Chapter 1:
Introduction

Problem-based learning or PBL in short, is an instructional approach that helps students develop flexible understanding and lifelong learning skills (Hmelo-Silver, 2004; Schmidt, Loyens, Van Gog, & Paas, 2007; Simons & Klein, 2007). In general, the main instructional material used in the PBL curriculum is the problem, which is designed to trigger learning at the start of the lesson. In the course of the PBL tutorial process, students are trained to collect information, analyse data, develop hypothesis, and apply strong deductive reasoning to the problem at hand (Barrows & Tamblyn, 1980; Hmelo-Silver, 1998; Schmidt, van der Molen, te Winkel & Wijnen, 2009). Throughout this process, learning supports (i.e. scaffolds) may be provided to students as form of guidance and assistance to their understanding of the problem or task assigned. Besides the problems, advocates of PBL do not forbid structured educational activities and guidance where appropriate (Brush & Saye, 2002; Ertmer & Simons, 2006; Simons & Klein, 2007; Taylor & Miflin,

2008). These additional sources of support include references, audiovisual aids and even lectures relevant to the problem.

The main focus of this thesis is about how scaffolds can be used to impact student learning in problem-based learning (PBL) environments. The studies presented in this thesis aim to provide more insights into the various types of learning supports that can be used in PBL to scaffold student learning, as well as investigate the impact of different types of scaffolds on students' learning. Based on the list of published literature studies related to PBL till date, it seems that the factors revolving around investigating effectiveness of the PBL tutorial process were emphasised, predominantly its social constructivism element which correlates to student learning. However research on the influence of different types of scaffolds on the PBL process and students' learning is relatively limited.

At the start of a PBL class, the first aspect of the curriculum that students come into contact would be the problem itself. After which, students are then expected to acquire knowledge relevant to the problem and suggest solutions to solve the problem statement.

Besides having experienced tutors around to facilitate this process of students transiting from 'fresh' to 'know-how' learners, there are certain concerns that educators may have in mind. "Is having the problem statement sufficient to guide the students right through the lesson today?", "Are there any other types of tools which can be utilized within the lesson to scaffold or maximize student learning for today's topic?", "Are we hindering the students' ability to think critically and creatively if more learning supports are provided?", "How can we administer various scaffolds within the PBL curriculum to ensure that students who are either academically weak and strong both benefit from the lessons?". This chapter provides an introduction of what is problem-based learning and a review of literature findings in relation to scaffolding in PBL, followed by an outline of the research questions of studies presented in this thesis. Lastly, an overview of the chapters will be given.

What is problem-based learning (PBL)?

PBL is essentially a learner-centred educational approach that allows learners to be actively involved throughout the problem-

solving process and by doing so, gain understanding of the concepts relevant to the subject matter (Barrows & Tamblyn, 1980; Ertmer & Glazewski, 2005; Hallinger, 2005). In PBL, learning is usually triggered by the problems which usually which consists of scenarios that require explanation (Khoo, 2003). Greening (1998) indicated that one of the desirable outcomes of PBL is to encourage deep learning in students. Previous studies conducted on this particular educational pedagogy revealed that students are likely to increase the use of meaningful approaches to relate to the task content, compared to reproductive approaches (Coles, 1985; Newble & Clarke, 1986). Furthermore, studies have demonstrated that PBL is effective in helping students acquire cognitive learning skills such as critical thinking (Hallinger, 2005; Hmelo-Silver, 2004; Schmidt, 1993; Schmidt, et al., 2007; Simons & Klein, 2007) as well as self-directed learning skills (Hmelo-Silver, 1998; Hmelo-Silver., 1998; Schmidt, et al., 2009; Simons & Klein, 2007).

The PBL tutorial process can be characterized as follows. First, students are presented with a problem. Next, the students form

small groups to discuss and analyze the information provided and then propose possible justifications for the phenomena (Norman & Schmidt, 1992). In order to encourage peer learning, the students are grouped into small PBL teams for further discussions on the problem. Throughout the discussion period, the student groups are guided by a tutor or facilitator, who is an expert learner and models good strategies for learning and thinking (Greening, 1998; Hmelo-Silver, 2004; Schmidt, et al., 2009). PBL essentially consists of three main phases - problem analysis, self-directed learning as well as a subsequent reporting phase (Barrows, 1988). As mentioned before, learning supports may be provided to students to scaffold their understanding of the problem or task assigned.

