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## Problem-based Learning and Theories of Teaching and Learning in Health Professional Education

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### ABSTRACT

Although problem-based learning (PBL) has been linked to several theories of teaching and learning, how these theories are applied remains unclear. The objective of this paper is to explore how theories of teaching and learning relate to and can inform problem-based learning within health professional education programs. We conducted a scoping review on current theories of teaching and learning and considered their relevancy to the problem-based learning approach. The findings suggest that no single theory of teaching and learning can fully represent the complexity of learning in PBL. Recognizing the complexity of the PBL environment and the fluidity between theories of teaching and learning, we proposed eight principles from across 11 theories of teaching and learning that can inform how PBL is operationalised in university-based health professional education: 1) Adult learners are independent and self-directed; 2) Adult learners are goal oriented and internally motivated; 3) Learning is most effective when it is applicable to practice; 4) Cognitive processes support learning; 5) Learning is active and requires active engagement; 6) Interaction between learners supports learning; 7) Activation of prior knowledge and experience supports learning; and 8) Elaboration and reflection supports learning. These eight principles provide the foundation for curriculum design recommendations relevant to PBL within university-based education programs. Specifically, our findings suggest that active engagement and interactions should be encouraged, that students should be prompted to activate their prior knowledge and experiences, and that elaboration and reflection on learning is critical. The small group format of PBL can facilitate this engagement if students question each other, consider alternative perspectives, and are actively involved in setting learning objectives. Further research is needed to develop the empirical basis for these principles and examine if PBL is an effective approach for implementing these principles.

**Keywords:** Problem-based learning, theories of teaching and learning, health professional education, scoping review methodology, university-based learning

### Introduction

Problem-based learning (PBL) was developed within the medical program at McMaster University in the mid-1960s as an active learning approach to help students synthesise and integrate large quantities of information (Solomon, 2005). Subsequently, the PBL approach has become an accepted instructional approach (Saarinen-Rahiika & Binkley, 1998; Solomon, Binkley, & Stratford, 1996) and has been adopted by many health professional programs worldwide (Neville, 2009). The literature describes PBL in three ways: a process of inquiry, a learning-to-learn approach, and a method for acquiring new knowledge (Schmidt, van der Molen, Winkel, & Wijnen, 2009). It consists of the following elements: 1) small groups of students are presented with a scenario; 2) the instructor role transforms from *impartor of information to facilitator of learning*; 3) emphasis is on self-directed learning; and 4) students engage in a problem-solving process (Hmelo-Silver, 2004; Schmidt, Rotgans, & Yew, 2011; Solomon, 1994; Walsh, 2004).

PBL has been linked to several theories of teaching and learning. However, how these theories are applied in a PBL environment remains unclear. One theory alone may be insufficient to account for the complexities associated with PBL. In recent years, there have been several developments in theories of teaching and learning that have implications for PBL-based curricula. Developments in cognitive science and information processing, for example, have raised questions about the effectiveness of PBL in helping students acquire knowledge needed for practice (Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006). Different perspectives of cognition have been applied to experiential learning and adult education, including the role of reflection, working through conflict, situated learning, learning through action and interaction, and resistance of power (Fenwick, 2000; Eames & Cates, 2011). Some evidence highlights the effectiveness of providing students with opportunities for choice and encouraging students to accept responsibility for their learning (Albanese, 2000); However, other evidence suggests that more structure and guidance is needed to help novice learners understand and integrate complex information (Kirschner et al., 2006). Thus, there is little agreement about the most effective way to support and guide student learning.

Evidence suggests that learning improves when theories of teaching and learning are implemented (Bergman et al., 2013). There is a need to understand how PBL should be implemented, what kinds of learning outcomes can be supported by PBL, and strategies educators can use to support student learning (Hmelo-Silver et al., 2007). The objective of this paper is to review literature on

theories of teaching and learning associated with university-based adult learning and to describe if and how these theories relate to and can inform the PBL approach within university-based education programs.

## Methods

Using the methodology described by Arksey and O'Malley (2005), we conducted a scoping review of the literature on theories of teaching and learning associated with university-based adult education and their relevancy to PBL. Scoping review methodology involves mapping the literature to identify "the current state of understanding" (Anderson, Allen, Peckham, & Goodwin, 2008, p. 10) by summarizing its extent, range, and nature (Arksey & O'Malley, 2005; Levac, Colquhoun, & O'Brien, 2010). It consists of six main steps, as outlined in Table 1. We identified relevant articles published between 1995–2014 by searching three electronic health sciences databases (MEDLINE, CINAHL and EMBASE) and an education database (ERIC). We identified 11 theories of teaching and learning relevant to PBL (see Table 2). We used these theories and the terms "problem-based learning" or "medical/health professional education" as keywords in our search. We excluded articles that focused on student attributes or outcomes, and those that were not related to university education. These searches yielded 368 abstracts that addressed a theory or theories of teaching and learning and university-based education. The abstracts were reviewed by the first two authors and were included if they addressed a link between theory and university-based education. From this process we identified 137 articles for full-text review.

