Chapter 2: Students' Perceptions of Impact of Scaffolds in Problem-Based Learning[1]

Abstract

The purpose of this study was to investigate whether students perceive certain types of scaffolds to have higher impact on their daily learning. The participants (*N = 229*) for this study are enrolled in an institution that uses problem-based learning (PBL) as the instruction method. The students' perceptions of the 16 types of scaffolds utilised in the curriculum were consolidated using a Scaffold Impact Questionnaire that was devised. Besides rating the level of impact of the scaffolds on their learning, the participants were also asked to provide written comments to state why they found the scaffolds useful or not useful. Confirmatory factor analysis using SPSS AMOS™ was also conducted to obtain a statistically validated model categorising three groups of scaffolds – hard, semi-soft and soft scaffolds. The data obtained was then analyzed by

[1] Authors: Choo, S. S. Y, Yew, E. H. J. & Schmidt, H. G.

means of analyses of variance. Results of the study indicated in general 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). However, 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. These findings suggest that scaffolds, especially soft scaffolds, do play a significant role in enhancing students' learning within the social constructivist framework of PBL. Furthermore, the importance of the role of facilitator and collaborative small group learning which are key features of PBL is again reinforced based on the outcome of this study.

Introduction

Problem-based learning (PBL) is an instructional approach aimed at helping students develop flexible understanding and lifelong learning skills (Hmelo-Silver, 2004; Schmidt, et al., 2007; Simons & Klein, 2007). In the process of learning, students develop the abilities to collect information, analyze data, construct hypotheses, and apply deductive reasoning to a problem at hand (Barrows & Tamblyn, 1980; Schmidt, 1993). The PBL tutorial process can be characterized as follows. First, students working in small collaborative groups are given a problem consisting of a scenario or a case study that requires analysis and an explanation. After initial discussion and brainstorming of learning issues, the students proceed to carry out some self-study before returning to their groups for further discussion and elaboration based on the knowledge acquired and proposes alternative justifications for the presented problem (Norman & Schmidt, 1992). Throughout these discussion sessions, the student groups are guided by a tutor, who models good strategies for learning and thinking (Greening, 1998; Hmelo-Silver, 2004; Schmidt, et al., 2009).

PBL is associated with social constructivism, whereby students construct knowledge through interactions (Greening, 1998; Savey & Duffy, 1996). In the context of social constructivism, the distance between what an individual can do with or without assistance or support is known as the zone of proximal development (ZPD) (Roehler & Cantlon, 1997; Vygotsky, 1978). Providing assistance in this ZPD is known as scaffolding. In order to qualify as scaffolding, the learning or teaching event should allow students to be able to eventually carry out and complete a task that they would not have been able to manage on their own (Verenikina, 2008). 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; Schmidt, et al., 2009). Good problems should be complex enough to promote thinking as well as motivate the students' need to learn (Hmelo-Silver, 2004). Besides the problems, advocates of PBL do not forbid structured educational activities and guidance where appropriate (Ertmer & Simons, 2006; Saye & Brush, 2002; Simons & Klein, 2007; Taylor & Miflin, 2008). These additional sources of support include references, audiovisual aids and even lectures relevant to the problem. In fact, most medical schools that have been implementing PBL include lectures and laboratory sessions as scaffolding tools to support student learning (Hamdy, 2008).

However, despite the common use of scaffolding tools in PBL, there have been differing opinions regarding the role of instructional guidance during PBL (Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006; Schmidt, et al., 2007). Kirschner et al. (2006) suggest that PBL is a minimally guided approach and is less effective than instructional approaches that place a strong emphasis on direct instruction. In contrast, there are others who assumed that PBL does provide extensive scaffolding and guidance to facilitate meaningful learning for students (Hmelo-Silver, et al., 2007; Schmidt, et al., 2007; Simons & Klein, 2007). Moreover the use of scaffolds to enhance inquiry and students' learning achievements was demonstrated by a study conducted by Simons and Klein (2007). The study 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). Since the tasks provided in the PBL curriculum may be complex to novice learners, scaffolds that structure these tasks will benefit both students as well as tutors. Besides reducing complexity of the tasks, scaffolds also augment the ability of the students in completing the required tasks independently (Clark & Graves, 2005; Ertmer & Simons, 2006). Furthermore, previous studies suggest that the verbal presentation of PBL problems may not necessarily provide sufficient information to prepare students to recognize visual or non-verbal cues that could be important in certain subject areas (Hoffman & Ritchie, 1997; Hung, 2011). In a recent study investigating the impact of scaffolds on student learning as perceived by students, it was found that out of the various types of learning supports provided in a PBL environment, students generally viewed tutor interventions as the most important scaffold for their learning (Choo, et al., 2011). Thus there is a need for flexible scaffolds within the PBL curriculum that could be used to adapt to the problem-at-hand, and to support the learning needs of students. However, there is no systematic overview of the types of possible scaffolds for social-constructivist learning environments like PBL. In addition, not much information about their actual or perceived effectiveness was studied in detail. Thus the objective of this study was to find out whether students perceive certain types of scaffolds to have higher impact on their daily learning process. With sufficient knowledge in this aspect, it would be easier for curriculum drafters to provide materials that could effectively and efficiently support the learning needs of students. The results reported in this article provide a first contribution to clarifying these issues. First however, some important theoretical distinctions need to be discussed.

Scaffolds

Till date, there are two types of scaffolds that have been distinguished in the literature, in a general context pertaining to scaffolding. These two scaffold types are referred to as hard and soft scaffolds. As defined by Saye and Brush (2002), hard scaffolds are basically static supports that are generally developed before a task is assigned. Such scaffolds may be provided once a task is assigned to the learner. Hard scaffolds may be in the form of online or paper-based cognitive tools such as reference books or readings which functions to provide hints or descriptions of the concepts that students should learn about in the process of understanding the problem (Saye and Brush, 2002). With reference to the description of hard scaffolds, it is likely that scaffolds of the above-mentioned nature may be of use to student learning under a PBL environment. In view that PBL do require students to be self-directed learners, hard scaffolds such as textbooks, provided article readings or practice questions pertaining to the topic at hand, may impact the students' understanding in a positive manner. Students may refer to such scaffolds while they are working on the learning tasks, and use them throughout the problem-solving process. Some studies have suggested that fading of hard scaffolds is possible and should be encouraged once the students have gained ability in performing the assigned tasks (Belland, Glazewski, & Richardson, 2008; Puntambekar & Hubscher, 2005). With increasing expertise, fewer resources should be provided to the students. In this way, independent learning is encouraged while providing a form of flexible scaffolding (Schmidt, et al., 2007).

On the other hand, "soft" scaffolds refer to the actions of the teacher or tutor in response to the learner's efforts when the learner indicates a specific need (Saye & Brush, 2002). Instances of such scaffolds in PBL would be tutor interventions based on student questions or peer responses within the small group. Soft scaffolds emerge when there are momentary needs. If these needs do not emerge, the scaffold need not be administered. Since one of the characteristics of PBL involves small-group learning whereby the students collaborate to think and generate possible solutions for the problem or task, brain-storming sessions of the solutions could be instances of 'soft scaffolds'.

As various institutions may employ various types of scaffolds in the curriculum to aid in student learning, scaffolds could be categorised differently into more distinct groups apart from 'hard' and 'soft'. As defined earlier, soft scaffolds emerge when there are momentary needs and within the PBL curriculum, there may be other types of scaffolds consisting of 'soft scaffold' elements, which could be developed or provided to enhance student learning. For example, students may utilise materials of hard scaffold nature such as worksheets or internet resources related to the subject matter either during self-directed learning or group discussions. Tutors may also use such scaffolds during their facilitation of the teams or class to check or affirm students' understanding of the subject matter. In the instance of a worksheet, the tutor could utilise some of the questions to guide the student's metacognitive processes, in the event that the student expresses particular concerns or demonstrates difficulties understanding certain concepts in relation to the lesson curriculum.

Similarly, internet resources or computer animations summarising information on concepts that could be relevant to the topic of interest may also serve as support tools in the tutor's explanations to the students. Therefore, the mode of how these types of scaffolds are administered in PBL could vary from that of a conventional non-PBL environment. To further distinguish between scaffolds of the above-mentioned nature, such examples of materials or scaffolding events may be referred to as 'semi-soft' scaffolds.

Thus it can be seen that various types of scaffolds could be deemed useful and even necessary in different situations in the PBL educational context. However, as there may be different forms of scaffolds provided for students in PBL, it would be useful if the value of each scaffold type is examined. In addition, there is a lack of studies providing an overview of the different types of hard and soft scaffolds. Therefore, one first step would be to find out the students' perspectives on which scaffolds they consider effective in contributing to their learning. This is because students are in the best position to assess the various scaffolds and their adequacy to support learning. Considering that they are exposed to problem-based learning throughout their course of study, it will be appropriate to use them as informants for this study. To that end, we administered a questionnaire to a cohort of 229 students who are enrolled in a tertiary institution that uses PBL as the learning pedagogy. The students were asked to rate and comment on the impact that different scaffolds have on their learning. The data obtained was then analysed. Using the obtained data, the first research question for the study aimed to firstly test the three-category theory of the scaffolds of this study which involves hard, semi-soft and soft scaffolds, which has not been carried out in any known studies till date. Validation of the scaffold categorization was then performed and analysed accordingly. The second research question aimed to unravel more insights to what extent the various types of scaffolds are perceived by students to have a different level of impact on their learning.

Methods

Participants

The sample consisted of 229 participants enrolled in courses at a polytechnic in Singapore, specifically in the respective areas of Biomedical Sciences, Biotechnology, Materials Science, Pharmaceutical Sciences and Environmental Science. The breakdown of the participants in terms of their years of study and frequencies of gender is shown in Table 1. Out of the total number students who were eligible for inclusion in this study (n=823), 28% of the students chose to participate.

Table 1

Gender and age range of participants in respective year of study

Year of study	**Total number of participants (n)**	**Gender**		**Age**	
		Male	Female	Mean	S.D.
Year One	95	43	52	16.54	0.97
Year Two	71	24	47	17.44	1.07
Year Three	63	31	32	18.73	1.30

Educational Context

In this particular institution, the instructional method is PBL for most of the courses it offers. In this approach, five students work together in one team under the guidance of a tutor or facilitator. Each class comprises four to five teams. A unique feature of the PBL approach used in this institution is that students work on one problem during the course of the day (Alwis & O'Grady, 2002). 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. The facilitator would then go through the PDT together with the students through discussions as a class. This is to allow the facilitator to guide or prompt the students' thinking towards understanding the learning objectives for the lesson. Subsequently, periods of self-study follow in which students individually and collaboratively try to find information to address the learning goals. At the end of the day, each team will come together to present, elaborate upon, and synthesize their findings. During the team presentations, there will be a series of class discussions generated by questions raised from either the students or facilitator, which encourage collaborative learning. By the end of the lesson, the facilitator will then provide a closure to the lesson by means of a concise presentation summarising the learning points generated throughout the day and relating them to the topic's objectives. Apart from the problem statement, there are other forms of learning supports (e.g. worksheets) provided for the students to utilise throughout the lesson and scaffold the learning process. Resources are also provided for students to access and enhance their knowledge before (e.g. recommended textbooks, pre- and post-lesson readings) and after (e.g. extracurricular talks, practice questions) lesson time. Examples of these scaffolds will be shared in further detail later in the next section.

Categorization of scaffolds

Although as mentioned earlier, scaffolds in general can be considered as either hard or soft, in this context of PBL, there are also scaffolds that can be regarded as a combination of both. For instance, due to the collaborative learning environment that students work in throughout the day, students tend to discuss and complete a worksheet together with their teammates, thus making the worksheet a form of flexible scaffolding instead of a hard scaffold. As mentioned in the Introduction section, the worksheet may also be a tool that facilitators utilize in different ways based on the learning needs of students during discussion time with the team or class. Likewise, the PDT is also used by the tutor to guide the students' cognitive processes by allowing them to organise their thoughts or inputs via team and class discussions. Hence, in this study, we aim to recognise the distinctiveness of such instances of learning supports which we classify as 'semi-soft' scaffolds (refer to *Educational Context* for more details). Table 2 below shows the list of the scaffolds used in the particular curriculum after classification into three categories of scaffolds – hard, soft and semi-soft.

Table 2

Categorization of types of scaffolds used in PBL

Type of scaffold or scaffolding event	**Category of scaffold**
Pre-lesson readings Recommended textbooks Extra-curricular talks or workshops related to the subject Post-lesson readings Practice questions provided after lesson	Hard scaffolds
Contributions of the facilitator (i.e. tutor) 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	Soft scaffolds

Worksheets	Semi-soft scaffolds
Hands on activities (e.g. demonstrations or practical activities in class)	
Presentation by facilitator at the end of the lesson	
Computer animations or videos	
Internet resources	
Additional resources (e.g. text documents) embedded in worksheets	
Problem Definition Template	

Instrument

Scaffold Impact Questionnaire. A Scaffold Impact Questionnaire was devised and administered to the participants to investigate what students perceive as important scaffolds that have an impact on their learning in a PBL environment. Students were asked to rate the level of impact different scaffolds have on their learning. They were also asked to provide written comments to justify the ratings for each item (i.e. scaffold). The list of 16 items that were measured for this study is shown in Table 1. This list was based on the types of learning supports that are utilized in the polytechnic.

