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Development and Validation of the Problem-based Learning Process Inventory (PBLPI)

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Abstract

The purpose of this study is to develop and validate an 18-item Problem-based Learning Process Inventory (PBLPI) for learning in this 21st century. Preservice teachers at the National Institute of Education (NIE) doing Educational Psychology are exposed to a Problem-Based Learning (PBL) environment. Findings from Exploratory Factor Analysis of 1,041 preservice teachers provided evidence for a three-factor solution – Problem Posing, Scaffolding and Connecting. Results from Confirmatory Factor Analysis of 1,029 preservice teachers provided additional support for the results obtained from Exploratory Factor Analysis. Moderate to high reliability coefficients for the PBLPI scores demonstrated PBLPI as a reliable and valid instrument to measure learners' perception of the key PBL processes.

Introduction

The 21st century is characterized by the accessibility of information, innovation-driven growth and rapid advancement in technologies. Education needs to change to help students cope with an increasingly complex world (Tan & Liu, 2015). It is not how much content we disseminate in the classroom that matters but rather the learning process that engages students' motivation and independent learning. More often than not, students have difficulty knowing what process to use or how to conceptualize problems or issues to be resolved (Bereiter & Scardamalia, 1989). Teachers need to design learning environments that allow students to experience and value learning processes such as initiating prior knowledge and elaboration, linking and applying new knowledge, justifying, evaluating and reflecting on their solutions. There must also be opportunities for students to solve problems together, learn from each other and build knowledge collaboratively as modelled against the real working environment. As mediators of students' learning, teachers' roles entail the teaching of heuristics, inquiry skills, scaffolding and connecting students not only to the milieu of knowledge in texts and online resources on the World Wide Web, but also through active communication and collaboration among themselves.

Problem-Based Learning (PBL) appears to be a promising approach to address the aforementioned issues holistically. It is a pedagogical innovation that harnesses and develops students' ability to deal with novelty and complexity as they engage in solving authentic problems (Tan, 2000, 2003). Through solving "real-life" problems, students are able to activate their prior knowledge, integrate their learning across different disciplines, and develop cognitive skills, attitudes and reflective practices that nurture them to be self-directed life-long learners in their profession practice.

Numerous studies have examined the theoretical promises of PBL, and its impact on learners' outcomes such as content knowledge acquisition, problem-solving skills, and attitudes towards learning. Meta-analysis on the effectiveness of PBL in medical schools (Albanese & Mitchell, 1993; Vernon and Blake, 1993) showed that learners who went through PBL viewed themselves as being more equipped with problem-solving, information gathering, reflective and self-directed learning skills. For teacher education, the PBL process of inquiry seemed to be able to develop preservice teachers' thinking skills, problem-solving skills, analytical skills, information processing skills and self-directed learning skills (Etherington, 2011; Koray, Presley, Koksal, & Ozdemir, 2008; McPhee, 2002).

Nonetheless, there were research studies that questioned the effectiveness of PBL. For instance, a review of literature by Colliver (2000) did not provide convincing evidence that PBL improved learners' knowledge or clinical performance. Similarly, Berkson (1993) argued that there was no significant difference in learners' outcomes between learners who went through PBL as compared to learners who went through the traditional courses. Hmelo-Silver (2004) mentioned that one of the aims of PBL was to enhance learners' motivation to learn but regrettably there was a lack of research that supported this viewpoint.

In spite of the substantial literature on PBL, its effects on gains in skills and knowledge as compared to more conventional approaches are inconclusive (Hmelo, Gotterer, & Bransford, 1997; Norman & Schmidt, 2000; Dunlap, 2005). A possible explanation for these contrary findings is the large number of "hybrids" PBL implementations due to the extensive use of PBL in various fields. Owing to the diversity of contexts and applications pertaining to PBL, previous studies on the "why" of PBL could not yield useful conceptualizations. Prior research treat PBL as a "whole intervention" and when studies show PBL intervention does not have a positive effect, some critics of PBL may simply conclude that "PBL does not work." Rather than be caught in the debate of the effectiveness of PBL, it is perhaps more meaningful to look into how PBL enhances learners' learning. Thus, instead of taking a broad stroke of PBL as a whole intervention, researchers should examine the contributing processes in PBL and how they support learners' learning (Albanese, 2000; Norman & Schmidt, 2000; Svinicki, 2007). Although a number of reviewed studies looked at different characteristics of PBL (e.g. Ge & Land, 2003; Sockalingam, Rotgans, & Schmidt, 2011; van Berkel & Schmidt, 2000), there is no established instrument that measures the component processes of PBL (Chua, 2013). The relationships between these contributing processes and learners' cognitive and affective measures can provide insights on how to scaffold and develop learners' cognitive, metacognitive skills, motivational orientations and self-efficacies to be effective problem-solvers, and self-directed, reflective learners.

Scale Construction of Problem-Based Learning Process Inventory (PBLPI)

In order to examine preservice teachers' perceptions of the key PBL processes, a self-report measure called the Problem-Based Learning Process Inventory (PBLPI) was designed. Conceptually, the identification of key PBL processes inherent in the Educational Psychology PBL environment at the National Institute of Education (NIE) was developed based on Tan's (2003) PBL schema and the principles of constructivist learning (Hendry & Murphy, 1995; Savery & Duffy, 2001; Schmidt, 1993). In this study, the psychometric properties of an initial conceptualisation of PBL processes with four components: problem posing (PP), scaffolding (SC), self-directed learning (SL) and collaborative learning (CL) were examined.

