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The Interdisciplinary Journal of Problem-based Learning

ARTICLE

The Impact of Transdisciplinary Threshold Concepts on Student Engagement in Problem-Based Learning: A Conceptual Synthesis

Maggi Savin-Baden (University of Worcester)

Abstract

There has been much recent discussion about student engagement in higher education, and in the last few years a number of authors have undertaken extensive international research on the topic, which has been summarized in a number of literature reviews. However, to date, there has been relatively little in-depth exploration of student engagement in problem-based learning (PBL) or the impact of different forms of engagement on distinct forms of PBL. Drawing on a number of studies over the last 15 years, this paper argues that student engagement in PBL can be troublesome as both a concept and a practice. It also suggests there are 4 transdisciplinary threshold concepts that have an impact on student engagement with PBL: liminality, scaffolding, pedagogical content knowledge, and pedagogical stance. The paper argues that by acknowledging these transdisciplinary threshold concepts and working with them, facilitators will be able to enhance student learning in PBL across disciplines, contexts, and diverse forms of PBL.

Keywords: problem-based learning, student engagement, threshold concepts, transdisciplinary threshold concepts, pedagogy, student learning

Introduction

There is extensive international research and literature and much discussion about student engagement in higher education, but few studies have explored it in-depth in relation to PBL. Furthermore, there are a growing number of constellations of problem-based learning (Savin-Baden, 2014) that illustrate the variety of options available for its use worldwide. There is relatively little understanding of the impact of these different PBL constellations on student engagement. Drawing from a qualitative research synthesis on student engagement (Wimpenny & Savin-Baden, 2013), research on tutors' and students' experiences of PBL (Savin-Baden, 2000), research on threshold concepts and PBL (Savin-Baden, 2006; Silén, 2000; Doody, 2009; Barrett, 2010; Fredholm, Savin-Baden, Henningsohn, & Silén, 2015; Chen, 2015; Major & Major, 2013), and recent literature in this area using PBL in immersive worlds (Savin-Baden et al., 2011; Beaumont, Savin-Baden, Conradi, & Poulton, 2012), this paper argues that student engagement in PBL is troublesome as both a concept and as a practice. In particular, it will be suggested that there are four distinct transdisciplinary threshold concepts that have an impact on student engagement with PBL: liminality, scaffolding, pedagogical content knowledge, and pedagogical stance. It will also be suggested that by acknowledging these and working with them, facilitators will be able to enhance student learning in PBL across disciplines, contexts, and diverse forms of PBL. In particular, this paper argues the following points:

1. Students who are learning through PBL are often initially unaware of PBL as a learning approach, the process of getting stuck in learning, or the notion of transdisciplinary threshold concepts.
2. Recognizing common transdisciplinary threshold concepts could improve student engagement in PBL.

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3. Facilitators who are aware of the impact of transdisciplinary threshold concepts in PBL are more likely to be able to enhance and support student engagement.

Since their inception, threshold concepts have been defined as follows:

> 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 (Meyer & Land, 2006, p. 3).

While this early definition does not specifically locate threshold concepts in disciplines, in fact, all the arguments and examples were based in the disciplines. Examples include "opportunity cost" in economics, "pain" in physiotherapy, and "deconstruction for text analysis" in English literature. Threshold concepts are seen as transformed ways of understanding, without which learners cannot progress, and have a number of key characteristics (Meyer & Land, 2003) that are summarized below:

- Transformative: Once understood, a threshold concept changes the way in which the student views the discipline.
- Troublesome: Threshold concepts are likely to be troublesome for the student; for example when knowledge is seen to be counterintuitive, alien, or seemingly incoherent.
- Irreversible: Given their transformative potential, threshold concepts are also likely to be irreversible, i.e., they are difficult to unlearn.
- Integrative: Threshold concepts, once learned, are likely to bring together different aspects of the subject that previously did not appear, to the student, to be related.
- Bounded: A threshold concept will probably delineate a particular conceptual space, serving a specific and limited purpose.

This paper argues that while the idea of threshold concepts being located within disciplines is useful to a degree, they need to be broadened. Instead, particularly in the context of PBL, transdisciplinary threshold concepts are more helpful. *Transdisciplinary threshold concepts* are defined here as: concepts which transcend disciplines and subject boundaries but which are challenging and complex to understand, but once understood, the student experiences a transformed

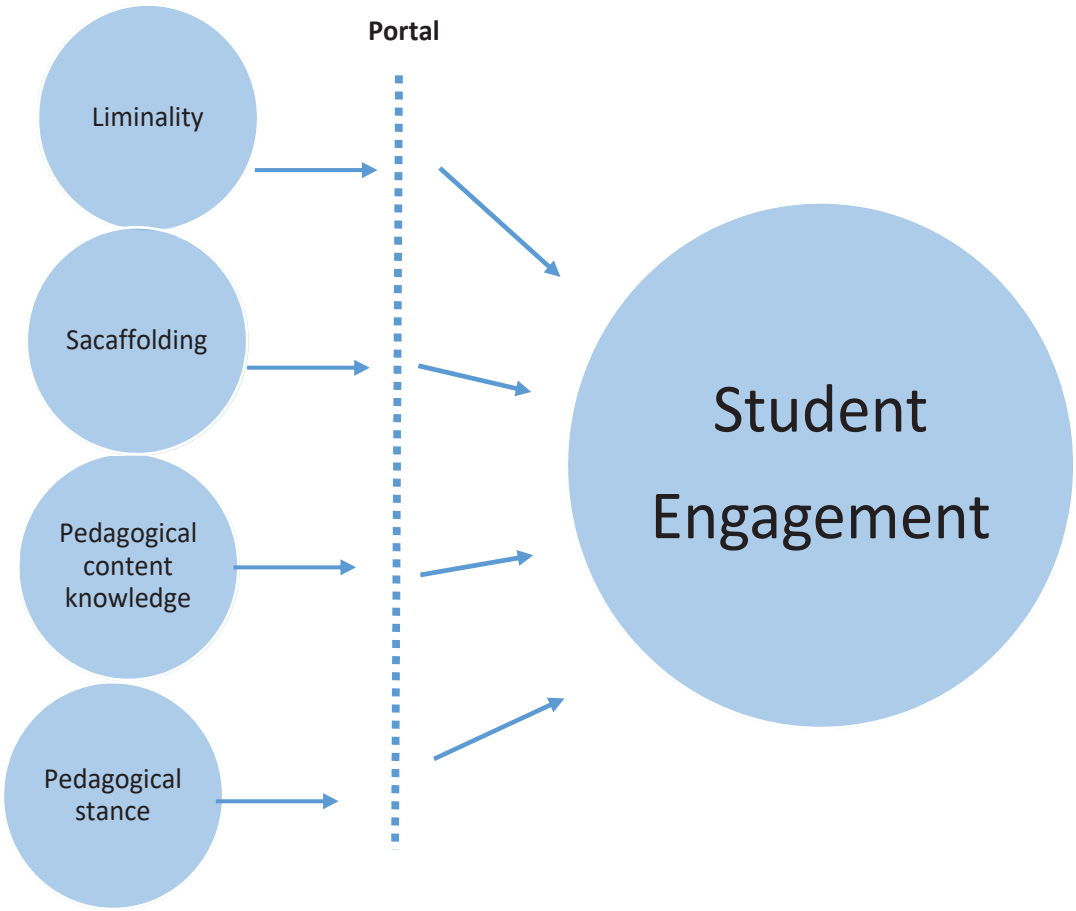

Figure 1. Transdisciplinary threshold concepts as barriers to student engagement in PBL.

way of understanding, without which the they would struggle to progress through the curriculum.

