Chapter 6:
Summary and conclusions

PBL is denoted as a learner-centred approach that encourages students to be actively involved all through the problem-solving process and in the process of doing so, obtain understanding of the subject matter or task at hand (Schmidt, 1993; Barrows & Tamblyn, 1980; Ertmer & Glazewski, 2005; Hallinger, 2005). On the whole, the main instructional material used in the PBL curriculum is the problem, which is designed to trigger learning at the start of the lesson (Schmidt, van der Molen, te Winkel & Wijnen, 2009). In the PBL tutorial process, students are trained to assemble information, analyze data, develop hypothesis, and apply logical reasoning to provide a solution to the problem at hand (Schmidt, 1993; Hmelo-Silver, 2004). Different forms of scaffolds may be provided to students as attempts to support their inquiry process and understanding of the assigned problem or task. Scaffolds can be generally classified into two groups, hard and soft scaffolds (Saye &

Brush, 2002). Hard scaffolds are in general static supports that can be developed or provided based on learner difficulties prior to an assigned task, whereas soft scaffolds refer to the teacher's actions in response to the learner's efforts when the learner has a specific need.

Based on literature studies till date, it seemed that the features revolving around investigating effectiveness of the PBL tutorial process were emphasised. Conversely, research on the impact of different types of scaffolds in relation to the PBL process and students' learning is a research aspect that can be further explored. Hence, the studies described in Chapters 2 to 5 in this thesis provided some insights to the research questions that were raised and recapped as follows:

1. 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)

2. 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)

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? Does students' perceived usefulness of scaffolds in their learning differ with duration of exposure and experience in PBL? (refer to Chapter 3)

4. 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)

Educational Context

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). The students are grouped into teams of five, within a total class size of between 20 to 25 students. One tutor is assigned per class to conduct or facilitate the lesson each day. A typical day starts with the presentation of a problem. Next, students discuss in their teams, come up with tentative explanations for the problem, and formulate their own learning goals (Hmelo-Silver, 2004; Schmidt, 1983, 1993). During this process, students are provided with a template (referred to as Problem Definition Template), which they utilize to organize and scaffold the points brought up during team discussion. This Problem Definition Template (PDT) basically consists of three columns for students to fill in what they know, do not know, and need to find out in order to solve the problem. Subsequently, periods of self-study

follow in which students individually and collaboratively try to find information to address the learning goals.

Apart from the problem statement, there are various forms of learning supports or scaffolds provided for the students to guide their learning process along the way. Examples of such scaffolds are worksheets, computer animations, pre-lesson readings, or provided text resources. Team discussions and tutor contributions (e.g. probing for students' understanding) may also serve as scaffolding events to enhance the learning progress. At the later phase of the lesson, individual teams are then required to present their findings and proposed solutions to their classmates and tutor. During the team presentations, there will be a series of class discussions generated by questions raised from either the students or tutor who encourages collaborative learning. The tutor will then conclude the day's learning at the end of the lesson by giving a presentation which summarises the learning objectives. Post-lesson resources such as post-lesson readings or practice questions may also be provided for to the students for revision purposes.

In this one-day one-problem approach, scaffolds are essential in the curriculum based on the following reasons. First, as the students transit from conventional lecture-based to a problem-based learning environment, it is essential to provide sufficient support and guidance for them. As PBL was first implemented in medical schools, there could be differences in the level of learning abilities between medical students and the students in the polytechnic who are generally younger learners. Secondly, as the institution consists of students from diverse academic backgrounds and abilities, it would be advisable to provide more tools for them to scaffold their learning. Third, since the students in the institution are required to come up with feasible solutions for the problem within a fixed time-frame, it is essential to ensure that there is timely support given throughout the lesson. By providing different types of scaffolds, this helps to ensure that the students receive necessary and relevant aid thru the process of solving the problem.

In this chapter, I will summarize my findings in regards to the research questions identified in Chapter 1. Limitations of the studies

conducted as well as associations of these studies with educational practice, coupled with recommendations for future research work will also be discussed.

Main conclusions

In this section, I will provide an overview of the main research findings from the studies described in Chapters 2 to 5.

Chapter 2

One of the main objectives of the studies described in this thesis was to explore the various types of learning supports that could scaffold student learning. The study featured in Chapter 2 aimed to consolidate all the possible types of scaffolding items or events that can be employed in a PBL environment, and attempted to categorise them accordingly to their scaffolding nature. A total of 16 scaffolds utilised in the curriculum were identified for this study. The focus of this study was to investigate if students perceived certain types of scaffolds to have higher impact on their daily learning. As an

attempt to find out the perceived influence of different scaffolds on student learning, I devised a Scaffold Impact Questionnaire which required students to rate the level of impact of the scaffolds on their learning. For each item (i.e. scaffold), students had to relate to the level of impact or usefulness this particular scaffold has on their learning. They were required to assign a score upon a 5-point Likert scale (from 0- Not at all to 4- Very much). In this questionnaire, students were also asked to provide written comments to state why they found the scaffolds useful or not useful. Based on the means reflected for each scaffold type, students seemed to identify that scaffolds such as worksheets, team dynamics, facilitator, practice questions and computer animations have more impact on their learning compared with other items in the list of scaffolds.

