Journal of Research, Policy & Practice of Teachers &
Teacher Education
Vol. 4, No. 1, June 2014, 5-14

A review of the impact of PBL on pre-service teachers' Learning

Mohamad Termizi Borhan*
Sultan Idris Education University, Malaysia

Inspired by positive results of Problem Based Learning (PBL) implementation within an array of disciplines, PBL was also implemented in teacher education fields since 1980's. Since then, the literature of PBL implementation and its impact teacher education have been growing. However, there was no review work reported to conclude on how PBL impact specific learning outcomes in teacher education. Hence the aim of the paper was to review the research evidences concerning the impact of PBL implementation focusing on pre-service teachers´ knowledge and skills. Resources (journal articles and paper proceedings) were obtained from bibliographic databases and key research journals. The resources were chosen based on specific inclusion criteria, followed by a common review framework to ensure commonality and comprehensiveness during the review. The review works concluded that a PBL experience within teacher education provided opportunities for pre-service teachers to simultaneously acquire knowledge and to develop skills deemed important for the future teachers. This information is important to further refine PBL employment especially in teacher education, and to contemplate rooms for improvement, which will subsequently lead to an improved constructivism learning experience for pre-service teachers.

Keywords: Problem based learning; pre-service teacher; teacher education; knowledge; skills.

Introduction

Call for the excellence in teaching and learning in higher education and university graduates with skills and competences is inevitable due to the results of globalization. Pedagogical practices in higher education are rapidly urged to reflect these calls. Lecture-based pedagogy, which dominantly represents pedagogical practices in higher education is no longer sufficient to prepare such traits of graduates. Being at the frontline in preparing school teachers, teacher educators must continually seek better ways to strengthen their students´ (pre-service and in-service school teachers) knowledge, skills and dispositions in order to be successful in diverse classrooms. Goh (2011) laid out some key challenges faced

* Email: termizi@fsmt.upsi.edu.my
Currently a UNESCO Chair in Problem Based Learning, Department of Development and Planning, Aalborg University, Denmark.

by teacher educators to keep abreast with the recent standards of teacher education. In recent years, Problem Based Learning (PBL), a teaching and learning approach has become one of the promising innovations in higher education. Defining PBL might be a challenge since researchers define it differently to reflect the aims and objectives, context of the implementation, learning principles or PBL models. In their seminal work on PBL, de Graaff and Kolmos (2003, 2007) define PBL based on their analysis of the learning principles and across variety of PBL models. PBL definition provided by de Graaff and Kolmos (2003, 2007) can be divided into three approaches:

i. The **cognitive learning approach** means that *learning is organized around problem* and will be *carried out in projects*. The problem is the starting point of the learning process, place students to learn in context, and learning is based on students´ learning experiences.
ii. The **contents approach** concerns with *interdisciplinary learning* that involved divergent of the subject related boundaries and methods. The contents approach also emphasize on linking the theory and practice
iii. The **collaborative or social approach** involves *team-based learning* whereby learning occur through dialogue and communication between group members. Students learn from each other by sharing the knowledge and organizing the group learning process.

Since its inception about 40 years ago in a medical educational program at

McMasters University (Barrows, 1996), PBL has evolved in many institutions worldwide and extensively applied in myriad fields such a architecture, law and social work (Bould and Feletti, 1991) and professional education such as nursing, design, engineering, optometry, architecture, law and business (Chappel and Hager, 1995). The flexibility and diversity of PBL make it possible to be incorporated in different ways, in variety of subjects and disciplines and in various contexts (Savin-Baden, 2001). Biggs (1999) viewed PBL as a promising strategy to align university courses with the real life professional works students are expected to undertake after graduations. Given the perceived advantages of PBL in other fields, there would appear to be a good case for the introduction of this teaching and learning approach within teacher education. In fact, PBL approach has become the centre stage in teacher education since 1980s (Merseth, 1996).