Other concepts used in this paper are defined as follows.

Student engagement is defined as student connection with the learning context, discipline, peers, and tutors that enable transition and voicefulness in learning. It also includes students "will to learn:" the degree of interest and attention students show when they are learning.

Discipline is defined as a field of study; it is a branch of knowledge that is taught and researched as part of higher education, which has a particular object of research, and tends to use specific terminology.

This paper suggests that in PBL students struggle to understand both what it is they are expected to learn and how they are required to learn it. Thus it argued that the transdisciplinary threshold concepts of liminality, scaffolding, pedagogical content knowledge, and pedagogical stance can help tutors to improve, support, and enhance student engagement in PBL. The relationship between transdisciplinary threshold concepts and student engagement is illustrated in Figure 1, which illustrates that these four concepts are often barriers to students' engagement in PBL.

Literature Review

New models and theories of learning have emerged over the last decade which have informed the concept of curriculum spaces. For example, the work of Trigwell, Prosser, and Waterhouse (1999) on teachers' conceptions of learning offers useful insights into the impact such conceptions have on student learning, along with Barnett's exploration of conditions of flexibility (2014). This body of work, along with shifts away from the certainty of learning styles toward more holistic conceptions of learner approaches, is important in developing the debate away from generalizations and cognitive foci toward understanding of learner and teacher identities and student engagement (Buckingham, Burn, Parry, & Powell, 2014; Carvalho & Goodyear, 2014; Savin-Baden, 2015). Over the last 15 years there has also been increasing interest in student engagement in higher education.

Student Engagement

There have been studies on student engagement ranging from those focusing on institutional achievement to those that focus on learning (for example, Porter, 2006; Hockings, *Cooke*, *Yamashita*, *McGinty*, & *Bowl*, 2008). Many current definitions of student engagement promote an institutional focus centered predominantly on outcomes such as retention and success rates (Kuh, Kinzie, Buckley, Bridges, & Hayek, 2007). However, the findings of a literature review on student engagement, conducted by Trowler and Trowler (2010), argued that student engagement has received extensive attention internationally. In their review, definitions of student engagement are presented, which include the extent to which students are engaging in activities that contribute to desired (high-quality) learning outcomes. Zepke and Leach (2010) also examined "high quality learning," but broadened their accepted definition to include a focus on the student's cognitive investment, active participation, and emotional commitment to their learning. However, Boughey (2008) takes a different stance toward the notion of student engagement. She questions the extent to which engagement is an autonomous skill, since the rules of engagement are formulated by academic expectations and traditions which students need to learn, in order to participate in academic dialogues, processes, and practices. Students often misunderstand the idea that an academic text comprises multiple voices, those voices used by the author to substantiate their position as well as the solo voice of the author. While academics are able to recognize and locate different voices, students are not always able to distinguish voices, and see books and articles often as flat textual pieces.

A recent study on student engagement (Wimpenny & Savin-Baden, 2013) recognized the diversity and complexity of the research and literature and undertook a qualitative research synthesis. Qualitative research synthesis (Major & Savin-Baden, 2010) is a research approach that was developed to synthesize qualitative data from the same research tradition in order to provide a sound synthesis of evidence. Such an approach was adopted to make sense of concepts, categories, or themes that recurred across the student engagement literature, in order to develop a comprehensive picture of the findings. The study by Wimpenny and Savin-Baden (2013) found student engagement could be classified as follows:

- *Engagement as connection and disjunction* – there was a variety of student experience ranging from those who had a more troublesome, questioning approach and toward those who had experienced a strong sense of disjunction.
- *Interrelational engagement* – whereby student engagement was characterized and experienced through connection to a wide set of relationships including student to tutor, student to student, student to family, and student to career.
- *Engagement as autonomy* – related to how students shifted from unfamiliarity and self-consciousness to self-sufficiency in learning.
- *Emotional engagement* – illustrated by intrapersonal capacity, in terms of student resilience and persistence.

The themes of the synthesis suggest that there are particular issues related to student engagement in the literature,

which to date have largely been overlooked by those designing learning and making policy in Higher Education (HE). Findings from the synthesis have revealed that when students are engaged in meaningful learning that they value, the potential for learning something new increases. The study also indicated engagement with learning is a deeply personal experience, but that tutor support of student learning needs as well as acknowledgment of students' struggles, insecurities, pleasures, and pains needed to be evident. Student engagement in this article is therefore defined as student connection with the learning context, discipline, peers, and tutors that enable transition and voicefulness in learning.

Student Engagement and Problem-Based Learning

There has been little exploration of the relationship between forms of learning (such as PBL) and student engagement. Although there is a considerable body of literature on facilitation and problem-based learning (Wilkie, 2004; Silén, 2000; 2004; Barrett, 2008; Savin-Baden, Poulton, Beaumont, & Conradi, 2016), few have been found to be central to enhancing learning and promoting student engagement in PBL, although Jacobsen (1997), Silén (2000; 2004), Wilkie (2004), and Barrett (2008) are notable exceptions. An early study by Jacobsen (1997) found that discussion about problems and issues beyond the problem-based learning team were vital to enable learning to take place. Jacobsen termed these discussions "frame factors," issues students raised that do not directly relate to the problem scenario but are important to students. Examples of frame factors include transport between campuses, the arrival of student uniforms, the previous night's television, and students' personal problems. Silén (2000) used ethnography to understand student-centered learning from the students' perspectives. She found that students' conceptions of responsibility and independence resulted in students seeing themselves on a continuum of frustration and stimulation. Students' views of their positions along the continuum appeared to affect their willingness to engage with self-direction. However, what is particularly interesting about Silén's work is the way in which students managed the interrelationship between their own personal learning needs and those of the curriculum. Students' ability to be independent learners, as opposed to dependent ones, was affected by their abilities to both engage with the dialectic between the prerequisites of the educational program and use these prerequisites to support and enhance their own learning needs. Wilkie (2004) examined the strategies adopted by new facilitators in a problem-based learning program and followed their progress for a two-year period. The study was undertaken in a school of nursing where the preregistration program utilized problem-based learning as a major teaching strategy. Although all the nursing lecturers possessed a formal teaching qualification, none had experience with problem-based learning. Participants represented a range of teaching experience, nursing practice backgrounds, and teaching styles. Her findings indicate not only the adoption of four different modes of facilitation over time and the impact of six elements on these modes, but also that several of the issues regarding facilitation related to the professional identities of the lecturers involved. Barrett (2008) used a critical discourse analysis approach as an effective methodology for analyzing the dialogue of problem-based learning tutorials. She argued that by experiencing and understanding the PBL process as a means of finding and being in flow, students were more readily able to transfer their use of problem-based learning and the sense of being in flow to a range of other contexts and situations.