Each item in the questionnaire was rated on a 5-point Likert scale: 0 (*not at all*), 1 (a little), 2 (*moderate*), 3 (much), and 4 (*very much*).

Procedure

The Scaffold Impact Questionnaire was made available to students enrolled in the applied sciences faculty, who were in their course of study of Year One, Two or Year Three (refer to *Participants* for more details). An email was sent out to encourage students to fill in and submit the questionnaire via an online portal. Students were given a week to respond to the questionnaire at their own free time, and submissions were on a voluntary basis. In other words, students were given a choice pertaining to their participation in this study. The submitted data was then consolidated and checked for errors.

Analyses

The analyses carried out for this study aimed to acquire insights pertaining to the research questions mentioned earlier in the

Introduction section. Means and standard deviations for each of the items were computed. In addition, free responses to the question on why they found a particular scaffold useful or not useful were collected. In order to test the three-category theory of the scaffolds of this study, a confirmatory factor analysis (using SPSS AMOS™) was carried out to test for construct validity of hard, soft and semi-soft scaffolds. ANOVA analyses were also performed to test for differences in the perceived usefulness of the three scaffold groups. As for the qualitative data i.e. the written comments, the data was consolidated and analysed. The statements provided by the respondents were manually screened by the first author and subsequently themed under the common reasons that were reflected at higher frequencies. These qualitative data, coupled with statistical analysis using the means obtained for the three scaffold groups, intends to provide insights to which types of scaffolds are perceived by students to be useful on their learning.

Results

Quantitative analysis

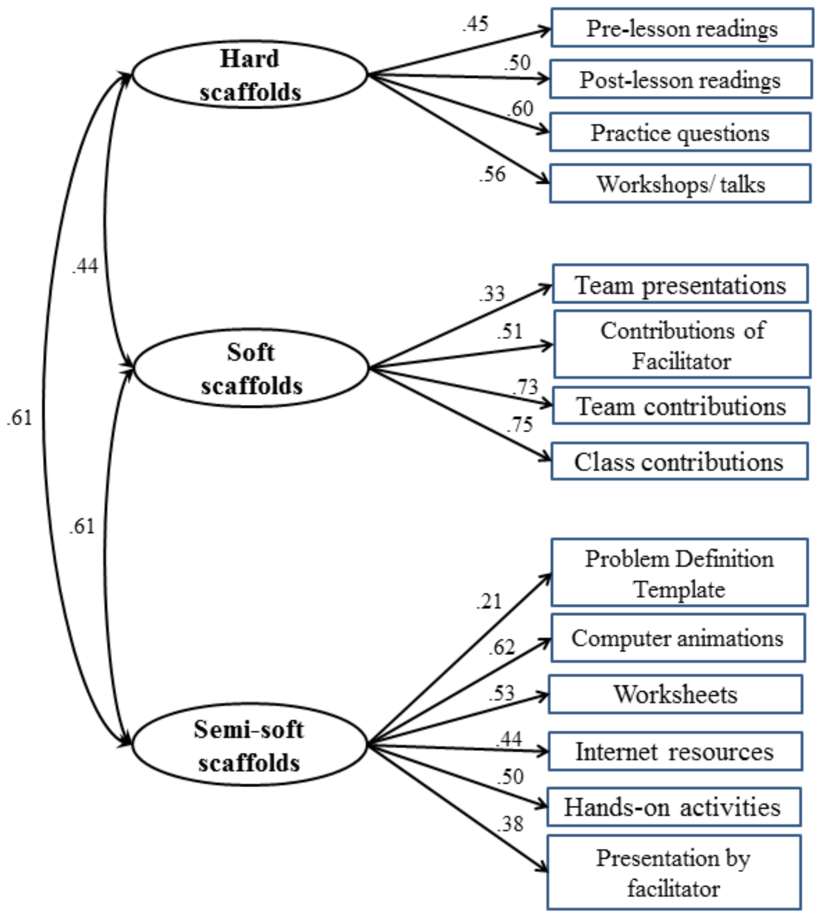
Construct validity. In order to assess the adequacy of the items under the three categories of scaffolds mentioned earlier under the Introduction section (i.e. hard, soft and semi-soft scaffolds); a confirmatory factor analysis was conducted to test for the validity of the model consisting of the 16 scaffold types.

A confirmatory factor model is assumed to fit the data well if the following criteria are met: (1) the chi-square divided by the degrees of freedom (CMIN/df) should be lower than 2 and have a p-value that differs from zero; (2) the *root mean square* error of approximation (RMSEA) should be lower than 0.05; and (3) the Comparative Factor (CFI) Index should be higher than 0.95. An inspection of the modification indices and the expected parameter statistics revealed that all 16 items fit appropriately in the model. For the model derived (Figure 1), the three conditions specified by Saris & Stronkhorst (1984) were met. A three factor model was found to be more specific compared to simpler models that resulted in lesser scaffold items omitted in order for the data to fit. The three-factor model constructed predicts possible directional influences amongst the various scaffold items, based on theory, and that these directional influences were confirmed through the confirmatory factor analysis.

The results for this model are: Chi-square = 123.4, df = 71, p = 0.029; RMSEA= 0.039; CFI = 0.95 indicating that this three-factor model fitted the data reasonably well. The model also suggests that the items within the three categories of scaffolds (hard, soft, semi-soft) do influence the impact of each item, hence showing validity of the three scaffold groups. For this final model that was constructed and validated, 14 out of 16 scaffolding items were retained. Figure 1 shows the relevant path coefficients. Only statistically significant path coefficients are displayed.

Figure 1

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



Perceived impact on learning of hard, soft and semi-soft scaffolds

After confirming the validity of the model obtained in Figure 1, further statistical analysis was conducted. The purpose was to find out if there are any significant differences between the three categories of scaffolds and students' perceptions of the impact of these scaffolds on their learning. Table 3 and Table 4 show the descriptive statistics of the individual scaffolds, and the three categories of scaffolds (hard, soft and semi-soft).

Descriptive statistics. For each of the items in the Scaffold Impact questionnaire, the mean scores and standard deviations were computed (as shown in Table 3). The average score per item is about 2.75, within a scale of 0 to 4, with an average standard deviation of approximately 1.1.

Table 3

Descriptive statistics of participant responses for individual scaffolds

Item (Type of scaffold)	**Mean**	**Std. Deviation**
Pre-lesson readings	2.40	1.08
Recommended textbooks	1.77	1.27
Problem Definition Template (PDT)	2.52	1.14
Worksheets	3.28	.77
Computer animations or videos	3.10	.90
Internet resources	2.92	.84
Additional resources embedded in worksheets	2.39	1.04
Hands on activities (e.g. demonstrations or practical activities in class)	2.84	1.09
Team presentations	2.66	1.01
Presentation by facilitator at end of lesson	3.00	1.02
Post-lesson resources	2.11	1.24
Practice questions	3.15	1.04
Extra-curricular talks or workshops related to the subject	2.61	1.11

Contributions of the facilitator	3.11	.92
Team contributions	3.19	.83
Class contributions	2.99	.83
Average	2.75	1.10

Based on the means reflected for each scaffold type, students seemed to perceive that scaffolds such as worksheets, team dynamics, facilitator, practice questions and computer animations have more impact on their learning compared with the other items in the list (Table 3). Soft scaffolds e.g. facilitator contributions (M = 3.11, SD = 0.92), semi-soft scaffolds e.g. PDT (M = 2.51, SD = 1.14), semi-soft scaffolds e.g. worksheets (M = 3.32, SD = 0.77) seemed to be rated higher compared to hard scaffolds e.g. recommended textbooks (M = 1.77, SD = 1.27) and post-lesson resources (M = 2.11, SD = 1.24). However, students also perceived that hard scaffolds such as practice questions (M = 3.15, SD = 1.04) may have a significant impact on student learning when compared with certain soft scaffolds such as team presentations (M = 2.66, SD = 1.01) and semi-soft scaffolds e.g.

additional resources in worksheets (M = 2.39, SD = 1.04). Based on the means, it seems to suggest that students perceive soft scaffold in general, to have a higher impact on their learning process.

Table 4

Means and standard deviations of hard, soft and semi-soft scaffolds

Category of Scaffold	**N**	**Mean**	**Std. Deviation**	**Std. Error**
Hard Scaffolds	229	2.48	.70	.05
Soft Scaffolds	229	3.10	.67	.04
Semi-soft Scaffolds	229	2.81	.53	.04

With reference to Table 4, it shows that soft scaffolds were perceived to have a higher impact on student learning followed by semi-soft and hard scaffolds. To further investigate this, ANOVA was performed. 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 ($M = 3.10$, $SD = 0.67$). This result reflected that students deem soft and semi-soft scaffolds to be more useful or have a higher influence in their learning. As an attempt to delve into the reasons why students perceived the level of usefulness of the different types of scaffolds, a qualitative analysis was incorporated into this study. The findings are presented in the following section.

Qualitative analysis

The participants were required to provide written comments to indicate why they perceive each scaffold listed in the Scaffold Impact Questionnaire to be useful or not. These written comments were then consolidated and analysed by the first author. As the comments provided by the participants for each type of scaffold are relatively similar, the statements listed were manually screened and themed under the common reasons that had the highest frequency. On the average, two statements were made for each type of scaffold, which comparatively reflected the perceptions listed in Table 5. Table 5 shows the student comments that had the highest frequency.

Table 5

Student perceptions of impact of scaffolds on their learning

Type of Scaffold	**Student perception of scaffolds**	
	<u>Reasons why students find scaffold useful</u>	<u>Reasons why students may not find scaffold useful</u>
Suggested pre-lesson readings	• Helps in lesson preparation (especially for subjects that are more difficult to understand) • Helps student to understand topic for the day	• Amount of scaffold provided is too much to cope at times

Recommended textbooks	• Good alternative besides online resources • Helps in self-directed learning • Useful for students who are academically weak or do not have prior knowledge	• Inconvenience of acquiring scaffold (e.g. borrowing of books) • Reliance on other provided scaffolds (e.g. online resources) • Lack of motivation to use scaffold
Problem Definition Template	• Helps to recall prior knowledge • Good starting point for the lesson • Gives students clearer view of what is required for the	• May be time consuming to complete

	lesson • Helps in brainstorming of ideas and allows students to organise their thoughts better • Prompts students to think further or deeper into context	
Worksheets	• Useful as a guide to understand more about the topic for the day • Helps to sieve out irrelevant information and prevents students from going off-track • Prompts students to think deeper into	• Reliance on other scaffolds provided (e.g. online resources)

	context about the topic	
Computer animations or videos	• Helps student to understand the topic, thus able to solve the problem more effectively • Easier to understand concepts when represented in the form of visuals • Enhances learning by making the lesson process interesting • Summarises the learning objectives in a concise manner	• Quality of visuals provided may not be clear at times
Internet resources (e.g. web links)	• Provide students a clearer view of the	• Some internet resources may

	learning objectives of the topic • Prompts students to think deeper into context	not seem easy to comprehend in students' perspective
Additional resources (e.g. text documents)	• Helps student to understand topic for the day • Gives students clearer view of what is required for the lesson	• Not effective as a scaffold if student has grasped the essential knowledge required to solve the problem statement
	• More detailed information provided compared to other resources e.g. web links	• Some resources could be either too lengthy or complex to understand in the students' perspective

		• Students may feel that it's time consuming to read through the resources
Hands on activities (e.g. demonstrations or practical activities in class)	• Helps students to better understand and remember the concepts covered during the lesson • Motivates students to be engaged in the learning process • Makes the learning process more interesting • Students are able to visualise what the theory/ concept is about	• Some students may feel that it's time consuming to carry out such activities • Students may fear that if the tasks are not executed properly, it may affect their learning

	• Allows students to gain experience related to real-life applications	
Team presentations	• Encourages sharing and cross-checking of ideas amongst teams • Allows clarification of doubts • Allows students to gain additional knowledge	• Some students may be uncertain if the correct information is presented by their classmates • Reliance on other scaffolds (e.g. facilitator)
Presentation by the facilitator at the end of the day's lesson	• Self-check of understanding for the topic of the day	• Concepts have been covered during the earlier stages of the lesson,

	• Useful as a summary for the topic of the day, especially for topics that involve more complex concepts	hence scaffold may not be deemed as essential by some students
Post-lesson resources	• Aids in further understanding of the topic • Useful for revision and preparation for tests	• Amount of scaffold provided is too much to cope at times, thus leading to lack of motivation to use the scaffold
Practice questions provided after lesson	• Reinforcement of knowledge acquired about the topic • Useful for revision and preparation for tests	• Some students may lack motivation to attempt the questions after lesson

Extra-curricular talks or workshops related to the subject	• Enhance student's course-related knowledge	• Students find it time-consuming to attend such extracurricular activities
Contributions of facilitator	• Facilitator provides guidance and corrects the students during the process • Motivates students to carry on with the learning process for the day • Prompts students to think critically	• Level of student learning varies according to the facilitator and difficulty of the topic e.g. if facilitator does not actively engage the students in discussions, the impact on learning may be lower

Team contributions	• Trains students to be cooperative • Student feel that good team dynamics will translate into better performance in learning and grades • Encourages sharing of opinions and ideas • Increases efficiency in completion of tasks	• In cases if the level of team dynamics is low, learning may be affected • Depending on the difficulty of the topic
Class contributions	• Encourages sharing of different ideas and learn from others • Allows sharing of the challenges faced during the learning	• Duration of time taken for discussions may be too long at times

	process • prompts further thinking and deeper understanding • Instils a sense of motivation to learn • Leads to clearer understanding of the topic

Discussion

Student perceptions of the impact of scaffolds

The objective of the present study was to investigate the students' perceptions of the different scaffolds provided to them in a PBL setting, and how these scaffolds impact their learning. By comparing means of the 16 items in the Scaffold Impact Questionnaire (Table 3), it was found that that students perceived the following types of scaffolds to be of significant impact on their learning: team, class and facilitator contributions (soft scaffolds); worksheets (semi-soft scaffold); PDT (semi-soft scaffold) and practice questions (hard scaffolds).