The initial development of the PBLPI items was practically informed by individuals whose expertise is in the field of PBL in the context of teacher education so as to ensure the content and face validity of the items. Items comprising the different subscales were specifically constructed based on (a) an understanding of the theoretical framework of constructivism and of Tan's (2003) PBL model, (b) reference to existing instruments that measure characteristics of PBL, (c) the suggestions of experienced professionals who have worked in the field of PBL or who have taught the core Educational Psychology course, and (d) an informed understanding of preservice teachers at NIE.

PP is a 4-item subscale that measures preservice teachers' perception of the problem scenarios in simulating interest and engagement of learning. Items in this subscale were specifically developed in the light of prior studies that measured problem-related characteristics in PBL (e.g., Sockalingam, Rotgans, & Schmidt, 2011; Soppe, et al., 2005; van Berkel & Schmidt, 2000). The key process of problem crafting and representation is crucial in enhancing learners' PBL experience and reaching the intended aims of nurturing critical and reflective thinkers, motivated self-directed learners, and active collaborators.

SC is an 8-item subscale that measures preservice teachers' perceptions on the structuring and the use of portfolios in facilitating preservice teachers' problem-solving process in PBL. The portfolio is defined as the design and structure of the scaffolds used in a PBL environment to facilitate preservice teachers' learning. Items comprising this subscale were devised in view of the existing literature pertaining to the role of scaffolding in PBL (e.g., Liu, Liau & Tan, 2008; McNaught & Lam, 2004). From a constructivist viewpoint of learning, incorporating scaffolding mechanisms is important to facilitate learning. Scaffolding learning by structuring their tasks through question prompts, resources and templates at every stage of PBL can provide learners with the mental support and guidance needed to acquire the disciplinary thinking necessary in PBL inquiry and knowledge construction process. These scaffolds force learners to pay attention to important learning processes such as questioning assumptions, establishing facts, articulating explanations, organizing thoughts, and reflecting on their learning. Prior research in PBL have indicated that scaffolding indeed motivates the learners by providing structure that reduces task complexity and learners' frustration which in turn leads to better achievement (Hung, Bailey, & Jonassen, 2003; Smith & Cook, 2012; Sulaiman, Atan, Idrus, & Dzakiria, 2004).

SL is a 4-item subscale that examines individual preservice teacher's understanding of course materials and applicability of the PBL process. Items in this subscale were formulated based on advice from experienced PBL tutors at NIE who have found that theory-practice links are the key to enhancing understanding in individual preservice teachers. Self-directed learning is an important learning process in learners' PBL journey. In a constructivist PBL approach to learning, learners will need to tap on their prior knowledge and learning strategies, experience cognitive dissonance, determine the areas where there are knowledge gaps, and acquire new knowledge to apply to the problem before their engagement in collaborative learning (Charlin, Mann, & Hansen, 1998). After their collaborative knowledge building process, it is crucial that the learners internalize their learning not only in the area of content knowledge but also in seeing the applicability of the whole PBL process. Kelson and Distlehorst (2000) reiterated the need for students to grow individually as learners and problem solvers within their PBL groups. In an inquiry-based approach to learning, the ability of a learner to direct his/her learning would have an impact on his/her learning experience and ultimately the learning outcomes. Taken together, it is apparent that SL is another potential key learning process in PBL.

CL is a 3-item subscale that measures preservice teachers' group collaborative knowledge building through sharing and commitment in the PBL context. Items comprising this subscale were constructed based on prior studies that looked into collaboration as the key characteristic of PBL (Ge & & Land, 2003; Janssen et al., 2010). According to Bereiter and Scardamalia (2000), collaborative knowledge building is one of the distinct features in PBL. Learning within a knowledge-building community encourages learners to develop multiple perspectives, articulate their views, and negotiate and reflect on ideas, resulting in a flexible and comprehensive knowledge base (Sulaiman, Atan, Idrus, & Dzakiria, 2004). Learners' commitment to group learning facilitates the group's processing of new information and acquisition of new knowledge (Schmidt, DeVolder, De Grave, Moust, & Patel, 1989). Research findings point to the fact that the process of generating knowledge always entails a social component (Fuchs-Kittowski & Kohler, 2002), and this collaborative effort enhances learners' cognitive and metacognitive development and impact positively on their achievements (Barkley, Cross, & Major, 2005; Millis & Cottell, 1998; Newman, 2005). It is argued that successful collaborative learning supports and promotes not only development at the cognitive but also the motivational level. When working together in a PBL environment, learners are engaged in collaborative knowledge building. This decreases the cognitive demands on individual learners thereby reducing their anxiety and uncertainty. As a consequence, the learners are likely to have an increase in motivation and satisfaction with their learning process (Harasim, Hiltz, Teles, & Turoff, 1997).