Based on past literature, only two types of scaffolding nature (hard and soft) used to describe scaffolds were identified till date. The study as described in Chapter 2 thus aimed to add in a new category of scaffolding nature, which can be used to define learning supports encompassing characteristics of both hard and soft

scaffolds. Based on how they were utilised within the curriculum, I grouped the 16 items and events into the following categories according to their scaffolding nature – hard, soft and semi-soft (Table 1).

Table 1

Categorization of types of scaffolds used in PBL

Type of scaffold or scaffolding event	**Category of scaffold**
Pre-lesson readings	Hard scaffolds
Recommended textbooks	
Extra-curricular talks or workshops related to the subject	
Post-lesson readings	
Practice questions provided after lesson	
Contributions of the facilitator (i.e. tutor)	Soft scaffolds
Team contributions (involvement of a small group of 5 students with the learning of the individual)	

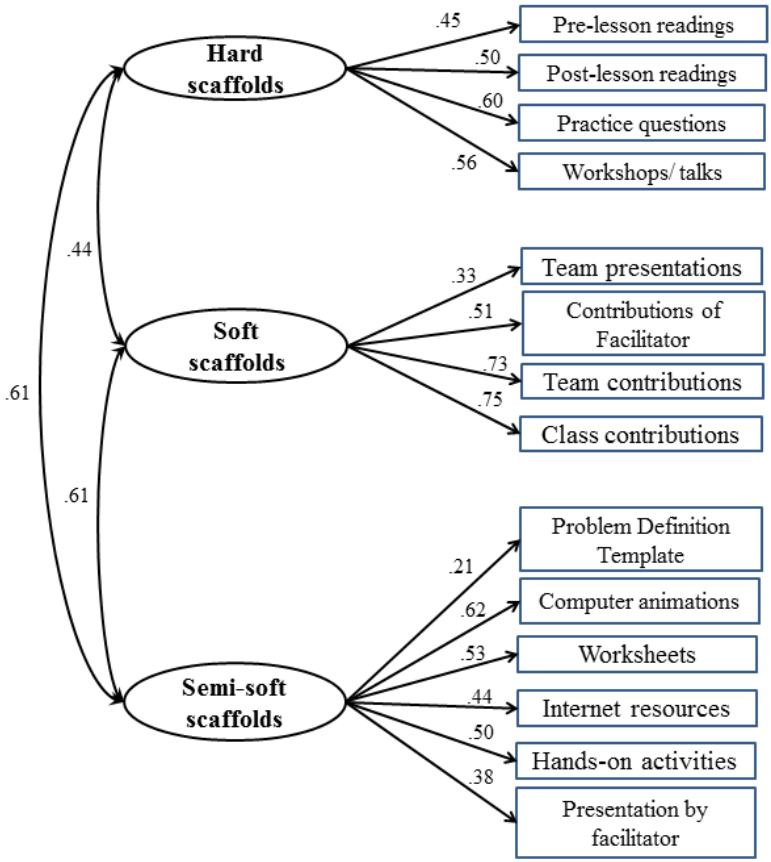
Class contributions (involvement of a larger group of about 25 students)	
Team presentations	
Worksheets	
Hands on activities (e.g. demonstrations or practical activities in class)	
Presentation by facilitator at the end of the lesson	Semi-soft scaffolds
Computer animations or videos	
Internet resources	
Additional resources (e.g. text documents) embedded in worksheets	
Problem Definition Template	

In order to assess the adequacy of the items under the three categories of scaffolds, a confirmatory factor analysis using SPSS AMOS™ was then performed to obtain a statistically validated model categorising the three groups of scaffolds into hard, semi-soft and soft scaffolds. The data obtained from the students' ratings of scaffold

impact was then analyzed by means of analyses of variance. Figure 1 shows the final model that was constructed and validated, showing the related associations between the three categories of scaffolds. 14 out of 16 scaffolding items were retained in this model.

Figure 1

Model illustrating types of hard, soft and semi-hard scaffolds (error terms are omitted for readability and only statistically significant path coefficients are displayed)



A repeated measures ANOVA with a Greenhouse-Geisser correction determined that the perceived usefulness of the scaffolds differed statistically significantly between the three scaffold groups [$F(1.888, 430.507) = 82.336$, $p < 0.05$, partial $\eta^2=0.3$]. Post hoc tests using the Bonferroni correction revealed that students perceived the impact of learning derived from using hard scaffolds ($M = 2.48$, $SD = 0.70$) is significantly lower ($p < .001$) compared to semi-soft ($M = 2.81$, $SD = 0.53$) and soft scaffolds ($M = 3.10$, $SD = 0.67$). From the above-mentioned findings, it can be inferred that students considered soft and semi-soft scaffolds to be more useful in their learning.

