DAI-LING CHEN AND JULIE RATTRAY

CRITICAL THINKING THRESHOLD CONCEPTS IN PBL

INTRODUCTION

Building on the threshold concepts framework, this chapter argues that critical thinking is a threshold concept that can be developed through problem-based learning. It is suggested that learners are able to develop epistemological, ontological and practical understandings of critical thinking using a problem-based approach. Through the selection of materials, abandonment of old beliefs and construction of new meanings with others, learners can work towards mastery of disciplines through the establishment of critical thinking. Critical thinking is a complicated concept that comprises a number of generalisable skills and capacities that are then applied in specific ways in a given disciplinary context. Problem-based learning (PBL) offers a potentially progressive learning experience supporting the development of critical thinking not simply within a given discipline but across disciplines. In other words, PBL as a pedagogical approach aims not only to prepare students to be competent in their chosen profession but also to cultivate their capacity for dealing with the unforeseen and multi-faceted complexities of the world. The journey to integrative understanding, however, is not an easy one.

Threshold concepts are described as conceptual gateways facilitating the integration of new concepts and entail conceptual and ontological transformations. To identify how PBL promotes the development of critical thinking as a threshold concept, this chapter uses thematic synthesis to review 40 empirical studies of the effects of PBL on critical thinking published between 2003 and 2017. From this synthesis, pedagogy, facilitation, and students with learning commitments are identified as the three PBL propelling forces for students to cross the portal and attain critical thinking.

LITERATURE REVIEW

Confronted with a fast-changing future, students are required to broaden their studies by focusing on a repertoire of capabilities rather than a particular profession (Dizik, 2017). The journey of PBL starting, as it does, with ill-structured problems can facilitate enquiry into real-life problems. Critical thinking is developed when students are exposed to contested points of view and critical discussion (Meyers, 1986). Without direct instruction, students are encouraged to engage in learning.

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They are expected to encounter difficulties associated with knowing, capabilities and identity change, integral to the threshold concepts framework proposed by Meyer and Land (2003). The identification of critical thinking as a threshold concept in PBL emerges from the following arguments:

- Critical thinking lays the conceptual foundation for achieving better understanding across domains at the pragmatic level. The critical thinking threshold concept in PBL can thus be viewed of as a threshold capability.
- Regarding knowing, capabilities and identity change, threshold concepts respond to critical thinking as a transformational process, unbolting epistemological, practical and ontological development in PBL.
- The troublesomeness of PBL may transform students' understanding of knowing and being. The vexatious experience, however, may also temporarily obstruct the route to the achievement, causing the 'stuck space' in liminality.

Threshold concepts might be bounded within disciplines, yet the context of PBL suggests critical thinking as the generic principles underlying fields of study with specific meanings for different disciplines and hence a cross-disciplinary concept for integrative purposes. Critical thinking might be defined as a 'multifaceted threshold concept' comprising conceptual and pragmatic levels together with epistemological, ontological and practical dimensions. Whilst critical thinking involves some skills common to all disciplines, it might be enacted differently for different disciplines. In the following sections, we will define the critical thinking threshold concept as it emerges through a PBL curriculum and identify critical thinking as a concept and capability that incorporates the epistemological developmental dimension, applying knowledge to practice, and linked to students' ontological shifts that push them towards the threshold.

CRITICAL THINKING AS A THRESHOLD CONCEPT IN PBL

Defining Critical Thinking

To define the critical thinking threshold concept in PBL requires considering critical thinking as a complicated and developmental notion across disciplines. Problem-based learning offers opportunities for students to explore the kinds of problems that they might encounter in practice..The problem elicits enquiry into knowledge and concepts, application of knowledge to practice, judgment-making and meaning-making, bringing about transformation in teaching and learning. The journey can accordingly be taken as a process of critical thinking development in relation to knowing and reasoning. General values underlining critical thinking such as clarity, analysis and evaluation have been advocated by many authors either at the conceptual or the skill level (Bailin, 1996; Cottrell, 2011). Such views of critical thinking stress the importance of the decision-making and problem-

solving aspects of critical thinking. To this end, critical thinking is conceived of as a means of embracing knowledge as the conceptual basis of thinking and skills as application. As Lipman (2003) argues, impartiality, accuracy, carefulness, truthfulness, coherence, abstraction and practicality are essential traits of critical thinking. It might be insufficient, then, to learn critical thinking without these temperaments. Bailin et al. (1999) argue for the importance of habits of mind such as 'an enquiring attitude' and 'open-mindedness' to restructure thinking for reasoned judgment in cognitive and conative domains. Distinct from their emphases on generic intellectual criteria for contextualised purposes used in curriculum, Paul and Elder (2006) view critical thinking as non-specific skills of logic applied in any subject. Based on the conceptual and practical levels of critical thinking, we too, argue for the generic values embedded in critical thinking but, argue for the importance of relevancy for particular purposes.