This research focuses on the development and validation of an instrument to assess preservice teachers' perception of the key processes in a PBL environment. The main research question to be addressed in this study can be broken down into the following specific questions, (a) "What is the factor structure of the 19-item Problem-based Learning Process Inventory (PBLPI)?" (b) "Does this factor structure reflect the initial conceptualization of the four component processes in PBL namely PP, SC, SL, and CL? "The first study used Exploratory Factor Analysis (EFA) to assess the dimensionality of the factor structure of items developed to assess key PBL processes. Confirmatory factor analysis (CFA) was then used in the second study to verify (cross-validate) the factor structure of the measurement model of the PBLPI generated by means of EFA.

Study 1: Exploratory Factor Analysis (EFA)

Method

The purpose of Study 1 was to generate an initial pool of items for a scale to measure preservice teachers' perception of the key PBL processes as well as to conduct an EFA to assess the factor structure of the scale items. In addition, initial estimates of the internal consistency as well as *between-construct* validity of the PBLPI scores were examined. The *within-construct* validity of the PBLPI is a type of validity that concerns the internal structure and psychometric properties of an instrument and its subscales. Another type of construct validity refers to *between-construct* validity (Marsh & Hau, 2007; Marsh, Martin, & Hau, 2006; Martin, 2007; Martin, Green, Colmar, Liem, & Marsh, 2011) which concerns the extent to which a given measured construct is positively related to other constructs that are theoretically and conceptually compatible or congruent (e.g., mathematics self-efficacy and mathematics self-concept) or negatively related to other constructs that are theoretically and conceptually opposing or antithetical (e.g., mathematics self-efficacy and mathematics test anxiety). Results showing the expected positive and negative associations, respectively, between certain construct and other target constructs provide evidence of *concurrent* and *discriminant* validity, respectively (Marsh & Hau, 2007; Marsh et al., 2006; Martin, 2007; Martin et al., 2011).

Participants

The participants for Study 1 were 1,041 preservice teachers completing a core Educational Psychology course at NIE using the PBL approach for the Fall 2009 intake.

In this research, the PBL component was designed to last seven weeks out of the thirteen weeks of the Educational Psychology course. During the first session of PBL, preservice teachers were given an overview of PBL, its philosophy, objectives and evaluation process. The preservice teachers were then divided into groups of three to five and were presented with the problem scenario and the PBL portfolio. The PBL portfolio comprised a set of question prompts for each stage of the PBL cycle to initiate and sustain preservice teachers' inquiry process.

The participants consisted of 333 males, 662 females, and 46 preservice teachers who did not indicate their gender. The mean age was 25.6 (*SD* = 5.41).

Measures

PBLPL is the measure used for this study. In addition, the amotivation scale used to provide further evidence for the construct validity of PBLPI was adapted from the Academic Motivation Scale by Vallerand et al (1992). Learners are amotivated when they do not perceive contingencies between outcomes and their own actions. They are neither intrinsically motivated nor extrinsically motivated and experience feelings of incompetence and lack of control (Deci & Ryan, 1985). The measure consists of 3 items and a sample item reads "I do my work/reading in this course but I really do not know why."

Preservice teachers were asked to rate their agreement to each item on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree).

Procedure

Participants were required to give their informed consent before they could participate in the study. The purpose of the study was explained to the preservice teachers. Preservice teachers were told that participation in the survey was voluntary and that they were free to withdraw at any time. Questionnaires were administered in quiet classroom conditions in the presence of their tutors. When completing the questionnaire, participants were informed that there were no right or wrong answers. They were assured of the confidentiality of their responses, and were encouraged to ask questions if necessary.

Results

Exploratory Factor Analysis

Four factors, namely PP, SC, SL and CL, were initially conceptualized and proposed to represent the 19 PBLPI items. Prior to conducting EFA, two indicators were examined to determine whether the sample's responses were appropriate to be subjected to factor analysis. The Kaiser-Meyer-Olkin measure of sampling adequacy index was .95 and Bartlett's test of sphericity (χ^2=14392.72, df= 153, $p < .001$) was significant. This indicated that EFA was appropriate for use with the participants' responses to the PBLPI. EFA with oblique (i.e., promax) rotation was carried out on the 19 items using SPSS 18.0. Oblique rotation was performed as the factors were conceived to be correlated to each other (Thompson, 2004).

Consistent with the number of factors proposed to represent the 19 PBLPI items (see Appendix), the first EFA conducted aimed to evaluate the four-factor solution. The soundness of factor solutions, however, is determined by a number of parallel criteria including the screen test and eigenvalues greater than 1.00 (i.e., the KI criterion; Hayton, Allen, & Scarpello, 2004) and, equally important, conceptual soundness and theoretical importance of the extracted factors (Marsh & Hau, 2007). The results of this first EFA showed that the four-factor solution explained

76.26% of the variance in participants' responses to the PBLPI. Factor 1, with an eigenvalue of 9.42, comprised the eight SC items and explained 52.13% of the variance. Factor 2, with an eigenvalue of 2.21, comprised one SL item and three CL items and accounted for 12.29% of the variance. Factor 3, with an eigenvalue of 1.45, consisted of four PP items and explained 8.04% of the variance. Lastly, factor 4, with an eigenvalue of 0.65, comprised two SL items and accounted for 3.62% of the variance. Although the four conceptually proposed factors were more or less extracted, they were not found to be clear cut. Moreover, one SL item ("The PBL process encourages self-directed learning"), with factor loadings of <.23, poorly loaded onto all the factors. According to Stevens (1996) and Comrey and Lee (1992), items with factor loadings that are greater than .40 on the relevant factor and less than .40 on all other factors are considered substantively meaningful. Hence, this particular SL item was subsequently dropped from further analyses.

