PROBLEM-BASED LEARNING: THE FUTURE FRONTIERS

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Education is about equipping people with the cognitive and socio-emotional skills to be highly adaptable in fast-changing environments. In science and technology it is now well recognized that multi-disciplinary pursuits are essential for the advancement of knowledge and applications. Examples can be seen in areas such as biotechnology, telecommunications, material science, nanotechnology, and supercomputers. In industries and businesses, innovative advances are made often without the benefit of traditional paradigms of learning. The real world thrives on both evolutionary and revolutionary innovations. In recent years psychologists, sociologists, anthropologists and scientists from various fields have shed considerable light on the nature of creativity, innovation and enterprise. One thing is certain – teachers need to recognize changes in the nature of knowledge and the need for change in the nature of participation in the classroom. Education needs a new science of dealing with knowledge and a new art of learning. A futuristic perspective of Problem-based Learning (PBL) is to understand PBL in terms of strategic as well as innovative design of learning and the learning environment.

INTRODUCTION – PBL IN EDUCATION AND POSSIBLE EFFECTIVENESS

Problem-based Learning (PBL) is an active-learning and learner-centred approach where unstructured problems are used as the starting point and anchor for the inquiry and learning process. PBL is not just about problem-solving processes; it is a pedagogy based on constructivism in which realistic problems are used in conjunction with the design of a learning environment where inquiry activities, self-directed learning, information mining, dialogue, and collaborative problem-solving are incorporated (Tan, 2004a). In recent years, PBL has gained new momentum as a result of several developments such as increasing demand for bridging the gap between theory and practice, information accessibility and knowledge explosion, new

possibilities in the use of multidisciplinary problems, emphasis on real-world competencies, and developments in learning, psychology, and pedagogy.

PBL approaches in a curriculum usually include the following characteristics (Tan, 2003):

- The problem is the *starting point* of learning.
- The problem is usually a *real-world* problem that appears unstructured. If it is a simulated problem, it is meant to be as authentic as possible.
- The problem calls for *multiple perspectives*. The use of cross-disciplinary knowledge is a key feature in many PBL curricula. In any case, PBL encourages the solution of the problem by taking into consideration knowledge from various subjects and topics.
- The problem challenges students' current knowledge, attitudes and competencies, thus calling for identification of learning needs and *new areas of learning*.
- *Self-directed learning* is primary. Thus, students assume major responsibility for the acquisition of information and knowledge.
- *Harnessing of a variety of knowledge sources* and the use and evaluation of information resources are essential PBL processes.
- Learning is *collaborative, communicative and cooperative*. Students work in small groups with a high level of interaction for peer learning, peer teaching and group presentations.
- Development of *inquiry and problem-solving skills* is as important as content knowledge acquisition for the solution of the problem. The PBL tutor thus facilitates and coaches through questioning and cognitive coaching.
- Closure in the PBL process includes *synthesis and integration* of learning.
- PBL also concludes with an *evaluation and review* of the learner's experience and the learning processes.

The goals of PBL include content learning, acquisition of process skills and problem-solving skills, and life-long learning. PBL in education is more about the ability to be flexible in the use of one's knowledge base (Chung & Chow, 2004), building on prior knowledge and connecting this meaningfully to real life situations (Tan, 2003; Carder, Willingham & Bibb, 2001). Breton (1999) found that students were also able to relate theory to practice and developed greater ability to remember and re-use what they had learnt, in the case of PBL in accounting education. In nursing education, for example, prior knowledge was utilized in relation to the problem and was seen as beneficial as students became more confident and were able to use the knowledge gained for practice (Darvill, 2003). It has been found that by reflecting upon prior learning, students are able to analyse and synthesise the contextual information, acquire further knowledge and assimilate it into their existing knowledge base (Nelson *et al*., 2004).

In their meta-analysis, Dochy, Segers, Van den Bossche and Gijbels (2003) showed that PBL has a significant effect on the knowledge application skills of students. Tan (2003, 2004b) explained that through PBL cycles students learn to connect information to prior knowledge, prior experience, theory, new facts and ideas, other people's perspectives and the real world context. This develops their capacity to apply knowledge gained to a variety of problem situations. Major & Palmer (2001) found that students trained in PBL were more likely to use versatile and

meaningful approaches to studying, compared to non-PBL students.