In educational settings, nevertheless, stuckness in the learning process may occur because learning can scarcely follow the 'rational' knowing and reasoning track. Baxter Magolda (2010) studied college students' development in intellectuality, identity and relationships. She developed her theory of self-authorship defined as internal capacity central to critical thinking. Conceptually, her focus on the epistemological and ontological dimensions from the constructive-developmental perspective responds to constructivist PBL where students work with peers and the teacher for meaning-making. In the collaborative process, students might progress once overcoming the troublesomeness and internalise new findings to form new concepts for practice. In this chapter, critical thinking is defined as a generic concept of enquiry, analysis, evaluation and integration for multifaceted applications across disciplines. The concept involves the capacity for practical progression and epistemological and ontological development.

Critical Thinking as a Transdisciplinary Threshold Concept in PBL

Locating critical thinking as a threshold concept may help in understanding various facets of it in PBL because threshold concepts are defined as 'akin to a portal' (Meyer & Land, 2003, p. 412) and 'conceptual gateways' (Land, Meyer, & Smith, 2008, p. x) which are transformative, troublesome, integrative, irreversible, and bounded. Drawing on the threshold concepts framework based on crossing to new conceptual territory, critical thinking threshold concept in PBL counts on ongoing collaborative exploration; but nonetheless, consists of individual variations.

Chen and Rattray (2017) refer to critical thinking as concerning varied but related elements from different theoretical perspectives, bringing together components for application in different subjects. They established the threshold capabilities framework based on Baxter Magolda's (1992) epistemological reflection model and Meyer, Land, and Davies's (2008) modes of variation with four phases respectively. The premise of this was that the capabilities result in students' shift in views of the world and themselves from a simplistic state to a sophisticated level, and the critical thinking threshold concept in PBL unlocks students' threshold capabilities transferable across domains. Savin-Baden (2016)

describes threshold concepts in PBL as transdisciplinary, for threshold experiences, along with cognitive and ontological change, are prone to general occurrences and recurrences not only confined to particular disciplines. In contrast to identifying critical thinking as a mere generic threshold concept sharing common cross-disciplinary values like argument, analysis and interpretation (Kiley & Wisker, 2009), it might be legitimate to argue that critical thinking is contextualised and its utilisation in disciplines can be differentiated with specific emphases.

PBL for critical thinking threshold concept moves along a reciprocal trajectory in which students start from individual experiences, working together with the teacher and peers, reflecting on the process, to continuing the exploration of a new territory. Learning in PBL involves studying the tension between groups and individuals as well as the dialogue between the old and new self. The learning orbit of reasoning and critical thinking, as Baxter Magolda (1992) suggests, involves ups and downs, moving towards the upward direction. In the transformed way of learning, however, students may experience stuckness or liminality, causing emotional reactions (Meyer & Land, 2005). This chapter continues to map out the learning route of critical thinking threshold concept in PBL concerning epistemological, ontological, and practical perspectives by building the conceptual model of critical thinking threshold concept development.

THE CONCEPTUAL MODEL OF CRITICAL THINKING THRESHOLD CONCEPT DEVELOPMENT

As argued, threshold concepts bring about transformation in knowing, identity, and capabilities; relatively, the critical thinking threshold concept clings to epistemological, ontological, and practical development. The epistemological dimension refers to knowledge development based on personal beliefs, the ontological dimension means having continuous willingness to learn, and the practical development signifies the constant monitoring of thinking to take action. On this basis, critical thinking threshold concept development moves in the shape of an open-ended spiral shell from the state of self-assumption to that of self-assurance, as shown in Figure 1.

