of training may influence the aspects of self-regulation that are considered troublesome. Novice students, who are not prepared for independent learning, face difficulties related to transition to more self-regulated learners (38). They feel it daunting to receive and organize information coming from multiple sources in the absence of single text book and dealing with workload. Due to the challenging nature, these self-regulating skills are discussed as threshold concepts and it is suggested to offer explicit guidance to help students learn those skills. However, for post graduate interns, high order thinking skills like decision making and relearning from different perspective is a threshold concept.

Likewise, expecting and managing uncertainty appeared to be a TC at undergraduate (24, 39) as well as post graduate level of training in medicine (25, 40) and surgery (34, 35) (Table 2,

4). Managing uncertainty is found troublesome because it is considered that medicine is not black and white and it is difficult for trainees to deal with the unexpected, for which they need careful preparation, effective coping strategy and senior help. Evgeniou et al. (34) have documented that unexpected events in microsurgery brings startling response and, with a predetermined plan in mind based on previous experience, trainees cannot deal with anything different. They need lateral thinking and different plans for different scenarios. Being professional, as a TC, is related to 'softer sciences' or non-medical sciences that have bearing on health and disease (39). Studies (24, 25, 39) are concerned about troublesome nature of responsibility. Moreover, in developing self, acquiring professional identity (41) and managing multiple identities (42) was considered troublesome by post graduate trainees or surgeons. Trainees appreciate that they are not just trainees but health care providers and educators. The troublesomeness associated with transition between roles is due to increasing challenges with higher training posts and sense of responsibility which poses compelling pressures on trainees (42).

Developing Social Capital

Developing social capital is the second major category emerged which includes TCs of professional identity formation and society as focus of health care. It is about building relationship between individual as professional, professional circle and society. Seeing a bigger picture of health care is appreciated as a threshold concept (24), and also that, it is not just a symptom to be treated or diseased to be cured, rather health care is more about health of individuals and for the benefit of society (39). A related theme is appreciated by post graduate trainees as 'becoming part of community of practice'. Studies are concerned about troublesomeness of understanding and building professional terms with senior colleagues, junior trainees and patients.

However, some threshold concepts are unique

to the level of post graduate training. In this regard, studies are concerned about development of cognitive skills like purposeful action (25), clinical judgment (42), and decision making (34), and thinking out of books (41). Studies are concerned that cognitive training of the trainees must be given substantial importance.

Discussion

Authors of the selected studies have variably used descriptors to define TC. Green and Rasmussen (43) validated identified TCs against all five criteria mentioned by Meyer and Land. Bhat et al. (25) also included all but mainly focused on two features, transformative and troublesome, as descriptors of TC, considering these as salient features of TCs; whereas, many authors including Horrigan (33), Smith et al. (35), Bowman (38), and Blackburn and Nestel (42), used only one criteria that of 'troublesomeness'. Wilkinson (36) identified troublesome areas and then analyzed those using criteria of TCs like integrative, irreversible, bounded and transformative. Blackburn and Nestel (42) justified their approach of using 'troublesomeness' considering that other four defining characteristic describe the aftermath not the experience of learning. Collett (39) also considered liminality along with characteristics of transformative, troublesome and integrative. Loertscher et al. (32) included 'troublesome' as primary criteria to identify TCs and then one of either irreversible, transformative, integrative. They did not include 'bounded' having belief that some of the concepts of biochemistry are interdisciplinary, and have merged edges particularly with biology and chemistry.

In most of selected studies two characteristics of TCs, that of 'transformative' and 'troublesome,' are considered to identify TC. In this context, Barradell (44) speculated that these two characteristics are probably easy to identify, and so, attention to these two characteristics is warranted. Probably, this is why, many researchers have not given substantial consideration to last two characteristics. In this context, Barradell and Peseta (4) have argued

that mindful attention to all characteristics of TCs might give better understanding of learning a discipline. However, in our analysis, this raises concern and opens a debate whether any concept not fulfilling all criteria of TC can still be called threshold concept.