What much of the literature on engagement seems to point to is the need for academics to understand that student engagement is strongly related to learner identity and students' pedagogical stances. While this is still an area that needs further development in higher education, in general this link is increasingly being made in the problem-based learning literature (for example, Sadlo & Richardson, 2003; Fredholm et al., 2015).

As mentioned above, early studies on PBL facilitation tended to examine how facilitation was undertaken and ways in which it could be improved to support students' learning. Yet more recent work has indicated that student engagement in PBL remains a complex and contested concept (for example, Yew & Yong, 2014) that requires further consideration in problem-based learning, and higher education in general.

Defining Threshold Concepts

The literature on threshold concepts to some extent builds on the theories from cognitive tradition (Meyer & Land, 2006) and concentrates on the identification of discipline-specific concepts which are in a sense essential in the acquisition of the thinking, learning, and communication of understanding within specific subject learning. For example, to think logically like a mathematician, or to think, learn, and express oneself like an economist. Developing understanding and use of these concepts is argued as crucial for student learning and knowledge construction. The thresholds literature is both fascinating and helpful, but Davies (2006) and Meyer and Land (2006) argue that threshold concepts are generalizable discipline-based concepts that can necessarily be embedded in a curriculum structure. Yet to argue for such a position immediately implies that threshold concepts are dislocated from learner identities.

The link between PBL and threshold concepts is important because PBL is a process, practice, and pedagogy in which students experience disjunction: the sense of students

getting stuck in learning. Yet the threshold concepts seen in PBL curricula are transdisciplinary in nature, since they tend to be experienced as more general occurrences not related directly to a given discipline. For example, many students have described becoming generally stuck in PBL and describe this disjunction as a little like hitting a brick wall; there is an overwhelming sense of "stuckness," and they have then used various strategies to try to deal with it.

Transdisciplinary Threshold Concepts and Problem-Based Learning

The early literature on PBL and threshold concepts focused on discipline-based threshold concepts; however, more recent work has expanded, and there are increasingly threshold concepts that are used in a more generalizable way. For example, an early study by Doody (2009) explored the idea of a threshold concept in computing. He undertook a study to examine the impact of using a hybrid PBL approach to teach an introductory software development module. A randomized controlled experimental design was used to measure changes in attainment, programming self-efficacy, motivation, approaches to study, and preferences for types of teaching. Questionnaires, data mining of learner activity, and attendance logs were used to provide additional information about learner behavior, and further analysis was undertaken using qualitative techniques, such as classroom observations and interviews. The findings indicate that PBL was effective in helping students master threshold concepts in computing and that the use of PBL to teach novice learners may also help to improve student retention.

However, there has been a trend toward what is referred to in this paper as transdisciplinary threshold concepts. In the field of education, Barrett (2010) argued that the concept of learning in PBL as "hard fun" is a threshold concept. She suggests that this understanding is irreversible, since it affects the ways in which tutors consider and implement PBL, while the concept of hard fun incorporates the challenges of learning through demanding activity and the subsequent transformation that ensues. More recently, Chen and Rattray (2015) undertook a study that explored the extent to which PBL contributed to the attainment of critical thinking as a threshold concept, using action research. They found in PBL that the development of critical thinking through PBL was not linear but oscillatory. Chen and Rattray (2015) argue that critical thinking, the idea of a threshold concept, goes beyond the level of a concept to the level of a theory resulting in capabilities, which ultimately challenges the teacher to reconsider quality of teaching and learning. However, today the links between these studies as well as the broader literature on thresholds, PBL, and student engagement remain inchoate. This paper remedies this situation by bringing together research and literature that synthesizes the transdisciplinary threshold concepts that appear to affect student engagement in PBL.

Methodology: A Conceptual Synthesis

This section presents a conceptual synthesis of threshold concepts in student engagement in problem-based learning. There have been many attempts to classify different types of literature reviews ranging from a position whereby existing research is simply reported and described to a more direct analysis of the literature. In practice, this synthesis was undertaken by seeing the synthesis not as a direct in-depth interpretive qualitative research synthesis, but rather as Form 5 research, as "part of a whole," as demonstrated in Figure 2, and described here as a conceptual synthesis.

Research as Part of Whole: A Conceptual Synthesis

This kind of synthesis requires collating information into a unified whole in a way that offers a bigger picture of what the collated findings indicate. This approach, research as "part of whole" involves locating and analyzing literature so that individual components can be viewed collectively to aggregate previous research. The synthesis began by defining inclusion and excision criteria as demonstrated in Table 1.

While there were over 25 articles that dealt with threshold concepts and PBL, the following were selected as meeting the inclusion criteria above (see Table 2).

Once the papers were selected according to these criteria, analysis was undertaken as follows.

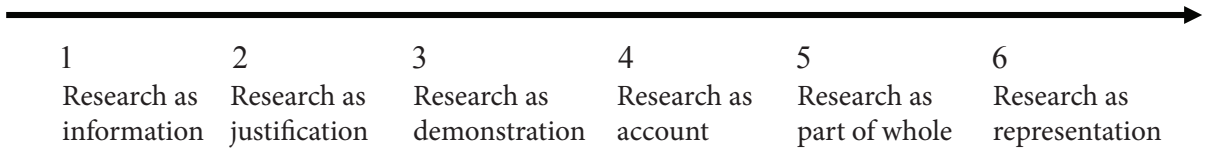

Figure 2. Forms of literature use, along a continuum (Major & Savin-Baden, 2010, p. 24).

Table 1. Inclusion and exclusion criteria.

Criteria	Include studies	Exclude studies
Topic	Sources and publications related to problem-based learning, threshold concepts, and conceptual thresholds	Sources with narrow discipline-based descriptions of threshold concepts
Context	HE	FE, School sector
Date	2000–2015	Prior to 2000
Research design	Primary empirical qualitative studies (to include case study research, narrative inquiry, ethnography, phenomenology, (participatory) action research, and grounded theory)	Quantitative studies, literature reviews, and research syntheses.
Location	International literature	Sources not in English language

Analysis

Each paper was read and reread several times, and a summary was created to enable the studies and concepts to be compared. The purpose of analysis was to move beyond comparison and explore the possibilities for locating transdisciplinary threshold concepts that might relate to student engagement with PBL. In practice, this involved:

- Combining ideas across studies
- Expanding or refuting possible transdisciplinary thresholds concepts
- Rereading data
- Developing a matrix to locate issues as transdisciplinary thresholds concepts (Tables 4–7)

Findings

This section draws on the included articles to suggest that there are four distinct transdisciplinary threshold concepts that can be seen in relation to student engagement with PBL: liminality, scaffolding, pedagogical content knowledge, and pedagogical stance. These transdisciplinary threshold concepts are neither sequential nor hierarchical but do appear to have an impact on one another, but further research in this area needs to be undertaken to understand these concepts in detail and depth. This section outlines each of the concepts, explains why they are transdisciplinary threshold concepts, and begins with a table that summarizes the threshold characteristics (see Table 3).