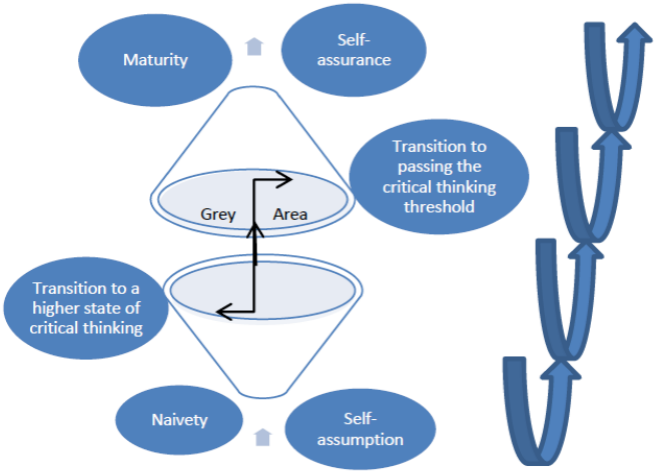

Figure 1. The concept model of critical thinking threshold concept development

Epistemological beliefs arising from personal assumption without evidence confine one's thinking to a narrow point; through the development of epistemological understanding, more perspectives are taken into consideration, widening the range of thinking and the scope of being. As the development goes on, thinking moves towards maturity after one becomes more independent and able to integrate and evaluate different ideas into one's thinking, changing one's mind, carrying out knowing and understanding of being towards self-assurance. The transformation progresses from unproven subjectivity, growing objectivity, transitions, evaluative objectivity, to sophisticated subjectivity. The hole at the top symbolises possibilities of ongoing exploration, whereas ups and downs occur in grey areas where students encounter self-collision. With a stimulative vehicle, the circuitous journey generally goes forward. The upward arrows in the diagram represent the tortuous ongoing development.

The Epistemological Dimension of The Critical Thinking Threshold Concept

The epistemological dimension tends to be tied up with students' knowing and reasoning development. Much of research on intellectuality related to critical thinking has been centred around evolution from naivety to maturity (Barber, King, & Baxter Magolda, 2013). Some authors suggest a relationship between epistemological theories to cognition and learning (Hofer & Pintrich, 1997; King & Kitchener, 1994). Critical thinking with multiple facets, as defined above, does not fall into a simple general concept with cognitive steps to follow but requires the elastic capacity for constantly modifying how personal knowledge can respond to the evolving self and the wider context. The capacity varies according to specific

needs and foci , reflecting that the dynamic epistemological development may is rarely occasionally generalised across domains.

Due to individual students' variations in learning, there may be 'grey areas' where students face blocks, and cannot find the way out. Barber, King, and Baxter Magolda (2013) take notice of the learning pattern of moving back and forth, eliciting the question about how to alter from one status into another. Meyer and Land (2005) characterise the stuck places of learning as states of 'liminality' where 'epistemological obstacles' blocking transformation and oscillation between states occur. Timmermans (2010, p.11) indicates that the troublesome nature of threshold concepts discloses their developmental potential, and discordance at the epistemological level inspiriting students to change their minds 'by transforming how they know'. Epistemological transformation suggests that the learning track of passing thresholds will probably never end. Mcentee (2007, p.150) claims that how students learn about Hollywood film can be analogous to using a set of binoculars with adjustable focus to see movies because students may 'oscillate between being entertained by movies and being analytic about them'. Students in the critical thinking threshold concept developmental process may encounter 'periodic ends' signifying temporary stops of epistemological gradation. With external stimulation or assistance like PBL to encourage internal realisation of knowledge and knowing, their learning engine can restart to continue to move forward.

The Ontological Dimension of The Critical Thinking Threshold Concept

The epistemological dimension serves as the root for understanding critical thinking and mastery of subjects; the ontological component plays an essential role in activating critical thinking development. It tends to be referred to as dispositions or attitudes pertaining to motivation and metacognition (Borich, 2006). To face an unknown future, Barnett (2004, p. 247) contends that learning calls for an 'ontological turn' rather than offering a definitive solution.ne can go forward, according to him, not because of possessing knowledge or skills but because of one's being with a will. Though it induces ontological risk liable to destabilisation, it may summon up courage to go on the adventurous voyage.