All five authors contributed to the study selection and charting processes (Arksey & O'Malley, 2005; Levac et al., 2010). We excluded articles about clinical education and focused on broad curriculum design in the university setting. We developed a charting grid to extract, organize, and synthesize relevant information from each article including: theory of teaching and learning addressed; key principles pertaining to the theory; relevance to PBL as interpreted by the reviewer; and, any supporting evidence. Opinion papers that did not draw on the available literature, or advanced a new perspective, were excluded. Decisions about including or excluding articles were discussed in team meetings. The first two authors reviewed all extraction grids. From this process, 60 relevant articles were included in the data charting.

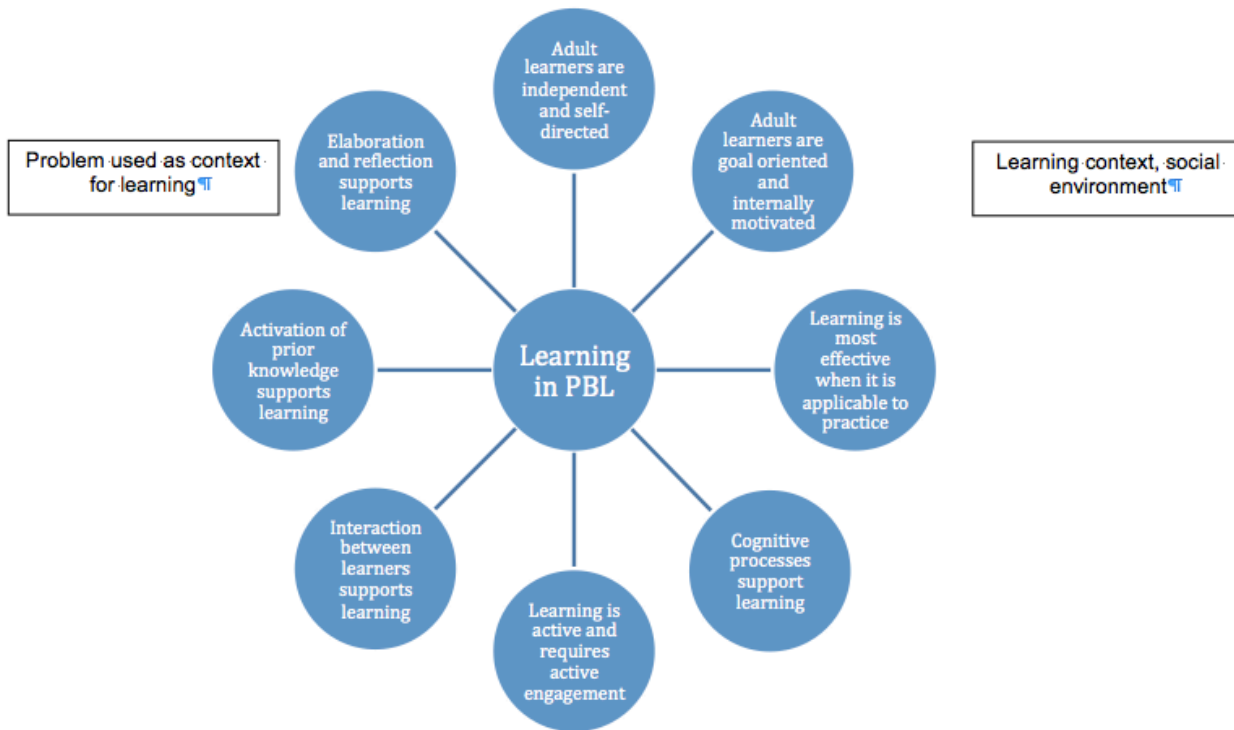
As we charted data from the articles, we also reviewed the theory descriptions offered by the original theorists to accurately describe each theory. There were overlap and commonalities between theories, making it hard to compare across theories. The principles of each theory were interpreted and described differently by different authors, and key principles were associated with more than one theory. For example, transformative learning theory (Kitchenham, 2008; Mezirow, 2003) was introduced as an adult learning theory (Knowles, 1990), described as "constructivist" (Forbes, Duke, & Prosser, 2001; Piaget & Inhelder, 1969; Vygotsky, 1962), and having much in common with experiential learning (Sewchuk, 2005). Consequently, we shifted our focus to the principles associated with the theories, and considered how these principles inform PBL. This focus provided a more fruitful way to synthesise the existing literature in order to develop recommendations for practice. Thus, we returned to the data extraction grids and identified eight distinct principles that emerged from our scope of the literature, crossed multiple theories of teaching and learning in university-based adult education, and were relevant for PBL in university-based education.