Scaffolding in problem-based learning

PBL is generally associated with social constructivism, whereby students are able to develop knowledge bases through interactions (Greening, 1998; Savey & Duffy, 1996). For instance in PBL, one of the vital teaching activities during the process would be

the way the tutor facilitates the students' thinking by asking questions that are challenging and value-add to the students' knowledge. In the context of social constructivism, the distance between what an individual can do with and without assistance or support is known as the zone of proximal development (ZPD) (Roehler & Cantlon, 1997; Vygotsky, 1978). Assistance in this ZPD is known as scaffolding. In order to qualify as scaffolding, learning or teaching events should allow students to eventually be able to carry out and complete a task that they would not have been able to manage on their own otherwise (Verenikina, 2008). According to Savery and Duffy (1996), learners use various forms of information resources and instructional materials as their support for inquiry or performance.

In recent years, there have been conflicting opinions with regards to the impact of instructional guidance during teaching (Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006; Schmidt, et al., 2007). Advocates like Kirschner et al. (2006) suggested that PBL is a minimally guided approach and is less

effective than instructional approaches that place a strong emphasis on guidance of the student learning process. On the contrary, there are others who argued that the PBL approach does provide extensive scaffolding and guidance to facilitate meaningful learning for students (Hmelo-Silver, et al., 2007; Schmidt, 1993; Simons & Klein, 2007). Hence, the studies (Chapters 2 to 5) presented in this thesis were conducted to find out more about the possible effects of scaffolding in guiding student learning in a PBL context.

Scaffolding of learning: Nature of scaffolds and Examples

As mentioned earlier, learners use various forms of information resources and instructional materials to support their inquiry or performance. Vygotsky (1978, p.86) believed that once the learner is within the ZPD for a particular task, by providing him or her with the proper aid would be sufficient for the student to complete the assigned task. Hence, the resources and materials used by students may serve as scaffolds that provide assistance in the ZPDs for any assigned tasks. According to Saye and Brush (2002),

scaffolds can be generally classified into two groups, hard and soft scaffolds.

Hard scaffolds are in general static supports that can be developed or provided based on learner difficulties prior to an assigned task (Saye & Brush, 2002). Such scaffolds can be provided once a task is assigned to the learner. Hard scaffolds can be in the form of computer or paper-based cognitive tools e.g. worksheets (Belland, Glazewski, & Richardson, 2008), reference books or other forms of text readings. For example, one way of guiding instruction can refer to the use of scaffolds like process worksheets (Merriënboer, 1997). The purpose of having worksheets as a scaffold is to prompt students to think further in-depth about the concepts related to the lesson curriculum to be delivered. They aid in redirecting the students' attention to important learning goals such as cross-checking counterclaims, articulating explanations and reflecting on their own learning progress. The worksheet is an instructional tool consisting of a series of questions and information designed to guide students to understand complex ideas as they

work through it systematically. Within this worksheet, other forms of hard scaffolds (e.g. online web resources, animations or videos) may be incorporated to provide information to guide the students.

As technology advances in recent years, researchers have been trying to investigate the use of multimedia in enhancing student learning. Hoffman and Ritchie (1997) suggested that multimedia programs provide learners with guidance in proceeding through difficult stages of problem solution. This thereby scaffolds learning, and supports development of the students' metacognitive skills (Hoffman & Ritchie, 1997). An example of a multimedia-enhanced PBL class could be in the setting whereby students are required to utilise computers in enhancing their learning in a self-directed manner e.g. searching for relevant resources. In a study conducted by Zumbach, Kumpf & Koch (2004), it was found that students from a multimedia-enhanced PBL class demonstrated significantly higher levels of motivation to learn and retention of knowledge compared to those in the conventional lecture-based class. However, it was also demonstrated that there were no significant differences in student

achievement between multimedia-enhanced PBL classes, compared to the traditional text-based PBL classes (Zumbach, et al., 2004). Based on the existing findings till date, it is still too early to conclude if the use of multimedia resources such as computer animations or videos is an important element in impacting student learning and achievement in a PBL context.