The discussion might explain why some students 'negotiate the liminal space', defined as pre-liminal variation opening up understanding and triggering 'coming into view' (Meyer & Land, 2005, p. 384). The belief to envision the possibility to transcend the threshold needs 'psychological coping strategies' to cope with the uncertain liminal phase (Rattray, 2016, p.73). Critical thinking threshold concept development accordingly celebrates 'the epistemic and ontological learning journey of becoming and being' (Meyer & Timmermans, 2016, p. 34). In the PBL course, students may encounter ontological insecurity probably on account of staying in a naïve state. Once they cross a threshold, they may feel assured of not just what they learn but who they become. The tortuous road to mastering a concept is accompanied by feeling comfortable in new knowledge, termed as threshold confidence (Felten, 2016). Critical thinking threshold concept development in PBL revolves around students' emerging identity with what they

know, how they know, how to carry knowledge into effect and how much they relate themselves to the broader environment. Cognitive and affective aspects of learning entangled with ontological development may pave the way for further breakthroughs.

The Practical Dimension of Critical Thinking Threshold Concept

Provided the epistemological and ontological foundation of critical thinking threshold concept, the 'How do I know?' question may draw forth responses driving critical thinking. As established, certain authors interpret critical thinking through the lens of competence, making much of the problem-solving process demanding higher order thinking and metacognitive skills. Asking deep questions and continuously monitoring the thinking process initiating action, in this regard, contribute to the practical dimension of critical thinking. Much has been made of the evaluation of the demonstration of critical thinking in various disciplines. For example, to improve nursing staff's critical thinking skills, Oermann (1999) proposed assessment strategies including questioning, clinical scenarios, conferences and context-dependent test items. The manifestation of critical thinking is assessed according to how much evidence is provided to justify knowing subject to the epistemological development at the practical level. Through repeated practice, new thinking at a higher level is integrated into epistemological progression.

For conceptual integration, Meyer et al. (2016) maintain that metacognitive assessment activities can be beneficial for students to progress from an understanding of a threshold concept towards a threshold capability. Practical skills supported by knowledge embedded in various subject areas are therefore developed as the process goes on; by reflecting on what they learn and how effective their learning is in PBL, further metacognitive development occurs (Downing, Kwong, Chan, Lam, & Downing, 2009). The affective issues entailed in the process vary with individual understanding and performance elaborated by Meyer, Land and Davis (2008) as variation 'viewed from the perspective of individual differences'. Exposed to variations in experiences within but not limited to domains, students are more likely to be engaged in continual learning applicable to not only the real life but the unknown future.

PBL FOR CRITICAL THINKING THRESHOLD CONCEPT DEVELOPMENT

This chapter has so far been concerned with students' knowing, being, and capabilities spaces of critical thinking. In PBL implementation, it can be more useful to see *how* students pass the portal rather than whether students make progress based on developmental stages. The three critical thinking threshold concept dimensions do not suggest that they definitely develop in parallel, inasmuch as there is difficulty in bridging theory and practice and discrepancy between epistemological and ontological progression. Pedagogy for critical thinking threshold concept development needs to be sensitive to the disarray. In

response to the problem-solving essence, it can be helpful to identify the forces for critical thinking in PBL inviting contested views in collaborative queries and investigation.

Methodology

Threshold concepts, as an area of research first emerged in 2003; a thematic synthesis review of published articles was undertaken from 2003 to 2017 with the keywords problem-based learning and critical thinking. Referring to the Web of Science, EBSCOhost academic search premier, and PubMed databases, the search included empirical studies about the effect of PBL on critical thinking in higher education from various disciplines in addition to the medical field. Among the 40 studies in which PBL and improved critical thinking were positively related, three themes emerged as seemingly important. *Pedagogy* associated with curricular implementation and problem design, *facilitation* meaning teachers or tutors' guidance, and *students* tendency for self-directed learning. Whilst the division between the themes might not be clear-cut, a particular theme was ascribed according to the argument emphasised. This is reported in Tables 1, 2 and 3.