PBL implementation in teacher education

In teacher education fields, PBL has been implemented in both graduate and undergraduate level and in variety of courses like Foundations of Education, Inclusion Classrooms, Elementary School Curriculum, Introductory Educational Psychology, Educational Research and Methods (Levin, 2001), and Science Education (Watters, 2007, Goodnough, 2003 and Peterson and Treagust, 2001). The drivers for PBL implementation in teacher education are varied from one case and another, but mostly devoted to better prepare the pre-service teachers to be more relevant in their future teaching professions. Issues such as diversity of students´ background, inclusive classrooms and ongoing development of technologies (Dean, 1998 and Goodnough, 2006) has changed teacher´s role in schools from merely imparting the knowledge to the one that inculcate creativity, intellectuality, problem solving ability and critical thinking skills among students. Beginning teachers need to be equip themselves with necessary skills, attitudes and disposition to correspond with the ever-changing and complexity of the school classrooms. A study by Lim et al. (2012) indicated that a major challenge to change student approach to learning is to change teachers´ perception of learning conception. In response to this call, PBL is seen as a platform to

enhance pre-service teachers´ acquisition of knowledge and skills, and to prepare them for varied roles of a teacher through PBL learning process that involves authentic PBL scenarios, group collaborations, authentic assessment and self-directed learning. Finkle and Torp (1995) described PBL as a curriculum development and instructional system that simultaneously develop both pre-service teachers´ problem solving strategies and skills by placing them in the active role of problem solvers confronted with an "ill-structured" problems that reflect real world problems. In similar arguments, De Simone (2008) suggests that a PBL problem scenario drawn from real-life problems could enhance pre-service teachers ability to define the problems, generate solutions, and application of practical and literature-based resources in search for problem`s solution. Research results from Watters (2007) concluded that PBL was effective in helping pre-service teachers to adopt a deep approach to learning and enhanced confidence to teach science in schools.

As a relatively new teaching and learning approach in teacher education, researchers of PBL in teacher education provides arguments on compatibility of PBL and teacher education. For example, McPhee (2002) suggests the teacher education itself should be seen in the frame of constructivism and devoted, but not limited to, child-centered perspective. A PBL problem scenario of *"an excel, highly motivated secondary school students with the sudden drop off of achievement, and change in behavior"* will serve the opportunity for pre-service teachers to explore interrelated issues like motivation, learning theories, learning behavior, and national standard and policy. Therefore, from a specific problem scenario, pre-service teachers will have the opportunity to experience interdisciplinary learning, which represent the central principles of PBL. Peterson and Treagust (2001) posit that the knowledge (content knowledge, curriculum and learners) integration and call to have lifelong learners in teacher education serves teacher education as appropriate for a PBL implementation. Levin (2001) provides an argument for the relevant of PBL application in teacher education course. The important to redesign an undergraduate teacher education course is to make learning more relevant and engaging, to help pre-service teachers perceived their profession as a true profession worthy of their intelligent and passion. Likewise, Dean (1999) seen PBL as an important vehicle to expose the pre-service teachers to the situation that they are likely to face as professional educators whilst simultaneously practicing a teaching and learning approach that encapsulates the central tenet of constructivism and social constructivism learning theory.

Review works of PBL implementations and its effects

Most of the review works to date are devoted for medical education (e.g. Albanese and Mitchell, 1993; Vernon and Blake, 1993; Norman and Schmidt, 2000; and Colliver, 2000) measuring the effectiveness of PBL approach over traditional or didactic methods. In general, these works concluded that PBL students perform better on clinical knowledge acquisition and skills, while their peers in conventional curriculum perform better on basic science knowledge acquisitions. Dochy's et al., (2003) meta-analysis and systematic review by van den Bossche et. al., (2000) on the effects of PBL concentrating on knowledge and skills across variety of fields further verified the above findings. Dochy et al., (2003) analyse 43 empirical studies on PBL in higher education articles and finding suggests a robust positive effects on students' skills albeit there is a tendency to negative effects when looking on the effect of PBL on the knowledge. van den Bossche´s et. al., (2000) systematic reviews yielded similar result pattern to affirmed PBL has positive effects on students' skills but negative effect on their knowledge. However, a literature review conducted by Colliver (2000) suggest a contradict results. The author found there was no substantial evidence that PBL improve neither knowledge nor clinical performance of students.