**Table 1:** Overview of the six-stage methodological framework for conducting a scoping study, as applied in this review (Arksey & O'Malley, 2005; Levac et al., 2010)

Stage	Description of Activities Completed
1. Identify the research question	"How can current theories of teaching and learning inform the PBL approach?"
2. Identify relevant studies	Searched four electronic databases (Medline, CINAHL, EMBASE and ERIC) Identified 368 abstracts for review
3. Study selection	Included articles that identify at least one theory of teaching and learning with implications to PBL Identified 137 articles for full-text review
4. Chart the data	Excluded articles that were not relevant to informing PBL within university-based health education Identified 60 articles for charting Developed a charting extraction grid to synthesize information
5. Collate, summarise, and report results	Identified eight principles from the articles
6. Stakeholder consultation	Not done formally Some discussion within the research team and our program curriculum committees about the relevancy of the findings to our PBL approach

**Findings**

The eight principles that emerged from our review of the literature on the theoretical foundations of PBL are presented in Figure 1. A key finding from our review was the significant overlap between theories of teaching and learning, and the undefined boundaries and connections between theories. Some theories have clear links to PBL and were explicitly noted in relation to PBL. While other theories have not been described in relation to PBL, they have potential applications and relevancies. We noted that adult learning and constructivist learning theories were most dominant and together captured the central elements of the eight principles that emerged. We also noted that there has been an increase in empirical studies related to theories of teaching and learning published in the last five years.



**Figure 1:** Eight principles associated with theories of teaching and learning that can inform PBL

**Principles that can inform PBL in health professional education**

We provide a brief overview of the eight principles based on the findings from the scoping review. The associated theories of teaching and learning are outlined in Table 2.

**Table 2:** Principles associated with theories of teaching and learning that can inform PBL

Theory	Key principles from the literature
<b>Constructivism</b>	<p>New knowledge is constructed based on prior knowledge and experience; activation of prior knowledge is an essential step in learning (Baker, 2000; Bergman et al., 2013; Chikotas, 2008; Mann, 2011; Taylor &amp; Hamdy, 2013; Terrell, 2006; Whitman, 1993).</p> <p>Learning comes from understanding interactions with the environment and alternative viewpoints (Baker, 2000; Chikotas, 2008; Dolmans, De Grave, Wolfhagen, &amp; Cp, 2005; Hean, Craddock, Hammick, &amp; Hammick, 2012; Hrynchak &amp; Batty, 2012; McCarlie &amp; Orr, 2010; Torre, Daley, Sebastian, &amp; Elnicki, 2006; Whitman, 1993).</p> <p>Cognitive conflict stimulates learning (Bergman et al., 2013; McCarlie &amp; Orr, 2010).</p> <p>Learning is active (Chikotas, 2008; Dolmans et al., 2005; Hrynchak &amp; Batty, 2012; Kantar, 2014; Mann, 2011; McCarlie &amp; Orr, 2010; Terrell, 2006; Torre et al., 2006).</p> <p>Knowledge retention is likely when a problem or scenario resembles real life (Bergman et al., 2013).</p>

Theory	Key principles from the literature
<b>Adult/Andragogy Learning</b>	<p>There are differences between novice and expert learners (Horii, 2007).</p> <p>Prior experience is an asset for the adult learner (Chikotas, 2008; David &amp; Patel, 1995; Horii, 2007; Merriam, 1996; Stagnaro-Green, 2004; Taylor &amp; Hamdy, 2013; Zigmont, Kappus, &amp; Sudikoff, 2011a, 2011b).</p> <p>Learning occurs in the context of the life stage of the adult learner and their readiness to learn (Kassirer, 2010; Merriam, 1996; Taylor &amp; Hamdy, 2013; Zigmont et al., 2011a, 2011b).</p> <p>The context, the tools available within that context, and social interactions with others are crucial to the nature of learning that takes place (David &amp; Patel, 1995; Horii, 2007; Kassirer, 2010; Merriam, 1996; Zigmont et al., 2011a).</p> <p>Learners must learn how to learn by being open to experience and change (Stagnaro-Green, 2004).</p> <p>Adult learners are autonomous, self-directed, goal-oriented, relevancy-oriented and internally motivated (Abela, 2009; Beckert, Wilkinson, &amp; Sainsbury, 2003; Bergman et al., 2013; Chikotas, 2008; David &amp; Patel, 1995; Hean et al., 2012; Merriam, 1996; Taylor &amp; Hamdy, 2013; Zigmont et al., 2011a, 2011b).</p> <p>Adults learn most efficiently through experiential techniques such as discussion or problem-solving (Stagnaro-Green, 2004; Taylor &amp; Hamdy, 2013).</p> <p>Learning is most effective when it is flexible (Beckert et al., 2003) and can be integrated into the demands of the learner's life (Abela, 2009; Hean et al., 2012).</p> <p>Adults are more interested in immediate problem-centered approaches (Abela, 2009; David &amp; Patel, 1995; Hean et al., 2012; Merriam, 1996) and application of learning to practice (Beckert et al., 2003).</p>
<b>Transformative/Emancipatory Learning</b>	<p>Learners develop their understanding of the world through their experiences (Kear, 2013; Parker &amp; Myrick, 2010; Williams, 2001).</p> <p>Learning involves revision or change to one's meaning scheme, frame of reference, perspective or worldview, and subsequent action (Jackson, Power, Sherwood, &amp; Geia, 2013; Parker &amp; Myrick, 2010). Learning is limited if assumptions are left unquestioned or unexamined (O'Connell, 2010).</p> <p>Learning is supported through critical reflection and stimulated by perceived discrepancies between learner's beliefs, values or assumptions and new information, knowledge and understanding (Eisen, 2001; Johnson, 2000; Kear, 2013; Mann, 2011; Milligan, 1999; O'Connell, 2010; Parker &amp; Myrick, 2010; Taylor &amp; Hamdy, 2013; Williams, 2001).</p> <p>Trusting relationships help learners validate their new perspectives and deal with discomfort inherent in change (Eisen, 2001).</p> <p>Transformative learning can be gradual with cumulative revisions to one's meaning schemes or frames of reference, or dramatic with respect to one's worldview (Yorks &amp; Sharoff, 2001).</p> <p>Learners become increasingly independent and autonomous thinkers (Johnson, 2000; Parker &amp; Myrick, 2010).</p>
<b>Experiential Learning</b>	<p>Draws heavily on Kolb's work which conceptualizes experience as the foundation and stimulus for learning (Maudsley &amp; Strivens, 2000; Poore et al., 2014; Shreeve, 2008).</p> <p>Highlights the need for different types of experiences (Potgieter, 1999) including concrete experience, observation and reflection, abstract conceptualization, and active experimentation (Lien &amp; Hakim, 2013; Mann, 2011; Poore, Cullen, Schaar, 2014; Zigmont et al., 2011a, 2011b).</p> <p>Learners take responsibility for their own learning and actively construct their experience (Shreeve, 2008; Zigmont et al., 2011a, 2011b).</p> <p>Learning is focused on process and experience, creating knowledge, addressing conflicting viewpoints and involves 'people-environment' transactions (Poore et al., 2014).</p> <p>Learning is a social and collective process that includes interactions and active engagement (Lien &amp; Hakim, 2013; Mann, 2011; Poore et al., 2014; Stegmann, Pilz, Siebeck, &amp; Fischer, 2012).</p>