With reference to previous studies, the findings for this study reinforced the view that tutor and small group learning are indeed perceived as important supports in the PBL environment. As mentioned earlier, tutors should have the relevant content knowledge to guide students throughout the process of solving the problem by asking open-ended questions to facilitate them (Hmelo-Silver, 2004; Hmelo-Silver & Barrows, 2008; Maudsley, 1999; Yee, Radhakrishnan, & Ponnudurai, 2006). The findings from this study also affirmed the role of a tutor or facilitator, as students rated the facilitator to have a relatively high impact on their learning. Through their written comments, they indicated that a facilitator provides guidance and encourages the students to think critically during the lesson. Earlier studies have also showed that collaborative small group learning plays an important role in PBL. The formation of small problem-solving groups helps to distribute the cognitive load and allows students to learn in complex domains (Hmelo-Silver, 2004; Hmelo-Silver, et al., 2007; Schmidt, et al., 2007). For instance, students who attempted the problem or certain scaffolds (e.g. worksheet, PDT) in groups could have learnt more compared to those who work individually. This could have lead to a higher rating for team contributions in this study. Furthermore based on the comments made by the students in the Scaffold Impact Questionnaire (Table 5), it showed that team contributions do help to promote sharing of opinions and increase efficiency in completing tasks at hand. In addition, class contributions also aid in prompting students to think further to promote deeper understanding.

Besides soft scaffolds, most of the scaffold items in the other three categories also seem to aid in the students' learning process. With reference to the written comments given by the students in their questionnaire responses, worksheets were useful in terms of guiding them through the concepts required for solving the problem (Table 5). Based on the justifications provided, scaffolds such as computer animations could serve as important visual aids especially for concepts that are more complex (e.g. process mechanisms). Students also commented that they are able to understand the concepts better if the processes are shown in the form of videos or animations, compared to reading plain text from resources (Table 5). However, there are other studies demonstrating that there are no significant differences in student achievement between multimedia-enhanced PBL classes, compared to the traditional text-based PBL classes (Zumbach, Kumpf, & Koch, 2004). Therefore, it is still too early to conclude if the use of multimedia sources (e.g. computer animations, videos) does play significant roles in impacting student learning and achievement.

Another two scaffolds that students perceive to have an impact on their learning are worksheets and practice questions, which offer good cues on what to focus during self-study periods. Based on the student feedback (Table 5), worksheets are perceived by students as guides for them to attempt the task or solve the problems. Practice questions are provided for the students to attempt after the day's lesson. According to majority of the responses collected, students felt that practice questions are good avenues of helping them understand the topic better, especially during revision before exams (Table 5). The questions also help students to gauge their own understanding, so that they are able to identify the areas in which they are weaker. Therefore, such scaffolds that support active processing of information may be important in student learning.

Comparison between hard, soft and semi-soft scaffolds

In this study, factor analyses were performed to test if the three categories (hard, soft, semi-soft) of the model construct are consistent with the nature of the respective items in the Scaffold Impact Questionnaire. After subsequent rounds of trials, a model (Figure 1), which fits the data and statistical conditions relatively well was derived. Further analysis was done to investigate if there were any significant differences between the four categories in the model. Based on the ANOVA results using pairwise comparison of means, it exhibited that students perceived soft scaffolds (e.g. tutor, team presentations) to have a significant higher impact on their learning, followed by semi-soft scaffolds and lastly hard scaffolds.

The above-mentioned observations and findings seemed to support the social constructivist framework of PBL, which emphasizes tutors providing guidance or meta-cognitive scaffolding, and students being active in social knowledge construction. As mentioned earlier, tutors are the experts who are able to effectively facilitate and enhance the students' learning process (Greening, 1998; Hmelo-Silver, 2004; Maudsley, 1999; Schmidt et al., 2009). The formation of small groups has also creates an environment for students to learn from their peers, thereby enhancing their depth of thinking. 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 then raise these issues for discussion and reach to a common solution. Through such processes, soft skills such as higher-order thinking and shared knowledge construction are then acquired by the students (Hmelo-Silver, 2009).

Since the ANOVA results indicated positive and significant differences between both soft and semi-soft scaffolds when compared to hard scaffolds, this thereby indicates that scaffolds are perceived to have certain advantages that students consider to be useful in their learning process. For example, students commented that the student team presentations (soft scaffold) are good ways of encouraging information sharing within the class. Through the team presentations, students tend to either gain additional knowledge or learn from each other's mistakes. This thus reflects the positive outcome of collaborative learning in a PBL classroom environment. In terms of semi-soft scaffolds, examples such as worksheets and PDTs are tools used as the subject of group discussions. Such scaffolds usually prompt further generation of ideas or information during the problem-solving process within the team or class. Despite the advantages of using soft and semi-soft scaffolds in PBL, there are certain hard scaffolds that aid in student learning too. In the case of hard scaffolds, students felt that practice questions that were provided as post-lesson material helped them in better understanding and preparation for tests. On the other hand, recommended textbooks do not seem to contribute much to the learning process based on the average perceived impact (Table 3) as students tend to have reliance on other provided scaffolds (Table 5). In addition, students also commented that there may be a lack of motivation to acquire the resources, which means borrowing of the textbooks. Hence the lower impact rating of recommended textbooks could have contributed to the outcome of how hard scaffolds are perceived in overall, by students to have a lower impact on their learning compared to the other two scaffold groups.

Limitations and Further work

One possible limitation that could have influenced the responses of the participants would be the lack of motivation of students to attempt the other categories of scaffolds. For example, students may not be keen to investigate more about the problem or they are confident in finding resources on their own to solve the problem. 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 necessary by the students. In overall, the findings from this study has provided evidence to support previous studies that PBL does provide extensive scaffolding and guidance to facilitate meaningful learning for students (Hmelo-Silver, et al., 2007; Schmidt, et al., 2007; Simons & Klein, 2007).

It remains an empirical question to see if there are any significant differences in the level of student dependence on scaffolds, as they progress from novices to individuals who have adopted relevant PBL skills gained throughout their course of study. As suggested by Schmidt et al. (1997), the degree of scaffolding should be lower in order to encourage independent learning. This can be done when the students have gained a certain level of prior knowledge or expertise in the subject matter (Schmidt, et al., 2007). One suggestion to consider for further research could be to conduct a longitudinal study, which monitors the same batch of students, as they progress from novice to final year of their course of studies. In this way, comparisons and inferences can be made about the students' reliance on the different types of scaffolds. Another aspect for further research would be to find out if students of varying academic abilities (low to high grade point average) have similar perceptions about the impact of the types of scaffolds. For example, if the student perceives hard scaffold to be more useful, would that also translate to a positive influence in his or her academic achievement?

Given the fact that scaffolds are diverse and guidelines on how they should be employed are still rather vague, more research could be conducted to investigate if there are any causal relationships between types of scaffolds and the students' learning styles and achievements.

Conclusion

In summary, the data obtained from this study were used to categorise scaffolds into three groups – hard, soft and semi-soft, based on the characteristics of various types of scaffolds. The model consisting of the three scaffold groups was statistically validated. The findings also revealed that, in general, scaffolds that require soft skills such as peer learning or facilitation are perceived by students to have a higher impact on their learning compared to hard scaffolds such as recommended textbooks. The results from this study reinforced previous studies presenting that scaffolds such as tutors and collaborative learning do play important roles in student learning, especially in PBL. In addition, there are other forms of hard and semi-soft scaffolds such as worksheets and practice questions which may be helpful in enhancing student learning.

Chapter 3: Effect of Scaffolds on Student Achievement in Problem-Based Learning[2]

Abstract

The purpose of this study was to investigate if there is any relationship between students' academic ability and how they perceived the impact of three categories of scaffolds (hard, semi-soft and soft scaffolds) on their learning. In addition, comparison of the perceived usefulness of hard, soft and semi-soft scaffolds was also examined for students at different stages of their three-year course. Participants for this study ($N = 384$) are enrolled in an educational institute that uses problem-based learning (PBL) as the instruction method. A Scaffold Impact Questionnaire, consisting of various types of scaffolds used in this curriculum was devised and given to the student participants to complete. Students were required to rate the level of impact that each scaffold has on their daily learning in school. In addition, the impact of the three scaffolding categories (hard, soft,

[2] Authors: Choo, S. S. Y, Yew, E. H. J. & Schmidt, H. G.

semi-soft scaffolds) on student achievement was also measured. The consolidated data was analysed by means of analyses of variance. Results obtained from this study suggested that students, particularly those with high academic ability, generally perceived 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).

Introduction

Problem-based learning (PBL) is an approach to learning and instruction which is student-centred (Akınoğlu & Tandoğan, 2007; Johnson & Malinowski, 2001; Schmidt, 1993). One of the main objectives of PBL is to enable students to gain both content knowledge and flexible thinking strategies through experiencing the process of solving problems (Hmelo-Silver, 2004; Schmidt, Loyens, Van Gog, & Paas, 2007; Simons & Klein, 2007). When students work on a problem, they are given opportunities to develop learning abilities or strategies, to merge their old knowledge with new knowledge, and to develop their critical thinking skills in a specific discipline environment (Akınoğlu & Tandoğan, 2007). Given that one problem may have several possible solutions, students would need to acquire or apply the skills of consolidating information, carry out data analysis, and then apply what they have researched on to the task at hand (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004; Schmidt, van der Molen, te Winkel & Wijnen, 2009). Besides being self-directed learners throughout this process, students are also required to work collaboratively in small groups to further discuss, analyse and suggest feasible solutions to the problem (Hmelo-Silver & Barrows, 2008; Norman & Schmidt, 1992). In order to facilitate and provide guidance throughout the entire process of the problem-solving activity, the students are guided by a tutor whose role is that of a cognitive coach, modelling good strategies for students to think deeper through a series of questioning and discussions (Collins, Brown, & Newman, 1989; Greening, 1998; Hmelo-Silver & Barrows, 2006; Schmidt, et al., 2009).

In summary, PBL follows the social constructivist framework whereby students develop knowledge in the course of interactions with others and with multiple instructional materials (Greening, 1998; Savey & Duffy, 1996). In order to assist in the students' learning process, it is believed that some form of scaffolding is required to guide students in carrying out a task that they would be able to handle alone (Roehler & Cantlon, 1997; Verenikina, 2008). The main instructional materials used in the PBL curriculum would be the problems. The problems used should encourage thinking and at the same time, be interesting in order to motivate students to attempt the problem (Hmelo-Silver, 2004; Khoo, 2003). Apart from the problems, there are also other learning supports that aid as tools to scaffold student learning. Examples of such learning supports include audiovisual aids, lectures, and laboratory sessions as well as provided references (Ertmer & Simons, 2006; Hamdy, 2008; Saye & Brush, 2002; Simons & Klein, 2007; Taylor & Miflin, 2008). Previous studies have indicated that PBL was able to facilitate and enhance student learning (Hmelo-Silver, Duncan, & Chinn, 2007; Schmidt, 1993; Schmidt, et al., 2007; Simons & Klein, 2007). According to a study conducted in a PBL setting by Simons and Klein (2007), it was demonstrated that students who were provided with scaffolds scored significantly higher in post-tests in comparison with the student group which did not receive any form of scaffolds. The outcome of this particular study reflected the importance of scaffolding in enhancing student inquiry and learning achievements (Simons & Klein, 2007). These findings seem to concur with other studies in both general and PBL contexts which suggested that the use of scaffolds may aid in reducing the complexity of assigned tasks, and also in developing students' abilities to complete the tasks (Clark & Graves, 2005; Ertmer & Simons, 2006).