On the other hand, soft scaffolds refer to the teacher's actions in response to the learner's efforts when the learner has a specific need (Saye & Brush, 2002). In the PBL context, instances of such scaffolds may refer to the guidance provided by the tutor or peer-teaching and learning within the small-groups. During the PBL process, tutors play a fundamental role in ensuring that students learn and progress satisfactory in the course of solving the problem (Maudsley, 1999). They are expert learners who model good strategies for thinking and provide meta-cognitive scaffolding to the students (Hmelo-Silver, 2009; Hmelo-Silver & Barrows, 2006; Schmidt, et al., 2009). In general, the PBL environment creates a cognitive apprenticeship between the tutor and the students (Hmelo-

Silver & Barrows, 2006; Schmidt, et al., 2009). In essence, a good PBL facilitator should be knowledgeable and able to effectively facilitate groups of students (Greening, 1998; Hmelo-Silver, 2004). In previous studies conducted, it was suggested that there are a few tutor characteristics that could influence student achievement and interest in PBL (Chng, Yew, & Schmidt, 2011; Schmidt & Moust, 1995; Schmidt & Moust, 2000). These three distinct characteristics are namely subject-matter expertise, cognitive and social congruence. As the name implies, subject-matter expertise refers to the tutor's level of content knowledge. Social congruence is refers to the tutor's ability to apply interpersonal skills such as informal communication and ability to empathise with students. Being able to do so, this allows the tutor to create a learning environment that encourages open exchange of ideas between the tutor and students (Schmidt & Moust, 2000).

Cognitive congruence refers to the ability of the tutor to express oneself using the concepts that students use, and explain in ways easily grasped by students. So how are these three tutor-related

behaviours related to one another? According to Schmidt & Moust (1995), a tutor with high social congruence would have higher chances of employing the subject-matter knowledge and being more cognitively congruent. The findings of this study suggest that the ability of tutors to communicate informally with students creates a less intimidating learning environment. This thus promotes better exchange of ideas, which has a greater impact on student learning with the tutor being able to explain concepts in an approach easily understood by students. Furthermore, higher levels of cognitive congruence tend to result in increased situational interest i.e. interest in subject matter, thus improving student achievement (Schmidt & Moust, 1995). This causal relationship of tutor-related characteristics was further supported by subsequent studies conducted by others as reviewed below.

For instance in a recent study done by Rotgans & Schimdt (2011), it was demonstrated that students supported by teachers who scored high on these three tutor-related behaviours had significantly higher levels of situational interest. In addition,

cognitive congruence was found to be the most significant predictor of situational interest based on the results of this study (Rotgans & Schmidt, 2011). Another study conducted by Chng, Yew & Schmidt (2011) on tutor-related behaviours on student learning and achievement indicated that tutors who were more socially congruent had a greater impact on student learning at each PBL phase compared to tutor's subject-matter expertise. One possible reason could be due to the creation of an informal learning environment by the facilitator, which in turn encourages students to be less intimidated to share and discuss ideas (Chng, et al., 2011).

This formation of collaborative problem-solving groups basically helps to distribute the cognitive load and allow students to learn in complex domains (Hmelo-Silver, 2004; Hmelo-Silver, et al., 2007; Schmidt, et al., 2007). It also encourages the activation of prior knowledge within the small group setting and allowing students to elaborate on the acquired knowledge (Schmidt, 1993; Schmidt, Rotgans, & Yew, 2011). For example in a team of five students, students who may have prior knowledge of the topic at hand could

share the information with their fellow teammates. If there are any discrepancies in the information researched by each individual, students can raise these issues for discussion and debate. These collaborative learning processes encourage the development of skills such as higher-order thinking and shared knowledge construction (Hmelo-Silver, 2009).

Past studies conducted on small PBL tutorial groups indicated positive cognitive effects in areas such as activation of prior knowledge, recall of information and causal reasoning (Dolmans & Schmidt, 2006; Hmelo-Silver., 1998; Schmidt, 1993). For instance in a study done by Schimdt et al. (2009), it was demonstrated that problem analysis in a small group had a strong activating effect on prior knowledge. In addition, group discussions in such PBL groups seem to have a positive influence on the students' interest in the subject matter (Dolmans & Schmidt, 2006; Schmidt, et al., 2009). This rise in interest may indirectly lead to an increase in the students' motivation level to learn. Students also need to be willing to participate in peer teaching, on top of being actively involved in the

group learning process in order for effective learning (Lohfeld, 2005; Schmidt, et al., 2009).