The development of problem-solving skills and problem-solving acumen are important objectives in PBL. PBL develops problem-solving skills by enabling students to transfer the problem-solving strategies that were modelled for them in PBL to a similar problem on a related topic (Pedersen & Liu, 2002). Tan & Ee (2004) observed that cognition, metacognition and self-regulation characterize effective PBL. Chung & Chow (2004) found that PBL promotes the ability to apply appropriate meta-cognitive and reasoning strategies. In PBL students learn to critically question and draw their own conclusions (Nelson *et al*., 2004). Bechtel, Davidhizar & Bradshaw (1999) found that PBL is helpful in developing proficiency in problem-solving skills and overcoming the theory-practice gap. PBL also helps promote critical thinking (Weissinger, 2004; Cooke & Moyle, 2002). I would also like to point out that PBL provides a learning environment where cognitive immersion happens. Traditional approaches and didactics are not able to provide for opportunities of learning where intuition and insights can occur.

Morrison (2004) argues that PBL creates an intrinsic interest and enhances self-directed learning skills. Students develop strategies for coping with challenges to their self-efficacy and reflection on their learning and information-seeking strategies (Hmelo-Silver, 2004). As Tan (2003) noted PBL creates goal-direction. Goal mediation is also important to the PBL process (Tan, 2004b). Self-directed learners become proactive in achieving their goals, adapting their personal strategies according to the situational demands. According to Hmelo-Silver (2004) the more reflective learners became, the greater the likelihood that they were able to adapt their self-directed learning strategies. The strategies adopted interacted with students' previous learning knowledge, self-regulated strategies, self-efficacy and the features of the learning environment. Students were able to transfer hypothesis-driven strategies from problem solving into their self-directed learning as they planned their learning using their hypotheses.

Lee and Tan (2004) highlighted the advantages of collaborative and communicative inquiry in PBL. Explaining one's ideas is important for productive collaboration and also serves to enhance learning (Chung & Chow, 2004). Evidence appears to support the usefulness of PBL in encouraging students to learn to work as a group (Sharp & Primrose, 2003; Barrow *et al*., 2002; Shelton & Smith, 1998). Through group dynamics students learn to deal with dysfunctional aspects of a group and address them in a constructive manner (Sharp & Primrose, 2003). To become effective collaborators, students as team members learn to establish a common ground, resolve discrepancies, negotiate group action and develop consensus. These tasks require learning to dialogue, and transparency and openness in the exchange of ideas.

Many studies have shown that students enjoyed PBL and were very positive of its practical application (Sharp & Primrose, 2003; Price, 2000; Carey & Whittaker, 2002; Michel, Bischoff & Jakobs, 2002; Shelton & Smith, 1998). Baker (2000) found a decrease in learning-environment stress, increased student satisfaction and graduate satisfaction. In a number of studies students had higher satisfaction using PBL, with no negative effect on academic grades (e.g., Nalesnik, Heaton, Olsen, Haffner & Zahn, 2004; Michel *et al*., 2002).

Problem-based Learning architecture typically involves a shift in three loci of educational preoccupation, namely: content coverage to problem engagement, role of lecturing to role of coaching, and students as passive learners to students as active problem-solvers. Figure 1 illustrates the key components in PBL approaches.