Classification of Scaffolds

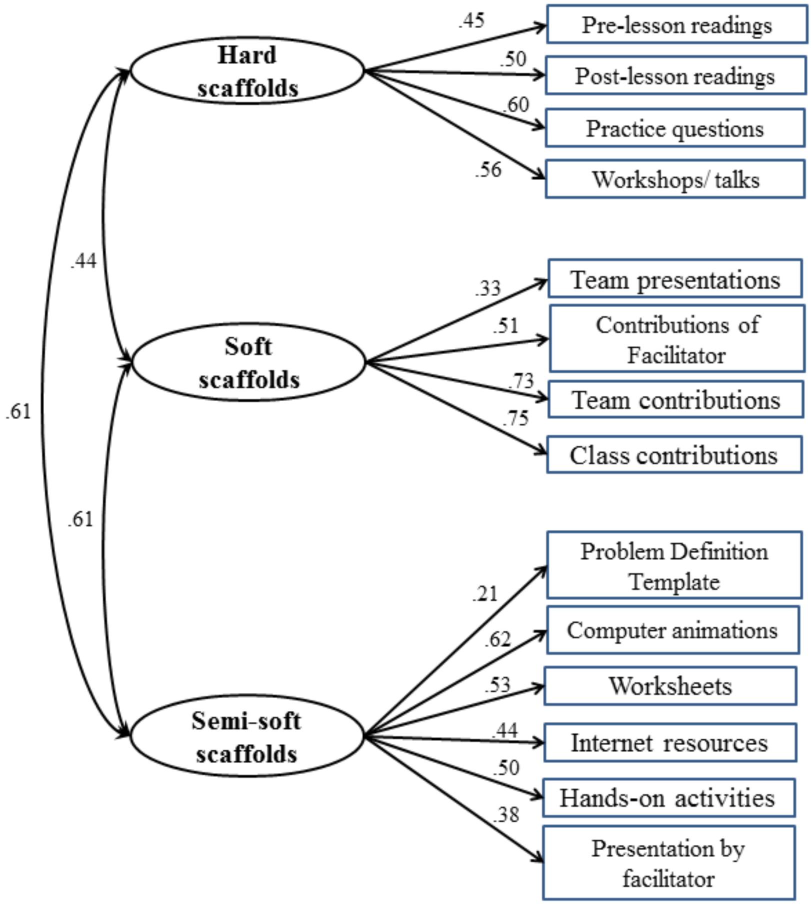
According to Saye and Brush (2002), scaffolds can be classified into two groups- hard and soft scaffolds. "Hard" scaffolds are basically static supports that can be provided to the student upon assignment of a certain task (Saye & Brush, 2002). Examples of such scaffolds can be in the form of computer or paper-based cognitive tools (Belland, Glazewski, & Richardson, 2008). One such form of scaffolds quoted by Belland et al. (2008) would be the use of process worksheets, which provide descriptions of learning issues students should master in the process of solving the problem. In contrast with hard scaffolds, "soft" scaffolds are generally defined by actions in response to the learner's efforts when the learner indicates a specific need (Saye & Brush, 2002). Examples of such scaffolds in PBL would be tutor interventions during discussions with students as well as collaborative interactions within the peer groups. Soft scaffolds are considered useful if there is a momentary need at times while completing the task at hand.

Previous studies have also indicated that tutors are one of the important elements in PBL, as they play the role as expert learners who model good strategies for thinking and provide meta-cognitive scaffolding to students (Hmelo-Silver, 2009; Hmelo-Silver & Barrows, 2006). Being the experts, tutors should be able to effectively facilitate student learning (Greening, 1998; Hmelo-Silver, 2004; Maudsley, 1999). In a study investigating the usefulness of scaffolds on learning based on student perceptions, the findings indicated that various types of learning activities or supports seemed to impact student learning differently. Students tend to view soft scaffolding events such as tutor interventions as more significant than other scaffolds such as worksheets (Choo, Rotgans, Yew & Schmidt, 2011). As for small-group learning, it encourages activation of prior knowledge within the small group setting as well as allows students to analyze and apply causal reasoning (Dolmans & Schmidt, 2006; Hmelo-Silver, 1998; Schmidt & Moust, 2000; Schmidt, Rotgans, & Yew, 2011). For example, students who may have prior knowledge of the topic at hand could share the information with their teammates, discuss any conflicting issues and derive feasible conclusions. By doing so, skills such as higher-order thinking and shared knowledge construction are acquired by the students (Hmelo-Silver, 2009). Additionally, group discussions in such PBL groups seem to have a positive influence on the students' interest in 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. Besides being proactive in the learning process, students should also participate actively in peer teaching to bring about effective learning (Lohfeld, 2005).

In the study described in Chapter 2 of this thesis, data of the perceived impact of the various types of scaffolds or scaffolding events were evaluated by the students and a statistical model was constructed as an attempt to categorise them into three major groups – hard, semi-soft and soft. As mentioned earlier, scaffolds in general can be considered as either hard or soft. However in the context of PBL, some scaffolds can be regarded as a combination of both. For example, a worksheet is a hard scaffold. However, there is also a tendency for students and tutors to use it as a flexible support tool for discussions and self-directed learning. In this context, a worksheet is used in a "just-in-time" fashion; the information is used when needed. Hence, such scaffolds can be referred to as "semi-soft" scaffolds. Figure 1 shows the model that was constructed and statistically validated after classifying various possible types of scaffolding tools or events that can be used in PBL under three categories – hard, semi-soft, and soft scaffolds. Examples of hard scaffolds that could impact student learning are recommended textbooks, as well as pre- and post-lesson readings. Apart from worksheets that are considered as semi-soft scaffolds, other tools such as computer animations and online resources also fall within that description of "semi-soft" scaffolds. As the problem definition template (PDT) serves as a template for individual teams to start the brainstorming process at the start of the lesson, it can be classified as a 'semi-soft scaffold'. In the PBL context, instances of soft scaffolds or scaffolding events that could affect student learning would consist of contributions by the tutor or facilitator, students from the small teams and the class as a whole. Further information on the different types of scaffolding tools or events will be provided in the next section of this chapter.

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)



Overall findings from the above-mentioned study indicated that students tend to perceive soft scaffolds to have a higher impact on their learning as compared to the other three scaffold categories. Although past studies seemed to suggest that students in the PBL educational context perceived 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 is 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. Thus a question worth further exploring would be whether students of differing academic ability find specific types of scaffolds more (or less) useful than others. Moreover, some studies have also suggested that the fading of hard scaffolds is possible and should be encouraged once students have gained ability in performing the assigned tasks (Belland, Glazewski, & Richardson, 2008; Puntambekar & Hubscher, 2005). With increasing expertise, fewer resources should be provided to the students. In this way, independent learning is encouraged while providing a form of flexible scaffolding (Schmidt, et al., 2007). A question that arises would then be whether students in a PBL context indeed develop greater independence from scaffoldings as they progress from their first year of study to the next.

Thus this study seeks to provide greater insights into the following research questions: 1) Is there a relationship between students' academic ability and the way they perceive the impact of hard, semi-soft and soft scaffolds on their learning? and 2) Do the perceived impact of hard, semi-soft and soft scaffolds on student learning differ at different stages (Year One, Two and Three) of the course?

Methods

Participants

The sample consisted of 384 participants enrolled in courses at a polytechnic in Singapore, specifically in the respective areas of Biomedical Sciences, Biotechnology, Materials Science, Pharmaceutical Sciences and Environmental Science. The breakdown of the participants in terms of their years of study and frequencies of gender is shown in Table 1. Out of the total number students who were eligible for inclusion in this study (n=823), 47% of the students chose to participate.

Table 1

Gender and age frequencies of participants, in respective years

Year of study	**Total number of participants (n)**	**Gender**		**Age**	
		Male	Female	Mean	S.D.
Year 1	169	72	97	16.60	1.13
Year 2	111	49	62	17.59	1.15
Year 3	104	51	53	18.89	1.66

Educational Context

In this particular institution, the instructional approach of PBL is followed for most of the courses it offers. In this approach, five students work together in one team under the guidance of a tutor or facilitator. Each class comprises of four to five teams. A unique feature of the PBL approach used in this institution is that students work on one problem during the course of the day (Alwis & O'Grady, 2002). 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; Schmidt, 1993). In this institution, a form of scaffold which is fairly unique to PBL is implemented. This scaffold is known as the Problem Definition Template (PDT). The PDT serves as a generic template for students to utilise their prior knowledge, brainstorm the possible learning issues and formulate an action plan to solve the problem. By categorising the students' contributions under three columns (What do we know?, What do we not know?, What do we need to find out?), this allows students to organise their thoughts better and devise an approach to solve the problem.

At the end of the day, each team will come together to present, elaborate upon, and synthesize their findings. 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 facilitator 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 facilitator. During the team presentations, there will be a series of class discussions generated by questions raised from either the students or facilitator who encourages collaborative learning. The facilitator 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 the students to utilise for revision purposes.

Procedure

Scaffold Impact Questionnaire. A Scaffold Impact Questionnaire was devised and administered to the participants in order investigate what students perceived as important scaffolds that impact their learning in a PBL environment. Students were asked to rate the level of impact that different scaffolds have on their learning. The list of 14 items that were measured for this study is as categorised and shown in Figure 1, in three groups – hard, semi-soft and soft scaffolds. This list was based on the types of learning supports that are utilized in the polytechnic. Each item in the questionnaire was scored on a 5-point Likert scale: 0 (not at all), 1 (a little), 2 (moderate), 3 (much), and 4 (very much). An example of a question is shown as follows.

'Please evaluate the level of impact that the following supports (1 to 16) have on your learning in Republic Polytechnic.

Worksheets

Not at all	*A Little*	*Moderate*	*Much*	*Very Much*
0	*1*	*2*	*3*	*4*

Reason for the choice stated above:

____,

The Scaffold Impact Questionnaire was made available to all students that were in their course of study, ranging from Year 1 to Year 3. An email was sent out to encourage students to participate in this study by completing and submitting the questionnaire. The participants were given a week to respond to the questionnaire at their own free time, and submission was voluntary. In other words, students were given a choice in regards to their participation in this study. The submitted data was then consolidated and checked for any errors.

Analyses. To investigate if students of varying academic ability perceived the impact of various scaffolds differently, quantitative analysis was conducted. Apart from descriptive statistics, analyses of variance were also conducted using the grade point average (GPA) and year of study of the participants. The GPA was computed after calculating the cumulative scores of the subjects that student have taken in their course of study. The scores from the

Scaffold Impact Questionnaire were computed in SPSS™, with student GPA as the factor. Prior to the computation, the participants were divided into groups of low (lower quartile), moderate and high (upper quartile) GPA.

Results

For this study, ANOVA was carried out to examine whether students of varied academic abilities (low, moderate, high GPA) perceived the impact of various scaffolds to be different. In addition, the analyses aimed to find out which scaffold types were deemed by the students to be most helpful in their learning.

Comparison between hard, semi-soft and soft scaffolds. One of the aims of this study is to examine the relationship between the students' academic achievements and their perceived impact of scaffolds on their learning. Based on data obtained from the Scaffold Impact Questionnaire, the mean differences of students' perceived impact of the three categories of scaffolds between students of varying academic abilities were analysed. In addition to examine the year group effects of the learning achievements versus the students' perceived impact of the three categories of scaffolds, the means and standard deviations were computed for the students enrolled in Year 1, 2 and 3 respectively. ANOVA was also performed for each of the year group to examine for any statistically significant differences in the data obtained. Table 2 below exhibits the descriptive statistics comparing the student academic level and their perceived usefulness of scaffolds in overall.

Table 2

Means and standard deviations comparing the student academic level and their perceived impact of scaffolds (Year 1 to 3 students)

	Academic ability	**N**	**Mean**	**Std. Deviation**	**Std. Error**
Hard scaffolds	Low	131	2.55	.78	.07
	Moderate	121	2.51	.77	.07
	High	132	2.68	.69	.06
	Total	384	2.58	.75	.04
Soft scaffolds	Low	131	2.91	.75	.07
	Moderate	121	2.96	.53	.05
	High	132	3.15	.54	.05
	Total	384	3.01	.62	.03
Semi-soft scaffolds	Low	131	2.94	.54	.05
	Moderate	121	2.92	.55	.05
	High	132	3.05	.51	.04
	Total	384	2.97	.54	.03

The results from a one-way ANOVA with GPA as the factor indicated that the perceived usefulness of soft scaffolds on student learning was statistically significant amongst the three GPA groups [$F=5.50(2, 1150)$, $p=0.004$]. Results of the post-hoc Tukey test 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. An ANOVA with scaffold category as a factor was also carried out, indicating significant differences within the three categories of scaffold [$F=52.13$ $(2, 1150)$, $p<0.001$]. The average means suggested that students of varying academic levels generally perceived hard scaffolds to have a lower impact on their learning. In general, semi-soft and soft scaffolds are perceived by students to have a higher impact on their learning. Based on the overall results obtained, the students seemed to prefer to utilise soft scaffolds followed by semi-soft and lastly, hard scaffolds. The following section further delves into the perceived impact of scaffolds by students of low, moderate and high GPA.

Comparison of various scaffold types. Table 3 show the means and standard deviations of perceived usefulness of the respective types of scaffolds, by students with varied academic abilities.