Liminality

Liminality tends to be characterized by a stripping away of old identities and an oscillation between states; it is a betwixt and between state and there is a sense of being in a period of transition, and an oscillation between states and personal transformation. The idea of a liminal state is taken from ethnographic studies on rituals; for example, rites of passage such as the initiation of adolescent boys into manhood. Turner (1969) adopted the term "liminality" (from Latin *limen*, "boundary or threshold") to characterize the transitional space/time within which the rites were conducted.

> These ethnographical examples relate primarily to liminality in life cycles . . . The concept of the "betwixt and between" liminal state then becomes easy to recognise in contemporary western culture—think, for instance, of the wedding ceremony where the "threshold" ceremony is followed by a "liminal" honeymoon. Think, too, of funerary ceremonies where the period from death to inhumation (or cremation) is equally "liminal" (Trubshaw, 2003, n.p.).

Liminality is a transdisciplinary threshold concept in student engagement in PBL because it is a complex, often covert learning space. It is invariably a place of incoherence and confusion for students and is a threshold concept because students (and often tutors) do not realize or accept that liminality, and the processes involved in managing it, can enable students to adopt deep approaches to learning and emotional engagement with the knowledge put before them. There has been increasing interest in the last five years in the concepts of liminality within the threshold concepts literature. For example, Land suggests that the liminal state can be seen as a "progressive function," which enables learners to realize the current shortcomings of their existing view (Land, 2014), while Ross argues that:

> transformation has to be understood as a matter of shifting subjectivity, not as deep changes to an essential selfhood. Subjectivity is best understood as always in process, and so shifts are commonplace, part of the negotiations that take place as a result of the discursive nature of subjectivity (2011, p. 226).

Table 2. The papers included in the synthesis.

Paper	Summary	Link to transdisciplinary threshold concepts
Trafford, 2008.	This chapter explores how doctoral candidates use conceptual frameworks in their research and theses and Trafford argues that conceptual frameworks engage with liminality as they attempt to understand them.	Liminality
Barrett, 2008.	Barrett explores PBL students' discussion about PBL in the PBL tutorials for an education development module. In chapter five she discusses how the concept of the problem as a provoker of a liminal space, a threshold, betwixt and between spaces, was derived from the data. It explores the three dimensions of this liminal space between old and new ways of knowing, old and new ways of being, and habitual and new forms of professional action.	Liminality
Silén, 2004.	This chapter describes a meta level of discernment that comes to the fore in the students' narratives about being learners in a problem-based learning context. The source of the students' actions and conceptions is their experience of facing the challenge to be responsible and independent in their learning processes. The metaphor for this is described as the dialectic relationship between chaos and cosmos.	Liminality
Major & Major, 2013.	In this article, the authors present information gathered from a marketing course designed for second-year students that centered on a problem-based project at a two-year institution. Using "learning context" as a theoretical frame for this classroom-based research, they explore student perceptions of the method and outline strengths and weaknesses of the approach. The authors make suggestions for research and practice based upon their findings.	Scaffolding
Savin-Baden, 2000.	This book explores staff and students' experiences across three professions and argues that scaffolding within subjects affects the kind of PBL offered. It is based on a 4-year study and discloses ways in which learners and teachers manage complex and diverse learning in the context of their lives in a fragile and often incoherent world.	Scaffolding
Jacobsen, 2004.	This chapter gives some examples from a study which found that despite an institution advocating and expressing a self-directed problem-based learning ideology, students often engaged in cue seeking and also focused on the surface structure of the proffered case descriptions. The case descriptions were often read as didactic texts rather than as representations of real life phenomena. This meant that the problems at hand were rarely discussed or indeed solved. Rather they triggered discussions as to what issues it might be strategic to raise.	Scaffolding
Savin-Baden, 2003.	This book explores a broad range of issues about facilitation, in particular: understandings of facilitation that have emerged from the author's recent research and ways of equipping and supporting staff. It also questions how students are assessed and suggests ways of designing problem-based curricula that enhance learning.	Scaffolding

Table 2. Continued.

Chen, 2015.	This study defines critical thinking as a threshold concept and established the epistemological threshold framework with conceptual and practical levels to investigate how PBL contributed to the development of critical thinking in a news media literacy class through students' learning experiences, academic performance, and perceptions of their development.	Pedagogical content knowledge
Fredholm, Savin-Baden, Henningsohn, & Silén, 2015.	This study investigates the relationship between autonomy in learning and narratives of personal challenge and development in the context of student PBL experiences in clinical education. The findings suggest that in order to create autonomy in learning in medical education, it is important to move away from the image of an independent learner who is learning from the patient toward a learner who learns together with the patient in a reciprocal relationship.	Pedagogical content knowledge
Beaumont, Savin-Baden, Conradi, & Poulton, 2012.	This article reports on the findings of a demonstrator project to evaluate how effectively immersive virtual worlds (IVWs) could support problem-based learning. The project designed, created, and evaluated eight scenarios within second life (SL) for undergraduate courses in health care management and paramedic training. Evaluation was primarily qualitative, using illuminative evaluation, which provided multiple perspectives through interviews, focus groups, and questionnaires with designers, facilitators, learning technologists, and students. Results showed that staff views about scenario design and pedagogical content knowledge affected facilitation and student engagement.	Pedagogical content knowledge
Savin-Baden, 2000.	This book presents the findings of a longitudinal study that used collaborative inquiry to explore tutors' expectations and experiences of being problem-based learning (PBL) facilitators. The findings indicate that tutors' pedagogical stances influence not only the PBL teams, but also the student learning experience. These findings are underpinned by earlier work in this field that explored both tutors' and students' experiences of PBL in four professions.	Pedagogical stance
Wilkie, 2004.	Wilkie examines the shifts made in the pedagogical beliefs of nursing lecturers implementing a problem-based diploma in a nursing programme. The lecturers expressed beliefs about teaching and student learning that reflected a problem-based learning philosophy, but their actions within seminars were similar to actions used previously in subject-based teaching. The findings raise issues related to the imposition of problem-based learning curricula and facilitator selection.	Pedagogical stance
Good, Howland, & Thackray, 2008.	This paper presents a case study in which university students were tasked with building an interactive learning experience using Second Life as a platform. The use of a virtual environment, combined with problem-based learning and constructionism, subtly changed the nature of the instructor–student relationship, allowed students to explore "problematic problems" in a motivating and relevant manner, provided students with greater ownership over their work, and allowed problems to be set which were flexible, but at the same time allowed for ease of assessment.	Pedagogical stance

Table 3. Summary of threshold concepts in student engagement in PBL.