Most of the researchers have adopted TCT with minimal or no critique. However, Collett (39) argued about another potential facet of threshold concept could be 'transferability' which points towards a new area for further exploration. On the other hand, Neve et al. (24) have shown concern regarding clarity of definition of TCs. They observed little overlapping boundaries between threshold concepts. They showed concern regarding bounded nature of the identified concepts. They argued that there were sets of concepts under major themes, hence speculated inter relating nature of threshold concepts as networks rather than isolated concepts. Bhat et al. (25) have also observed interlinked nature TCs and critiqued bounded nature of TCs. Moreover, researchers have critiqued the use of qualifiers like 'probably' or 'often' in defining characteristic of TCs and lack of clarity of TCs in comparison with core, key or fundamental concepts (37). Similar issues have been discussed earlier by Barradell (44).

Most of the researchers of the included studies have used semi structured interviews (25, 33, 34, 36) or reflective diaries (24, 39, 40). Some researchers (37, 43) have gathered experts' perception, whereas, for some authors, involvement of students in perception gathering is considered pivotal and not including student participants is a limitation. However, in previous work by Barradell and Peseta (4), it is argued that complicated nature of TCF make it challenging to derive from students' perspectives, wherein, disciplinary experts tend to interpret from students' conversations. In our research, studies are concerned that identification of TC demands dialogue between lecturers, students and educational developers. Literature supports that transactional curricular inquiry involving wide range of stakeholders can be

helpful to guide TC curriculum designs (4). This qualitative synthesis reveals that threshold concepts can be either subject specific, which are about 'knowledge'; or general TC which are about 'practice'. Knowledge related TC are conceptually difficult, whereas, threshold concepts of practicing are tacit in nature, hence considered troublesome. On the other hand, an author of the included study argued that teachers expect students to apply theoretical knowledge into practice but don't actually teach how to apply it, so it remains tacit and troublesome for students. In this context, Meyer and Land (1) have mentioned that threshold concepts related to body of knowledge like mathematics, physics and medicine are easily identified as compared to ways of practicing which hold pivotal threshold value in transformed learning. Analysis of included researches found three major categories of TCs related to ways of practicing; one is practitioner as individual agency; second is about society or community; and third is about patient. Proper attention paid to these three work spheres may maximize the competence of graduates (Figure 3). Educators and curricular developers must provide scaffold to help students cross TCs. Health professionals pay more attention to declarative knowledge, and that, it is not just declarative knowledge which students find troublesome (4). We suggest that medical



Figure 3: Three overlapping work spheres based on threshold concepts required for clinical competence

educators must focus on threshold concepts related to ways of practicing.

Level of training also influence the perception of any concept as threshold; however, there are some TCs which are appreciated as troublesome irrespective of the level of training, like 'Expecting and managing uncertainty'. Even concept of uncertainty is common to many other disciplines (39). Having compared their results with that of Collett's (13), Randall et al. (40) also suggested that there are some universal concepts that are central to preparedness to patient care and operate at both junior and senior level. Bhat et al. (25) have also discussed that there is no linear relationship between threshold concepts and stage of training. Some trainees at different level of training may be struggling with TCs but not the others. Likewise, Neve et al. (24) didn't observe any pattern of threshold crossing across the years. They also have shown concern that, due to difference in level of training of the participants, some TCs may be transformative for some, integrative for others, and troublesome for third. This may be an important repercussion in implementing TCF.