Based on past literature studies mentioned above, there can be a variety of hard and soft scaffolding administered to encourage or enhance student learning processes. However more research still needs to be done to further evaluate how effective these scaffolds are in helping students learn.

Implementing scaffolds in PBL

In PBL, the main instructional materials used in the curriculum are usually the problems, which should be carefully designed to be relevant and interesting for the students (Khoo, 2003). Good problems should be complex enough to promote flexible thinking as well as motivate the students' need to learn (Hmelo-Silver, 2004; Schmidt, et al., 2009). However, past literature studies have also suggested that students could utilise different forms of materials to enhance or support their learning processes (Savery & Duffy, 1996; Ertmer & Simons, 2006; Hamdy, 2008). Besides the

problems, supporters of PBL do not forbid structured educational activities and guidance (Ertmer & Simons, 2006; Simons & Klein, 2007; Taylor & Miflin, 2008). Additional sources of support such as references, audiovisual aids, lectures relevant to the problem can also be included as further guidance for students. In fact, most medical schools that have been implementing PBL have lectures and laboratory sessions as scaffolding tools to develop student learning (Hamdy, 2008).

There have been differing opinions about how resources or scaffolds should be delivered in a PBL curriculum (Taylor & Miflin, 2008). Some institutions believe that PBL curricula should be characterized by as few lectures as possible, in commitment to the understanding of the concept of self-directed learning that prevails in their schools. However, others believe that there should be more structure in the curricula. Due to its different interpretations, educators are often not provided with clear and specific guidelines on how scaffolding can be used to achieve successful teaching (Verenikina, 2008). On the whole, the use of scaffolds in general and

in the PBL context has demonstrated varying degrees of impact on student achievements. Some studies have shown effectiveness of scaffolds in supporting student learning (Cho, 2002; Roehler & Cantlon, 1997). For example, in a study done by Simons and Klein (2007), they examined the impact of scaffolding and student achievement levels in a PBL environment, whereby students were subjected to different scaffolding conditions. Results from this study revealed that students who were given access to scaffolds performed significantly better in the post-tests, compared to the group with no scaffolds provided (Simons & Klein, 2007). Based on the findings, it indicated that scaffolds may enhance inquiry and student learning achievement levels.

According to previous studies, it was suggested that as students become more experienced with PBL, tutors will progressively fade their scaffolding as the students would have adapted to the learning environment (Hmelo-Silver, 2004). This flexible scaffolding provided by the tutors could be as effective compared to scaffolds such as worksheets (Schmidt, Rotgans, & Yew,

2011). According to Hmelo-Silver (2004), appropriate scaffolding is required especially for students who are lower in self-directed learning skills. Hence, this triggers the question of whether students who are novice learners require more scaffolds to aid them in the learning process compared to students who are in their mid or late phase of the course. This will be explored in Chapter 3 of this thesis.

However, there are other research findings suggesting that students often fail to appropriately use the scaffolds provided due to the lack of meta-cognitive awareness to apply the strategically use the scaffolds (Land & Hannafin, 1997; Simons & Klein, 2007). Land and Hannafin (1997) commented that there are instances whereby students might have the tendency to perceive and interpret information inaccurately, despite having scaffolds (e.g. computer simulations and print-based materials) provided to them within the lesson curriculum. Hence this calls for the need to investigate the utility of different types of scaffolds that can be employed in the PBL curriculum. In Chapters 2 and 3, we will be reviewing the various types of scaffolds and their characteristics. Chapter 4 and 5 will then

describe testing the role of scaffolds and how to effectively implement scaffolding in PBL.

Research questions

Based on the literature findings on scaffolding in PBL, the following research questions are raised and will be investigated in the studies presented in this thesis:

- Majority of the studies done on PBL are focused on the effects of tutor-student interactions and small-group collaborative learning, which are considered as soft scaffolds. What other types of learning supports are provided within the PBL curriculum that may be useful as either hard or soft scaffolds? What is the impact of these scaffoldings on students' learning? What is the relationship between the types of scaffolds and their impact on student learning? (refer to Chapters 2 to 4)

- Besides the traditional distinction between hard and soft scaffolds, could there be a type of scaffold that has characteristics of both hard and soft scaffolds? What would be an appropriate

model to categorise the different types of learning supports with a mix of hard and soft scaffold elements? (refer to Chapter 3)