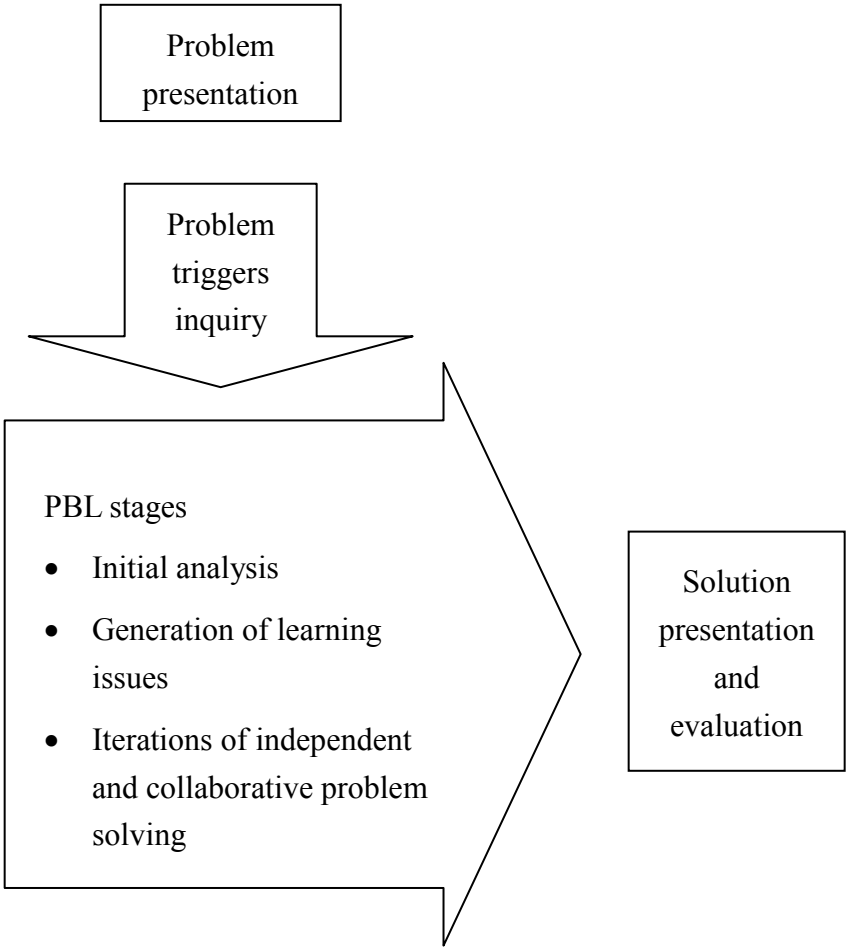

Figure 1: Components of the PBL approach
(Source: Tan, O.S. (2003, p. 32*). Problem-based Learning Innovation: Using problems to power learning in the 21st century*. Singapore: Thomson Learning)

Whilst PBL is a promising approach to educational innovation, implementation deficiencies often occur in problem design, facilitation processes and student readiness and preparation. PBL curricula also emphasize the acquisition of process skills, development of problem-solving skills, reflective and evaluative thinking (Tan & Ee, 2004). The hallmark of learning in all of these is the use of inquiry. There is however much development needed in this area of cognition in PBL.

LOOKING BACK TO LOOK FORWARD: INFUSION OR CONFUSION OF PROBLEMS

Whilst there are important challenges pertaining to dealing with change in any kind of educational innovation, I will not deal with these general issues of mindset changes. I assume that in most PBL implementations it is recognized that staff development and preparation of students are essential.

Confusion of goals for implementing PBL

The last thing one should do is to implement PBL because it is the latest fad in educational innovation. PBL implementation can happen at various levels, as illustrated in Figure 2. If you are in a position to influence major changes in your institution, you may advocate a change from the mega level, which entails a total revamp of curricula in terms of course structures, assessment structures and the design of the entire learning environment. It is, however, not always easy or necessary to implement PBL at this level, although there are newly established institutions that may be prepared to adopt such challenges, having been convinced of the potential benefits of using PBL approaches. Such implementation would require a great deal of planning, expertise and resources for it to be successful. One should be aware, however, that PBL is not a "one size fits all" methodology. It is more of a philosophy and approach that emphasizes the effective use of problems through an integrated approach of active and multidisciplinary learning. A review of the desired graduate profile of the programme, the nature of the disciplines, disciplinary goals, assessment criteria, current resources and the profile of students is essential to bring about the effective introduction of a PBL curriculum. With good planning, management support, resource allocation and staff development, PBL can become a predominant mode of learning supplemented by a range of good instructional methodologies (Tan, 2000a; Tan 2002). Many medical schools (Berkson, 1993; Norman & Schmidt, 2000; Nalesnik et.al., 2004) and several engineering programmes (Perrenet, Bouhuijs & Smits, 2000; Polanco, Calderon & Delgado, 2004) have successfully adopted PBL in their curricula.