Theory	Key principles from the literature
<b>Social Learning, including vicarious learning</b>	<p>Learning is supported by meta-cognition, modeling/observing others and feedback received from others (Bahn, 2001; Stegmann et al., 2012; Torre et al., 2006).</p> <p>Learning is self-directed and active (Bahn, 2001).</p> <p>Learning is supported by the experience of others (Roberts, 2010).</p> <p>Learning is a social and collective process that includes interactions and active engagement (Mann, 2011).</p>
<b>Information Processing</b>	<p>Learning is influenced by how the information is received (Rauk, 2003).</p> <p>What the learner does with the information affects the learning outcome and performance (Rauk, 2003).</p> <p>Learners are actively involved in the learning process (Rauk, 2003).</p> <p>Individuals can exercise control over what is learned (Rauk, 2003).</p> <p>Learning is a process of linking new information with prior knowledge and establishing meaning (Rauk, 2003; Torre et al., 2006). Students use knowledge they already possess to understand and structure new learning (Albanese, 2000).</p> <p>The more closely a situation in which something is learned resembles the situation in which it will be applied, the more likely it is that transfer of learning will occur (Albanese, 2000).</p> <p>Information will be better understood and remembered if there is opportunity for elaboration (Albanese, 2000).</p>
<b>Collaborative/Cooperative Learning</b>	<p>Learning requires active student involvement and group work (Copp, 2002; Lin, 2013).</p> <p>Individuals need to learn together; learning occurs through mutual interaction and shared understanding (Albanese, 2000; Bergman et al., 2013; Dolmans et al., 2005).</p> <p>Accepting responsibility for learning as an individual and as a member of a group enhances intellectual development (Copp, 2002).</p> <p>Articulating one's ideas in a small-group setting enhances a student's ability to reflect on his or her own assumptions and thought processes (Copp, 2002; Lin, 2013).</p> <p>Developing social and team skills through the give and take of consensus-building is a fundamental part of liberal education (Copp, 2002).</p> <p>Belonging to a small and supportive academic community increases student success and retention (Copp, 2002).</p> <p>Appreciating diversity is essential for the survival of a multicultural democracy (Copp, 2002).</p>
<b>Contextual Learning</b>	<p>Learners need to develop the ability to discern what is relevant and meaningful given the context of the situation (Forneris &amp; Peden-McAlpine, 2006).</p> <p>All learning is situated (Dolmans et al., 2005) and influenced by what the learner wants to learn (Forneris &amp; Peden-McAlpine, 2006).</p> <p>Problems presented in a professionally relevant context stimulate transfer of knowledge (Bergman et al., 2013).</p>
<b>Cognitive Load</b>	<p>Cognitive load is affected by the nature of the material and the strategies for information presentation (Khalil et al., 2005a, 2005b).</p> <p>Learning is promoted when learners engage in strategies such as elaboration, abstraction and drawing inferences (Khalil et al., 2005a, 2005b).</p> <p>Expertise develop as learners combine simple ideas into more complex ones (van Merriënboer &amp; Sweller, 2010).</p> <p>Novice and advanced learners require different learning strategies; Novice learners cannot always distinguish between important and unimportant information (Khalil et al., 2005b).</p> <p>Learning occurs best in an environment that takes into account the student's existing human cognitive architecture (Hessler &amp; Henderson, 2013).</p> <p>Learning interference is related to the amount of effort associated with thinking and reasoning (Kaylor, 2014; Pociask, DiZazzo-Miller, &amp; Samuel, 2013). Work should challenge learners but not exceed their capacity (Schumacher, Englander, &amp; Carraccio, 2013).</p>