In summary, the results of this study as described in Chapter 2 suggested that soft scaffolds (e.g. facilitator, team and class contributions), semi-soft scaffolds (e.g. worksheets) were perceived to have higher statistically significant impact on learning compared to hard scaffolds (e.g. textbooks).

Although studies done on PBL seemed to emphasise more learning supports that have more of the soft scaffold element (e.g.

tutor, small-group learning), there are also certain hard scaffolds such as practice questions and computer animations that are deemed by students to keep them actively engaged in the learning process, thereby seen as having an impact. One area noted in this study for further research would be to find out if students of varying academic abilities or achievements (low to high grade point average) have similar perceptions about the impact of the types of scaffolds. For example, if the student perceives hard scaffolds to be more useful, would that also relate to his or her academic achievement? More insights to this research question were provided by the findings attained from the study mentioned in Chapter 3.

Chapter 3

Although past studies seemed to advocate that students in the PBL educational context recognize soft scaffolds to be more useful than hard scaffolds, it is likely that the academic ability of students would influence their perception of which scaffolds are more (or less useful). This could be because students of a higher

academic ability may have more prior knowledge compared to their fellow peers, thus require less need for structure provided by hard scaffolds. Furthermore, some studies mentioned that with increasing expertise in the subject matter, fewer resources should be provided to the students thus encouraging independent learning (Belland, Glazewski, & Richardson, 2008; Puntambekar & Hubscher, 2005; Schmidt, et al., 2007). Hence, it would be interesting to know if students in a PBL environment would develop greater independence from scaffoldings as they progress from their first year of study to the next.

After conducting the study mentioned in Chapter 2, the idea of how scaffolds can be categorised based on their scaffolding nature and how students perceived the level impact of scaffolds to be varied gradually became clearer. Hence, in the study described in Chapter 3, I sought to find out if there is any relationship between students' academic ability and their perceived usefulness of the types of scaffolds which were categorised into the three groups (hard, semi-soft and soft scaffolds) mentioned in Chapter 2. In addition, the

students' reliance on different types of scaffolds at different stages of the diploma course was also examined. The methodology used in this study was the same as described in Chapter 2, whereby the Scaffold Impact Questionnaire was administered to the student participants. The impact ratings of the 14 scaffolding items or events in the validated model derived from the study (Figure 1) were used. In addition, the association between student's learning achievements in the form of grade point average (GPA) and their perceived impact of scaffolds was studied. The students were grouped into low, moderate and high GPA. The consolidated data was evaluated by means of analyses of variance.

The ANOVA results showed that the perceived impact of soft scaffolds on student learning was statistically significant amongst the three GPA groups [$F=5.50$ (2, 381), $p < .0014$). Post-hoc analysis indicated that students of higher academic ability perceived soft scaffolds to have a higher impact on their learning relative to the moderate- and low-GPA group. This finding was further supported by the outcome of the ANOVA which compared the individual scaffolds

that students in the three GPA groups perceived to play a significant role in their learning. The perceived impact of semi-soft scaffolds (worksheets, computer animations, PDT) and soft scaffolds (e.g. facilitator, team and class contributions) on student learning were statistically significant. Post-hoc analysis showed that students with high GPA in general perceived worksheets and facilitator contributions to have a higher impact on their learning, compared to the low GPA student group. Assuming that this group of students has a higher prior content knowledge compared to the other two GPA groups, they may have already read up in-depth resources. Thus, in order to stretch these students' ability to gain more knowledge and further encourage critical thinking, learning supports with soft scaffolding elements such as questioning by the tutor and worksheet-based discussions may enhance effective learning.

Another interesting finding from this study was that students with low GPA deemed PDT to have a higher influence on their learning. As for the students with lower academic ability, they may need more guidance from the start of the problem-solving process in

terms of organising and clarifying their thoughts. Since the process of filling up the PDT requires students within the class to contribute information and opinions, this encourages collaborative learning thus allowing students with lower or slower learning abilities to acquire knowledge more efficiently. Furthermore, students of lower academic ability may require more assistance from peers to aid in their understanding, especially at the beginning of the task or assigned problem. This thereby explains why students perceived class and team dynamics to have a significant impact on their learning as well.

In order to find out if there are any deviations between the levels of student reliance on scaffolds at different stages of their course of study, I carried out an ANOVA utilising the data for the respective year groups (Year 1, 2 and 3). For Year 1 students, the ANOVA results indicated that there were no statistically significant differences between the GPA groups for all three scaffold categories. Nevertheless, the value derived for soft scaffolds is close to significant level ($p=0.062$). Similar to the findings for the overall

cohort, students of higher GPA perceived that soft scaffolds have a positive effect on their learning. In the case of Year 2 students, students of high academic ability perceived hard scaffolds to have a higher impact on their learning compared to their fellow peers with low and moderate academic achievements.