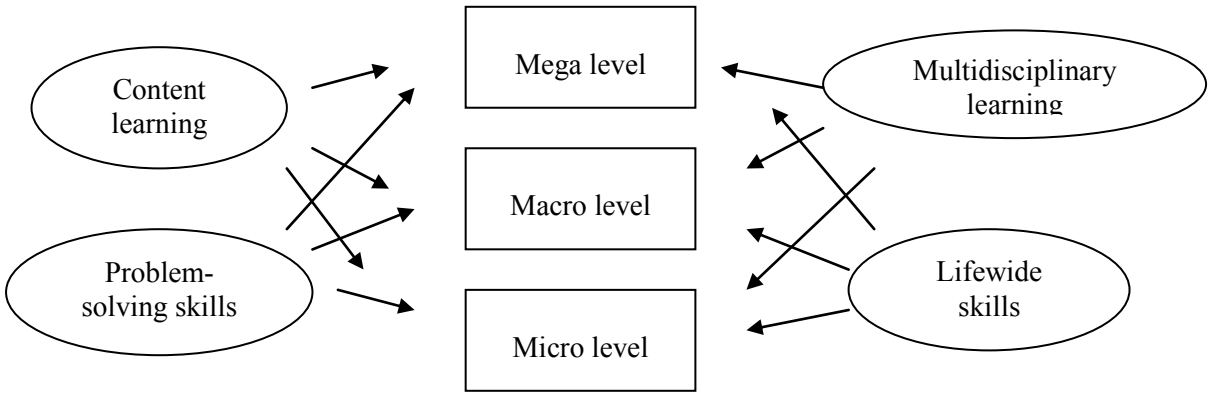

Figure 2. Infusing PBL approaches into the curriculum
(Source: Tan, O.S. (2003, p. 93). *Problem-based Learning Innovation: Using problems to power learning in the 21st century*. Singapore: Thomson Learning)

Although the benefits of PBL may be apparent, the practical conversion from a traditional curriculum to a PBL curriculum can be a daunting task owing to administrative and logistical considerations as well as the lack of resources. Therefore, introducing changes at the macro level is more common, where certain courses or modules adopt a PBL approach. Such hybrid approaches may in fact be a promising way to go, as observed by Armstrong (1991) and Marincovich (2000). Many high school and secondary school curricula are also restrained by limitations posed by national or state assessment systems and the academic requirements of college entry systems. The lack of curriculum flexibility will limit the ways in which PBL can be used. Nevertheless, there are hopeful signs of gradual change with the diversification of national assessment modes, and the PBL process will have an increasing role.

Teachers can begin at the micro level by using PBL in project work or in certain subjects. However, we do not want too much of the same thing, such as repeating the same emphasis of the PBL cycle in all courses. It may suffice to have a few courses or modules where generic problem-solving, collaborative learning and communication are emphasized through the use of PBL approaches. It would be overly repetitive if in every course students had to spend a large amount of time doing peer and group presentations. The key is to use PBL *strategically* and align the approach with desired educational outcomes.

I would next like to raise several specific issues and misconceptions in PBL. For convenience I will use the three foci described earlier to point out some common misconceptions that arise in PBL transitions and implementations.

Confusion pertaining to dealing with content

Firstly, in the name of changing student mindsets some PBL curricula are advocating inquiry in a vacuum where students do not have prerequisite foundations and basic tools of learning**.** Here I think there is a chasm between advocates of so-called "pure" or "authentic" PBL and the reality of students' experience (Tan, 2001). There are those who claim that PBL need not activate prior knowledge and that we could start with a problem from the onset in a domain totally unfamiliar to students. It appears that in practice there are many instances where such an assumption is questionable. There are disciplines and subjects where foundation knowledge is best disseminated first. Effective PBL entails the activation of prior knowledge. Examples of such prior knowledge would be foundation principles of Physics, Mathematical tools and so on. The axioms, language and tools of certain domains are examples of essential prior knowledge. Apart from foundational knowledge it is important ask to what extent the problem scenarios should build on and activate prior knowledge (Woods, 2000). There is no contradiction in teaching these things first. The research in the psychology of learning tells us that we should use a diversity of appropriate pedagogies for dealing with the acquisition of a variety of skills, knowledge and attitudes (Tan, Parsons, Hinson and Sardo-Brown, 2003). PBL is not an all-encompassing approach to learning.

Next, whilst PBL has often been advocated for the teaching of what I call lifewide skills (e.g., collaborative learning) it should be noted that disciplinary knowledge should never be

compromised. The "just-in-case" syndrome in traditional examination-based curricula tends to have too much coverage for the sake of comprehensiveness, i.e., just in case it may be required by the examination or a particular professional or accreditation body. Whilst we take a somewhat "just-in-time" model where we attempt to empower learners with skills of "learning how to learn" there is often a core-body of disciplinary knowledge that should be defined. The purpose of PBL here is to enable students to appreciate the depths of the inquiry often unique to the discipline.