Theory	Key principles from the literature
<b>Cognitive Learning</b>	<p>Focused on what the mind is doing during learning process, taking into account the learning context and implications of learning (Brandt, 1996).</p> <p>Personal mental frameworks, which are developed through years of experiences, influence perception and interpretation, and provides the vintage point through which learners understand situations (Brandt, 1996).</p> <p>Humans are more likely to learn when they are intellectually active and construct and assign meaning to events consistent with their mental frameworks (Brandt, 1996; Torre et al., 2006).</p> <p>Knowledge is made meaningful when it is learned in the situation in which it will ultimately be used (Brandt, 1996).</p> <p>Reflection, or thinking about thinking, is a key component of learning (Brandt, 1996).</p> <p>Humans reach a threshold for learning complex skills independently; novice learners may require expert guidance (Brandt, 1996).</p>
<b>Discovery Learning</b>	<p>Learning is active, builds on prior knowledge and can change attitudes and values (Svinicki, 1998).</p>

### 1. *Adult learners are independent and self-directed*

This principle is one of the central principles of andragogy (Abela, 2009; Beckert et al., 2003; Bergman et al., 2013; Chikotas, 2008; David & Patel, 1995; Hean et al., 2012; Merriam, 1996; Taylor & Hamdy, 2013). However, it is also addressed within transformative/emancipatory learning (Johnson, 2000; Parker & Myrick, 2010), social learning (Bahn, 2001), and cognitive learning theories (Brandt, 1996). Learners are thought to become increasingly independent and autonomous as they transition from novice to expert learners (Brandt, 1996; Johnson, 2000; Parker & Myrick, 2010), and become more self-directed (Bahn, 2001; Shreeve, 2008). Thus, learners are able to take responsibility for their learning and actively construct their experience (Copp, 2002; Shreeve, 2008). As they become more independent, they can better evaluate their own learning needs.

Although this principle is mentioned in several articles, the papers draw almost exclusively on theoretical evidence. For example, Schumacher et al. explored how theories of teaching and learning inform the development of master learners (Schumacher et al., 2013). These authors note that the motivation to learn is driven in part by a sense of autonomy and competence, as posited by self-determination theory. Within the context of the PBL tutorial, tutors can encourage students to be self-directed by inviting them to articulate the next steps in their learning and ensuring that their ideas are valued. Regular affirmative feedback can foster a sense of competence and create a safe environment for the provision of constructive feedback.

### 2. *Adult learners are goal-oriented and internally motivated*

Also consistent with andragogy, this principle was discussed in several articles (Abela, 2009; Beckert et al., 2003; Bergman et al., 2013; Chikotas, 2008; David & Patel, 1995; Hean et al., 2012; Merriam, 1996; Taylor & Hamdy, 2013; Zigmont et al., 2011a, 2011b). It suggests that adults are ready to learn when they experience the need to learn (Merriam, 1996; Stagnaro-Green, 2004; Taylor & Hamdy, 2013). Although all learning environments have extrinsic motivators (e.g. grades), the focus in andragogy is students' desire to acquire new knowledge. Some articles explicitly link PBL to self-directed learning and learning motivation (Mann, 2011; Taylor & Hamdy, 2013), suggesting that PBL tutorials can provide an ideal learning context to support student-directed learning.

While prominent in the andragogy literature, little empirical evidence is offered to support this principle. As an example of theoretical support, Stagnaro-Green (2004) reviewed the literature on adult learning principles in the context of medical education and highlights that time for self-reflection should be emphasised in order to stimulate self-directed goals and internal drive for learning. As an exception, Beckert et al. (2003) studied the effects of a voluntary, after-hours course designed in collaboration with medical students to address student identified study needs. In PBL tutorials, students identified learning objectives based on their learning needs. The findings highlight that student satisfaction with the course was high on value and relevance, and that performance on examinations was enhanced.

### 3. *Learning is most effective when it is applicable to practice*

This principle is consistent with andragogy and constructivism. Adult learners want to see a clear link between what they are learning and what they want to achieve in practice (Abela, 2009; Beckert et al., 2003; Bergman et al., 2013; Hean et al., 2012; Hrynchak & Batty, 2012; Merriam, 1996; Roloff, 2010). Kassirer (2010) states: "people learn new knowledge and skills most effectively when they are presented in the context of the application of new knowledge to real-life situations" (pp. 1118-1119). Hean et al. (2012) highlight that ensuring learning is relevant to practice should guide the selection of teaching and learning strategies.

Despite the lack of empirical evidence to support this principle, application to practice is addressed within PBL in health professional education. The PBL curriculum is planned around health care scenarios inspired by clinical situations. Learners are required to be explicit about their clinical reasoning and decision-making processes as they work through the scenario, explaining and providing rationale for what they would do if they encountered this situation in practice.