	Irreversible	**Bounded**	**Transformative**	**Troublesome**	**Integrative**
Liminality	The very nature of liminality means that it is irreversible after transition.	Usually bounded by the issue that has resulted in the liminality.	It is transformative since the liminality itself helps students to see the world anew.	Liminal spaces are complex and uncomfortable by their very nature.	Understanding the concept and value of liminality for learning is integrative.
Scaffolding	The realization that the availability of different forms of scaffolding means students and tutors are unlikely to go back.	This is bounded by the type of scaffolding adopted by tutor.	This is transformative because high-level flexible scaffolding prompts the valuing of scaffolding differently.	Reviewing scaffolding results in questioning what has been required by the adoption of it.	Recognizing that some forms of scaffolding are valuable is integrative.
Pedagogical content knowledge	The recognition of new forms of knowledge means there is little likelihood of returning to older views.	This is bounded by the type of knowledge presented.	New views of knowledge result in shifts in critical thinking.	Dealing with different forms of pedagogical content knowledge challenges views about what counts as knowledge.	Realizing the existence and impact of pedagogical content knowledge is integrative.
Pedagogical stance	Tutors and students are unlikely to return to a previous state once they have gained a new learning perspective.	This is bounded by students' and tutors' perception of their stances.	Changes in pedagogical stance enable new perspectives about knowledge values.	Shifts in pedagogical stance prompt troublesome challenges to learner identity.	Acknowledging the impact of pedagogical stance in learner identity is integrative.

The difficulty here is the assumption that transformation is seen as rather more cognitive than connected to shifts in learner identity, which would indeed result in deep changes—certainly in stories from students' journeys in PBL, the PhD here being seen as the ultimate form of PBL: Trafford explored threshold concepts in PhD supervision and offers some fascinating insights into threshold encounters. What is poignant is the consistent sense of a conceptual state of being lost that students experience, as if they were slipping in and out of liminal variation and across diverse forms of liminality. For example, one student said

> each new concept looked interesting and provided insights on my data. I felt like using it to analyse my data, but a week later a different theory seemed just as promising. I was conceptually lost (Trafford, 2008, p. 281).

Another said

> I did ask for help. I sat with my colleagues and asked them about their conceptual frameworks. Everybody was talking about "IT," but most of them were looking at an illusion. They thought they knew what IT was but gradually I doubted it. I then felt at peace when I realised that most of them were still looking for their conceptual framework (Trafford, 2008, p. 282).

This sense of being lost and looking for something seems a shift away from liminal variation. This is a response to both preliminal variation in terms of encountering the portal, and liminal variation in terms of how the liminal space is entered and negotiated. Yet it would seem that here students speak of the realization of being lost and needing to look for something that is there, or having an expectation that this sense of lostness will disappear.

Transitions and transformation resulting from disjunction and subsequent liminality appeared to prompt students to interrogate the achievements and experiences of the past in relation to what was then presently occurring for them. Students who engage with disjunction tend to speak not of constructing a voice, but of "gaining a voice" (Savin-Baden, 2000), as a way to depict an intellectual and ethical process whereby the development of a sense of voice, mind, and self are interlinked. This then would seem to be a developmental transformation, which is increasingly being seen in other studies. For example, Chandler (2015) suggests that there are five thresholds evident in theological reflection and that these are both cognitive and developmental. Further, Land (2014) and Rattray (2014) do seem, at points, to suggest that engagement with threshold concepts requires both cognitive shifts as well as ontological and emotional shifts that result in more than a cognitive transition. In terms of PBL, students struggle to know how to learn independently and to take up a pedagogical stance. The result is a shift into liminality which both students and tutors struggle to understand or accept. The impact for both tutors and students can be liminal experiences as delineated below in Table 4.

For some tutors the reaction to students' experiences of liminality in PBL can result in their feeling a need to provide more structure and more scaffolding. This can be helpful,

Table 4. Forms of liminality.

Form of liminality	Description	Evidence drawn on
A moment of aporia	A moment of aporia[1] is when a misconception becomes apparent and the student needs to explore and examine the assumption underlying their views or beliefs about an issue.	Burbules, 1997.
A moment of conceptual puzzlement	A moment of conceptual puzzlement is where feeling stuck results in a sense of feeling paralyzed or fragmented.	Savin-Baden, 2008a.
Recurring liminality	This is where someone may understand that he or she needs to move away from a particular position of stuck space, but does not know how or where to move results in a constant cycle of liminality, where there is a perpetual return to the same stuck space.	Savin-Baden, 2008b.
Reflexive metaxis	This is a reflexive position in which the liminality and stuckness is recognized but where there also, amidst the moving on, a recognition of transition, is a sense of continual oscillation between threshold crossing and liminal states, resulting in an ongoing sense of metaxis.	Savin-Baden & Falconer, 2016, forthcoming.

depending on the type of scaffolding, but it can also bring with it a greater sense of disjunction and liminality. Tutors and students may also struggle with liminality because of their beliefs about the value of scaffolding.

Scaffolding

There is a strong focus in higher education and particularly in professional education on the notion of scaffolding learning. Emerging from Vygotsky's zone of proximal development (Vygotsky, 1978), it is the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers. The concept of scaffolding refers to the context provided by knowledgeable people to help students develop their cognitive skills. For example, Orsini-Jones (2008) presents a process of scaffolding for learning grammar, but found a mismatch between students' perceptions of what was difficult and what they found to be difficult, in relation to the categorization of particular grammatical categories. While scaffolding can be helpful, it can also lead to a sense of preliminal variation in terms of how students perceive or encounter the portal. What Orsini-Jones's study appears to indicate is that difficulty occurs that leads to a consequential increase in stuckness, either when the students do not understand the lecturer's map for learning, or there is disjunction between the lecturer's map and the student's map, or perhaps in more cases than we would wish to acknowledge, the student's map is better than that of the lecturer. Thus it would seem that tutors' need to scaffold learning is troublesome and results in student disenchantment. Even those innovative suggestions for scaffolding provided by Hmelo-Silver, Duncan, and Chinn (2007) and Belland, Kim, and Hannafin (2013) essentially position the tutor as being the orchestrator of the learning process over the student.

Hmelo-Silver, Duncan, and Chinn (2007) argue against Kirschner, Sweller, and Clark (2006), who suggested that PBL and inquiry learning are minimally scaffolded and therefore affect effective student engagement. What Hmelo-Silver and colleagues (2007) argue is that PBL is scaffolded, but in particular ways. However, their argument is somewhat simplistic in that it does not take account of diversity in learning, pedagogical content knowledge, or learner identity, since they believe

> scaffolded inquiry and problem-based environments present learners with opportunities to engage in complex tasks that would otherwise be beyond their current abilities. Scaffolding makes the learning more tractable for students by changing complex and difficult tasks in ways that make these tasks accessible, manageable, and within students' zone of proximal development (Rogoff, 1990; Vygotsky, 1978). (Hmelo-Silver et al., 2007, p. 100)

Belland, Kim, and Hannafin (2013) suggest that many tutors using PBL believe that providing students with authentic problems will necessarily result in student engagement. They argue that this is not the case and provide clear guidance and a rationale for designing scaffolds that enhance cognitive outcomes and student motivation. While this is laudable, it tends to take little notice of learner differences, diversity, or levels of student criticality, as well as learner identities and pedagogical stances.