Table 1. Prompt one to develop critical thinking in PBL

Theme 1: Pedagogy	*This theme is concerned with PBL as a method, model or curriculum. Curricular, problem design, and collaboration between the teacher and students are thus involved.*
Chan (2013)	Songs, poems and role plays increased students' awareness of critical thinking, indicating the design of an appropriate curriculum.
Chang &Wang (2011)	They presented a systematic model using PBL to cultivate engineering ethics and critical thinking.
Cowden & Santiago (2016)	This paper constructed problem-based curriculum to improve student critical thinking skills in an interdisciplinary collaboration.
Gholami, Moghadam, Mohammadipoor, Tarahi, Sak, Toulabi, & Pour (2016)	After performing the PBL method, overall critical thinking and its sub-scales of evaluation and deduction were significantly improved.

Hung, Tang, & Ko (2015)	Their study supported that systematic analysis and curiosity in PBL facilitate the development of critical thinking.
Johnsen, Finkeistein, Marshall, & Chalkley (2009)	The student and faculty member worked together to decide the measurements into an evaluation on progress toward competence.
Kek & Huijser (2011)	The article reflected on how critical thinking can be developed through PBL in an aligned learning and teaching context.
Kong, Qin, Zhou, Mou, & Gao (2014)	They found that most effect sizes for subscales of the California Critical Thinking Dispositions Inventory and Bloom's Taxonomy favored PBL.
Lyons (2008)	An experimental pre-post treatment comparative design was utilized to determine the effects of PBL on critical thinking.
Macklin (2008)	In the use of PBL for teaching information and communication technology skills, the formative feedback supported critical thinking about the information retrieval process.
Mok, Whitehill, & Dodd (2008)	The review argued that PBL to facilitate critical thinking allowed more meaningful learning integrating theory and clinical practice.
Nargundkar, Samaddar, Mukhopadhyay (2014)	Their approach used a textbook presenting problems with blank spaces for students with instructor guidance to work them out.
Oja (2011)	The studies reviewed indicated a positive relationship between PBL and improved critical thinking in nursing students.
Pan &Allison (2010)	This study argued for the necessity of a process model of critical thinking embedded in PBL to enable deeper learning.
Roy & McMahon (2012)	This study adopted video-centred cases to ensure that PBL represents a successful simulation of real-life encounters.

Santiprasitkul, Sithivong, &Polnueangma (2013)	In this one group pretest posttest design classroom research, students demonstrated higher overall critical thinking after the PBL process.
Schell & Kaufman (2009)	They discovered that the technology supported PBL, especially the dialogue among the students and between the facilitator in the students.
Sendag & Odabasi (2009)	This study revealed that online PBL has a significant effect on increasing critical thinking skills.
Sommers (2014)	This study considered how culture affected learning and critical thinking skills.
Stefaniak (2010)	The approach assisted students in learning how to determine rhetorical problems throughout various forms of discussion.
Tayyeb (2014)	PBL was identified as an effective instructional tool to foster critical thinking, clinical reasoning skills and problem solving skills.
Tiwari, Lai, So & Yuen (2006)	This study emphasised that PBL tutorials and students' self-regulation in active participation enhanced critical thinking.
Thomas (2009)	Critical thinking is identified as a key link between transformative learning, sustainable education and PBL, implying the challenge to transform pedagogy across all disciplines.
Pan & Allison (2010)	The mapped process of critical thinking provided a worked example of helping students build design solutions.
Yuan, Kunaviktikul, Klunklin, & Williams (2008)	The PBL students had a significant improvement on the overall California Critical Thinking Skills and test, analysis, and induction subscale scores compared with the lecture students.

Prompt One: Pedagogy

Pedagogy is the biggest group involving curricular implementation and teaching and learning as a whole. PBL as a pedagogical approach to improving teaching and

learning can be interpreted from either the teacher or students' perspectives (Dahlgren, Castensson, & Dahlgren, 1998). Using the student-centred strategy or teaching method (Hoffman & Ritchie, 1997; Wood, 2008), the teacher and students collaborate in multi-disciplinary curriculum to work on problems enabling the applicable idea-integration. To view PBL from the perspective of pedagogy, problem design should respond to the intention of the course or learning goals (Jonassen & Hung, 2008; Sockalingam, Rotgans, & Schmidt's, 2011). Subject knowledge, ideally, should be applied to challenging problems to inspire proactive thinking (Mitchell, Canavan, & Smith, 2010), consistent with students' practical development. Mauffette, Kandlbinder, and Soucisse (2004) cogitate on group dynamics and suggest that interactions between problems and participants modify and change over time. Designing problems for future practice is to take the interplay between problems and the context including what they know, what they should know, who they are, and who they will be into account. It denotes that pedagogy contribute to the knowing, capability, and being evolution of students.