Table 3

Mean score of each scaffold item for students with low, moderate and high GPA

Category of scaffold	**Item (Type of scaffold)**	**Mean**	**Std. Deviation**
Hard Scaffolds	Pre-lesson readings	2.44	1.078
	Post-lesson readings	2.15	1.235
	Practice questions	3.17	.960
	Talks or workshops	2.55	1.139
Soft Scaffolds	Facilitator	3.17	.878
	Team contributions	3.21	.828
	Class contributions	2.99	.855
	Team presentations	2.65	.973
Semi-soft Scaffolds	Worksheets	3.31	.744
	Computer animations	3.10	.934

Internet resources	2.99	.847
Hands on activities	2.90	1.049
Problem Definition Template (PDT)	2.53	1.100
Presentation by facilitator	3.02	.999

As determined by one-way ANOVA, there were statistically significant differences between the three scaffold groups for the following scaffolds: Computer animations [$F(2,383)=6.85$, $p=0.012$], Practice questions [$F(2,383)=6.12$, $p=0.002$], Contributions of facilitator [$F(2,383)=5.62$, $p=0.002$], Team contributions [$F(2,383)=4.52$, $p=0.006$], Class contributions [$F(2,383)=5.26$, $p=0.006$], Worksheets [$F(2,383)=4.47$, $p=0.012$], Problem Definition Template [$F(2,383)=4.25$, $p=0.015$]. A Tukey post-hoc test was then performed to find out which GPA groups differed from each other for the scaffolds that indicated significant differences. The post-hoc analysis revealed that scaffolds such as computer animations, practice questions and team contributions were statistically significant between all the three GPA groups. In overall, the mean differences for each of the scaffolds increased as the academic competency increased. As for scaffolds like worksheets, contributions of facilitator and PDT, there were statistically significant differences between the responses submitted by the high and low GPA groups. In the case of worksheets and facilitator contributions, the results indicated that students with high GPA perceived these two scaffolds to have a higher impact on their learning, compared to students with low GPA. This was the reverse in the case for PDT whereby students with low GPA deemed PDT to have a higher influence on their learning.

Differences between years of study. After looking at the overall sample population, the perceived impact of the three categories of scaffolds for respective year groups (Year 1, 2 and 3) were further analysed. The findings are presented in Tables 4 to 6.

Table 4

Means and standard deviations comparing the perceived impact of hard, semi-soft and soft scaffolds on student GPA (Year 1 students)

Category of scaffold	**Academic ability**	**N**	**Mean**	**Std. Deviation**	**Std. Error**
Hard scaffolds	Low	35	2.59	0.78	0.13
	Moderate	55	2.48	0.80	0.11
	High	79	2.59	0.72	0.08
	Total	169	2.55	0.75	0.06
Soft scaffolds	Low	35	3.14	0.59	0.10
	Moderate	55	2.91	0.55	0.07
	High	79	3.12	0.51	0.06
	Total	169	3.06	0.55	0.04
Semi-soft scaffolds	Low	35	3.11	0.54	0.09
	Moderate	55	2.94	0.50	0.07
	High	79	3.00	0.50	0.06
	Total	169	3.00	0.51	0.04

In the case for Year 1 students, the means obtained reflected that the impact of hard scaffolds on the students' learning was much lower compared to the other three categories (Table 4). The average mean of soft scaffolds is rated the highest, followed by semi-soft then hard scaffolds. A two-way mixed repeated measures test was conducted to test the influence of student academic abilities on their perceived value of different scaffold groups. The results showed no statistically significant interaction between the student GPA and their perceptions of using scaffolds [$F(4, 330) = 0.631$, $p = 0.641$, $\eta^2 = 0.01$]. On the other hand, there are statistically significant differences within the three scaffold type groups [$F(2, 165) = 39.83$, $p < 0.001$, $\eta^2 = 0.326$]. To further assess the magnitude of this outcome, the partial eta squared value is >0.14 thus implying that the effect size is large. The test between-subjects outcome based on the three GPA groups (low, moderate, high) revealed that the academic abilities of Year One students has no significant effect on the way they perceived usefulness of scaffolds ($p = 0.178$, $\eta^2 = 0.021$).

Table 5

Means and standard deviations comparing the perceived impact of the hard, semi-soft and soft scaffolds on student GPA (Year 2 students)

Category of scaffold	**Academic ability**	**N**	**Mean**	**Std. Deviation**	**Std. Error**
Hard scaffolds	Low	44	2.45	0.78	0.12
	Moderate	39	2.46	0.69	0.11
	High	28	2.90	0.62	0.12
	Total	111	2.57	0.73	0.07
Soft scaffolds	Low	44	2.86	0.65	0.10
	Moderate	39	2.87	0.43	0.07
	High	28	3.11	0.58	0.11
	Total	111	2.93	0.57	0.05
Semi-soft scaffolds	Low	44	2.88	0.52	0.08
	Moderate	39	2.92	0.51	0.08
	High	28	3.14	0.55	0.10
	Total	111	2.96	0.53	0.05

In the case for Year 2 students, the mixed repeated measures ANOVA result demonstrated there was no statistically significant interaction between the student GPA and their perceptions of using scaffolds [$F(4, 214) = 0.476$, $p = 0.753$, $\eta^2 = 0.09$]. On the other hand, there are statistically significant differences within the three scaffold type groups [$F(2, 107) = 15.092$, $p < 0.001$, $\eta^2 = 0.220$]. The test between-subjects using GPA as the factor revealed that the academic abilities of Year Two students do influence their perceived impact of different types of scaffolds on their learning ($p = 0.007$, $\eta^2 = 0.088$). To further affirm the above mentioned outcome, the ANOVA result indicated that hard scaffolds [$F(2, 110) = 4.14$, $p = 0.018$] have a significant impact on student learning achievements. Results of the post-hoc Tukey test indicated that compared to the students of moderate ($M = 2.46$, $SD = 0.78$, $p=0.37$) and low ($M = 2.45$, $SD = 0.78$, $p = 0.26$) academic abilities, the high GPA ($M = 2.90$, $SD = 0.62$) student group perceived hard scaffolds to have higher impact on their learning. Based on the averages obtained (Table 5), it appeared that semi-soft ($M = 2.96$, $SD = 0.57$) and soft ($M = 2.96$, $SD = 0.57$)

scaffolds are generally perceived by students to have a higher impact in their learning. In overall, Year 2 students with high GPA tend to utilise all scaffolds, with a higher preference for semi-soft and soft scaffolds.

Table 6

Means and standard deviations comparing the perceived impact of the hard, semi-soft and soft scaffolds on student GPA (Year 3 students)

Category of scaffold	**Academic ability**	**N**	**Mean**	**Std. Deviation**	**Std. Error**
Hard scaffolds	Low	52	2.61	0.78	0.11
	Moderate	27	2.63	0.82	0.16
	High	25	2.69	0.67	0.13
	Total	104	2.63	0.76	0.07
Soft scaffolds	Low	52	2.79	0.88	0.12
	Moderate	27	3.18	0.57	0.11
	High	25	3.27	0.57	0.11
	Total	104	3.00	0.77	0.08

Semi-soft scaffolds	Low	52	2.89	0.56	0.08
	Moderate	27	2.90	0.69	0.13
	High	25	3.12	0.50	0.10
	Total	104	2.95	0.59	0.06

In the case for students in the last year (Year 3) of their course, the outcome of the repeated measures ANOVA revealed that there was no statistically significant interaction between the student GPA and their perceptions of using scaffolds [$F(4, 214)=0.476$, $p=0.753$, $\eta^2=0.09$]. On the other hand, there are statistically significant differences within the three scaffold type groups [$F(2, 100)=11.463$, $p < .0010$, $\eta^2=0.187$]. The test between-subjects outcome indicated that the academic abilities of Year Three students do affect their perceived impact of scaffolds on their learning achievements ($p=0.100$, $\eta^2 = 0.045$). The ANOVA results unravelled that soft scaffolds are generally perceived to have a significant influence in their learning [$F(2, 103)=4.50$, $p = 0.013$]. After performing a post-hoc Tukey test, the results confirmed that there is a significant difference (p = 0.024) between the high (M = 3.27, SD = 0.57) and low (M = 2.79, SD = 0.88) GPA student groups under the soft scaffold category. This positive difference reflected that students of better academic ability perceived soft scaffolds to have a greater impact on their daily learning.

Discussion

Comparison between hard, soft and semi-soft scaffolds: In order to examine if there is any relationship between the students' learning achievement and their perceived impact of hard, semi-soft and soft scaffolds, statistical analyses were conducted. Based on the averages derived from the sample population used in this study (N = 384), it was demonstrated that students of all academic abilities generally perceived hard scaffolds to have a lower impact on their learning, followed by semi-soft and soft scaffold (Table 2). This finding was further tested and affirmed via ANOVA, which revealed statistically significant differences between the three GPA groups within the soft scaffold category. It was found that for students of higher academic level, soft scaffolds play an essential role in their learning progress. One reason accounting for this phenomenon could be that soft scaffolds help to effectively clarify their prior or newly acquired knowledge compared to fixed sets of information that hard scaffolds provide. Students could use semi-soft scaffolds (e.g. worksheet questions and computer animations) as triggers for discussions which encourages cognitive and self-directed learning. Such instances of learning supports also prompt more contributions from the facilitator and students, either as a class or within the team. Since collaborative small-group learning are guided by a tutor or facilitator who models good strategies for learning and thinking (Greening, 1998; Hmelo-Silver, 2004; Schmidt & Moust, 2000), it is unavoidable for soft scaffolds to play an important role in a PBL environment. Unlike hard scaffolds, semi-soft and soft scaffolds allow a certain level of flexibility whereby information can be provided to the students when deemed necessary.

Effects of various types of scaffolds: Comparing the various types of scaffolds or scaffolding events available in a PBL classroom environment, one of the findings revealed that learning supports under the soft scaffold category could have a significant influence in student learning. As further affirmation, 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 found to be statistically significant. 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. One possible reason could be that students with higher academic or learning abilities may already have the prior and current knowledge of the subject matter, hence prompting them to proceed to attempt learning supports such as the worksheets to find out more about the topic of interest. Assuming that this group of students has a higher content knowledge compared to the other two GPA groups, they may have already read in-depth resources which required more facilitation (soft scaffold) to prompt their critical thinking. In a previous study conducted, it showed that students from a multimedia-enhanced PBL class showed significantly higher level of motivation to learn and retention of knowledge compared to those in the conventional class (Zumbach, Kumpf & Koch, 2004). Hence, semi-soft scaffolds such as computer animations do aid in enhancing student learning.

Another finding from this study was that students with low GPA deemed PDT to have a higher influence on their learning. As for 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 efficient knowledge acquisition for students with lower or slower learning abilities. 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. Hence, semi-soft scaffolds such as PDT that encourages collaborative learning may help in increasing student engagement during the problem-solving process.

Lastly, hard scaffolds such as practice questions also seemed to have a significant impact on student learning. Such learning tools serve as a good mode of revision material which enables students to recap and assess their acquired knowledge from lessons. Hence, students perceived practice questions as important in impacting their learning of the subject matter.

Perceived impact of scaffolds from novice to advanced stages: To find out if the above-mentioned findings would differ for students at different stages of their course, comparison of means were performed for the data obtained from Year 1, 2 and 3 students respectively.

Year 1 students (Novice stage). Based on the means obtained for students in their first year of PBL environment, it is suggested that the usage of hard scaffolds is least preferred compared to the other two categories of scaffolds (Table 4). 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. Judging from the findings obtained, students who are novices in PBL seemed to deem soft scaffolds such as contributions from facilitator, teammates or classmates to be more important in impacting their learning achievement. Take team or class contributions for instance, previous studies conducted on small PBL tutorial groups indicated positive cognitive effects in areas such as activation of prior knowledge and causal reasoning (Dolmans & Schmidt, 2006; Hmelo-Silver, 1998). Furthermore, group discussions in these PBL groups appeared to have a positive influence on the students' interest in the subject matter (Dolmans & Schmidt, 2006; Schmidt, et al., 2009), which may indirectly lead to a rise in the students' motivation level to learn. Facilitators, who fulfil the role of providing soft scaffolding, help in moderating discussions by probing, resolve occasional conflicts and encourage active contributions from students (Akınoğlu & Tandoğan, 2007; Hmelo-Silver & Barrows, 2006). Hence by doing so, this promotes more effective learning for students and increases understanding of the topic at hand.

Year 2 students (Intermediate stage). Year 2 students are at the intermediate stage of their course which allows them to take subjects that are more specialised for the areas that they would want to major in. This could have caused a slight shift in the trend as observed in the case for Year 1 students, whereby the impact of hard scaffolds seemed to be more significant. The repeated measures ANOVA result indicated that the students' academic abilities do influence their perception of which scaffolds are useful. Upon conducting a post-hoc analysis, it was found that 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. The overall means obtained for soft and semi-soft scaffolds was slightly higher than hard scaffolds (Table 5), proposing that students still perceived that scaffolds with elements of soft scaffolding may influence their learning better. Overall, the findings for the Year 2 cohort suggested that hard scaffolds serve as useful avenues to provide information, thus supplementing the lack of prior knowledge for subjects that could be more specialised and complex compared to those taken in Year 1.

Year 3 students (Advanced stage). Based on the overall means obtained for the Year 3 students, it was found that they preferred semi-soft and soft scaffolds compared to hard scaffolds (Table 6). The test between-subjects outcome indicated that the academic abilities of Year Three students do affect their perceived impact of scaffolds on their learning achievements. The ANOVA results indicated significant differences for the scaffolds within the soft scaffold category. Furthermore, the post-hoc analysis 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 involve 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 would be of great importance in prompting and guiding the students to derive feasible justification to solve assigned tasks or problems.

General conclusions

Based on the results obtained from this study, the following conclusions can be made in general. First, hard scaffolds are perceived as less influential in impacting student learning achievements compared to semi-soft and soft scaffolds, with the exception of students in their intermediate year of study. Second, soft scaffolds are perceived by students to have a significant impact on their learning achievements.