As far as can be determined, there are no review reports on the implementation of PBL in teacher education despite the growing number of PBL in teacher education literature. Reflecting on the cumulative empirical evidence on how PBL impact pre-service teachers´ knowledge and skills holds the potential to refine its employment, and contemplating any rooms of improvement, which will subsequently leading to an improved constructivism learning experience for pre-service teachers. In addition, this review works will contribute to the knowledge gap of the scarcity of PBL implementation in teacher education programme (Kwan, 2008 and Chappel and Hager, 1995). Therefore this article reports the findings from a review work of research evidence of PBL implementation in teacher education focusing on the knowledge and skills acquisitions of pre-service teachers.

Methods and procedures of review process

To begin the review process, the previous empirical research articles that serve as the data sources for the review purposes were search thoroughly to obtain most of the relevant empirical research articles, if it is not all. These empirical research articles were retrieved from several bibliographic databases for education and social science research such as Educational Resources Information Center (ERIC), British Educational Index, Web of Science (for Science Citation Index, Social Science Citation and Art and Humanities Citation Index), PsycINFO, key research journals (e.g. European Journal of Teacher Education and Asia Pacific Journal of Teacher Education) and searches in System for Information on Grey Literature in Europe (SIGLE) for grey literatures. Subject headings and keywords based on "problem based learning" were combined with "teacher education" and "pre-service teachers" produced number of titles. The periodic indices and content table of issues were search manually by reading the abstracts. To ensure a thorough and standard selection of articles, the study established a specific selection criterion to choose suitable articles for inclusion in the review process. The articles should present the empirical data of the PBL implementation in teacher education domain that may include educational research methodology, psychology in education, pedagogy, philosophy in education, teaching and learning approach in school and sociology in education. The next criterion is on the research variable measured. The variable should report on the impact of PBL on pre-service teachers´ knowledge and skills, regardless whether these are the main or complimentary variable measured in that study. Since PBL can be define from variety of perspectives, it is also essential to choose a specific PBL definition yet broad enough to represent the central concepts of PBL. Therefore, the study chooses widely-accepted de Graff and Kolmos (2003, 2007) definition of PBL. Table 1 summarizes the specific criteria for choosing the articles for review purposes:

Table 1. Four criteria to select articles for review process

Criteria		Description
i.	Type of studies:	Original and empirical studies with primary data
ii.	Focus:	Employment of PBL intervention in teacher education context
iii.	Scope of variable:	Mainly report on the participation of knowledge and skills of pre-service teachers after engaging learning through PBL
iv.	PBL characteristics:	Identification of types of intervention or learning environment which fulfill the PBL learning principles define by de Graaff and Kolmos (2003, 2007): i. The **cognitive learning approach** means that

learning is organized around problem and will be *carried out in projects*. The problem is the starting point of the learning process, place students to learn in context, and learning is based on students´ learning experiences.

ii. The **contents approach** concerns with *interdisciplinary learning* that involved divergent of the subject related boundaries and methods. The contents approach also emphasize on linking the theory and practice

iii. The **collaborative or social approach** involves *team-based learning* whereby learning occur through dialogue and communication between group members. Students learn from each other by sharing the knowledge and organizing the group learning process.