Lastly, the analysis for the Year 3 student group revealed that students of high academic ability perceived soft scaffolds to have a stronger impact on their learning, compared to students who are academically weak. One possible reason for Year 3 students to rely more on semi-soft and soft scaffolds could be due to the subjects that are covered in the final year of study, which involved coverage of more advanced or complex concepts. Since such subjects could be more challenging for the students to understand just by reading up resources, scaffolds of the 'semi-soft' or 'soft' nature may be of great importance in prompting and guiding the students to derive feasible justification to solve assigned tasks or problems.

In summary for the study in Chapter 3, the findings proposed that students, especially those with high academic ability generally

perceive soft scaffolds to have a significant impact on their learning in a PBL environment. It was also demonstrated that hard scaffolds may play a more essential role when the learner starts to undertake subjects that are more specialised i.e. subject fields for which they have negligible or inadequate knowledge. Hence, despite that advocates of PBL tend to believe that soft scaffolding such as interactions between the tutor and peers would promote effective student learning, providing of hard scaffolds may benefit students who have lower academic ability or are just starting to adjust to the problem-based learning approach.

Chapter 4

The purpose of this study was a preliminary attempt to investigate the effect of worksheets as a scaffolding tool used in students' learning process in a PBL environment. Some previous studies have shown effectiveness of scaffolds in supporting student learning (Cho, 2002; Roehler & Cantlon, 1997; Simons & Klein, 2007). For example, Simons and Klein (2007) 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. The findings indicated that scaffolds may influence student inquiry and performance in a PBL environment. However, one of the limitations for this study would be the distribution of experimental groups. Only one class was assigned to the no scaffolding condition, whereas it would have been more desirable if the sample size of two classes was used to achieve the same number of classes in each experimental condition. Therefore, this study that I conducted (as described in Chapter 4) aimed to explore how scaffolds in the form of structured worksheets could aid student learning in a PBL environment.

An experimental approach was chosen in which one group of students received a scaffold during PBL and another not. The seventeen PBL classes (N = 241) that participated in this study were randomly assigned to two experimental groups - one with a

worksheet provided and the other without. For the experimental group a worksheet scaffold was devised, with the purpose to guide students towards ideas to consider during the process of accomplishing the task for the day. This was carried out by including hints or providing some information within the worksheet. The worksheet was provided as a learning support tool that students may complete it on their own or in discussion with their teammates. For the control group, the students were only provided with the problem statement, which is the assigned task to solve for the day's lesson. Students' learning of the topic at hand was then evaluated by comparing results from pre- and post-lesson concept recall tests. As mentioned earlier, a concept recall exercise was designed to estimate the number of relevant concepts that students were able to recall before the start of the problem analysis phase (pre-test), and at the end of the reporting phase (post-test). Both tests consisted of the same instruction to the students, which was to list down all the concepts they think are relevant to the lesson objectives of the problem. Students were instructed to only list keywords or

terminologies they thought were relevant, and not write in paragraphs or sentences. No discussion of answers or referencing to any resources was allowed. After consolidating the completed concept recall tests, answers were then analyzed by awarding one point to each relevant concept written by the student.

Furthermore in this study, I also acquired some preliminary information about students' perceptions of factors impacting their learning via a Learning Impact Questionnaire. This questionnaire contained five items measuring how certain features of the learning environment could impact student learning: worksheet, problem statement, tutor, team dynamics (i.e. level of involvement within a small group of 5 students) and class dynamics (i.e. level of involvement between teams or in a larger group of about 25 students). Similar to the Scaffold Impact Questionnaire as described in Chapter 2, the ranking was done on a 5-point Likert scale (1-Strongly disagree to 5 – Strongly agree). Students were requested to complete the questionnaire based on their overall experience in a PBL environment. To ascertain whether there are significant

differences in terms of student learning between the experimental and control groups, an analysis of covariance (ANCOVA) was done. The dependent variable was the post-test score and the independent variable was the scaffolding condition. In order to compare the item scores of the Learning Impact Questionnaire, an ANOVA was also carried out.

Based on the outcome of the data analysis, the results showed that there was no statistically significant difference between the levels of understanding for both experimental and control groups. The ANOVA results revealed that the control group (N=143) scored significantly higher on the post-test than the treatment group (N=98) using the worksheets ($F(1, 239) = 6.47$, $p = .01$, eta-squared = .03). The mean score for the control group was $M = 5.91$ ($SD = 3.95$) and for the treatment group $M = 4.76$ ($SD = 2.57$). My hypothesis for this study was that the worksheet would be beneficial to student learning, which seemed to be otherwise based on the derived outcome from this study. This finding is rather surprising because it suggested that the worksheet had no significant influence on students' learning

during the PBL day; on the contrary, not having a worksheet seemed to result in better learning for the day. An explanation for this unexpected outcome could however be that despite the random assignment of the groups, the control group had by chance more knowledge about the topic than the treatment group. In order to test for this possibility, another ANOVA was performed to examine whether there were any initial differences on the pre-test scores between the two groups. The results of the ANOVA revealed that there were indeed significant knowledge differences in favour of the control group: $F(1, 239) = 15.08$, $p < .01$, eta-squared = .06. The mean score for the control group on the pre-test was $M = 2.32$ ($SD = 3.36$) and for the treatment group $M = 1.00$ ($SD = 1.65$). The results of the pre- and post-tests are summarized in Table 2 below.