Confusion pertaining to role of teacher

This brings me to the next point. It is unfortunate that some PBL advocates are saying that there is no need for content expertise. Some even claim that PBL can be facilitated by non-content experts so long as they are trained in PBL facilitation skills. I would argue that such assumptions are the surest way to prepare a generation of superficial learners. The acquisition of problem-solving skills, depth of disciplinary inquiry and discipline-related reasoning skills are of utmost importance for the challenges of the knowledge-based era. The use of PBL is often limited by inexperienced facilitators who do not have appropriate coaching skills, such as how to respond to questions, how to guide students through the PBL cycle and stages, use of resources and more open-ended solutions (Blackford & Street, 1999).

The role of the teacher as coach is to fulfill these tasks as cognitive and subject-disciplinary coaches (Tan, 2000b; Tan & Ee, 2004). In some PBL curricular, teachers are just playing the role of facilitating camaraderie and teamwork. If your goals for using PBL are simply to encourage team learning, that is fine, but I am sure for many educators PBL is about more serious business of learning. In short, the teacher as a coach needs process skills and disciplinary expertise. In fact, Barrow, Lyte and Butterworth (2002) observed that without tutor prompting, the use of prior knowledge may not be able to surface in the process.

I would just touch on one other point relating to the teacher's role. This relates to providing a closure for the PBL cycle. Whilst we advocate the idea that there is often more than one solution to allow for divergence and creativity, it is often necessary for the PBL tutor or co-ordinator to provide a proper closure by commenting on the quality of solutions presented and providing his/her perspective of the current-state-of-the-art. Too often things are left open-ended in the name of providing open-ended inquiry. Disciplinary expertise is required to help with a "helicopter view" of what kinds of solutions would be optimal vis-à-vis different problem contexts. Further thinking is encouraged where students reflect on how they might use their solutions should the problem scenario have other parameters or new elements.

Confusion pertaining to the learner

The last point pertains to the sense of empowerment or helplessness for the learner as active problem-solver. Firstly, the problem should be well-designed to provide context and meaningfulness, taking into consideration the background, needs and prior knowledge of the students. The purpose is to motivate and engage the student with problems. Too often problems presented are truly "ill-structured" with only a paragraph of scenario. Problems need to be well-

written although the issues are unstructured. Many times the real-world context presented is often unclear and "hypertexts" and further information are not thought through by the PBL teachers. In good problem designs various layers and hypertexts of information are available as students inquire, although not all of these may be made explicit initially. The structure of the PBL curricula should always be given. Students often prefer the traditional lecture approach over PBL as they are uncertain about what is required from them, and as a result become highly anxious (Green *et al*., 2004). Students also do not develop responsibility for their own learning easily (Shelton & Smith, 1998). It is thus important to prepare students for the PBL process by introducing the PBL cycle and associated learning strategies prior to its commencement. It is also important to remind students of the principles of PBL at every stage of the PBL programme (Biley, 1999).

Next, the tutor's role is that of an active facilitator of process. As a cognitive coach the tutor poses questions that probe students' thinking to develop their acumen in solving problems and critical thinking in that knowledge field. The teacher often needs to scaffold through a protocol of questions. In one of my research studies, I discovered a PBL class where students nicknamed their tutor "Mr. What Do You Think?". The reason is that the tutor's repertoire of questioning appeared to be only "What do you think?"

Last but not least the issue of self-directed learning is often taken for granted. Independent learning and self-regulated learning is a desirable outcome of education. In many PBL curricula self-directed learning is tantamount to students taking on the role of the teacher: the students determine the learning objectives, decide on probable resources, mine for information, plan the learning task and decide on depth of inquiry, monitor their own thinking and progress and peer-teach. Many times students are unsure if the learning objectives or issues they identified are appropriate and relevant. They can be totally unsure about what and where to start in terms of learning resources. They are also unsure about the scope of the topic in the particular discipline and may be totally unclear as to what keywords to use. Students may not be sure how to plan the learning task or how much to study, and often have limited time to read, reflect and achieve the depth of learning. Research in educational psychology tells us that feelings of competence, motivation and self-efficacy are often attained through appropriate scaffolding **(**Tan, Parsons, Hinson and Sardo-Brown, 2003). In many PBL curricula students are plunged into self-directed and self-regulated learning without appropriate mediation. This often resulted in unproductive use of time, unnecessary anxiety, loss of interest, helplessness and superficial learning. Students also end up producing mediocre work in their presentation. The lack of mediation and modeling of learning and inquiry may result in producing novice learners contracting the original goals of PBL.