Upon completing the selection process, the snowball method was employed whereby the selected articles were fully read to identify of further relevant sources either in the content/ text or in bibliographic section of the articles. Rickinson (2001) posits this methods as a means to achieve comprehensiveness in a literature search, in which the search process is continuous until no new citations emerge. Following the selection criteria, each individual article underwent reviewing process to determine the impact of PBL on pre-service teachers´ knowledge and skills. To ensure commonality and comprehensiveness of review process, a review framework were established as depicted in Table 2:

Table 2. The review framework for selected articles

Component		Description
i.	Research aims	A summary of the aims of the research study as reported by the researcher in their article
ii.	Theoretical/conceptual approach	Summary of the key theoretical/conceptual assumptions that underpin the work reported (but only in so far as these are explicated and acknowledged by the authors)
iii.	Methodology	The broader epistemological and theoretical framework that surround and underpin the method of the study (only in so far as these are explicated and knowledge)
iv.	Validity measures	A value aim at measuring validity or reliability (howsoever conceived) that are reported by the author (s)
v.	Methods	Summarized detailed of the reported procedures of data collection and data analysis
vi.	Main findings	Summary of the study´s main findings as reported by the author
vii.	Key conclusions	Summary of the main conclusions drawn from the study´s findings by the author(s)

(derived after Rickinson (2003), pg.271)

The review process begins by reading briefly the selected articles based on the components as listed on the above table. *Research aims* of an article are a general description of what to achieve in the research. As for *theoretical/conceptual approach*, the key assumption of theory application or theory generation is the one that underpin PBL which including constructivism, active learning and social constructivism. To achieve what is claimed in the articles, the *methodology* should sufficiently explained the alignment between research approach, data collection and data analysis. To measure pre-service teachers´ knowledge and skills, the instrument or tool that used to collect the data should also discuss on the *validity measure* that may include Cronbach alpha for qualitative measure or validity value for quantitative measure. Entailing the validity measure description is *methods* whereby author explains on the procedure in collecting the data and the analysis approach that aligned with the aims of the research. Next is the *main findings* that reported on how the PBL implementation impact pre-service teachers´ knowledge and skills. Some articles might have other findings which are also helpful to understand more on the impact. Last component to review is the *key conclusions* that drawn from main findings that may also include implications and suggestions.

Results and discussions

Skills

It is widely enunciate that PBL fosters skills acquisition, development and improvement among the learners. As in teacher education field, the call for the pre-service teachers to develop and equip with critical and analytical abilities to deal with the complexities and diversities of their classroom is inevitable. Consonant to this calls, PBL is seen as a vehicle for skills inculcation since its emphasize active learning experiences that pre-service teachers engaged during their teaching preparation course. The first research evidence of skills acquisitions was from Edwards and Hammer (2004) in their research on pre-service teachers and change towards PBL. The authors concluded that the PBL approach is particularly suited for teacher education as it offers them the opportunity to acquire skills and theoretical content relevant to their future careers. Furthermore, pre-service teachers also associated the benefit of participating in a PBL scenario that deals with the realistic nature of the experience and saw the opportunity to develop skills considered to be necessary to them as future teachers.

De Simone (2008) measured pre-service teacher`s problem solving skills between experimental class (PBL approach) and control group (traditional approach). The author found out that experimental group exhibit better skills in constructing the central problem, elaborate the problem, connection between solution and problem and used of multiple resources. Similarly, Senocak et al., (2007) employed a quasi-experimental research design to compare pre-service science teachers´ achievement. Pre-service teachers were invited to evaluate their PBL learning experience on four different scales. The results indicated that PBL help them in developing variety of skills such as critical thinking, literature searching, self-directed learning and problem solving. These findings are supported by Taplin and Chan´s (2001) research outcome. The authors observed the development of skills and understanding of pre-service teachers as problem solvers. The use of journal entries and evaluation forms to probe pre-service teachers´ self-reflection as problem solvers and possible change in their thinking about teaching yielded mixed results. Although the pre-service teachers do not favour to tackle the pedagogical problems and reluctant to make their own decision to solve the problems presented, they showed ability to develop appropriate problem solving strategies skills and understanding in short time.