Given the less satisfactory results of the first EFA, another four-factor EFA was run with the remaining 18 items. This analysis showed that the four-factor solution was able to explain 77.11% of the variance in the participants' responses to the PBLPI. Unlike the first EFA, however, all items in this factor solution had a factor loading greater than .40 and no cross-loading greater than .40. Examination of the composition of items in the different factors showed that the analysis yielded a similar factor structure to the earlier one. More specifically, factor 1, with an eigenvalue of 8.92, comprised the eight SC items and explained 52.49% of the variance. Factor 2, with an eigenvalue of 2.14, comprised four PP items and accounted for 12.60% of the variance. Factor 3, with an eigenvalue of 1.40, consisted of three CL items and one SL item and explained 8.22% of the variance. Lastly, factor 4, with an eigenvalue of 0.65, comprised only two SL items and accounted for 3.80% of the variance. The findings that the fourth factor had an eigenvalue less than 1.00 and comprised only two items may suggest that the 18 PBLPI items may better be represented by a three-factor solution. Hence, the next analysis aimed to examine a three-factor EFA solution of the 18 PBLPI items.

The procedures resulted in an 18-item instrument that accounted for 71.81% of the variance in the participants' responses to the PBLPI. The factor pattern and factor loadings are presented in Table 1. Factor 1, which accounted for 51.26% of the variance and with an eigenvalue of 8.92, consisted of eight SC items and was therefore labeled **scaffolding** (SC). This factor contained items that measure preservice teachers' perception of the learning processes stimulated by helpfulness and clarity of the scaffold structure (inclusive of question prompts and deliverable cues at every PBL stage). Factor 2, which accounted for 12.80% of the variance and with an eigenvalue of 2.14, consisted of three CL items and three SL items. This second factor, labeled **connecting** (CO), contained items that reflect preservice teachers' perception of the connective processes that build new knowledge through individual and collective inquiries. The integration of the three SL and the three CL items as one factor was probably not too surprising as the collaboration emphasized in PBL provides individual members with opportunities to question, elaborate, negotiate, clarify, and evaluate each other's ideas which, in turn, help promote the self-construction of knowledge of individual members (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Pea, 1993; Sulaiman, et al., 2004). Lastly, Factor 3, which accounted for 7.75% of the variance and with an eigenvalue of 1.40, consisted of four PP items and was labeled as **problem posing** (PP). It contained items that evaluate preservice teachers' perception of the problem scenario in stimulating interest and student engagement. Taking this conceptual soundness and statistical consideration, the extracted factors are robust as they encompass three of the key PBL processes grounded on the characteristics of PBL and constructivism.

Table 1. Rotated Factor Pattern and Factor Loadings for PBLPI.

	Item	Factor Loadings		
		Factor 1 (SC)	**Factor 2 (CO)**	**Factor 3 (PP)**
1.	The PBL portfolio helped us learn how to solve problems in a systematic and effective way.	.92		
2.	The PBL portfolio helped us improve our problem-solving skills.	.91		
3.	The PBL portfolio helped scaffold the PBL process for us.	.90		
4.	The PBL portfolio helped navigate the PBL process systematically.	.89		
5.	Clear instructions were provided in the PBL portfolio so that we knew how to proceed and navigate.	.86		
6.	The questions in the PBL portfolio were useful to guide our discussions at each stage of the PBL process.	.82		
7.	The PBL portfolio helped us structure our learning.	.80		
8.	The aims of each stage in the PBL process were clearly spelt out in the PBL portfolio.	.74		
9.	My group members were able to share thoughts and opinions actively throughout the PBL project.		.93	
10.	My group was committed and actively involved in the PBL project.		.91	
11.	Interactions among my group members were facilitated by good communication among all.		.79	
12.	PBL helps me to apply knowledge to new situations to solve problems and to reach decisions.		.75	
13.	PBL is a good way to help student teachers understand the course materials.		.66	
14.	The PBL process allows me to approach the course materials from a more practical perspective, not just at a theoretical level.		.55	
15.	The PBL scenario called for integration of concepts and theories in teaching and learning.			.93
16.	The PBL scenario had real-world relevance.			.91
17.	The PBL scenario was complex enough to trigger curiosity and offer challenge.			.88
18.	The PBL scenario stimulated collaborative inquiry.			.82

Note: The portfolio is defined as the design and structure of the scaffolds used in PBL environment to facilitate preservice teachers' learning.

The means, standard deviations, zero-order correlations, and Cronbach's alpha for the three components of the PBLPI are reported in Table 2. The reliability alpha coefficients for SC, CO and PP were .95, .88 and .91, respectively. According to DeVellis (1991) and Weiner, Freedheim, Graham, & Naglieri (2003), an alpha of .60 and greater indicates acceptable levels of internal consistency.