Findings from this study collectively revealed that students perceive semi-soft and especially soft scaffolds to have a significantly higher impact on their learning in a PBL environment. This thereby aligns with previous studies which suggested that the tutor and collaborative learning plays an important role in student learning, especially in PBL. However, this does not mean that hard scaffolds are not useful in enabling learning. Hard scaffolds may play a more essential role when the learner starts to undertake subjects that are more specialised i.e. subject fields that they have negligible or inadequate knowledge. With reference to hard scaffolds such as pre-lesson readings or practice questions, fundamental concepts of the subject matter is efficiently instilled and reinforced. Third, students of high academic achievement deemed all three scaffolds, particularly soft scaffolds to have a more extensive influence on their learning. These students would have a higher level of motivation to perform well in their studies and thus, this could have led to higher utilisation of available resources or scaffolds that are provided within the curriculum. Lastly, different types of scaffolds may be effective in impacting student learning achievements, based on the needs of the learner. The types of learning supports or events identified earlier which has extensive effects on student learning would be the following: practice questions (hard scaffold), contributions of the facilitator, team and class (soft scaffolds); worksheets, PDT, computer animations (semi-soft scaffolds). These scaffolds, either individually or used in combination, could help in the students' knowledge acquisition and address any learning obstacles.

Limitations and Further work

The findings obtained from this study indicated that soft scaffolds are generally preferred by students in terms of impacting their learning. According to Schmidt et al., the degree of scaffolding should be lesser when the students have gained a certain level of prior knowledge or expertise in the subject matter (Schmidt, et al., 2007). Data obtained from the respective years reflected that students are generally more reliant on soft scaffolds for enhancing learning. However, it cannot be concluded 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 this study consist of different students. In order to examine if the level of dependence of certain scaffolds would diminish as they progress from Year 1 to 3, a suggestion for further research could be to conduct a longitudinal study which monitors the progression of students from novice to final year of their course of studies.

One limitation of this study is that the level of motivation of students was not known, which could have helped in unravelling more information about the students from the three different academic achievement groups. Students of lower and moderate academic ability could have lacked motivation in using the scaffolds provided. They may not deem it necessary to investigate more about the problem. Furthermore, they could be confident in finding resources on their own compared to using the scaffolds that are designed or provided 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 recent study, it was suggested that when students gain more autonomy from tutor and team members, they would exhibit more cognitive engagement in class (Rotgans & Schmidt, 2011). For students with stronger academic background, they may be able to gain more autonomy from their peers during discussion as they may have more content knowledge to contribute during discussions. This may increase the level of motivation in learning for this group of students. In addition, another study suggested that students 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 to occur (Lohfeld, 2005). For students of weaker academic ability, they may not be confident in contributing their opinions thus reducing their level of motivation in contributing to team or class discussions, which are considered as soft scaffolds. For such instances, they may find hard scaffolds to be more useful in impacting their learning. Therefore, another suggestion for future work could be to examine the motivated learning strategies of students with varying academic abilities, and to observe for any correlations between motivation levels to usage of scaffolds. In addition, it will also add value to the findings of this study to investigate if the amount or certain types of scaffolds could be adjusted and provided to students on a more flexible level (e.g. provide scaffolds only when deemed necessary). This would help to find out if there are any differences in student learning achievements, in terms of encouraging independence in learning.

Conclusion

The results obtained from this study generally concluded that students, especially those with high academic achievement generally perceive semi-soft and soft scaffolds to have a significantly higher impact on their learning in a PBL environment. Based on this study, semi-soft and soft scaffolds are noted to be useful by students who are still novices to PBL due to the encouragement of peer learning. This study also revealed that as the students progress from novice to intermediate stage of their studies, they would require hard scaffolds to aid in their learning as the subjects are more difficult. In addition, findings from this study seem to align with previous studies which suggested that tutor interventions (soft scaffold) and collaborative small group learning (semi-soft and soft scaffolds) enhances student learning.

Chapter 4:
Effect of Worksheet Scaffolds on Student Learning in Problem-Based Learning[3]

Abstract

The purpose of this study was to investigate the effect of worksheets as a scaffolding tool on students' learning achievement in a problem-based learning (PBL) environment. Seventeen PBL classes (N = 241) were randomly assigned to two experimental groups - one with a worksheet provided and the other without. Students' learning of the topic at hand was evaluated by comparing results from pre- and post-lesson concept recall tests. We also obtained information about students' perceptions of factors impacting their learning using a Learning Impact Questionnaire. The data was analyzed by means of analyses of variance. Results of the study indicated that there was no statistically significant difference between the levels of understanding for both groups of students. In addition, survey

[3] Choo, S. S. Y., Rotgans, J. I., Yew, E. H. J., & Schmidt, H. G. (2011). Effect of worksheet scaffolds on student learning in problem-based learning. Advances in Health Sciences Education, 1-12.

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. These findings suggest that scaffolds such as worksheets may not play a significant role in enhancing students' learning within the social constructivist framework of problem-based learning. On the other hand, the importance of the role of tutor and collaborative small group learning which are key features of PBL is reinforced.

Introduction

In recent years, a debate erupted among researchers about the question of how much guidance do students need in problem-based learning (PBL) (Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006; Schmidt,, et al., 2007). For instance, Kirschner et al. (2006) suggest that problem-based learning (PBL) is a minimally guided approach and is less effective and efficient than instructional approaches that place a strong emphasis on guidance of the student learning process. However, there are others who argued that the PBL approach does provide extensive guidance and scaffolding to facilitate meaningful learning (Hmelo-Silver, 1998; Hmelo-Silver & Barrows, 2008; Schmidt, 1993; Schmidt, et al., 2009). Several authors describing the PBL process include descriptions of additional structured educational activities and sources of guidance such as references, audiovisual aids and lectures relevant to the problem as scaffolds to enhance student learning (Ertmer & Simons, 2006; Saye & Brush, 2002; Simons & Klein, 2007; Taylor & Miflin, 2008). However, till date, there have been different opinions about how resources or scaffolds should be used in a PBL curriculum (Taylor & Miflin, 2008). Some institutions believe that PBL curricula should be characterized by as few lectures as possible, whereas others believe that there should be more structure in the curricula. The objective of this study is to investigate the influence of worksheets as a tool used to scaffold students' learning in a PBL environment.

According to Saye and Brush (2002), scaffolding can be generally classified into two groups – hard and soft scaffolds. Soft scaffolds refer to the teacher actions in response to the learner's efforts when the learner has a specific need (Saye & Brush, 2002). An example of such scaffolds would be the tutor or facilitator in PBL. Tutors play a significant role in ensuring that the students learn and progress satisfactorily in the course of solving the problem (Maudsley, 1999; Schmidt & Moust, 1995; Schmidt, et al., 2009). They should be knowledgeable and able to effectively facilitate groups of students (Greening, 1998; Hmelo-Silver & 2004; Rotgans & Schmidt, 2011; H.G. Schmidt, et al., 2009). Another instance of soft scaffold, which is also characteristic of PBL, would be the formation of collaborative problem-solving groups which 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). Research done on small PBL tutorial groups indicated positive cognitive effects in aspects such as activation of prior knowledge, recall of information and causal reasoning (Dolmans & Schmidt, 2006; Hmelo, 1998). 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 & Moust, 2000). 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, as well as being actively involved in the group learning process in order for effective learning (Lohfeld, 2005).

On the other hand, hard scaffolds are in general static supports that can be developed 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). For example, one way of guiding instruction can refer to the use of scaffolds like process worksheets (Merriënboer, 1997). Such worksheets provide hints or descriptions of the phases one should go through when solving the problem. Students can consult the process worksheet while they are working on the learning tasks and they may use it to monitor their progress throughout the problem-solving process.

Some studies have also suggested that fading of hard scaffolds is possible once the students have gained ability in performing the assigned tasks (Belland, Glazewski, & Richardson, 2008; Puntambekar & Hubscher, 2005). For example, novices in a PBL environment may engage in unrelated literature searches, which indirectly results in inefficient learning (Schmidt, et al., 2007). Hence, it is often essential that novice students in a PBL environment are provided with some resources to scaffold their learning, as being able to successfully search for literature and other resources usually requires a certain level of prior or domain knowledge. With increasing expertise, fewer resources should be provided to the students. In this way, independent learning is encouraged while providing a form of flexible scaffolding (Schmidt, et al., 2007).

On the whole, the use of scaffolds in general and PBL context has demonstrated varying degrees of impact on student learning achievements. Some 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, the present study sought to explore how far scaffolds, in the form of structured worksheets, help students in their learning in PBL. A quasi experimental approach was chosen in which one group of students received a scaffold during PBL and another not. Differences in their learning were determined by comparing the mean scores on a concept recall test.

Method

Participants

The sample consisted of 241 participants who were in their second year of study in the institution. The participants were enrolled in 17 classes for a Biomedical Science-related subject (Immunology) at a polytechnic in Singapore. The response rate for this study was approximately 89%. The breakdown of the participants in terms of frequencies in age and gender is presented in Table 1 below.

Table 1

Gender and age range of participants in respective year of study

Total number of participants (n)	**Gender**		**Age**	
	Male	Female	Mean	S.D.
241	114	127	17.55	0.98

Educational Context

In this polytechnic, the instructional method is PBL for all its modules and programs. In this approach five students work together in one team under the guidance of a teacher. Each class comprises four to five teams. A unique feature of the PBL approach used in this polytechnic is that students work on one problem during the course of each day (Alwis & O'Grady, 2002) A typical day starts with the presentation of a problem. Students discuss in their teams what they know, do not know, and need to find out. In the process, students activate their prior knowledge, come up with tentative explanations for the problem, and formulate their own learning goals (Hmelo-

Silver, 2004; Schmidt, 1983, 1993). Subsequently, periods of self-study follow in which students individually and collaboratively try to find information to address the learning goals. At the end of the day the teams come together to present, elaborate upon, and synthesize their findings.

Materials

Problem. The problem used is a case scenario of a patient suffering from reoccurring infections due to deficiency in one of the proteins required for activating certain immune responses within the body. Some clinical data was provided in the case study for the students to infer and analyze.

Worksheet scaffolding. For the experimental group a worksheet scaffold was devised, which aimed to guide the students towards ideas to consider during the process of analyzing and approaching the task for the day. This was carried out by including hints or providing some information within the worksheet. For example in this study, students were required to find out about the role of complement proteins in the immune system. One of the questions in the worksheet prompted the students to investigate more about the different immune processes that complement proteins are involved in. For this question, students were required to fill in a table to guide them in learning more about the various processes that involve complement proteins. At the end of the question, students were then required to summarize the functions of complement proteins with the aid of diagrams and the information gained in the earlier part of the question as hints. (Refer to Appendix section for an example of the worksheet question).

Thus 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. It was provided as an additional scaffold apart from the problem trigger, and 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 trigger.

Pre- and post-tests. 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 following instruction: "List down all the concepts that you think are relevant to today's problem on the complement system." (Understanding the complement system was the focus of the learning for the day). Students were instructed to only list keywords or terminologies they thought were relevant, and not write in paragraphs or sentences. They were not allowed to discuss their answers or to refer to any resources when completing the exercise. Students' answers to the concept recall procedure were analyzed by awarding 1 point to each relevant concept given by the student. Rating was done by the first author and a colleague of similar expertise in the field of immunology. Differences in opinion were resolved by discussion.

Learning Impact Questionnaire. In addition to concept recall tests, a Learning Impact Questionnaire was administered to the participants in order to find out what students perceive as important factors that impact their learning in a PBL environment. The questionnaire consisted of five items measuring how certain features of the learning environment impact student learning: worksheet, problem statement, tutor, team dynamics (level of involvement within a small group of 5 students) and class dynamics (level of involvement between teams or in a larger group of about 25 students).

The following questions were included in this questionnaire: (1) "*The worksheet has a strong impact on my learning*"; (2) *The problem statement has a strong impact on my learning*"; (3) "*The tutor has a strong impact on my learning*"; (4) "*Team dynamics have a strong impact on my learning*"; and (5) "*Class dynamics have a strong impact on my learning*". The items were scored on a 5-point Likert scale: 1 (*Strongly disagree*), 2 (*disagree*), 3 (*neutral*), 4 (*agree*), and 5 (*strongly agree*). Students were asked to answer the questionnaire based on their overall experience in a PBL environment.

Procedure

The 17 classes were randomly assigned to the treatment condition (7 classes) and the control condition (10 classes). Each class had an average of 25 students. At the beginning of the PBL day, students completed the pre concept recall test, which took about 10 minutes. After that they commenced with the lesson. The PBL day was exactly the same for both groups, except that the treatment group received a worksheet with the problem. They were asked to complete the worksheet during the self-study periods. For students in the treatment group, the teacher would briefly check on their progress of the worksheet during the team discussions. After both groups had completed the PBL day, they responded to the post concept recall test, which was identical to the pre-test. In addition, the participants completed the learning impact questionnaire. As students were asked to complete the questionnaire based on their overall experience in the course of study within the institution, students who were not provided a worksheet were also able to evaluate the impact of worksheets (in general) on their learning in the PBL context.