Analysis of the included studies offers some educational implications. Lecturers and study advisors have a role in helping novice students pass through the threshold concepts related to learning in a new environment (38). TCF can help in understanding how troublesome areas are learnt (37). TCF gives opportunity to better understanding of how to support students through troublesome areas and difficult shifts in roles or identity (39). In postgraduate training, cognitive skills like decision making fit to the criteria of TC as compared to practical skills (34). Workshops on decision making, relationship at new work environment, handling adverse events and other TCs can help surgeons better prepared for the professional roles. Moreover, formal mentoring may be needed to help junior surgeons grow (35). In this context, Blackburn and Nestel (42) have proposed that trainers must recognize liminal states of trainees. Likewise Green and Rasmussen (43) have argued that instructors must be aware of the TCs in

courses, and must know when their students are struggling with those TCs. Identifying TCs may help educators to proactively share the challenges of training with trainees and help them learn how to deal with those. Authors of included study suggested incorporation of TCs for trainees' professional development and even in assessments of entrustable professional activities (25). Using example of clinical documentation as an EPA, it is argued that trainee must be supervised until the threshold of 'documentation as an essential practice' is crossed.

Inferences from the studies have identified some challenges in embedding TCF, which include content focused view of knowledge; take of stakeholders on importance to content; timing of introducing TC; constraint of individual variability and assessment of threshold crossing. Authors of studies are concerned about why some concepts are troublesome for some students and not for others. TCs are found to be 'agent relative' in that these may not be troublesome for all (37). Even variability may exist in perceptions of experts or between senior and junior trainees (37, 42). It is speculated to be due to differences in the level of training (25), or it may be due to prior level of understanding, which may influence the construction of new knowledge on weak foundation or knowledge pool (33). Horrigan (33) argued why some concepts in physiology are troublesome to some students and not to others. Students found calculations of concentrations with equation of physics, drawing and interpretation of graphs of action potentials and muscle contractions, as troublesome areas to understand. Horrigan speculated that prior level of students' understanding may influence the construction of new knowledge. There is some role of physics, calculations and biochemistry in physiological phenomenon which, due to poor prior understanding and inability to bring knowledge into practice hinders the understanding of new concept, hence, remains subliminal. Horrigan endorsed that incorporating TCF can promote conceptual learning. Incorporating TCF may help in identifying those weak areas to be emphasized

before they learn the concept based on those forgotten facts or inert knowledge. Moreover, students feel difficulty in making connections in physiological phenomena and integration of concepts in mind which is another potential reason for troublesome knowledge.

Horrigan quoted Meyer and Land that one need to know bits before one begins to integrate. Constraint of variability has also been voiced by Hyde et al. (27) who argued that students need to acquire basic knowledge before they start integrating different concepts. Introducing TC either too early or too late in the course may hamper attainment of integrative or transformative function of TC (27). Moreover, crossing of threshold concept is gradual process and trainee may pass through threshold at different points in their career (36). Meyer and Land (1) have mentioned in their initial work on TCs that transformation, as result of internalizing a threshold concept, may be sudden or may take considerable period of time. This review suggests that aforementioned issues should be considered while using TCF to guide curriculum.

Limitations

This review was a pilot project to explore the TCs in medicine and surgery training. A big limitation of this review is the use of single data base 'google scholar' to collect data, however, author intends to expand it in future. Second, the analysis and thematic synthesis of studies is done by single author. Involvement of multiple reviewers or member checking by the authors of included studies may have further enhanced the rigor in the analysis.

Conclusion

There are concepts which young doctors struggle to understand. Rather than overstuffing the curricula there is need to identify discipline specific TC and to ensure proper allocation of teaching and learning resources to the areas which most students find troublesome. In that case, TCF offers innovative approach to teaching and learning. TCs should not be

the part of hidden curriculum and must be made explicit and essential while doing content mapping and standard setting in assessments. The objective of curricular development must focus on providing authentic learning experiences that help them develop ways of thinking and practicing (WTP). Most of the included studies are about identifying TCs; however, its not just the identification of TC that matters. Authors are concerned that further research on how to operationalize TCF to guide curriculum and teaching practices in medical training is needed. A synthesis of literature related to TCs done by Barradell and Peseta (4), was published in 2016. This review is different from that in two main aspects; firstly, it includes recent researches; secondly, unlike to their work, it is discipline specific, attempts to explore threshold concept in medicine and surgery in both undergraduate and postgraduate training.

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