Table 2. Factor Correlations, Means, Standard Deviations and Cronbach Alpha Coefficients for the Subscales of PBLPI.

	Subscale	1.	2.	M	SD	∝
1.	Scaffolding (SC)			3.38	.78	.95
2.	Connecting (CO)	.55		3.91	.63	.88
3.	Problem Posing (PP)	.54	.61	3.90	.70	.91

Note: All the correlations are significant at 0.001 level.

Further Evidence of Construct Validity of the PBLPI

Based on previous research, PBL was supposed to enhance learners' motivation and problem-solving skills. Learners who went through PBL and benefited from scaffolding had significantly higher problem-solving skills (Chen & Bradshaw, 2007) and were more motivated (Smith & Cook, 2012). Thus, the key PBL processes of PP, SC, and CO were predicted to be positively associated with preservice teachers' problem solving scores and negatively with preservice teachers' amotivation. Consistent with the prediction, these correlations showed that preservice teachers' scores of PP, SC and CO were positively correlated with problem solving scores and negatively correlated with amotivation. The inter-construct correlation coefficients are presented in Table 3. The effects for the positive correlations between PP, SC and CO scores with the problem solving score were large in magnitude (Cohen, 1988). On the other hand, preservice teachers' PP score, SC score and CO score were negatively correlated with the amotivation score with effects ranging from small to moderate. Taken together, these correlations provided evidence for concurrent and discriminant validity of the three PBLPI subscales (Marsh & Hau, 2007; Marsh et al., 2006; Martin, 2007; Martin et al., 2011) such that the PBLPI can be used in further studies and analyses with confidence.

Table 3. Factor Correlations for PP, SC, CO, Problem Solving and Amotivation.

	Subscale	1.	2.	3.	4.	5.
1.	Scaffolding (SC)	1				
2.	Connecting (CO)	.55	1			
3.	Problem Posing (PP)	.54	.61	1		
4.	Problem Solving	.41	.51	.50	1	
5.	Amotivation	-.18	-.29	-.31	-.24	1

Note: All the correlations are significant at 0.001 level.

Study 2: Confirmatory Factor Analysis

Method

Purpose

The purpose of Study 2 was to test the factor structure of the scores obtained from the 18-item PBLPI in Study 1, with an independent sample, through the use of Confirmatory Factor Analysis (CFA).

Participants

The participants for Study 2 consisted of 1,029 preservice teachers completing the same core

Educational Psychology course with the PBL approach for the Fall 2010 intake. The participants included 279 males, 571 females, and 179 preservice teachers who did not indicate their gender. The mean age of the sample was 24.7 (*SD* = 5.35).

Measures

The 18-item PBLPI derived in Study 1 was used.

Results

CFA was conducted to test the factor structure of the scores obtained from the 18-item PBLPI using AMOS 18 (Arbuckle, 2007). As reported above, the EFA yielded three major factors representing the three key PBL processes of PP, SC, and CO. Maximum likelihood estimation was used to estimate the CFA model in this study as it is regarded as a robust method for moderate to large sample sizes (Hoyle, 1995). Table 4 presents the means, standard deviations, zero-order correlations, and Cronbach's alpha for the three components of the PBLPI. The reliability coefficients for the three subscales, namely SC, CO and PP, were .94, .83 and .89 respectively, indicating good reliability. Figure 1 presents the factor structure of the hypothesised model. The CFA comprised a 3-factor model consisting of SC, CO and PP. Results showed that all the standardized factor loadings were statistically significant and substantial (>.59). It is stated that Root Mean Square Error of Approximation (RMSEA) with values around .05 demonstrate excellent fit (Browne & Cudeck, 1993; Brown, 2006; Marsh, Balla, & Hau, 1996), whereas Tucker Lewis Index (TLI) and Comparative Fit Index (CFI) values greater than .90 and .95 are taken as indicative of acceptable and excellent fit (Hu & Bentler, 1999; McDonald & Marsh, 1990). Thus, this model fits the data well (χ^2= 660.29, df=127, TLI=.94, CFI =.96, RMSEA = .06) and further affirmed the within-construct validity of the PBLPI. Furthermore, the good fit of this model provided the sound measurement basis for tests of substantive questions using the PBLPI in the subsequent studies. Table 5 shows the standardized parameter estimates in the three-factor PBLPI.

Table 4. Factor Correlations, Means, Standard Deviations and Cronbach Alpha Coefficients for the Subscales of PBLPI.

	Subscale	1.	2.	M	SD	∝
1.	Scaffolding (SC)			3.45	.70	.94
2.	Connecting (CO)	.51		3.84	.52	.83
3.	Problem Posing (PP)	.52	.65	3.90	.61	.89

Note: All the correlations are significant 0.001 level.