Table 2. Prompt two to develop critical thinking in PBL

Theme 2: Facilitation	*This theme refers to the teacher's or tutor's guidance to help students in the process.*
Ding (2016)	This study argues that it is wise for the tutor to help learners from heterogeneous groups reduce students' negative affections.
Khoiriyah, Roberts, Jorm and Van der Vleuten (2015)	This study focused on the correlation between self-directed and critical thinking and enhancing self-assessment by scaffolding.
Martyn, Terwijn, & Kek (2014)	This study revealed that aspects of the PBL approach to teaching influenced the approaches to learning and students' critical thinking readiness.
Oldenburg & Hung (2010)	Increased support and additional teaching presence designed carefully are needed to facilitate students in the learner-focused environment.
Papinczak, Tunny, & Young (2009)	They highlighted the need for tutors to regularly review the PBL tutorial processes and group dynamics.
Semerci (2006)	Students reflected that they expected something from the teacher and they were not used to studying for themselves.

Prompt Two: Facilitation

The teacher in PBL provides students with 'non-expert facilitation' enabling their appreciation of the nature of knowledge and the collaborative learning process (Mitchell, Canavan, & Smith, 2010, p. 594). A good teacher-facilitator is described as elastic, knowing how much they should intervene and keeping students' learning active by offering 'challenge and support' through learning partnerships (Baxter Magolda, 2004, p. 43). Different epistemological beliefs and conceptual understanding brought into the classroom suggest the requirement of flexibility and adjustment in the teacher's facilitation. Given that scaffolding does not necessarily leave every individual student feeling sustained, working with small-group students and observing their learning development may help the teacher reflect on how to proceed. The way students view knowledge and approach the knowing process can be affected in such a nurturing environment, although personal beliefs and attitudes are not easily altered (Sahin, 2010).

Table 3. Prompt three to develop critical thinking in PBL

Theme 3: Students	*This theme revolves around students' dispositions to activate self-directed learning.*
Asad, Iqbal, & Sabir (2015)	Students' self-directed learning and intrinsic motivation were enhanced; teamwork and critical thinking skills were particularly promoted.
Choi, Lindquist, &Song (2014)	Critical thinking was found positively associated with problem-solving and self-directed learning..
Dehkordi & Heydarnejad (2008)	In the PBL group, a positive learning attitude was observed and learning motivation was higher than in the traditional-based method.
Eren &Akinoglu (2013)	Total points of critical thinking dispositions of the PBL experiment group significantly increased compared to those of the control group.
Itatani, Nagata, Yanagihara, &Tabuchi (2017)	Using PBL could help students' active learning to resolve issues and improve communication.
Kong (2014)	Engaging students in interactive discussion, higher order critical thinking and knowledge application were acknowledged through student feedback.

Kumar & Refaei (2017)	PBL seemed to provide an engaging context for students to use the writing concepts of audience, purpose, content, and support.
Ozturk, Muslu, & Dicle (2008)	The active self-directed nature of PBL encouraged students to think critically, be tolerant of the ideas of others and evaluate conflicting information.
Yu, Zhang, Xu, Wu, & Wang (2013)	PBL significantly enhanced nursing students' critical thinking dispositions given that pronounced differences in overall posttest scores were found between PBL and lecture-based learning groups.

Prompt Three: Students

Apart from the teacher's assistance, another way to make students feel supported comes from their peers because in PBL, they learn to be their own masters. Engagement in collaborative learning with peers involves the identification of problems, searching and evaluating information, integrating for decision-making, and reflecting on the process. PBL forces students into 'unfamiliar territory' (Downing, Kwong, Chan, Lam, & Downing, 2009, p. 620) in which the learning stress can be 'buffered by the support of the small group' (Lam, 2004, p.381). The value of peers' work lies in exchange and communication of a diversity of opinions, promoting idea-negotiation in a social context. Much of the research has affirmed the advantages of group work, future research needs to consider the impact on cognitive development for less participating learners.This issue may be related to personal attitudes or dispositions. The willingness points to a real commitment to PBL activating development and transforming identity in learning.