#### 4. *Cognitive processes support learning*

This principle is derived primarily from information processing and cognitive load theories. It is concerned with strategies for reducing cognitive overload and promoting knowledge acquisition (Kaylor, 2014; Khalil, Paas, Johnson, & Payer, 2005a, 2005b). Cognitive load is affected by the nature of the material and strategies for information presentation (Hessler & Henderson, 2013; Kaylor, 2014; Khalil et al., 2005a, 2005b; Pociask et al., 2013). Learning is promoted when learners engage in strategies such as elaboration, abstraction, drawing inferences and combining simple ideas into more complex ones (Khalil et al., 2005a, 2005b; van Merriënboer & Sweller, 2010). Cognitive demands should challenge, but not exceed cognitive capacity (Schumacher et al., 2013). Furthermore, Khalil et al. (2005a) noted that novice and advance learners require different learning strategies. Specifically, novice learners cannot always distinguish between important and irrelevant information. Thus, novice learners may need more guidance to identify critical information and develop focused learning objectives and plans.

Schumacher et al. (2013) argue that giving learners “an optimal amount of developmentally appropriate work” will avoid cognitive overload, which is detrimental to learning (p. 1637). This perspective is supported by Pociask et al., (2013) who examined the effectiveness of instruction designed to improve learning among occupational therapy students in a gait analysis course. Findings show that students receiving modified instruction aimed at reducing cognitive load without altering content or total instructional time, performed significantly better than the control group and reported significantly less instructional difficulty. Their study suggests that matching cognitive demands with the learners’ cognitive capabilities and adopting instructional approaches to reduce cognitive load can optimize learning.

#### 5. *Learning is active and requires active engagement*

This is a key principle of many learning theories including constructivism, experiential learning, social learning, information processing, collaborative/cooperative learning, cognitive learning and discovery learning. Active learning is considered fundamental to constructivism where learning involves a process of constructing knowledge, rather than acquiring it (Bergman et al., 2013; Brandt, 1996; Chikotas, 2008; Copp, 2002; Dolmans et al., 2005; Hrynchak & Batty, 2012; Mann, 2011; McCarlie & Orr, 2010; Terrell, 2006; Torre et al., 2006). This principle suggests that learners should have the opportunity to actively engage in the learning process (Rauk, 2003; Shreeve, 2008), work towards solving problems (Hrynchak & Batty, 2012; Lien & Hakim, 2013), discover new knowledge through active participation and cooperation (Lin, 2013), construct new knowledge in light of past experience or existing knowledge (Bergman et al., 2013; Mann, 2011), and hypothesise possible outcomes (Svinicki, 1998).

Although this principle is mentioned in several articles and is associated with multiple theories of teaching and learning, the papers draw almost exclusively on theoretical evidence. As an example, a review of the literature on PBL in nursing highlights the importance of constructivism and the need for active involvement of learners (Kantar, 2014). However, in a study conducted by Bergman et al. (2013), the findings highlight that active engagement in the learning process was one of the most preferred strategies among students in an anatomy course. Specifically, active engagement allowed for a more tailored learning experience, where students could progress at their own pace and create a personalized learning experience.

#### 6. *Interaction between learners supports learning*

This principle is explicitly identified within seven theories, including constructivism, adult learning theory, social learning, experiential learning, collaborative/cooperative learning, contextual learning and vicarious learning. It provides the basis for learning in small groups where discussion and debate occur (Albanese, 2000; Bergman et al., 2013; Copp, 2002; David & Patel, 1995; Dolmans et al., 2005; Horii, 2007; Hrynchak & Batty, 2012; Lin, 2013; Merriam, 1996; Rolloff, 2010). Learning is a collective and social process (Mann, 2011; Poore et al., 2014; Schmidt et al., 2011) where learners are encouraged to share knowledge and understanding, present and explore alternative perspectives, and explore the advantages and disadvantages of their perspectives (Baker, 2000; Chikotas, 2008; Dolmans et al., 2005; Jackson et al., 2013; McCarlie & Orr, 2010; Torre et al., 2006; Whitman, 1993). Working in a PBL context, learners support each other by identifying challenges related to the scenario, and clarifying concepts. Furthermore, learning is promoted through peer observation and feedback (Stegmann et al., 2012).

Lin (2013) compared the effect of technology-based cooperative learning with technology-based individual learning among nursing students. Although there were no significant differences in skill performance, cooperative learning led to improvements in critical thinking and knowledge enhancement. The authors suggest that encouraging students to work together and appreciate different perspectives through peer dialogue is critical to learning. Furthermore, Bergman et al (2013) found that students were more satisfied with a teaching method that relied on collaboration (in addition to other learning principles). Although not associated with strong empirical evidence, these findings suggest that interaction between learners is an important principle that can support learning.