Murray-Harvey and Slee (2000) applied PBL in attempts to help pre-service teachers make connection and applying their online learning to life. To measure the impact of PBL, the authors used their feedback and peer reflection as the data resources. Evaluation of pre-service teachers´ responses showed their agreement that PBL process help developed their critical skills, reflective skills and skills needed by teaching professions. McPhee (2002) used pre-service teachers´ learning feedback and questionnaires to investigate their learning experience in issues-based learning in the classes. Pre-service teachers described the benefits of PBL as a ways to improve their skills in communication, team working and retrieving relevant information. Murray-Harvey et al., (2004) evaluate pre-service teachers´ assessment of their learning in PBL environment across four area of skills development: group processes, problem solving, knowledge building, and interpersonal skills through a self-rating questionnaire. To determine any growth of these competences between two case studies, the authors run a statistical test and found out that on all competences, pre-service teachers had a significant increment in their performances and skills across two case studies.

Knowledge

In documenting the research evidence of the impact of PBL on pre-service teachers´ knowledge, there are two categories of knowledge reported: Pedagogical Content Knowledge (PCK) and conceptual content knowledge. PCK is a notion coined by Shulman (1986) and is define as *"the most powerful analogies, illustrations, examples, explanations and demonstrations- in a word the ways of representing and formulating the subject, that make it comprehensible for others".* Despite criticism that PBL emphasize in higher order thinking and problem solving skills at the expense of low level knowledge acquisitions, there are some empirical research evidences to suggest PBL is also promote knowledge acquisitions.

Inspired by the limitation of science knowledge among pre-service teachers, Peterson and Treagust (1998) developed a PBL learning framework that address pre-service teachers´ knowledge base for teaching (science content knowledge, curriculum knowledge and knowledge of the learner) and pedagogical reasoning ability (comprehension, transformation, instruction, evaluation, reflection and new comprehension). Using case studies as way to elicit the impact of PBL, pre-service teachers have been reported to develop their knowledge base and pedagogical reasoning that correspond to their current belief in primary teaching and school student learning. So and Kim (2009) integrate PBL in information and communication technology (ICT) with the aim of better preparing future teachers of having pedagogically sound technology integration, or technological pedagogical content knowledge (TPCK). From the surveys and the lesson design artefacts, pre-service teachers has had understandings of pedagogical knowledge about PBL, despite reporting of having difficulty to crafting authentic and ill-structured problems and designing tasks with a balance between teacher guidance and student independence.

The concept of conceptual knowledge is defined as the amount and organization of subject matter knowledge held in the mind (Shulman, 1986). Askell-William et al., (2005) investigated pre-service teachers´ written reflection to elicit the changes in their mental model of teaching and learning following the experience of a PBL activity. Categories derived from pre-service teachers´ manuscript indicated that PBL process especially related to the case study expand their knowledge about factors influence child development. Kwan (2008) gauge learning experiences of pre-service teachers towards 3 modes of PBL delivery, namely Mode 1: The classical PBL, Mode 2: The Alternate PBL and Mode 3: The Modified Model. The findings revealed that both Mode 1 and Mode 3 were deemed feasible by pre-service teachers in constructing their knowledge because its require substantial mental

processes that lead to meaningful discussion (Mode 1), and they are able to cover broader perspective of factual knowledge within limited class time (Mode 3). In preparing future teachers for teaching with technology, Albion and Gibson (2000) combine an interactive multimedia (IMM) packages based on PBL principles to help pre-service teachers integrate technology in their teaching and learning sessions. Their evaluation of the approach elicited from a survey revealed that pre-service teachers gained insights and knowledge in technology, self- organization and classroom management.