Scaffolding is a transdisciplinary threshold concept as students *believe* they need it and tutors *believe* they must provide it, since both consider it vital for students to learn the "correct" information. In practice, tutors who over-scaffold can inhibit student learning and prevent both disjunction and resultant movement over any threshold. Furthermore, scaffolding is a transdisciplinary threshold concept because most tutors do not understand that it can be unhelpful to the learning process, since they do not recognize the value of stuckness. Thus removing or minimizing scaffolding can enable tutors to improve student engagement in PBL, since it will assist students to move more effectively through the multiple learning portals available in the PBL process. Removing scaffolding is likely to increase the possibility of disjunction in a range of learning areas and thus augment threshold crossing.

> For example, Sally's belief that her learning was someone else's responsibility stemmed from her uncompromising experiences in life: brought up in a religious family, Sally believed that there were clear guidelines and right answers. Her low self-esteem—she described herself as being "not particularly intelligent," had emerged from her position in the family as one of the few who had not achieved high grades at Advanced ("A") level whilst at school. This meant that she not only wanted to be told what to learn but also needed to be affirmed in the choices she had made: "You need to know, are you doing the right thing? Are you doing the wrong thing? You don't know if you've never come across it before what is right and what is wrong, do you? What is the right way to go about something and what is the wrong way? And you might be doing it all wrong but because nobody's said any different to you, you go through with the feeling you're doing it right." . . . . Sally expected not only that the tutors would provide her with the knowledge and skills that she needed to become a nurse, but that they would also show her how to make connections between herself and what she was learning (Savin-Baden, 2000, p. 69).

As the scaffolding was removed, Sally shifted away from the idea of right answers and tutors as purveyors of knowledge. In many ways this supports the arguments suggested by Rogers (1983) and hooks (1994) for freedom to learn and teaching to transgress. In the context of PBL it is important to note that scaffolding is essentially a cognitive construct and relies on cognitive learning theory and students' cognitive capabilities. There is increasing focus in the 21st century on what and how students learn and on ways of creating learning environments to ensure that they learn effectively, invariably with a focus on scaffolding this learning—although much of this remains contested ground. During the learning process, many students fail to locate what Perkins (2006) refers to as the episteme, or underlying game (what it is that is required by the tutor). Tutors' attempts to communicate the underlying game have taken a number of forms. For example, Kinchin, Cabot, and Hay (2010) suggest that providing information in chains is unhelpful to students, and that such a strategy merely constitutes procedural sequences. What they argue is that teaching students within a linear lecture structure fails to help students link different knowledges together. Instead we should teach networks of understanding, illustrating how knowledges and practices are connected so that knowledge is integrated and holistic. Chains and networks are one helpful exemplar, but a particularly popular one is that of scaffolding. The following forms of scaffolding (in Table 5) are seen within PBL.

Scaffolding for most tutors is currently seen as a "good thing," when to see scaffolding as problematic is in fact a threshold concept and will help students to engage with PBL. Movement over the threshold for both tutors and students relies on *not* over-scaffolding, but instead allowing for disjunction and threshold exploration to occur in the context of scaffolding that is pedagogically informed. Scaffolding may reduce the possibilities for imaginative curriculum making—for students as well as a tutor. Thus, it might be that tutors, through scaffolding, lead students around disjunction and into liminality, thereby only guiding students into transitional states rather than transformative opportunities. Yet scaffolding can occur too through misplaced notions of pedagogical content knowledge.

Pedagogical Content Knowledge

Pedagogical content knowledge is seen as central to the idea of thinking like an engineer, physiotherapist, or teacher. While subject knowledge and pedagogical knowledge are perhaps self-evident, pedagogical content knowledge draws upon knowledge that is specific to teaching particular subject matter. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring to their learning of those most frequently taught topics and lessons (Shulman, 1986, p. 9–10). In the UK there has been increasing

Table 5. Forms of scaffolding.

Form of scaffolding	Description	Evidence drawn on
Scaffolding tasks	This is where tutors provide and students expect tasks/scenarios to be guided step by step through the PBL process.	Belland, Kim, & Hannafin, 2013. Hmelo-Silver, Duncan, & Chinn, 2007.
Scaffolding group processes	This is where tutors guide students through the group process, the ways of managing a group and dealing with conflict, rather than this all being organized and dealt with by the group.	Hmelo-Silver, Duncan, & Chinn, 2007.
Scaffolding problem-solving	Problem-solving is seen as being guided through a set of procedures rather than being open, flexible, and innovative in the process of problem management.	Hmelo-Silver, 2004.
Scaffolding autonomy	This is where the form and degree of autonomy that is allowed is guided by the tutor, such as the pedagogical content requiring engagement or the group process that is permitted.	Belland, Kim, & Hannafin, 2013.

discussion about discipline-based pedagogy (which is parallel to pedagogical content knowledge), particularly in the debates about the relationship between research and teaching. Jenkins and Zetter (2007) argue that disciplines shape the nature of pedagogy and such pedagogies reflect the practices and culture of the discipline. Shulman (1986) describes pedagogical content knowledge as the ways of representing and formulating the subject that make it comprehensible to others. Pedagogical content knowledge may draw on other forms of knowledge as well as knowledge from other disciplines. Students may have, for example, studied psychology in high school, but the use and portrayal of psychology in a medical or theology degree is reformulated to reflect the pedagogical content knowledge. The result is that knowledge for a particular discipline is taught and fashioned within it and for it, and thus it is for many students a threshold concept. Few students realize that in order to think like an engineer, for example, they have to see knowledge through the lens of the discipline. However, perhaps more pertinently, there is also an assumption by tutors that knowledge has to be gained in a particular way related to the pedagogy of the discipline. Tutors see their role as inducting (or forming) students into the discipline, and rarely recognize their assumptions about pedagogical content knowledge or its impact on learning. Pedagogical content knowledge is a threshold concept because it is bounded; once tutors appreciate this they realize that knowledge, and the teaching of it has to be seen afresh. For example, a facilitator explained his position:

> I try not to be directive although at times I say to the group, I think I'm taking my problem-based learning hat off for a few minutes is that okay, so they know the difference, now I'm putting on my nursing lecturers hat and I will throw something out to them which is possibly a gaping hole in their argument and they should have identified it, so I will give it to them. Now go back and play with that ball, and I'll put that problem-based learning hat back on again. I think I'm that kind of facilitator, not directive, give them a long lead, do a lot of listening, try to play the game they want to play as long as they look at the objectives of the problem-based learning, and they are heading in that direction. I'm quite happy to believe that there are many different routes to achieve the learning outcomes, you don't have to go down a specific road, as long as at the end of the problem-based learning they have achieved them, for the students and for the patients.
>
> His perception of himself as not being directive does not square with "putting on my nursing lecturer's hat" so that he can supply students with the practical knowledge they need to be safe with patients and achieve the learning objectives (Savin-Baden, 2003, p. 40).