Table 2

Summary of ANOVA comparing the Pre-test and Post-test Scores of Participants

Concept recall test	**Experiment condition**	**Sample size (N)**	**Mean**	**Std. Deviation**	**Std. Error**	**Sig.**
Pre	Without worksheet	143	2.32	3.362	.281	.000
	With worksheet	98	.90	1.646	.166	
	Total	*241*	*1.74*	*2.877*	*.185*	
Post	Without worksheet	143	5.91	3.953	.331	.012
	With worksheet	98	4.76	2.573	.260	
	Total	*241*	*5.44*	*3.500*	*.225*	

*p<0.01

As an attempt to statistically correct for this initial difference in pre-test scores, an analysis of covariance (ANCOVA) was carried out. The covariate was the pre-test score, the independent variable as the condition and the dependent variable was the post-test score.

Despite correcting for the initial differences, the ANCOVA revealed that the differences in post-test scores were not significantly different: $F(1,238) = 1.58$, $p = .21$, eta-squared = .01. This outcome suggested that using a worksheet as a scaffold for learning had no significant effect on student learning, even after correcting for initial knowledge differences. In addition, the ANOVA results revealed that the strongest factor perceived by students to impact their learning in a PBL context is the tutor followed by team and class dynamics, while the influence of the worksheet was rated lowest.

As mentioned in Chapter 1, there is a lack of clarity on how scaffolding can be used to achieve successful teaching (Verenikina, 2008). Hence, the contribution of this study is to suggest that scaffolds such as worksheets may not play a significant role in enhancing student learning within the social constructivist framework of problem-based learning. This is supported by the results obtained from the Learning Impact Questionnaire, which revealed that the strongest factor perceived by students to impact their learning in a PBL context is the tutor followed by team and class

dynamics, whilst the influence of the worksheet was rated lowest. Therefore, this finding has further affirmed the prominence of the tutor's contributions and collaborative small group learning which are identified by past literature studies as the key features of PBL.

Some limitations that could have influenced the outcome of these findings may be firstly, the students who are less motivated in learning might not necessarily attempt to use the worksheet for their learning. Students who are either not keen to investigate more about the problem, or are confident in their ability to search for relevant resources to solve the problem may not deem the worksheet to be essential in scaffolding their learning. Moreover, it was unfeasible to unravel differences between using a worksheet individually or as a group. Students who completed the worksheet in groups could have learnt more compared to those who completed the worksheet individually, thereby resulted in higher ratings of the team dynamics in the learning impact survey. The second limitation was that although the concept recall test could provide an indication of the quality of student learning, it may not thoroughly measure students'

understanding of the topic (Yew & Schmidt, 2011). Other modes or forms of quantitative data obtained from the students' academic achievements (e.g. test mark for question on the topic that study used, grade average point) for could be taken into account in the analysis, as a measure to cross-check the results of the concept recall tests.

Lastly, the participants for this study were already at their second year of the diploma course that they were enrolled in. Henceforth, they would have some prior knowledge and experience in searching for literature and other resources during their first year, when they were still novices to PBL. This could have led to the students being less reliant on the worksheets to grasp the concepts related to the topic for the day. Therefore, it would be beneficial to know if there are any significant differences in the level of student dependence on hard scaffolds such as worksheets, as they progress from novices to individuals who have adopted relevant PBL skills gained throughout their course of study. The preliminary postulations concluded from this study triggered the research questions on what are the various types of learning supports that

could be used to scaffold student learning in PBL. Do students perceive all of these scaffolds to positively impact their learning? These questions were investigated in Chapters 2 and 3 of this thesis.

Chapter 5

Based on the two studies described in Chapters 2 and 3, one common finding was that students generally perceived learning supports with 'soft scaffolding' characteristics to have a significant impact on their understanding. In addition, past literature reviews also mentioned that the fading of hard scaffolds is possible and should be encouraged once students have gained ability in performing the assigned tasks (Belland, et al., 2008; Puntambekar & Hubscher, 2005). One proposed research development in the nearby future that may be worthwhile to implement in PBL would be to explore a more flexible approach in the provision of scaffolds to students. Schmidt et al. (2007) believed that PBL is an instructional approach which focused more on the flexible application of knowledge or guidance. According to Schmidt et al. (2007), one of the