Conclusions

Across an array of university courses and programme, PBL implementation in higher education is strive to forge the innovative pedagogical approach with the real world of professionals. In the current study, the general aim of PBL implementation in teacher education is to better prepare them with variety of school and classroom issues such as change in educational policy, use of technology in classroom, and diversity of the school students. The central tenets of PBL that highly emphasize the disciplinary knowledge integration and development of higher order thinking skills accelerate the merge between the desire to initiate new pedagogical practice in teacher education at one hand, and to equip pre-service teachers with knowledge, skills and dispositions on another. School-based assessment, inclusion of generic skills in school curriculum and shift toward outcome-based education are among the seminal issues that create a call to prepare teachers that both knowledgeable and skilful. From the collective empirical evidences of PBL impact of implementation on pre-service teachers´ skill and knowledge acquisitions, it is clear that PBL enhance their knowledge and skills. Current review works have shown that PBL appears to be appropriate in inculcating skills demanded in teaching profession such as information processing-related skills, critical thinking skills, self-directed learning skills, problem solving skills and social skills. Though PBL emphasize more on skills acquisition over knowledge, knowledge acquisition is seen as equally important as skills for the pre-service teachers. The review work also revealed that PBL address both pre-service teachers PCK and conceptual knowledge. Both type of knowledge are particularly important to acquire by pre-service teachers for them to be relevant in teaching professions. As Peterson and Treagust (1998) suggest, PBL in teacher education could converge in addressing the development of content knowledge and PCK, and the central characteristics of PBL problems could lead to the development of range of knowledge from curriculum knowledge to how children learn. These findings indicated that PBL is one of the most feasible teaching and learning approach in preparing our teachers for today´s schools. It is concluded that a PBL experience within teacher education facilitates pre-service teachers learning not only on the content level, but also on the methodological and behavioural level by providing skills to formulate and action teaching and skills. These skills will be required of school teachers when they are to be abreast with variety of school issues. Therefore, in effort to engage and retain the teachers for schools, improving teaching and learning strategy should be improved to strengthen their knowledge, skills and disposition and from this review work, PBL is one of the answers.

References

Albanese, M., and Mitchell, S. (1993). Problem-based learning: a review of literature on its outcomes and implementation issues. *Academic Medicine: Journal of the Association of American Medical Colleges, 68 (1),* 52-81.

Askell-William, H., Murray-Harvey, R., and Lawson, M. J. (2005). Extending teacher education students´ mental models of teaching and learning through Problem Based Learning. Paper presented at the 2005 Annual Conference of the Australian Association for Research in Education, Sydney, November 28th, 2005.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: a brief overview. In L. Wilkerson, and W. H. Gijselers (Eds.), *New direction for teaching and learning*, 68(3-11). San-Francisco: Jossey-Bass Publishers.

Biggs, J. (1999). Teaching for quality learning at university. Buckingham, UK. SRHE and Open UniPress.

Boud, D., and Feletti, G. (Eds.). (1991). *The challenges of problem-based learning*. New York: St. Martin´s Press.

Chappel, C. S., and Hager, P. (1995). Problem-based learning and competency development. *Australian Journal of Teacher Education*, 20, 1-7.

Colliver, J. (2000). Effectiveness of problem based learning curricula. *Academic Medicine, 75*, 259-266.

Dean, C. (1998). *PBL and meeting the challenges of teacher education*. Retrieved January 30, 2012, from http://www.samford.edu/pubs/pbl/pblins1.pdf.

Dean, C. D. (1999). Problem-based learning in teacher education. Paper presented at the Annual Meeting of the American Educational Research Association (Montreal, Quebec, Canada, April 19-23, 1999).

de Graaff, E. and Kolmos, A. (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education.* 19(5), 657-662.

de Graaff, E. and Kolmos, A. (2007). *Management of Change; Implementation of Problem-Based and Project-Based Learning in Engineering.* Rotterdam / Taipei: Sense Publishers.

De Simone, C. (2008). Problem-Based Learning: a framework for prospective teachers` pedagogical problem solving. *Teacher Development, 12*(3), 179-191.

Dochy, F., Segers, M., Van den Bossche, P. and Gijbels, D. (2003). Effects of problem-based learning: a meta-analysis. *Learning and Instruction, 13*, 533-568.

Edwards, S. & Hammer, M. (2004). Teacher education and Problem-Based Learning: Exploring the issues and identifying the benefits. Paper presented at the International Conference of the Australian Association for Research in Education. Melbourne, November.

Finkle, S. L., and Torp, L. L. (1995). Introductory Documents. Illinois Math and Science Academy. Aurora, Illinois.

Goh, P.S.C (2011). Improving teacher competence through the new Malaysian Teacher Standards: Exploring the challenges for teacher educators., Journal of Research Policy & Practice of Teachers & Teacher Education . 1(1), 88- 99.