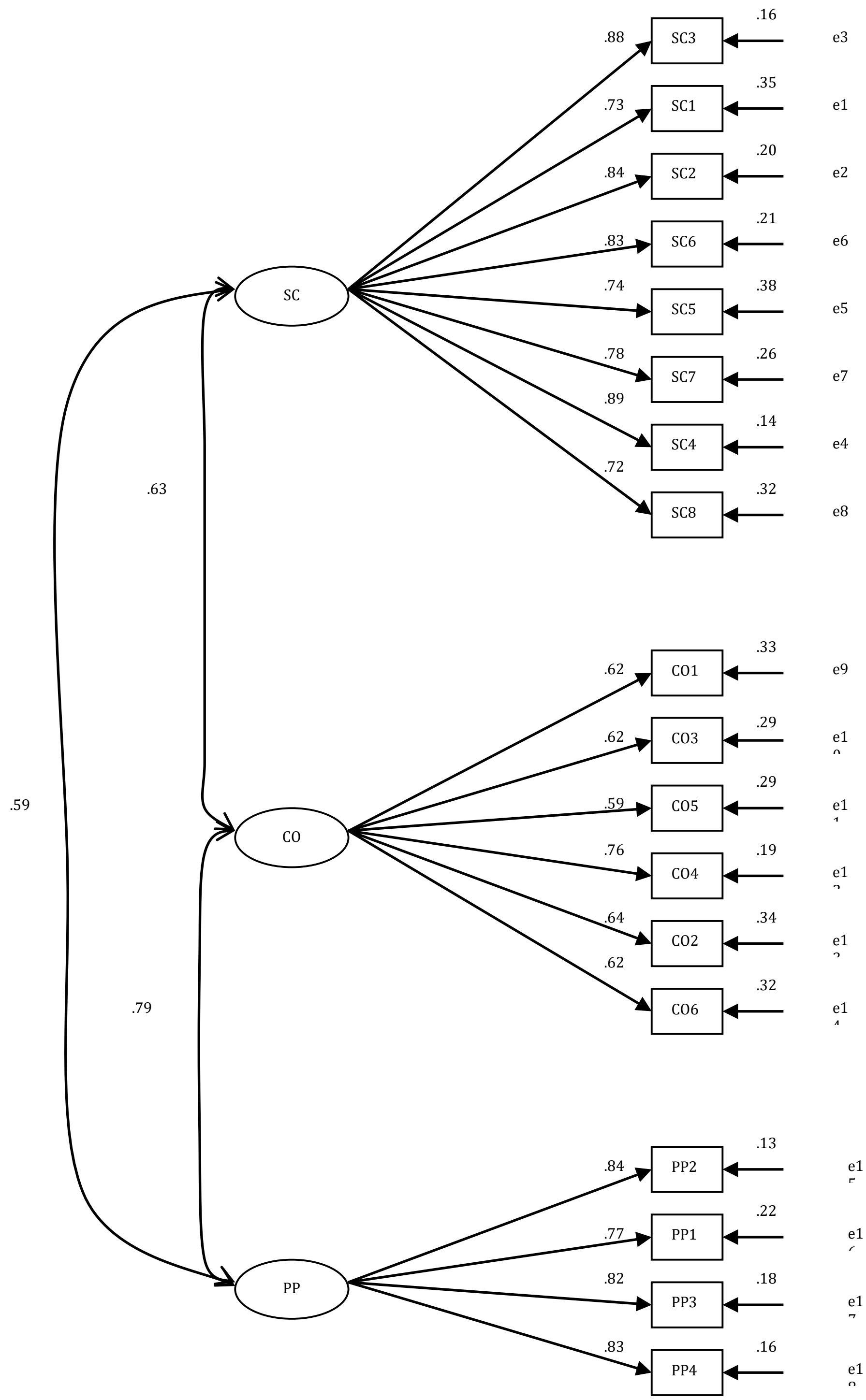

Figure 1. Standardized Estimates for the 3-factor, 18-item Problem-based Learning Process Inventory (PBLPI)

Note. e = error

Table 5. Measurement Model Standardized Factor Loadings in the Three-Factor PBLPI Using Data from PBL Approach for Fall 2010 intake.

	Item	**SC**	**CO**	**PP**
1.	The PBL portfolio helped us learn how to solve problems in a systematic and effective way.	.88		
2.	The PBL portfolio helped us improve our problem-solving skills.	.73		
3.	The PBL portfolio helped us scaffold the PBL process for us.	.84		
4.	The PBL portfolio helped us navigate the PBL process systematically.	.83		
5.	Clear instructions were provided in the PBL portfolio so that we knew how to proceed and navigate.	.74		
6.	The questions in the PBL portfolio were useful to guide our discussions at each stage of the PBL process.	.78		
7.	The PBL portfolio helped us structure our learning.	.89		
8.	The aims of each stage in the PBL process were clearly spelt out in the PBL portfolio.	.72		
9.	My group members were able to share thoughts and opinions actively throughout the PBL project.		.62	
10.	My group was committed and actively involved in the PBL project.		.62	
11.	Interactions among my group members were facilitated by good communication among all.		.59	
12.	PBL helps me to apply knowledge to new situations to solve problems and to reach decisions.		.76	
13.	PBL is a good way to help student teachers understand the course materials.		.64	
14.	The PBL process allows me to approach the course materials from a more practical perspective, not just at a theoretical level.		.62	
15.	The PBL scenario called for integration of concepts and theories in teaching and learning			.84
16.	The PBL scenario had real-world relevance.			.77
17.	The PBL scenario was complex enough to trigger curiosity and offer challenge.			.82
18.	The PBL scenario stimulated collaborative inquiry.			.83

Note. The portfolio is defined as the design and structure of the scaffolds used in PBL environment to facilitate preservice teachers' learning.