PBL curricula includes resources for self-directed study such as articles or books. To be able to successfully search for literature and other resources, one must have a certain level of prior or domain knowledge. Novices may engage in unrelated literature searches, which indirectly results in inefficient learning. Hence, it is essential that novice students in a PBL environment are provided with some resources as supports for their learning. Furthermore, it was suggested that with increasing expertise, lesser resources should be provided to the students. In this way, independent learning is encouraged (Schmidt et al., 2007). This thus raised a research question on whether students in a PBL environment could learn better under conditions of 'just-in-time' or flexible scaffolding. Till date, there have not been any studies done on comparing the ways of how scaffolds are being administered to students in a PBL environment. Studies conducted so far have only indicated that the scaffolds were provided at the start of the task. Therefore, the study as described in Chapter 5 sought to examine the effectiveness of flexible scaffolding on students' learning achievement in a PBL

environment. This experimental design aimed to provide insights to the following research questions: (1) How do different scaffolding conditions influence student learning in a PBL environment?, and (2) Is there a difference in student learning if the scaffolds are made available to all students before the given task, or only provided during the lesson when there is a need to address doubts? This study was carried out to examine and evaluate students' understanding of a certain topic under two scaffolding conditions - (i) fixed scaffolds provided and (ii) scaffolds provided upon the need arises (i.e. flexible or 'just in time' scaffolding).

In this study, the students (n=72) were randomly assigned to three groups (two experimental and one control) and were given a group task to complete within teams of three to four. The methodology used to measure students' understanding of the topic at hand was by using pre- and post-lesson concept recall tests, which was of similar format to the ones used in the study described in Chapter 4. The task assigned to the student teams was to summarize and submit a literature review of a journal article. In order to allow

flexible scaffolding to occur effectively, part of the responsibility may fall on the tutor. Being the expert in managing small-group tutorials, the tutor would need to monitor and assess if each student member within the group is contributing adequately to the team. Therefore, the tutor should be able to provide flexible adaptation of hard or soft scaffolds by taking into account the varying learning requirements (e.g. level of cognitive thinking or motivation) of individual students (De Corte, 2000; Dochy, Segers, van den Bossch & Struyven., 2005). Hence, in order to ensure that the scaffolding condition was the only variable, I was the only tutor who facilitated the participants for this preliminary study. For one of the experimental groups, the worksheet was provided at the start of the task hence, which can be termed as an example of 'fixed scaffold'. In the case of the other experimental group, I utilized questions from the worksheet or responded to student enquiries given only when they displayed learning or understanding difficulties during the process of executing the assigned task. Therefore, I termed this scaffolding condition as

'flexible scaffolding'. For the control group, the students were only provided with the journal without any tutor assistance.

ANOVA was used to find out if there were any significant differences between the following groups: (1) pre-lesson concept recall test score, (2) post-lesson concept recall test score, (3) total score for post-lesson concept recall test and group task (i.e. summary of topic), and (4) difference between pre- and post-lesson concept recall test scores. The comparisons of these four values are presented in Table 3 below.

Table 3

Summary of ANOVA Comparing the Pre-test and Post-test Scores of Participants

Scores tabulated		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Pre- test	Between Groups	30.5	2	15.254	2.61	0.081
	Within Groups	403.7	69	5.85		
	Total	434.2	71			
Post- test	Between Groups	106.9	2	53.445	2.94	0.059
	Within Groups	1254.0	69	18.174		
	Total	1360.9	71			
Total for post-test and group task	Between Groups	162.8	2	81.422	4.48	0.015*
	Within Groups	1254.0	69	18.174		
	Total	1416.8	71			

Difference between pre- and post-test	Between Groups	106.4	2	53.184	4.03	0.022*
	Within Groups	911.0	69	13.202		
	Total	1017.3	71			

*p<0.05

The findings from this study showed that flexible scaffolding has a significant impact in student learning, in terms of encouraging understanding of the subject matter. Results obtained from this study demonstrated that in comparison with the fixed scaffold group, the combined mean score of post-concept recall and group task obtained for the flexible scaffold group was significantly higher. Based on the ANOVA results reflected in Table 4, the significant differences within the experimental groups seemed to be higher for the score measuring difference between concept recall tests. Since the literature review (i.e. group task) required the students to work in teams, collaborative small-group learning could be a factor that

contributed to the higher scores obtained thus resulting in a significant difference. As the pre- and post-concept recall tests were attempted by the students without discussion with their teammates, the group task allowed students to interact and learn together throughout the duration of this study. This finding aligned with past studies which reinforced the positive effects of small-group learning in PBL environments.

One limitation of this study was that the impact of collaborative learning was measured at the small group level (i.e. team of four to five students). Thus, the impact of collaborative learning in a bigger group (e.g. inter-teams or as a class) was not evident in the outcome. One suggestion to refine the experimental conditions in any future work related to this would be to consider including a class discussion at the end of the task. This would aid to find out if class dynamics play any role in impacting students learning under the conditions of flexible scaffolding.

In conclusion, the preliminary findings from this final study in this thesis seemed to suggest that that by providing the required

support to the learner on a timely basis, the level or impact of understanding may be more effective. However, more modifications can be done in future to affirm these findings.