THE FUTURE FRONTIERS

My observation is that whilst PBL is a useful innovation, PBL approaches should be underpinned by sound educational and cognitive psychology. One major reason for the PBL confusion is the failure to understand the psychological basis of learning when infusing Problem-based Learning approaches into the curriculum. More consideration and research should be done in these areas.

We need more informed knowledge on the developments in learning, psychology and pedagogy to refine the practical models of PBL.

PBL provides excellent opportunities for the application of psychology to education. In the last few decades the challenge of pedagogy has progressively changed, from making content knowledge visible to learners, by enhancing clarity of explanations and elucidating difficult terrains of knowledge, to making teachers' thinking visible through pedagogy that supports and models process skills, problem-solving skills, and thinking skills, and then to making students' thinking visible through design of learning environments and processes that enable students' ways of thinking and knowing to be manifested in active, collaborative, and self-regulated learning.

As noted by the National Research Council (1999) of the U.S. National Academy of Sciences:

> The quest to understand human learning has, in the past four decades, undergone dramatic change. Once a matter for philosophical argument, the workings of the mind and brain are now subject to powerful research tools. From that research, a science of learning is emerging (p. 5).

Advances in neuroscience and the advent of brain imaging technologies have contributed to our understanding of the brain and learning, while recent developments in psychology have led to better understanding of the psychological processes of learning, memory, and intelligence. A broadened conceptualization of intelligence and an emphasis on practical intelligence, problem-solving, and insightful thinking create opportunities for PBL models to be linked to some of these theoretical frameworks as well as applications. PBL provides possibilities of new ways of engaging the individual that can take into account "plasticity of development," individual differences, as well as problem-solving in cultural, community, and social environmental contexts.

The desired outcomes of education worldwide often include two indispensable qualities: the ability to be an independent, autonomous lifelong learner, and the exercise and harnessing of higher-order thinking. Two decades or so of research on teaching thinking points to a confluence of greater understanding of the individual as thinker and the importance of thinking about thinking, namely, metacognition (Ee, Chang & Tan, 2004). There are excellent opportunities for research findings on the incorporation of self-regulated learning and metacognition in pedagogy and learning to be applied in PBL environments.

Progress in cognitive science has given new support for the use of problems in learning. For example, seeing configurations (the whole is more than the sum of its parts), understanding perceptions, cognitive dissonance, problem solving, and insightful learning are important aspects of learning (Tan, 2004b). It can perhaps never be overemphasized that insightful, flexible, inventive, and breakthrough thinking develops best when people are immersed in solving a problem over an extended period of time. The pedagogy of PBL helps make visible or explicit the thinking as well as the richness of the cognitive structuring and processes involved. PBL can benefit from many recent studies in psychology, such as human tutoring (e.g., Chi *et al*., 2001),

how people evaluate information (e.g., Chin & Brewer, 2001), making hypotheses (e.g., Evans, Venn, & Feeney, 2002), reasoning (e.g., Manktelow, 1999), and insightful thinking (Sternberg, 1990; Sternberg & Davidson, 1995).

The psychological perspective is probably the best way forward for PBL practices. PBL models should be developed and rooted in research on understanding of cognitive functions, metacognition, cognitive coaching, and problem-solving (Gijselaers, 1996; Tan, 2004b). The other related area is understanding of the roles of emotion and interpersonal intelligence that underpin self-regulated learning and collaborative learning. Neuroscience and related research has provided new insights into the functioning of the "emotional" brain and the importance of emotion, such as learned optimism and resilience, in problem-solving. PBL can incorporate emphases of these specific developments, apart from general aspects of self-directed and collaborative learning.

Lastly, Internet technologies have opened up a myriad of new possibilities in the landscape of learning for a new generation of learners. The power of these technologies in advancing PBL remains largely untapped (Chen & Tan, 2002). There are abundant avenues for research and experimentation on instructional design in e-learning with PBL approaches. PBL projects such as those in USA where universities, schools and NASA collaborate are excellent examples (Grabowski et.al., 2004). There are many opportunities for the creative combination of face-to-face mediation, technological mediation, and e-learning.

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