General Discussion

Two samples of preservice teachers doing an Educational Psychology course at NIE were involved in the study. EFA conducted with the first sample (N = 1,041) revealed that PBLPI had three distinct factors, namely, PP, SC and CO. This three-factor structure was confirmed via CFA with the second sample (N = 1,029). Multiple fit indices provided evidence that the three-factor model for the PBLPI had a good fit. Reliability estimates of internal consistency for the PBLPI subscales were acceptable.

The validation of these factors affirms that PBL is not a unitary process, but is made up of at least three distinct component processes. The development of the inventory provides researchers with a tool to study PBL in greater depth. Knowledge gleamed from such research will help practitioners understand where and how to improve the PBL cycle using targeted interventions.

From the theoretical perspective, the identification of the three PBL processes supports the accepted PBL schema (refer to Tan, 2003), and is in line with the underpinning theoretical framework of constructivism. It is also consistent with previous PBL literature. In this study, **Problem Posing** is identified as a distinct factor in the PBLPI. This underscores the notion that crafting and representation of the problem scenario is important and is a key process in PBL. From the pedagogical perspective, problem design affects participants' learning process and warrants careful consideration and planning (Sockalingam, et al., 2011; Sulaiman, et al., 2004). Previous studies have shown that the design of PBL problems affects the effectiveness of PBL courses and curricula (Duch, 2001; Trafton & Midgett, 2001). Cohen (1994) specifically pinpointed the nature of the instructional task as the key determinant behind the total amount of interaction within a group, and their subsequent achievement. Therefore, it should not be assumed that the use of any relevant problem scenario will elicit the intended problem-solving processes in PBL learners. The quality of the problem posed in PBL is pivotal in nurturing critical thinking skills, problem-solving skills, self-directed learning skills and promoting collaborative efforts (van Berkel & Schmidt, 2000; Jacobs, Dolmans, Wolfhagen, & Scherpbier, 2003; Moust, van Berkel, & Schmidt, 2005; Schmidt & Moust, 2000; Sockalingam, Rotgans, & Schmidt, 2011; Sockalingam & Schmidt, 2011; Weiss, 2003). Problems that are unstructured, complex and have practical relevance engage learners' interest and motivate them to probe deeper which allow knowledge acquisition and skill development (Boud & Feletti, 1991; Hmelo-Silver, 2004; Duch, Allen, & White, 1999). The unstructuredness of the tasks helps learners define the problem from their perspectives and promotes understanding to tease out the appropriate learning issues (Kahney, 1994). In this way, participants are motivated to learn as they own their learning through relating and constructing personal meaning within their individualized professional practice contexts throughout their problem-solving process (Wheeler, Kelly, & Gale, 2005). As such, it is imperative that our teacher educators maximize the authenticity of scenarios to best reflect realistic school contexts and real challenges in the classrooms.

In a PBL environment, solving rich, open-ended and complex tasks often impose heavy cognitive demands on the learners. Initially, learners may lack the reasoning, cognitive and metacognitive processes needed to engage in collective inquiry and problem-solving activities. As such, there is an immense need to support the development of inquiry skills, self-directed learning and problem solving in PBL. Thus, it is not surprising that **Scaffolding** was identified as a distinct process in this study. This purports the importance of providing certain structure and guidance to promote and sustain students' self-directed learning and problem-solving process (Barrows & Tamblyn, 1980). The process of scaffolding allows intentional instructional support such as metacognitive prompts and cognitive cues to facilitate learners' knowledge building processes (Scardamalia & Bereiter, 1994). In this study, the scaffolds included question prompts, cognitive and metacognitive cues, explanatory information, specific goals, templates and feedback at every stage of the PBL process. The questions facilitate the breaking down of an unstructured complex problem-solving process into a systematic and manageable learning process. The cognitive cues and templates help the preservice teachers navigate to prominent aspects of the problem, encourage deliberate effort to elaborate, explain, justify, reflect and evaluate their learning (Bransford & Stein, 1993; Ge & Land, 2003). Clear instructions, explanatory information, specific goals and feedback at each PBL stage help the preservice teachers plan, monitor and reflect on their thinking (Kuhn, 2005). Even though it is well established that scaffolding is an important PBL process, it is an ongoing challenge for PBL facilitators to design appropriate instructional support that allows quality intervention of learning either through human mediation or the support of technology. In view of the current findings, despite the challenges, it is worth investing resources in the development of good scaffolds and training of good facilitators.

Connecting is the third process identified through the PBLPI. Through this validation exercise, the initial conceptualization of two separate factors of Self-Directed Learning and Collaborative Learning merged into a single factor. A plausible explanation is that in practice, SL and CL are not distinctly demarcated as we would expect. Owing to the dialogue and influence of ideas gained in group or peer exchanges, the learners in a PBL environment may attribute more learning as being the result of interpersonal discussion rather from individual pursuit. Previous literature also support that learners appreciate collaborative over individual learning in a PBL environment (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006).