Association of studies conducted in relation to PBL

In summary, the conclusions mentioned earlier for the respective chapters in this thesis have provided relevant insights to how scaffolds could be used in PBL. It is evident that most of the findings from the studies conducted are in line with each other, as well as with past research studies done by other advocates in PBL. The discoveries presented in this thesis have reinforced the fact that the role of tutors and collaborative small-group learning are vital to enhance student learning in PBL. These two instances of soft scaffolds have been perceived by students to have a positive impact on their learning process. Furthermore, one of the studies presented in this thesis (Chapter 5) provided preliminary insights to the effectiveness of flexible scaffolding. The findings from this study aligned with past literature which suggested that scaffolds should be

faded over time when the learner becomes more independent. In overall, majority of the results obtained from the studies presented in this thesis are positively associated with each other, except for one of the findings mentioned and discussed as follows.

One finding that contradicted with the study mentioned in Chapter 4 is that students perceived that worksheets played a significant role in their learning process, whereas the conclusion for the previous study suggested otherwise. One reason to account for this could be that for the study described in Chapter 4, the students who participated were all in their second year of study, compared to the students involved in this study who were in either Year 1, 2 or 3 of their diploma course. The impact of worksheet, based on one experimental run for one topic as described in Chapter 4, did not seem to have a significant impact on student learning. However, this does not mean that the applicability of worksheets is not useful for other subjects covered in either Year 1 or 3 of the diploma course. Furthermore, the study described in Chapter 4 was a preliminary analysis of the roles only a few factors or scaffolds (n=5) that are

present in the PBL environment. In this study, the numbers of scaffolds (n=16) listed are much more compared to the previous study, thus providing more factors for comparison. In addition, the study mentioned in Chapter 4 tested the role of scaffolds for only one problem, whereas the study described in Chapter 2 measured the perceptions of students of the various scaffolds in relation to their overall learning experience in school. Hence, the findings from the study mentioned in Chapter 2 can be considered as a more detailed and accurate analysis of the impact of scaffolds in student learning. In overall, the findings from this study suggest that scaffolds, especially those with soft scaffolding nature, are crucial in enhancing students' learning within the social constructivist framework of PBL. Once again, the results from this study provided supporting evidence that the role of tutor and collaborative learning is vital for student learning in a PBL environment.

Reflections and recommendations for future work

The objectives of this thesis revolve around the various types of scaffolds and their level of effectiveness in enhancing student learning. Through the studies conducted which were described in Chapters 2 to 5, I was able to gain valuable and authentic information about how students deem the level of effectiveness attributed by various types of scaffolds to be different. I was also able to obtain more insights on certain research areas pertaining to scaffolding in PBL, which have not been explored by any past studies. For instance, I used statistical analysis to categorise the scaffolding nature of different types of learning supports into soft, hard and semi-soft. Till date, scaffolding has only been grouped as either soft or hard scaffolds. Hence, the studies mentioned in this thesis have added in another aspect into the scaffolding nature by introducing a new category termed as 'semi-soft scaffolds'. This would help to refine the process of categorizing different types of learning supports that may have overlapping nature of hard and soft scaffolding elements. Some

limitations of the research work that I have done are presented below with some recommendations for further studies.

One possible limitation that could have influenced the responses of the student participants who did the Learning Impact or Scaffold Impact questionnaires (refer to Chapters 2 to 4) would be the lack of motivation of students to attempt the other categories of scaffolds. Take the findings as described in Chapter 3 for instance; the results inferred that students of lower and moderate academic ability could have lacked motivation in using the scaffolds provided. Hence, they may not see a need to investigate more about the problem. Furthermore, students could be confident in finding resources on their own compared to using the scaffolds that are provisioned to aid in solving the problem. Compared to students with high academic achievement, students of weaker academic achievements may have lower level of motivation which could affect their choice or decisions in utilising scaffolds. Previous studies have indicated that there is a positive effect on motivation, interest and

learning when students have a choice to determine what they wish to learn (Deci, Vallerand, Pelletier, & Ryan, 1991). In a study done by Rotgans and Schmidt (2011), it was suggested that when students gain more autonomy from tutor and team members, they would exhibit more cognitive engagement in class with the task at hand especially when they are doing individual self-study. By integrating either hard or semi-soft scaffolds into the PBL curriculum, this may diminish the students' level of autonomy. This may result in a lower level of student engagement and learning (Rotgans & Schmidt, 2011). Hence for such cases, hard and semi-soft scaffolds may not be fully utilized or deemed to be useful by the students. In addition, assuming that certain hard scaffolds tend to impose the theories on students, this may affect the process of the students' knowledge construction. However since this is only a tentative explanation, more research is required to establish the link between autonomy reduction and hard scaffolds in PBL.

Another limitation that may have influenced the outcome for the studies described in Chapter 4 and 5 would be the accuracy of

measuring understanding via the use of concept recall tests. The concept recall test is based on the assumption that students build networks of concepts in the process of learning and the more students have learned about a topic, the more coherent and detailed each network would be (Glaser & Bassok, 1989). Students who have learned more effectively would therefore be able to recall more concepts and also would be able to do so more easily (Collins & Quillian, 1969; Rumelhart & Norman, 1978). Nevertheless, it is probable that though the concept recall test could provide an indication of the quality of student learning it may not thoroughly measure students' understanding of the topic (Yew & Schmidt, 2011). Thus, more tools such as quizzes with structured questions could be administered together with the concept recall tests, in order for the analysis to be more quantitatively accurate.