Goodnough, K. (2003). Preparing pre-service science teachers: Can problem-based learning help? Paper Presented at the Annual Meeting of the American Educational Research Association (84th, Chicago, IL, April, 21-25, 2003).

Goodnough, K. (2006). Enhancing pedagogical content knowledge through self-study: an exploration of problem-based Learning. *Teaching in Higher Education, 11*(3), 301-318.

Kwan, T. Y. L. (2008). Student-teachers´ evaluation on the use of different modes of problem-based learning in teacher education. *Asia Pacific Journal of Teacher Education, 36*(4), 323-343.

Levin, B. B. (Eds.). (2001). *Energizing teacher education and professional development with problem-based learning*. Alexandria, VA: Association for Supervision and Curriculum Development.

Lim, C. H., Ratnavadivel, N., Yassin, M. S., Saad, N. S., Nagappan, R., Radzi, I. M. (2012). The challenge to transform learning: Changing teachers' theory of teaching. *Journal of Research, Policy & Practice of Teachers & Teacher Education , 2*(1), 6-15.

McPhee, A. (2002). Problem Based Learning in initial teacher education: taking the agenda forward. *Journal of Educational Enquiry, 3*(1), 60-78.

Merseth, K. K. (1996). Cases and case method in teacher education. In *Handbook of Research on Teacher Education*, ed. J. Sikula, 722-44. 2nd ed. New York: Macmillan.

Murray-Harvey, R. and Slee, P. (2000). Problem based learning in teacher education; Just the beginning. Paper presented at the annual conference of the Australian Association for Research in Education, Sydney, Australia, 4-6 December 2000.

Murray-Harvey, R. Curtis, D. D., Cattley, G., and Slee, P. (2004). Enhancing learners´generic skills through Problem-Based Learning. Paper presented for the annual conference of the Australian Association for Research in Education, Melbourne, Australia. November 28-December 2, 2004.

Norman, G. R., and Schmidt, H. G. (2000). Effectiveness of problem-based learning curricula: theory, practice and paper darts. *Medical Education, 34*, 721-728.

Peterson, R. F. and Treagust, D. F. (1998). Learning to teach primary science through problem-based learning. *Science Education, 82*, 215-237.

Peterson, R. F. and Treagust, D. F. (2001). A problem-based learning approach to science teacher preparation in D.R. Lavoie and W. –M. Roth (eds.) *Models of Science Teacher Preparation*, 49-66. Kluwer Academic Publishers. Netherlands.

Rickinson, M., (2003). Reviewing research evidence in environmental education: some methodological reflections and challenges. *Environmental Education Research, 9*(2), 257-271.

Rickinson, M., (2001). Learners and learning in environmental education: a critical review of evidence. *Environmental Education Research, 7*(3), 209-320.

Savin-Baden., M. (2001). The problem-based learning landscape. *Planet-Special Edition Two*, November 2001, 4-6. http://www.gees.ac.uk/planet/p4/msb.pdf

Senocak, E., Taskesenligil, Y. and Sozbilir, M. (2007). A study on teaching gases through problem-based learning. *Research in Science Education, 37*, 279-290.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

So, H., and Kim, B. (2009). Learning about problem based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology, 25*(1), 101-116.

Taplin, M. and Chan, C. (2001). Developing problem solving practitioners. *Journal of Mathematics Teacher Education, 4*, 285-304.

van den Bossche, P., Gijbels, D. and Dochy, F. (2000). *Does problem-based learning educate problem solvers? A meta analysis of the effects of problem-based learning.* Paper presented at the Seventh Annual EDINEB International Conference, Newport Beach, CA.

Vernon, D.T., and Blake, R. L., (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*(7), 550-563.

Watters, J. J. (2007). Problem-based learning in pre-service elementary science teacher education: Hostile territory. In proceedings *PBL conference in Problem-Based Learning in Undergraduate and Professional Education*, Birmingham, Alabama, USA.