Regardless of the explanation for the finding, it is apparent that connecting is an important process in PBL. In such collaborative effort, learners question, elaborate, negotiate, validate and evaluate each other's ideas. They enhance their problem-solving and higher-order thinking, which in turn, promotes their co-construction of knowledge (Blumenfeld, et al., 1996). This collaborative effort helps to distribute the cognitive load among group members thus reducing the anxiety, uncertainty and stress learners experience when handling complex tasks (Pea, 1993; Sulaiman, et al., 2004). This reduction of anxiety and uncertainty motivates learners further in their learning (Harasim, Hiltz, Teles, & Turoff, 1997).

While collaborative knowledge building is an important characteristic of PBL, the process embedded in this key feature has not been empirically measured. In this research, it is validated through the merger of the two initial proposed factors (SL and CL); the process of collaborative knowledge building goes beyond the active sharing of thoughts and ideas through discussions and exchanges among committed members. It is about the connective processes of making meaningful links, applying and building this new knowledge through active sharing and contextualization. It involves both individualized and collaborative learning. The PBL process of connecting is catalytic in connecting learners to other people's perspectives, connecting through new and multiple perspectives, connecting to prior knowledge, connecting to new knowledge, connecting to context, connecting to meta-awareness, and thinking about how one is learning and changing.

By looking into the key processes that are embedded within the PBL environment, this present study provides further understanding of learners' perceptions of PBL in terms of the complexity, structuredness and quality of PBL problems (Jacobs, Dolmans, Wolfhagen, & Scherpbier, 2003; Sockalingam, Rotgans, & Schmidt, 2011) and characteristics of the PBL learning environment (Choo, Rotgans, Yew, & Schmidt, 2011; Senocak, 2009). The key processes of Problem Posing, Scaffolding and Connecting are anchored on the schema of PBL process and constructivism and strongly supported by prior PBL literature. Appropriate statistical procedures (both EFA and CFA approaches) supported the reliability and validity of the instrument. Therefore, educators and researchers in teacher education now have an instrument with which they can measure the processes–the "why" in PBL through the componential perspectives environments. For PBL researchers, viewing PBL and its componential processes together with the development of PBLPI will extend the possibilities of studying PBL and its processes. For PBL educators, the identification of these key processes using PBLPI would assist in the refinement or design of PBL environments. For example, environments that score lower in terms of scaffolding would indicate that improvements would have to be made in terms of the guidance and clarity of the scaffolds. A more in-depth analysis may allow educators to intuitively develop a sort of PBLPI profile that is associated with various types of learners. Most importantly, careful thought is needed by PBL course or curriculum designers to include features in their learning environments that will trigger these processes that impact the effectiveness of PBL.

Conclusion

In conclusion, the present investigation has presented initial evidence for the reliability and validity of the obtained scores from the 18-item PBLPI. PBL is a complex learning process and the possible existence of other key processes such as knowledge integration cannot be precluded. In addition, this research was positioned within the context of an Educational Psychology course at NIE. Thus, the generalizability of this research may be bound to the structure of the specific course. However, the identification of the key processes has its strong theoretical underpinning on Tan's (2003) PBL cycle which is consistent with PBL schema adopted by institutions worldwide. As we are in the initial stage of the instrument development, future research may address to the other aspects of construct validity, namely generalizability, external and consequential validity (Messick, 1995) and suggest possible refinement and validation of this instrument.

Nonetheless, this study has extended the current PBL literature which has limited existing studies that elucidate key processes that are inherent in a PBL environment within the context of teacher education. Thus, by addressing to the need to first develop a measure that assesses preservice teachers' perception of these key PBL processes, future research that looks into how key PBL processes influence learners' cognitive and motivational outcomes can be facilitated. Findings from these studies will then provide deeper insights into how existing PBL practices can be refined to optimize students' PBL experience and bring forth the intended learners' cognitive and motivational outcomes.

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Appendix

Proposed Items in PBLPI

Scales	Items
Problem Posing (PP)	1. The PBL scenario had real-world relevance
	2. The PBL scenario called for integration of concepts and theories in teaching and learning
	3. The PBL scenario was complex enough to trigger curiosity and offer challenge
	4. The PBL scenario stimulated collaborative inquiry
Scaffolding (SC)	1. The PBL portfolio helped us learn how to solve problems in a systematic and effective way
	2. The PBL portfolio helped us improve our problem-solving skills
	3. The PBL portfolio helped to scaffold the PBL process for us.
	4. The PBL portfolio helped us navigate the PBL process systematically
	5. Clear instructions were provided in the PBL portfolio so that we knew how to proceed and navigate
	6. The questions in the PBL portfolio were useful to guide our discussions at each stage of the PBL process
	7. The PBL portfolio helped us structure our learning
	8. The aims of each stage in the PBL process were clearly spelt out in the PBL portfolio.
Self-directed Learning (SL)	1. PBL helps me to apply knowledge to new situations to solve problems and to reach decisions
	2. PBL is a good way to help student teachers understand the course materials
	3. The PBL process allows me to approach the course materials from a more practical perspective not just at a theoretical level.
	4. The PBL process encourages self-directed learning.
Collaborative Learning (CL)	1. My group members were able to share thoughts and opinions actively throughout the PBL project.
	2. My group was committed and actively involved in the PBL project.
	3. Interactions among my group members were facilitated by good communication among all.