#### 7. *Activation of prior knowledge and experience supports learning*

Although most widely associated with constructivism (Baker, 2000; Chikotas, 2008; Terrell, 2006; Whitman, 1993), activation of prior knowledge is implied by many theories of teaching and learning and is fundamental to information processing (Albanese, 2000; Rauk, 2003; Terrell, 2006). Learners build upon their existing knowledge and experience as they explore new areas and acquire new knowledge and skills (Bergman et al., 2013; Chikotas, 2008; David & Patel, 1995; Horii, 2007; Mann, 2011; Merriam, 1996; Poore et al., 2014; Schmidt et al., 2011; Stagnaro-Green, 2004; Svinicki, 1998; Taylor & Hamdy, 2013; Zigmont et al., 2011a, 2011b). Building on their existing knowledge allows learners to challenge their beliefs, values and understanding of the world, and consider alternative perspectives.

Although identified as a key learning principle, the supporting evidence is almost exclusively theoretical. As an exception, Bergman et al. (2013) found that students preferred a teaching format that stimulated them to build upon existing knowledge when learning anatomy in a PBL course. The pervasiveness of this principle within the literature suggests that the link between activating prior knowledge and ongoing learning is widely accepted. However, further study is required to build the empirical basis for this principle.

#### 8. *Elaboration and reflection supports learning*

Elaboration and reflection are key components of adult learning theories, providing opportunity for learners to analyze, synthesise and integrate newly acquired knowledge through application to a case scenario and to future practice (Albanese, 2000; Eisen, 2001; Johnson, 2000; Khalil et al., 2005a, 2005b; Milligan, 1999; O'Connell, 2010; Parker & Myrick, 2010; Williams, 2001). Learners can broaden their learning and take stock of the knowledge they have acquired by revisiting their learning objectives and reflecting on further learning needs (Bergman et al., 2013; Brandt, 1996; H. F. Hodges, 2011; Hrynychak & Batty, 2012; Schmidt et al., 2011). Other authors have highlighted the use of reflective journals (Lien & Hakim, 2013), peer observation with feedback (Mann, 2011; Stegmann et al., 2012) and debriefing (Poore et al., 2014; Zigmont et al., 2011a, 2011b) to provide a forum for elaboration on content, for enhanced learning.

Complexity science, within a PBL context, provides a framework for active learning and transformation by pushing students out of their comfort zones towards uncertainty (Fraser & Greenhalgh, 2001). It can specifically provide an approach that stimulates innovative problem solving by considering multiple questions and possible answers that vary under different conditions. As an example, H. F. Hodges (2011) conducted a pilot study of a PBL strategy guided by the principles of complexity science with nursing students. In this study, students were specifically prompted to elaborate and reflect on their learning and consider innovative problem solving to adapt to change and improve their performance. The findings revealed high levels of satisfaction among students, and stronger performance on the assignment. However, further study of the effects of elaboration and reflection are required in order to establish the empirical basis of this principle and its impact on learning.

### Discussion

Our findings highlight that no single theory of teaching and learning can fully represent the complexity of learning in PBL. Our review highlights the diversity within the literature in terms of how theories of teaching and learning are described and applied. These findings are consistent with the literature that has emphasised the need to draw on multiple theories of teaching and learning in university-based health professional education (Albanese, 2000; Bergman et al., 2013; Dolmans et al., 2005; Hean et al., 2012). Recognising the complexity of the PBL environment and the fluidity between theories of teaching and learning, we propose eight principles from across 11 theories that can inform how PBL is operationalised in university-based health professional education. These key principles have much theoretical support and some empirical support.

The principles expand on existing literature and allow for recommendations for curriculum design that are relevant to PBL and can be operationalised within university-based education programs (see Table 3). Specifically, our findings suggest that active engagement and interactions should be encouraged, that students should be prompted to activate their prior knowledge and experiences, and that elaboration and reflection on learning is critical. The small group format of PBL can facilitate this engagement if students question each other, consider alternative perspectives and are actively involved in setting learning objectives. Although these are common steps in the PBL process (Walsh, 2004), the findings presented here highlight and reinforce their importance. Furthermore, these principles could be of use to those charged with curriculum design within university-based education programs. Specifically, the principles can prompt reflection about how to promote active engagement, provide multiple opportunities for student interaction, encourage students to draw upon their prior knowledge and experience, and support elaboration and reflection on learning within university instructional design. A PBL model based on these principles, rather than on a single theory of teaching and learning, can contribute to building a collaborative partnership for learning within the small student group and between students and faculty. This collaborative partnership can support students as they develop their capacity to recognize the unknown, respond to the unpredictability of the discussion stimulated by the problem, and participate in the discovery process, thereby enhancing their ability to function in a clinical environment.

A limitation of this review is that we did not examine learning outcomes; therefore, we are unable to make any claims about the effectiveness of PBL for promoting learning or operationalising these principles. Rather, the findings provide indication of the theoretical basis of PBL and highlight several key components of the PBL process. Another limitation is that we restricted our review to teaching and learning theories; it can be argued that other theoretical frameworks could guide the operationalisation of PBL in health professional education, such as socio-cultural or bio-scientific theories. Furthermore, we excluded papers related to clinical education in order to focus on teaching and learning in the university environment, which limits the suggestions in Table 3 to the university environment. However, one of the principles that emerged from this research highlights that learning is most effective when it is applicable to practice. This finding suggests that the connection between classroom-based learning and real-world application should be made explicit (Eames & Cates, 2011). All eight principles outlined in our findings could be applied to clinical education. For example, the implication of the fourth principle (cognitive processes support learning) in a clinical setting would focus on offering learners the optimal exposure to developmentally appropriate work. Further research could explore the extent to which PBL principles are used in clinical education and if the application of these principles in clinical education enhances performance.