When this study was carried out, the institution had not yet formed an Institutional Review Board (IRB) through which formal ethical approval for the study could be sought. However, measures were taken to ensure that ethical standards were met. First, the problem selected for this study was one which did not normally provide a worksheet scaffold. The students in the control group (with no scaffold provided) were therefore not disadvantaged by being in the control group. Moreover at the end of the day, the worksheet was made available to all students, including those in the control group. Second, all students and tutors who participated in this study gave informed consent, and were given a choice in regards to their participation.

Statistical analysis

In order to test whether there are significant differences in terms of students learning between the treatment and control groups, an analysis of variance (ANOVA) was performed. The dependent variable was post-test score and the independent variable was the condition. In addition to the F-value and p-value, the eta-squared value was generated as a measure of the effect-size. In order to compare the items scores of the learning impact questionnaire, an ANOVA was also conducted.

Results

The results of the ANOVA 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 $M = 4.76$ ($SD = 2.57$). This outcome is rather surprising because it suggests 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, we conducted another ANOVA to examine whether there were 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 favor 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 concept tests are summarized in Table 2.

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

In order to statistically correct for this initial difference in pre-test scores, we conducted an analysis of covariance (ANCOVA). 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: $F(1, 238) = 1.58$, $p = 0.21$, eta-squared = 0.01. This outcome suggests that using a worksheet as a scaffold for learning had no significant effect on student learning, even after correcting for initial knowledge differences.

We next compared the scores to the items of the Learning Impact Questionnaire to examine how students perceive various aspects (scaffolds) present in a PBL classroom environment and their respective impact on learning. The results are summarized in Table 3.

Table 3

Summary of ANOVA comparing factors students perceive as important in impacting their learning in a PBL environment

Aspect of learning environment	**Sample size (N)**	**Mean**	**Std. Deviation**	**Std. Error**
Problem statement	242	3.82	.692	.044

Worksheet	222	3.54	.949	.064
Tutor	243	4.09	.730	.047
Team dynamics	244	4.23	.699	.045
Class dynamics	244	4.11	.712	.046

*$p < .01$

The ANOVA revealed that there were statistically significant differences between the scores of the items in absolute sense: F(4, 218) = 39.88, $p < 0.01$, eta-squared = 0.16. Considering the mean values and pairwise comparisons based on the LSD, students in our sample rated the worksheets as having the lowest impact on their learning (worksheet scored lowest as compared to all other items $p < 0.01$). There are no differences in mean scores reported in Table 2 between experimental and control group, except for the worksheet (p=0.013; mean score for experimental group = 3.71; mean score for control group = 3.40). Although the p-value for worksheet is not smaller than .01, it is smaller than .05 which may be considered as a statistical significant difference. The highest impact on students' learning was related to team dynamics, which was rated higher than for all other items ($p < 0.01$). The other factors of the learning environment fell within between these two extremes. The tutor and class dynamics were rated second most important and the problem statement third.

Overall, the results demonstrate that worksheets may not have a significant influence on students' learning in a PBL classroom. This was inferred from our post-test achievement data, and also by students' responses to the Learning Impact Questionnaire.

Discussion

The objective of the present study was to investigate the effects of worksheet scaffolds on students' learning achievement in a PBL environment. Based on the results obtained from this study, there was no statistically significant difference between the levels of achievement in terms of learning outcomes for both the experimental and control group. As mentioned in the introduction to this study, there is a lack of clarity on how scaffolding can be used to achieve successful teaching (Verenikina, 2008) in PBL. The contribution of this study is the evidence that, at least in this PBL context, scaffolds such as worksheets may not play a significant role in enhancing students' learning within PBL. 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.

With reference to prior studies, the findings obtained from this study reinforced the view that soft scaffolds, such as tutoring and collaborative small group learning, are crucial for student learning in a PBL environment. Tutors should have the relevant content knowledge to guide students throughout the process of solving the problem by asking open-ended questions to facilitate them (Hmelo-Silver & 2004; Hmelo-Silver & Barrows, 2008; Maudsley, 1999; Yee, Radhakrishnan, & Ponnudurai, 2006). A recent study conducted by Rotgans & Schmidt (2010a) discussed that one of the options to increase interest would be to enhance the tutor's subject-matter expertise, thereby leading to an increase in cognitive congruence. This could be done by providing modes of additional resources (e.g. briefing sessions, reading materials) for tutors to gain more in-depth knowledge of the problem (Rotgans & Schmidt, 2010a). In this study we have conducted, the responses obtained from the Learning Impact Questionnaire showed that the tutor was rated as being more significant for students' learning and not the worksheet. Based on this finding, it may be more beneficial for student learning in PBL if the tutor provides soft scaffolding like what previous studies have suggested. This study also suggests that collaborative small group learning (team dynamics) plays a significant role in enhancing student learning. Studies have indicated that collaborative groups in PBL creates an appropriate environment for students to learn the concepts by allowing them to investigate each others' comments and encourage further discussion (Dolmans & Schmidt, 2006; Hmelo-Silver & 2004; Schmidt, 1993; Will, 1997). Overall, this seems to support the finding from our study as to why students perceive team dynamics to have a significant impact on their learning.

Limitations

In overall, the outcome of this study seems to align with previous studies pertaining to scaffolds. Schmidt et al. (1997) commented that as students gain a certain level of prior knowledge or expertise, the degree of scaffolding should be lower (i.e. fewer resources) so as to encourage independent learning. In this study, the participants were already in their second year of the diploma course that they were enrolled in. 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 lead to the participants being less reliant on the worksheets to grasp the concepts related to the topic for the day. Furthermore, there are other limitations that could have influenced the student's reliance on using the worksheet to enhance their learning.

First, students who are less motivated in learning might not necessarily attempt to use the worksheet for their learning. According to Merriënboer (1997), students can refer to the worksheet and use it to monitor their progress during the process of solving the problem. 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 may possibly have learnt more compared to those who completed the worksheet individually. Hence, this could have lead to the high rating of the team dynamics in the learning impact survey.

Secondly, 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). However it is possible 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).

Third, through the PBL process, students are required to come up with tentative theories to explain the phenomena presented in the problem. 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 study or learn (Deci, et al., 1991). In a recent study, 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 (Rotgans & Schmidt, 2010b). By integrating hard scaffolds such as worksheets into the PBL curriculum, this may reduce students' feeling of choice and autonomy, which leads to less engagement and learning. Since students in a PBL environment are expected to engage in their own knowledge construction to solve the problem, there could be a possibility that worksheets and PBL are not reconcilable. As worksheets tend to impose the theories on the students, this may affect the process of the students' knowledge construction. However this is only a tentative explanation, as more research is needed to establish the link between autonomy reduction and hard scaffolds in PBL.

The following suggestions could be taken into consideration for further research: (1) Results from this study generally indicated that worksheets may not be that effective as a form of scaffolding to enhance student learning in PBL in this educational context. However, it remains an empirical question to see 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 the course of study. Since this study involved participants who are in their second year of the diploma course, it is suggested that it could be helpful to conduct similar studies on students who are in their novice and final year of the course. In this way, comparisons and inferences can be made about students' perceptions and reliance on worksheets as a scaffold in a PBL environment. (2) Most of the previous studies conducted have demonstrated a certain level of success rate of adopting PBL in the field of science, in particular medical education. Hence, it is suggested that the influence of worksheets on students' learning in other subject fields (e.g. engineering, arts) could be further investigated. (3) Considering that the worksheet design may vary based on the curriculum to be delivered, data could be collected for a range of topics for more conclusive findings. (4) Since tutors play an important role in observing learning processes of the students throughout the lessons, it would be beneficial to examine what are the tutors' perceptions of using worksheets as a form of scaffolding to facilitate students' learning. (5) One of the aims of PBL is to encourage students to move away from passive learning to active engagement during the process of solving the problem (Davis & Harden, 1999). Students who are generally passive learners could be relying more on the worksheet for guidance instead of being engaged in collaborative small group learning. Hence, this may indirectly affect the responses to the Learning Impact Questionnaire. More research could be conducted to investigate if there is any correlation between the learning styles and achievement level of the students.

Chapter 5: Effects of Flexible Scaffolding in Active Learning[4]

Abstract

The objective of this study was to investigate the relationship between different ways of providing learning supports or scaffolds in a problem-based learning (PBL) environment and their impact on student learning. This study aimed to provide some preliminary 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 involved 72 participants enrolled in an educational institute that uses PBL as the instruction method. It was carried out to examine and compare students' understanding of a certain topic under two scaffolding conditions – (i) fixed scaffolds

[4] Authors: Choo, S. S. Y, Yew, E. H. J. & Schmidt, H. G.

provided and (ii) scaffolds provided upon the need arises (i.e. flexible scaffolding). Participants were randomly assigned and were assigned a group task to complete within teams of three to four. Students' understanding of the topic at hand was measured by comparing results from pre- and post-lesson concept recall tests, administered before and after entire completion of the assigned task. The obtained data was then analysed by means of analyses of variance (ANOVA). The findings from this study suggested that flexible scaffolding has a significant impact in student learning, in terms of encouraging understanding of the subject matter. The factors that play an important role in influencing the effectiveness of flexible scaffolding would be mainly the tutor, and also collaborative team learning within the students.

Introduction

Problem-based learning (PBL) is 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; Schmidt, 1993). Greening (1998) indicated that one of the desirable outcomes of PBL is to encourage deep learning in students. Past research studies done on PBL showed that students tend to increase the use of meaningful approaches to relate to the task content, compared to reproductive approaches (Coles, 1985; Newble & Clarke, 1986). Studies have demonstrated that PBL is effective in helping students acquire cognitive learning skills such as critical thinking (Hallinger, 2005; Hmelo-Silver, 2004; Schmidt, Loyens, Van Gog, & Paas, 2007; Simons & Klein, 2007) as well as self-directed learning skills (Hmelo-Silver, 1998; Schmidt, van der Molen, te Winkel & Wijnen, 2009; Simons & Klein, 2007). In PBL, students are required to work both collaboratively within small groups as well as individually through self-directed learning in order to analyze and derive solutions to the problem assigned for the lesson (Hmelo-Silver & Barrows, 2008; Norman & Schmidt, 1992). This process of learning is accompanied by appropriate guidance to the teams by the PBL tutor or facilitator who play the role of a cognitive coach to probe students' knowledge and model strategies for students to apply critical thinking (Hmelo-Silver & Barrows, 2008; Maudsley, 1999; Norman & Schmidt, 1992; Savey & Duffy, 1996; Schmidt, et al., 2009). Since PBL may require students to attempt tasks of certain complexity, it is essential to provide scaffolding to assist students in managing their findings and to facilitate the learning process (Quintana, 2004). Up till recent years, there have been several studies done on investigating the effectiveness of the PBL process, particularly its social constructivism element that contributes to student learning. In terms of measuring the effectiveness of scaffolds provided to students that may complement the PBL process and eventually impact learning, there is lesser research conducted in general. It may also be beneficial to know if the way of administering scaffolds to students would impact their learning. Therefore, this study aims to provide some preliminary insights on different ways of scaffolding, by comparing the impact of student learning under fixed and flexible scaffolding conditions which will be mentioned in detail later.

The PBL process is anchored by a problem structured in which there are could be a few feasible solutions and ways of deriving them. Students undergo a range of activities to scaffold and increase their understanding of the problem, refer to relevant resources and recommend possible solutions (Saye & Brush, 2004; Simons & Klein, 2007). Since PBL involves a social constructivist framework whereby students develop knowledge bases in the course of interactions (Greening, 1998; Savey & Duffy, 1996), it is essential to provide them with the necessary tools to scaffold their learning effectively (Verenikina, 2008). One characteristic of PBL would be the main instructional materials used in the curriculum, which are the problems. Past studies suggested that problems have an overall influence on the learning process of the students, which eventually affects the outcome variables such as academic achievements (Dochy, Segers, & Buehl, 1999; Dochy, Segers, Bossch & Struyven, 2005; Gijselaers & Schmidt, 1990). The problems used in a PBL curriculum should not only promote meta-cognitive thinking but also increase students' motivation to know more about the subject matter (Dochy, et al., 2005; Hmelo-Silver, 2004; Khoo, 2003). In order to aid the students to efficiently solve the problems, there are also additional learning supports that may serve as tools to scaffold the process of student learning. Examples of such learning supports consist of audiovisual aids, lectures, laboratory sessions as well as provided references (Ertmer & Simons, 2006; Hamdy, 2008; Saye & Brush, 2002; Simons & Klein, 2007; Taylor & Miflin, 2008). According to a study conducted in a PBL setting by Simons and Klein (2007), it was demonstrated that students who were provided with scaffolds scored significantly higher in post-tests in comparison with the student group which did not receive any form of scaffolds. The outcome of this particular study reflected the importance of scaffolding in enhancing student inquiry and learning achievements (Simons &

Klein, 2007). The findings from the above-mentioned study seem to correspond with other studies in both general and PBL context which suggested that the use of scaffolds may aid in reducing the complexity of assigned tasks, and also in developing students' abilities to complete the tasks (Clark & Graves, 2005; Ertmer & Simons, 2006).

Significance of Scaffolds in PBL

In both general and PBL context, scaffolds can be classified as hard and soft scaffolds. "Hard" scaffolds are basically static supports that can be provided to the student upon assignment of a certain task (Saye & Brush, 2002). Examples of such scaffolds can be in the form of computer or paper-based cognitive tools (Belland, Glazewski, & Richardson, 2008). "Soft" scaffolds are generally defined by actions or situational supports provided in response to the learner's efforts when the learner indicates a specific need (Saye & Brush, 2002; Su & Klein, 2010). Examples of such scaffolds in PBL could refer to tutor interventions during discussion time with students as well as collaborative interactions within the peer groups. Soft scaffolds are only applied if there is a transient need sometimes during completion of the task.