Although the studies mentioned in this thesis provided some insights which supported that students may be more reliant on soft scaffolds to impact their learning, it cannot be established that the students' level of dependence on certain scaffolds increases or

diminishes throughout their course of study. This is because the sample populations for each respective year for the study described in Chapter 3 consisted of students of different year cohorts. Therefore, one recommendation for further research would be to conduct a longitudinal study which monitors the progression of students from novice to final year of their course of studies. This would help to investigate if the level of dependence of certain scaffolds would diminish as the students progress from Year 1 to 3 of their course.

As mentioned in Chapter 5, one limitation of the study conducted was that the impact of collaborative learning was measured at the small group level which comprised of a team of four to five students. Consequently, the impact of collaborative learning in a bigger group was not evident in the outcome. One suggestion to refine the experimental conditions could be to include a class discussion at the end of the task to investigate if class dynamics contributes to impacting students learning under the conditions of flexible scaffolding. As mentioned earlier, more tutors can be

involved in the facilitation process, in order to monitor and further substantiate the positive impact of tutor interventions on student learning under different scaffolding conditions.

In overall after considering the limitations presented above, it is evident that more research should be designed and carried out to further investigate test variables such as types of scaffolds or impact of different tutors in administering 'just-in-time' scaffolds in a systematic manner.

Educational implications

The studies featured in this thesis have provided insights into the various types of scaffolds that could be used in PBL, as well as relating how each of these scaffolds could impact student learning achievements. Some repercussions of the outcomes of these studies on educational practice are suggested below.

The findings of my studies have added value to the research area on scaffolding, particularly in problem-based learning. These

studies have shown that students do perceive different types of scaffolds to have varied levels of influence on their daily learning processes. Hence, one consideration that educators have to deliberate about when designing or incorporating scaffolds in the curriculum would be the whether to have a wide range or lesser variety of scaffolds within a subject curriculum. For the studies described in Chapter 2 to 4, the findings generally showed that students perceived scaffolds that encompass the 'soft' element such as contributions of tutor and team mates do help them in their learning progress and understanding of subject matter. Nonetheless, the study described in Chapter 3 revealed that as students progress from novice to intermediate stage of their studies, they still require hard scaffolds to aid in their learning as the subjects tend to be more complex.

After having gathered some written comments from the students from the study mentioned in Chapter 2, the findings triggered the question of 'How well can the scaffold complement the

problem for the day's lesson?' As the purpose of having a scaffold in place is to serve as a learning support for the students, it must be able to complement the problem statement in a positive way. If the scaffold fails to address the concepts, there will not be any productive learning. McKenzie (1999) mentioned that an effective scaffold that impacts students' learning should be one that directs students to the worthy sources. This may in turn lower the chances of students trying to interpret unreliable or confusing resources. Therefore, one way to ensure that students understand the underlying concepts related to solving the problem would be to have relevant scaffolds that help to trigger their prior knowledge. Once a connection is established via prior knowledge, it will in turn make learning more effective for the students. This is supported by findings obtained from the studies mentioned in Chapter 3, whereby certain types of learning supports or events were identified to have extensive effects on student learning. As mentioned in Chapter 3, these learning supports belong to different scaffolding nature listed as follows: practice questions (hard scaffold), contributions of the

facilitator, team and class (soft scaffolds); worksheets, PDT, computer animations (semi-soft scaffolds). Therefore this shows that various learning supports of varied scaffolding nature (hard, soft or semi-soft), either individually or used in combination, could help in the students' knowledge acquisition and address any learning obstacles.

If the problem of the day requires students to understand complex concepts, there may be a need to include scaffolds (e.g. worksheets) that could create a momentum for students to focus on addressing the underlying concepts or possible learning obstacles. However, one disadvantage of providing too many scaffolds may lead to undermining of the students' ability to think independently. In some of the students' written comments in the Scaffold Impact Questionnaire used in studies described in Chapter 2, having too many or extensively long scaffolds that are time-consuming to attempt may divert the students' attention away from the problem. Hence, tutors should bear in mind to consider the feasibility of

students' ability to attempt the scaffolds when designing the lesson curriculum.

Although the study described in Chapter 5 presented some preliminary findings on how scaffolds such as worksheets can be administered on a 'just-in-time' basis, the outcome of this study suggests that flexible scaffolding may have a positive impact in encouraging students' understanding of the subject matter. The effectiveness of such method of scaffolding lies mainly on the tutor, and also collaborative team learning within the students. Therefore, the above-mentioned conclusion from this study seeks to inform educators that in PBL, the role of the tutor and management of small-group learning is vital to the students overall understanding during lesson time.

In summary, after examining the relationships between the various types of scaffolds and their effects on students' learning achievements, it is possible to enhance the implementation of scaffolding in PBL. This will lead to higher efficiency and

effectiveness in improving student understanding and academic achievements.