This struggle for tutors in deciding how and whether to impart knowledge to students is also evident in more recent work (Conradi et al., 2009). Here tutors involved in PBL in virtual worlds tended to take on one of two specific roles:

Table 6. Forms of pedagogical content knowledge.

Form of pedagogical content knowledge	Description	Evidence drawn on
Content knowledge	Knowledge (facts, concepts, theories, and principles) that is seen as central to content, that is seen as needed to be "covered" within a discipline.	Zepke, 2013.
Subject knowledge	Knowing the content knowledge of a discipline well enough to teach it as a subject within a classroom. This requires not only knowing about the subject, but also knowing how the knowledge belongs to the discipline and how it should be taught in the context of the discipline.	Zepke, 2013.
Epistemic knowledge	Knowledge used by the discipline to create systems of meaning to serve the discipline, such as the creation of models or theories that are discipline specific.	Trowler, 2012.
Pedagogical knowledge	Knowledge about how and why a discipline teaches what it teaches in ways that are acceptable to the discipline.	Jenkins & Zetter, 2007. Bernstein, 1972.

either a technical role assisting students by offering guidance on how to use the environment or the role of clinical subject matter expert. Pedagogical content knowledge is a transdisciplinary threshold concept in PBL because once tutors realize that it can disable students' learning in PBL, they change their approach to facilitation to reflect this, as Wilkie's study (2004) demonstrates. Thus as tutors shift to seeing pedagogical content knowledge as troublesome, since they recognize the need for greater flexibility about what counts as knowledge, this in turn tends to result in increased autonomous engagement for the students as they shift toward owning knowledge for themselves.

The following quotation from Beaumont and colleagues illustrates a focus on both scaffolding and the need for pedagogical content knowledge:

> In the paramedic scenarios, one tutor confirmed that the scenarios assumed students had a level of knowledge that they could apply and the scenario focussed on developing clinical reasoning and decision making in simulated real-life situations. However, his original intention for the pedagogic model required that prerequisite knowledge (background) would be incorporated within the Second Life scenario and that the scenario could therefore be used to promote learning of theory in addition to application to practice. He envisaged an active facilitator approach; which would vary as students repeatedly visited a scenario and would "*direct them how to learn and where to find information . . . and follow them until I make sure they are heading the correct way*." (Beaumont et al., 2014, p. 135)

In terms of student engagement, this quotation illustrates the hidden "texts" in tutors' expectation of students learning. For example, Boughey (2008) argues that students believe their work should reproduce regarded texts and hence feel discouraged when they are criticized for reproducing facts and tutor perspectives. Thus the uses of language are deeply related to issues of engagement—both for students and academics—and are not just social, cultural, or political skills.

This illustration also exemplifies the impact of pedagogical stances on student engagement in PBL.

Pedagogical Stance

Pedagogical stance depicts the way in which students see themselves as learners in particular educational environments. The choices students make within a learning situation and the particular learner history which they bring to

Table 7. Types of pedagogical stance.

Type of pedagogical stance	Description	Evidence drawn on
Reproductive pedagogy	Students may revert to methods of learning that they have always used, despite the considerable difference they may have encountered between methods of learning experienced at school compared with those at university. Learning, for these students, is expected to be safe and predictable, requiring neither personal initiative nor critical thought.	Savin-Baden, 2000.
Strategic pedagogy	Students in this domain may use several different learning strategies, but these are all within the remit of what is acceptable to both the authorities (institution, tutor, profession) and the student. Adapting their learning will ensure that they are equipped with the necessary skills and knowledge for the workplace.	
Pedagogical autonomy	Students here adopt a position of learning that they perceive will offer them the greatest degree of autonomy. Students opt to learn in a way which suits them and that will offer them, as far as they are concerned, the most effective means of learning, meeting their own personally defined needs as learners, yet also ensuring that they will pass the course.	
Reflective pedagogy	Students see learning and knowledge as flexible entities; they evaluate personal knowledge and propositional knowledge on their own terms; thus the student both engages with knowledge and questions it.	

a learning environment both influence students' pedagogical stance. Pedagogical stance is a transdisciplinary threshold concept because tutors and students rarely recognize that they have a pedagogical stance, nor the impact it has on facilitation and student engagement.

These types of pedagogical stance can be seen as transdisciplinary threshold concepts, in that they are stages through which students pass on the way to high-level deep engagement in learning. Thus they journey across multiple thresholds on their way toward reflective pedagogy. However many students in PBL appear to become stuck because of tutors' views of knowledge and the way in which they scaffold PBL. For example, a student in an engineering program explained that

> he found that even by buying into the academics' notion of problem-based learning he was not always enabled to develop himself and explore areas which he valued. Application and understanding were issues which he felt were key to being able to apply his knowledge. They were skills which had enabled him to learn to resolve or manage problem situations effectively by using his knowledge in a way in which he had been unable to do upon the mechanical engineering course in the first year. However, now, in the fourth year, he felt angry when some tutors imposed their own strategies upon students. He believed he had not been offered the opportunities to develop his problem-solving capacity fully. He objected to these artificial discipline boundaries, and the ways in which he had been prevented from exploring various aspects of the given problem due to the inculcation of a step-by-step approach to problem-solving by some of the staff (Savin-Baden, 2000 p. 82).

Students' stories of problem-based learning could not be separated from the ways in which they talked about themselves and their pedagogical stances. However, although pedagogical stance has been presented here as reflecting students' journeys through liminal states and over thresholds, tutors too hold pedagogical stances that affect student engagement in PBL. Issues of power and control in problem-based learning were ones that were spoken of many times by tutors (Savin-Baden, 2003, ch. 3). There was a sense that these staff were dislocated not just because problem-based learning did not fit with their pedagogical stances but also because they felt unable to let go. Letting go was partly about control, but it was also about feeling safe enough with this method of learning and feeling that students could be trusted. Many facilitators later remarked on how part of the transition they had made was learning to trust the students to learn for themselves.