DISCUSSION: PBL AS A PROPELLER FOR CRTICAL THINKING THRESHOLD CONCEPT DEVELOPMENT

PBL is purported to establish a link between theory and practice. Through working on problem scenarios, students work with the teacher and peers for the resolution of the problem. The application of knowledge in the learning expedition gives rise to students' capability development along with their epistemological and ontological independence because of metacognitive activities involved. Pedagogy triggers practice buckled into all three dimensions. The teacher's facilitation tends to contribute to students' epistemological development, whereas students need to helm their learning, transforming their being. Critical thinking requires the integration of the three dimensions to pass the threshold.

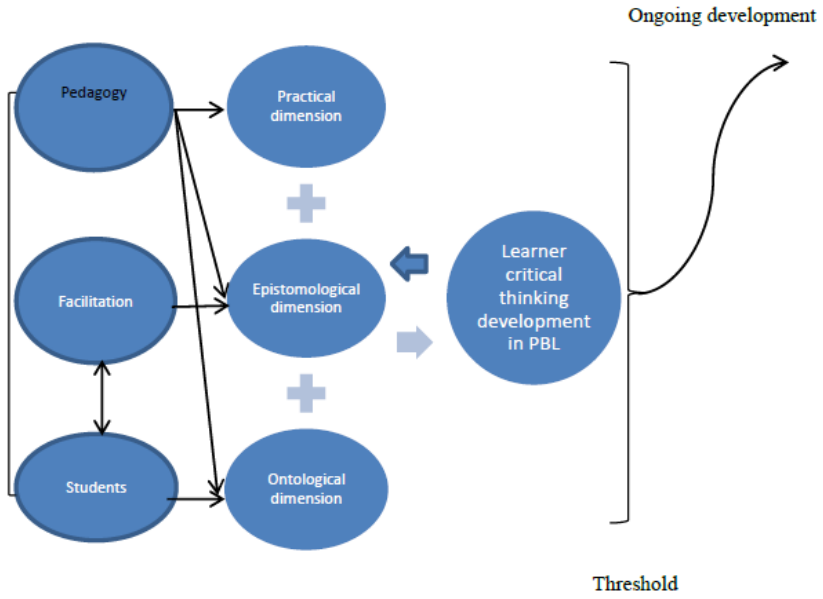

Figure 2. PBL for critical thinking threshold concept development

PBL for critical thinking threshold concept development is sensitive to the cultivation of 'the whole person's way of being in the world' against unforeseen challenges and problems (Mentkowsi et al., 2000, p. 105). Critical thinking as a multifaceted threshold concept in PBL resonates with 'threshold concepts as a pedagogy of uncertainty' (Land, 2016) and pedagogy tolerating liminal uncertainty (Land, Rattray, & Vivian, 2014), lighting up the road to the threshold for further excursions.

CONCLUSION

This chapter has defined critical thinking as a 'multifaceted threshold concept' with generic principles underlying specific emphases applied in PBL across disciplines for integration. On the basis of transformative and troublesome threshold concepts, epistemological, ontological, and practical dimensions of critical thinking require PBL as a propeller to pass the gateway. A thematic synthesis of the PBL research on critical thinking identified the three forces as pedagogy responding to overall dimensions, facilitation linked to epistemological development, and students associated with ontological shifts. Though the elements in themes may be overlapping, it is useful to learn how PBL contributes to critical thinking threshold concept development in particular dimensions. The findings were confined to studies from specific database and period of publication. More systematic empirical research is then necessary.

Given the nature of multifaceted critical thinking as a concept towards capabilities, PBL promoting critical thinking threshold concept can be implemented across disciplines in response to the encouragement of interdisciplinary knowledge. Learning may progress or regress through colliding with contested views, and there may be discrepancies in students' epistemological, ontological, and practical development of critical thinking. Grounded on the conceptual model of critical thinking threshold concept development and PBL for the development, the PBL process is likened to a bouncing ball promoting two-way communication. To design a PBL curriculum includes reciprocal metacognitive activities taking the teacher and students as partners rather than merely a tutor and learners. The journey to critical thinking in the context of PBL can result in intrinsically transformation in knowing, capabilities and identity not for students but also for the teacher after solving conundrums one after another.

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