Previous studies indicated that tutors are one of the important elements in PBL, as they will encourage students to reflect deeper on the subject matter (Dochy, et al., 2005; Hmelo-Silver, 2009; Hmelo-Silver & Barrows, 2006). Tutors should be able to facilitate small tutorial groups and create a collaborative learning environment to enhance the learning process (Dolmans & Schmidt, 2006; Greening, 1998; Hmelo-Silver, 2004; Maudsley, 1999; Schmidt, 1993). Findings from a recent study demonstrated that different types of learning activities or supports seemed to have varying impact levels on student learning. Based on this study, students perceived soft scaffolding events such as tutor interventions to have a higher impact on their learning, compared to other scaffolds such as worksheets (Choo, Rotgans, Yew & Schmidt, 2011). As for small-group learning, it encourages activation of prior knowledge within the small group setting as well as allowing students to analyze and apply causal reasoning (Dolmans & Schmidt, 2006; Hmelo-Silver, 1998; Schmidt, 1993; Schmidt, Rotgans, & Yew, 2011). By learning in small groups, students may complement each other throughout the process of solving the problem and thus, the sharing or discussion sessions within the group could scaffold the learning process of the student (Hmelo-Silver, 2009; Woods, 1994).

Flexible utilisation of scaffolds in PBL

In the studies described in Chapters 2 and 3 of this thesis, data of the perceived impact of the various types of scaffolds or scaffolding events were evaluated by the students. In addition, the relationship between students' academic ability and their perceived impact of scaffolds on their learning was investigated. Results obtained from these two studies generally concluded that students, especially those with high academic achievement generally perceive scaffolds with 'soft' elements to have a significant impact on their learning in a PBL environment. Some studies have also suggested that the fading of hard scaffolds is possible and should be encouraged once students have gained ability in performing the assigned tasks (Belland, Glazewski, & Richardson, 2008; Puntambekar & Hübscher, 2005). With increasing expertise, fewer resources should be provided to the students. In this way, independent learning is encouraged while providing a form of flexible scaffolding (Schmidt, et al., 2007). One example of encouraging flexible scaffolding could fall on the role 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. The tutor should also be responsible for create conducive conditions for each student to learn effectively. Therefore, the tutor should be able to provide flexible adaptation of scaffolds (be it hard or soft) by taking into account the varying learning requirements (e.g. level of cognitive thinking or motivation) of individual students (De Corte, 2000; Dochy, et al., 2005).

A question that arises would then be whether students in a PBL environment learn better under conditions of flexible scaffolding. Till now, 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 used scaffolds provided at the start of the task. Therefore, the purpose of this study is to investigate the effectiveness of flexible scaffolding on students' achievement in a problem-based learning environment. A study involving 72 participants was carried out to examine and evaluate students' understanding of a particular topic under two scaffolding conditions – (i) fixed scaffolds provided and (ii) scaffolds provided when the need arises (i.e. flexible scaffolding). This experimental design aims 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 (i.e. 'just in time' scaffolding)?

Materials and Methods

Participants

Participants were 72 first-year students enrolled in a science-related course at a polytechnic in Singapore. An email invitation was sent to all first year students of the Diplomas of Biotechnology, Biomedical Sciences, Materials Science, Pharmaceutical Sciences and Environmental Science from the School of Applied Science. Participation was voluntary and all students were briefed and gave informed consent before taking part in the activity. The breakdown of the participants in terms of frequencies of age and gender is shown in Table 1. Out of the total number students who were eligible for inclusion in this study (n=737), 10% of the students chose to participate.

Table 1

Gender and age range of participants in respective year of study

Total number of participants (n)	**Gender**		**Age**	
	Male	Female	Mean	S.D.
72	30	42	16.39	0.86

Procedure

Overview of the study. Participants were randomly assigned into groups of approximately equal size (control group with no scaffolds provided; experimental group 1 with hard scaffolding, experimental group 2 with flexible scaffolding). They were provided with a journal article on an infectious disease known as *Shigellosis* (Ramamurthy, Deen, & Bhattacharya, 2004). The article described a case study which would inform the readers about how diseases of the gastrointestinal tract such as *Shigellosis* are transmitted. The case study was intended to be the starting point of discussion for the participants, which would allow initiation of active learning. The group task given to the participants was to read the case study in the article and write a brief literature review of not more than 300 words on *Shigellosis* and related digestive infectious diseases. Prior to working on the task, students were required to complete a pre-lesson concept recall test to gauge their level of prior knowledge on the topic. After completing the test, students were then randomly grouped into teams of four or five and assigned to complete the group task. At the end of the activity, students received a post-lesson concept recall test, of the same format and content as the pre-lesson concept recall test. The pre- and post-lesson concept recall tests, as well as the team submissions were then marked by the first author and another colleague of similar expertise.

Fixed scaffold and flexible scaffold groups. For the two experimental groups, a worksheet scaffold was crafted for the activity and provided to guide the students in accomplishing the task for the day. The worksheet is an instructional tool consisting of a series of questions and information (e.g. websites) designed to guide students to understand complex ideas as they work through it systematically. It was provided as a scaffold that students may attempt by themselves or use for discussion with their teammates. In this study, the worksheet was crafted by including hints or providing some information relevant to the case study to guide students in the thinking process. For instance, students were expected to find out more about Shigellosis in order to complete the task. Thus some of the questions in the worksheet prompted the students to find out more about the pathogen that caused Shigellosis and also provided links to online video, diagrams and text. 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, the tutor either utilized questions from the worksheet or respond to student enquiries given only when students seemed to demonstrate learning or understanding difficulties during the process of accomplishing the assigned task. Therefore, this type of scaffolding may be termed as 'flexible scaffold'. Both experimental groups were facilitated by the same tutor. For the control group, the students were only provided with the journal without any tutor assistance.

Pre- and post-lesson concept recall tests. 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 following instruction: "In the table below, please list down all the concepts (keywords/phrases) that you think are relevant to 'Shigellosis or digestive system infections'. Explain, in one or two sentences, how each concept is related to Shigellosis or digestive system infections." Students were not allowed to discuss their answers or to refer to any resources when completing the exercise. The answers to the concept recall procedure were scored by awarding 1 point to each relevant concept given by the student.

Analyses. One-way ANOVA was used to find out if there were significant differences between the fixed scaffold and flexible scaffold groups in terms of the following: (1) pre-lesson concept recall test score, (2) post-lesson concept recall test score, (3) total score for post-concept recall test and group task (i.e. summary of topic), and (4) difference between pre- and post-lesson concept recall test scores.

Results

Table 2 shows a summary of the descriptive statistics of the two types of scaffolding conditions with scaffolding provided – fixed scaffolding and flexible scaffolding. Table 3 shows the results of the ANOVA, comparing the two scaffold groups.

Table 2

Summary of means, standard deviations and standard errors between the two scaffolding conditions

Scores tabulated	**Scaffolding condition**	**N**	**Mean**	**Std. Deviation**	**Std. Error**
Pre- test	Fixed scaffolding	26	3.29	2.52	0.49
	Flexible scaffolding	22	3.70	2.49	0.53
	Total	48	3.49	2.50	0.51
Post- test	Fixed scaffolding	26	8.60	4.43	0.87
	Flexible scaffolding	22	11.59	4.05	0.86
	Total	48	10.10	4.24	0.87
Total for post-test and group task	Fixed scaffolding	26	13.90	4.43	0.87
	Flexible scaffolding	22	17.34	4.05	0.86
	Total	48	15.67	4.24	0.87

Difference between pre- and post-test	Fixed scaffolding	26	5.31	2.89	0.57
	Flexible scaffolding	22	7.89	3.65	0.78
	Total	48	6.60	3.27	0.68

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 ANOVA result (Table 3) revealed that there were statistically significant differences within the experimental groups for the combined score of post-concept recall test and group task [$F(2, 71) = 4.480$, $p = 0.015$] and score for difference between the concept recall tests [$F(2, 71) = 4.028$, $p = 0.022$]. A post hoc Tukey test showed that there were significant differences for the combined score and score difference between pre- and post-concept recall tests.

For the combined score of post-concept recall test and group task, the mean scores obtained for the flexible scaffold group (M=17.34, SD=4.27) were significantly higher (p=0.018) compared to the groups with fixed scaffolds (M=13.90, SD=4.43) provided.

As for the mean scores that measured differences between the pre- and post-concept recall tests, there were also some significant differences detected. The score for the group with flexible scaffolding (M=7.89, SD=3.65) was significantly higher (p=0.044) compared to the fixed scaffold group (M=5.30, SD=2.89).

Discussion

Based on the above findings, the scores obtained for the flexible scaffold group were generally significantly higher compared to the fixed scaffold group. The results seem to propose that flexible scaffolding may impact the students' learning process. This aligns with past literature studies suggesting independent learning may be encouraged by fading of scaffolds or only providing scaffolds when deemed necessary (Belland, Glazewski, & Richardson, 2008; Puntambekar & Hübscher, 2005).

In addition, the 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. The main contrast between these two groups was the amount and level of situational support provided to the students throughout the learning process. For the flexible scaffold group, the tutor provided students with the required support only at the time when the need for guidance was recognized. This support could be in the form of questioning or providing the students with resources such as web-links or additional pieces of information. In the case of the fixed scaffold group, the teams were provided with a fixed set of information in the form of an activity sheet that they may refer to and utilize during the process of executing the task.

Although the teams are provided with this additional learning support at the beginning of the task, they may choose to not utilize the scaffold eventually. Given that the tutor still provides support to the teams' learning via soft scaffolding (e.g. probing for understanding and giving relevant excerpts of information at times), one question that raises curiosity is whether there is a need for fixed set of learning scaffolds (e.g. activity sheets) to be provided at the start of task or could the information be disseminated to the students in a more effective and timely manner?

Based on the results obtained from this study, the preliminary findings comparing flexible and fixed scaffolding does seem to indicate that by providing the required support to the learner on a timely basis, the level or impact of understanding may be more effective. One of the main factors that play an important role in flexible scaffolding would be the tutor, which also contributes extensively to the process of facilitating the learning process within a PBL class. As defined by past literature studies, the role of the PBL tutor is to monitor the progress of students and intervene when support or guidance is deemed necessary (Hmelo-Silver & Barrows, 2006; Saye & Brush, 2002). Therefore, successful implementation of flexible scaffolding depends primarily on the tutor. In this preliminary study, the process of facilitation was conducted by one tutor. Hence it may be advisable to measure the impact of student understanding under the facilitation of more than one tutor, to provide more insights about impact of tutor on student learning.

In comparison with the score that measured the difference between concept recall tests, the significant differences within the experimental groups seemed to be higher. 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-lesson 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 indicated the positive effects of small-group learning in PBL environments. Sharing, discussing information and acquiring knowledge within small PBL tutorial groups are the main processes that encourage collaborative and effective learning (Barrows, 1988; Dolmans & Schmidt, 2006; Hmelo-Silver, 2004). By working in small groups, students learn the essence of team cooperation, being more actively involved in the learning process and thus more motivated in using their time more productively (Dochy, et al., 2005; Dolmans & Schmidt, 2006; Woods, 1994). In addition, the score for the group with flexible scaffolding was higher compared to the group with fixed scaffold provided, which further supports the hypothesis that flexible scaffolding could impact student learning in a positive way.

Limitations and further work

Given that this study provides a preliminary analysis about flexible scaffolding in PBL, further studies on this area of research can be conducted. 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 could be to include a class discussion at the end of the task to investigate if class dynamics play any role in 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 justify the positive impact of tutor on student learning under different scaffolding conditions.

Next, the concept recall test is based on the assumption that students build networks of concepts in the process of learning. The more students have learned about a topic, the more coherent and detailed each network would be (Glaser & Bassok, 1989). Therefore, 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). However it is possible 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). Hence, other tools such as quizzes consisting of structure questions relating to the subject matter can be used to further assess the level of student understanding.

As the participants involved in this study were all Year One students, it was assumed that the level of prior knowledge was similar at the start of the study. To find out the impact of flexible scaffolding for students at the novice or advanced stages of PBL, it may be feasible to carry out comparison studies between students from different years of their course of studies. For instance, a student at the third year of his or her course of study may require lesser amount of flexible scaffolding compared to a Year One student, due to the longer immersion duration in a PBL environment. As there are various types of scaffolds that could be utilized as learning supports in PBL (e.g. animations, worksheets), another recommendation for future work could be to find out the individual impact of different types of scaffolds under fixed and flexible ('just in time') scaffolding conditions.

Conclusion

In conclusion, the findings from this study suggested that flexible scaffolding may have a positive impact in student learning, in terms of encouraging understanding of the subject matter. The factors that play an important role in influencing the effectiveness of flexible scaffolding would be mainly the tutor, and also collaborative team learning within the students. As this study provides a preliminary evaluation of the impact of flexible scaffolding in PBL, more studies still need to be carried out to further investigate on the effect and proper implementation of such scaffolding condition.