Discussion

What the PBL literature and the literature on student engagement appears to indicate is that although transdisciplinary threshold concepts may share certain characteristics, the experience of them differs between people and invariably relates to identity transitions and transformations. Thus it would seem that transdisciplinary threshold concepts are both affected by the spaces in which they occur and through the pace of change in learner experience and learner identity. Although in the thresholds literature the term "concepts" might be seen as both cognitively and ontologically positioned, there still needs to be a greater emphasis on the relationship between learner identities and threshold concepts than there is in some of the current research and literature to date. For example, the difficulty with the notion of locating ideas of troublesomeness around "knowledge," "concepts," or "theories of difficulty" seems to somewhat dislocate the concerns from the identities and biographies of learners and teachers. However, the overemphasis on cognitive dimensions to threshold concepts, as delineated by Entwistle (2006), is where this difficulty seems to be most apparent. For example, Entwistle argues that engaging with threshold concepts is related to *conceptual* change and relates his argument to Perry's conceptions of knowledge (Perry, 1970) and Säljö's conception of learning (Säljö, 1979). Thus, there would seem to be too much emphasis on epistemology and not enough on identity; for example, work carried out with postgraduate students in terms of their development of conceptual-level thinking and engagement with the research question and the interdisciplinary disciplines—the disciplinary mix in their writing of the thesis—has identified moments of "learning leaps" (Wisker, Kiley, & Aiston, 2006; Kiley & Wisker, 2008; Wisker, Robinson, & Kiley, 2008). Learning leaps are where students cross conceptual thresholds to raise the level of their critical thinking and expression. Conceptual threshold crossings are moments when students make the learning leaps and start to work at a higher and more conceptual, critical, and creative level. Transdisciplinary threshold concepts enable student engagement, although they need to be linked to personal learning and experiences of individual disjunction, rather than overly generalizable, simplistic threshold concepts.

Barnett has described the modern world as super complex (Barnett, 2000). From his perspective, the role of the university is to prepare the students for a world in constant change, being exposed to several and sometimes conflicting frameworks for understanding. By seeing these four concepts as transdisciplinary threshold concepts, tutors can help to improve student engagement in PBL, as mapped in Table 8.

Table 8. Constellations of PBL, threshold engagement, and facilitation.

	Constellation 1 Problem-based learning for knowledge management	**Constellation 2** Problem-based learning through activity	**Constellation 3** Project-led problem-based learning	**Constellation 4** Problem-based learning for practical capabilities	**Constellation 5** Problem-based learning for design-based learning	**Constellation 6** Problem-based learning for critical understanding	**Constellation 7** Problem-based learning for multimodal reasoning	**Constellation 8** Collaborative distributed problem-based learning	**Constellation 9** Problem-based learning for transformation and social reform
Level of scaffolding	High Promoting competence in knowing and managing knowledge	High Learning through guided activity	High Project-led, step by step	Medium Guided toward practical resolutions	Medium Guided toward design-based solutions	Low Supported in gaining knowledge with action	Low Supported in managing dilemmas	Low or none Defined by team	Low or none Prompted to see alternatives
Form of facilitation	Directive	Directive	Directive	Guide to practice	Guide to practice	Coordinator of knowledge and skills	Orchestrator of learning opportunities	Enabler of group reflection	Decoder of cultures
Level of threshold engagement	Interrelational engagement	Interrelational engagement	Interrelational engagement	Interrelational engagement	Engagement as autonomy	Engagement as autonomy	Emotional engagement	Engagement as connection and disjunction	Engagement as connection and disjunction

By acknowledging these transdisciplinary threshold concepts and working with them, facilitators will be able to enhance student learning in PBL across disciplines, contexts, and diverse forms of PBL. The result will be that instead of curricula being over-planned, over-organized, and over-prepared spaces, they should be spaces for meddling with. McWilliam has argued that

> the nature and purposes of *what counts as preparation must change*. From fixed and immutable, curriculum needs to be conceptualised as *content for meddling with*. And this means a significant shift in what many teachers prioritise in their teaching (McWilliam, 2005, p. 13, original emphases).

Despite moves, in the UK at least, toward flexible pedagogies, considerable resistance seems to remain. The focus seems to be on shoring up the disciplines and using outcomes, benchmarking, and standards to pin down knowledge and quality, rather than opening them up.

If the role of the university is to prepare the students for a world in constant change and exposure to several and sometimes conflicting frameworks for understanding, then it is vital to recognize that transdisciplinary threshold concepts do have an impact on student engagement and need to be explained to students and engaged with by tutors. Tutors need to support students in recognizing the ways in which aspects of their lives impact engagement in pedagogic spaces. However, it is important to note that while these are generally seen as transdisciplinary threshold concepts that affect students, they may also affect tutors. For example tutors who believe in the value of high level scaffolding or fail to recognize liminality may become stuck or troubled in the process of facilitating PBL. Further, it would seem from this conceptual synthesis that unless tutors encounter and work through their own transdisciplinary threshold concepts when designing PBL curricula, students may struggle to experience engagement in PBL. A student-centered pedagogy must be viewed as a lens of students' exploration and discovery. Such a critically transformative pedagogy (Zyngier, 2007) will support an improved communal and social connection amongst students and tutors, and encourage autonomy and agency as well as reduce students' conceptions of isolation and alienation. Furthermore, as Bernstein (1992) has argued, it is through their experiences as students that individuals within HE form their identities. He has suggested that identity formation may be seen as the construction of pedagogic identities, which will change according to the different relationships that occur between society, HE, and knowledge.

University education should engage students by bringing problems and questions to students, and not merely pass on scaffolded knowledge. Students need to be free to discriminate; make judgments; and develop the capacity to improvise, inquire, and take intellectual risks. If we are to see curricula as content for meddling with, then we also need to see PBL differently. Yet there are few authors who offer strategies for dealing with negative performative practices, upheld by constructive alignment and narrowly defined learning outcomes. Perhaps what is needed is more "deliberative pedagogy" where deliberation rather than outcomes is seen as the organizing principle of the PBL curriculum. This would mean that consensus decision-making, consciousness-raising, and knowledge creation are the responsibilities of both learners and teachers, and deliberation is the hallmark of facilitation.

Implications and Futures

The challenge for higher education is to prepare for unpredictability and uncertainty. Today's challenges in higher education are highly complex, and solutions may be found only by crossing discipline borders and by defining new and emergent ontologies. It is clear then that research is needed on how curricula are designed and which underpinning pedagogical frameworks are adopted, as well as more detailed questions, such as:

- What kinds of activities prompt engagement with transdisciplinary threshold concepts in PBL?
- To what extent do particular activities improve student engagement in PBL?
- Why are particular models of PBL located in particular disciplines, and in what ways do they prevent or enhance students' engagement?
- What forms of scenarios prompt engagement with transdisciplinary threshold concepts in PBL?
- How can understanding transdisciplinary threshold concepts help to promote effective facilitation in PBL?

Conclusion

Building on theories of threshold concepts developed in undergraduate disciplines, as well as research into conceptual threshold crossing in doctoral learning journeys, may help to improve and understand different levels of student engagement in PBL. It would be easy to dismiss the notion of transdisciplinary threshold concepts for engagement in PBL as being too difficult, too troublesome, to take on. The risk of not engaging, of over-scaffolding, and not living with the liminal will result in a poverty of PBL experiences, performative pedagogies, and curricula in search of criticality.

Note

1. Aporia (Greek: Απορια: impasse; lack of resources; puzzlement; embarrassment) is a puzzle or an impasse, but it can also denote the state of being perplexed, or at a loss, at such a puzzle or impasse, from Aporia, the spirt of difficulty.

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*An asterisk indicates that the source is also cited in the review.

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