Although we did not include a formal approach to stakeholder consultation as the sixth step in the scoping review methodology, the authors of this paper are university-based educators in health professional programs that utilise PBL. We engaged in regular and ongoing team discussions about how the emerging findings resonated with our experiences as educators in PBL programs. Furthermore, we brought our findings to our respective curriculum committees for further discussion.

Our scope of the literature also revealed that educational research has evolved over the 20 years. Theories of teaching and learning are becoming increasingly prominent in the literature and referred to in discussions about approaches, methods and strategies for health professional education. Recent literature also contains more robust studies about teaching and learning in health professional education. This trend is promising. However, our findings emphasise the need for further research exploring the relationship between theories and learning outcomes. Further research could also be directed at examining the effectiveness of PBL as a method of implementing these key principles and promoting learning.

**Table 3:** Recommendations for PBL curriculum in health professional education based on eight principles of teaching and learning

Principle	Recommendations
Adult learners are independent and self-directed	<p>Include student-directed learning opportunities such as the establishment of personal learning objectives and identification of relevant learning strategies and resources.</p> <p>Allow opportunities for students to develop confidence in their own skills and knowledge by providing opportunities for self, peer and tutor feedback.</p> <p>Involve students in the development of the problems/scenarios, and/or offer choice in selecting the problems/scenarios that students will work on.</p>
Adult learners are goal-oriented and internally motivated	<p>Provide a rationale for the curriculum design, specifically the principles derived from teaching and learning theories.</p> <p>Derive learning goals and objectives from what students want to and need to learn within the context of the scenario or problem.</p> <p>Provide regular feedback to encourage self-assessment and self-reflection.</p>
Learning is most effective when it is applicable to practice	<p>Ask learners to verbalise their clinical reasoning and clinical decision-making processes, and consider what they would do if they encountered the scenario described in the problem.</p> <p>Facilitate a discussion about the relevance of the content and the learning process to clinical practice.</p>
Cognitive processes support learning	<p>Initiate explicit discussions with novice learners about their learning process, specifically differentiating between essential and non-essential information, low and high quality resources, and how to synthesise information in a meaningful way.</p> <p>Prompt learners in the upper years of a PBL curriculum to use strategies such as elaboration, abstraction and drawing inferences to support knowledge acquisition.</p> <p>Challenge learners in ways consistent with their level of study. For example, students entering a program should be presented with less complex scenarios.</p>
Learning is active and requires active engagement	<p>Evaluate students on the learning process in addition to content. This includes the ability to work with others, prepare and present their knowledge and reasoning and participate in formal self, peer and tutor evaluations.</p> <p>Students collectively set the agenda for class and are responsible for ensuring that each item on the agenda is met within the scheduled time. Tutors provide suggestions and encourage critical thinking as needed.</p>
Interaction between learners supports learning	<p>The PBL process should be based on active discussion and debate with the problem as the stimulus.</p> <p>Foster a culture of mutual respect and collaboration as the tutor and students share their strengths and limitations over time. Group members will then be able to identify how they can support one another in the learning process.</p> <p>Prompt learners to share their knowledge and experiences, explain concepts to each other and consider alternative viewpoints.</p>
Activation of prior knowledge and experience supports learning	<p>Encourage students to provide potential explanations for the problem by drawing on their prior knowledge and experience.</p> <p>When setting learning objectives, students should articulate their previous understanding and demonstrate how their learning objectives build on this learning.</p>

Principle	Recommendations
Elaboration and reflection supports learning	Elaboration and reflection on acquired knowledge and application of new learning to the problem being considered should be distinct steps and included in the PBL evaluation criteria.  Students should explain why the knowledge they obtain through their independent research is meaningful and applicable to the problem or scenario, as well as to their future practice as health professionals.

## Conclusions

Our scoping review suggests that PBL is grounded in key principles that are common to many theories of teaching and learning that can guide how PBL is implemented in university-based health professional programs. While it has been argued that health professional education should be based on theory and evidence, (Bordage, 2009), B.D. Hodges and Kuper (2012) suggest that theories are “dynamic, evolving and always at risk of being disproven” (p. 32). Our findings address both claims by suggesting that there is an emerging theoretical basis for PBL grounded in key principles that represent multiple theories of teaching and learning. The eight principles, derived from multiple theories of teaching and learning, provide guidance for how PBL can be implemented and operationalised within health professional education. Further work is needed to develop the empirical basis for these principles and examine if PBL is an effective means of implementing them within university-based education programs. Research is also needed to identify how other theories could, more broadly, inform PBL (B. D. Hodges & Kuper, 2012).

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