- How do students perceive the impact of various types of learning supports as scaffolds? (refer to Chapters 2 and 3) Would students of different academic abilities perceive the usefulness of various types of scaffolds differently? Also, do students' perceived usefulness of scaffolds in their learning differ with duration of exposure and experience in PBL? (refer to Chapter 3)

- Since PBL encourages students to be self-directed learners, should the amount of scaffolding be reduced or provided only when the students have difficulties understanding or executing the assigned task at hand? What might be the impact on students' learning in a PBL environment when scaffolding is provided based on the momentary ('just-in-time') learning needs of individual students or teams? (refer to Chapter 5)

Outline of thesis: Studies conducted

The studies featured in Chapters 2 to 5 aimed to provide more insights to the above-mentioned research questions. The studies reported in this thesis were conducted at a polytechnic in Singapore. One aspect that is unique to this polytechnic's approach to PBL is that students work on one problem during the course of one day (Alwis & O'Grady, 2002), which will be explained in further context within the subsequent chapters.

In brief, the educational context in this institution requires students to work on an assigned task (i.e. problem statement) throughout the day. All students are required to have a personal laptop, which allows them to access resources via the internet. Throughout the lesson for the day, different forms of learning supports (dependent on the lesson objectives) are provided to the students to assist them and scaffold their learning process. Examples of such scaffolds could be worksheets, computer animations or tutor-facilitated discussions. In addition, students are also grouped in teams of five in class which encourages collaborative small-group

learning. Apart from scaffolding student learning during the lesson, there are also other forms of learning tools that may be provided to students either before or after lessons. Such instances of scaffolds include pre- and post-lesson readings, practice questions, extra-curricular workshops etc. Given the wide range of learning supports that are provided with the aim to aid student learning, the studies described in this thesis seek to investigate how scaffolds could influence or impact student learning.

The studies conducted in Chapters 2, 3 and 4 investigate the impact of different types of scaffolds on student learning in terms of student perceptions. The tools used for these studies were questionnaires which I devised to gauge how students feel that a particular scaffold could influence or impact their learning. All quantitative data obtained from the studies mentioned in this thesis were analysed using analysis of variance. The studies in Chapters 2 and 3 included most of the possible learning supports which could be employed in a PBL environment, whereas the scope of the study in Chapter 4 tested on the impact of worksheets as scaffolds on student

learning. The methodology used in the three studies were relatively similar, apart that the learning impact questionnaires administered in studies described in Chapters 2 and 3 included written comments from students on how they perceived individual scaffolds to have an impact on their learning. In addition, the study in Chapter 2 explored categorising the various types of scaffolds in the form of a validated model via confirmatory factor analysis. This study aimed to add in a new category of scaffolding nature, which can be used to define learning supports that comprise elements of both hard and soft scaffolds (i.e. semi-soft scaffolds). The focus of this study was to investigate if there is any relationship between students' academic ability and the way they perceived the impact of three categories of scaffolds (hard, semi-soft and soft scaffolds) on their learning in a PBL environment. It was hypothesized that semi-soft and soft scaffolds should have a higher influence on student learning, compared to hard scaffolds.

To further investigate if students of varying academic abilities would perceive different types of scaffolds to affect their

learning process or achievements, the study as described in Chapter 3 was carried out. In this study, the students' grade average point (GPA) was used as a gauge of their learning ability and achievements. This study also examined for differences in students' perceived usefulness of different types of scaffolds at novice, intermediate and advanced phases in PBL. As the studies in Chapter 2 and 3 would provide an overview of the characteristics of the various types of scaffolds, the study featured in Chapter 4 presents some preliminary findings on the role of worksheet in student learning. After gaining more insights about different types of scaffolds and their possible impact on learning, the final study in this thesis as described in Chapter 5 attempted to find out if scaffolding can be faded or administered on a flexible basis. The hypothesis for this study was that scaffolding could be more effective and meaningful if learning supports are provided to students, only when the student demonstrates difficulties in understanding or executing assigned tasks.

The final chapter (Chapter 6) will then summarize and discuss the findings of the preceding chapters. Implications raised in the studies described in Chapters 2 to 5 leading to issues to be explored by future research will also be suggested in Chapter 6.